Management Of Networked IoT Wearables – Very Large Scale Demonstration of Cultural Societal Applications
(Grant Agreement No 732350)

D9.3 Replication Reference Book and Roadmaps for MONICA Market Replication

Date: 2020-03-31

Version 1.0

Published by the MONICA Consortium

Dissemination Level: Public

Co-funded by the European Union's Horizon 2020 Framework Programme for Research and Innovation under Grant Agreement No 732350

Document control page

Document file: D9.3 Replication Reference Book and Roadmaps for MONICA Market Replication_v1.0.docx
Document version: 1.0
Document owner: IN-JET

Work package: WP9 – Pilot Impact Assessment and Replication
Task: T9.5 – Scalability and Replicability of the Demonstrators
Deliverable type: R

Document status: ☒ Approved by the document owner for internal review
☒ Approved for submission to the EC

Document history:

Version	Author(s)	Date	Summary of changes made
0.1	Helene Udsen (IN-JET), Veronica Chesi (IN-JET)	2019-10-21	ToC and initial content
0.5	Ján Beňadik (ATOS), Helene Udsen	2019-11-28	Content of Chapter 12, restructuring and additional text and editing
0.6	L. Riley, T. Sørensen, V. Chesi, J. Thestrup (IN-JET)	2020-03-08	Added Chapter 4-10
0.7	Veronica Chesi (IN-JET), Agata Tringale, Francesco Sottile (LINKS)	2020-03-15	Added sections on Reference Deployments, Demonstrations and Results, Reproducibility
1.0	Veronica Chesi (IN-JET)	2020-03-30	Addressed reviewer comments and finalised document
1.0	Veronica Chesi (IN-JET)	2020-03-31	Final version submitted to the European Commission

Internal review history:

Reviewed by	Date	Summary of comments
Sonja Löwa (FHH-SC)	2020-03-30	Approved with minor comments
Constanze Ritzmann (FIT)	2020-03-30	Approved with minor comments

Index:

1 Executive Summary

The MONICA project has been hugely successfully demonstrated in 22 planned events and four replications in six major cities across Europe.

It has demonstrated to very many stakeholders, both from the supply side and the demand side of the value chain, how a large scale IoT ecosystem using innovative wearables, IoT sensors and actuators, can be integrated into an interoperable, cloud-based solution with closed-loop services that are capable of offering a multitude of targeted applications for event organisers and smart city operators. Security and privacy enhancing features in a trust federation scheme allow all solutions to protect personal data and privacy in compliance with the GDPR regulations. Both event participants and ordinary citizens was involved in validation activities to investigate privacy, security, collective awareness and co-creation.

Moreover, a set of software tools and technical guidelines for developers and system integrators complete the package of results from the MONICA project. Finally, the project validated a range of new business model proposals based on new value propositions for involved actors to explore.

This document presents guidelines for market up-take of the MONICA results so that potential customers, event planners, Smart City operators or solutions developers, can have an overview of the necessary investments and the expected results of the MONICA solutions. As such, it serves as a foundation for commercial purposes.

The MONICA solutions include: Crowd and Capacity Monitoring, Crowd Management and Communication, Sound Level Monitoring, Adaptive Sound Field Control, the Collective Awareness Platform, the User Experience App, and the MONICA platform.

Technical partners and pilots made here available all the knowledge acquired in three years of testing and demonstrations, so that other stakeholders in the Creative and Cultural Industries can replicate the MONICA experience.

For each solution, a scenario description is presented with the definition of the challenges, the benefits, potential stakeholders interested in the replication.

The section dedicated to the technical aspects is very detailed and topics such as integration with other MONICA solutions and scalability, are also addressed.

Information of installation and regulations (technical and GDPR-related) to comply with are provided.

The business aspects are discussed to provide stakeholders (mainly Smart City operators) with crucial information on the size of the investments needed to purchase and deploy the MONICA solution(s). The business model canvas reported in this deliverable come from D11.5 New Markets Segmentation and Sustainable Business Models for IoT Platforms.

The section “Potential for Replication” gives practical suggestions for an easy set-up and deployment of the solution: the technical partners have listed all lessons learned accumulated in two years of demonstrations in real-world situations. The contacts of the technical partners are also provided so that whoever is interested in replicating the MONICA solution can directly get in touch with the right developer.

Finally, the description ends with concrete example of MONICA demonstrations (Reference Deployments, Demonstrations and Results), where the reader can find details, pictures, diagrams and all the tools that have supported the sound and security staff during the events where the project’s consortium operated.

This replication book is completed with links to the MONICA toolbox designed in WP7, so that solution developers can develop new applications to be deployed on the MONICA platform. Specifically, a tool called Scalability/Replicability Matrix has been developed by ATOS, to support stakeholders/customers in the identification of the components necessary to execute the different usage scenarios.

Apart from this deliverable, an online version accessible from the MONICA website, has been designed as defined by the DoA. The context is the same, but the whole structure is interactive, with pop-up windows for technical contents insights, and pictures. The organisation of the information has been specifically planned in order to ensure an easy research of the contents according to the target group to which the reader belongs.

2 Introduction

2.1 Purpose

The aim of this deliverable is to present the Reference Book and Roadmaps for MONICA Market Replication to provide sufficient information to establish what the MONICA Solutions can do for potential customers, whether they are Event Planners, Smart City Operators or Solutions Developers.

This deliverable has also been uploaded on the MONICA website so to have a greater dissemination. In the online version the more technical sections are described well in detail, with specific pop-up windows for the developers who are interested in knowing more about the architectural structure of the MONICA solutions. The interactive online version of this document is available here: https://www.monica-project.eu/monica-replication-reference-book.

2.2 Content, context and scope of this deliverable

The document is structured as follows:

Chapter 3 provides an overview of the MONICA solution areas and tools. For each of the six solution areas, the related usage scenarios (use cases) are listed.

Chapter 4 provides a detailed description of the MONICA Platform architecture.

Chapters 5 through 10 each consist of scenario descriptions, technical aspects, business aspects, potential for replication and information about reference deployments for the six solution areas, respectively:

- Chapter 5 – Crowd and Capacity Monitoring
- Chapter 6 – Crowd Management and Communication
- Chapter 7 – Sound Level Monitoring
- Chapter 8 – Adaptive Sound Field Control
- Chapter 9 – Visitor Experience
- Chapter 10 – Collective Awareness Platform

At the end of each of the solution sections there is also a list of contacts for further information and purchasing.

Chapter 11 addresses general regulatory aspects relating to GDPR and technical regulations.

Chapter 12 contains detailed technical information for the MONICA solutions at component level, useful for deployment and integration purposes. This section also includes details of the MONICA Tools.

2.3 Acronyms and Abbreviations

Acronym or Abbreviation	Meaning
API	Application Programming Interface
ASFC(S)	Adaptive Sound Field Control (System)
CAP	Collective Awareness Platform
CC	Control Centre
CCTV	Closed-circuit television
COP	Common Operational Picture
CPU	Central Processing Unit
DB	Database
GDPR	General Data Protection Regulation

Acronym or Abbreviation	Meaning
GOST	Global Operating Systems Technology
GPS	Global Positioning System
GPU	Graphics Processing Unit
GW	Gateway
HLA	High Level Architecture
HLDFAD	High Level Data Fusion Anomaly Detection
IoT	Internet of Things
LiPS	Live Positioning Information System
MONICA	Management Of Networked IoT Wearables – Very Large Scale Demonstration of Cultural Societal Applications – project funded by the European Commission
OGC	Open Geospatial Consortium
PA	Public Address
QZS	Quiet Zone System
RED	Radio Equipment Directive
RTSP	Real Time Streaming Protocol
SCRAL	Smart City Resource Adaptation Layer
SFN	Security Fusion Node
SHM	Sound Heat Map
SLM	Sound Level Meter
SPL	Sound Pressure Level
SRD	Short Range Device
UAS	Unmanned Aircraft System
UI	User Interface
UWB	Ultra-Wide Band(width)

3 Overview of MONICA Solution Areas and Tools

Sections 3.1 through 3.6 list the MONICA Solution Areas and their individual Usage Scenarios, the latter usually referred to as *Use Cases* by software developers.

Section 3.7 briefly introduces the MONICA Toolbox and Scalability/Replicability Matrix.

3.1 Crowd and Capacity Monitoring

- Monitor crowds based on capacity
- Detect high-risk queues
- Re-direct high-risk queues
- Manage crowds based on capacity

Detailed information can be found in Section 5.

3.2 Crowd Management and Communication

- Inform staff
- Inform visitors
- Guide people to exits
- Missing Person
  - Locate staff member
- Security Incidents
  - Detecting an incident
  - Reporting an incident
  - Handling an incident
- Health Incidents
  - Detecting an incident
  - Reporting an incident
  - Handling an incident
- Safety incidents
  - Precautions at unsafe wind speeds

Detailed information can be found in Section 6.

3.3 Sound Level Monitoring

- Monitor sound level

Detailed information can be found in Section 7.

3.4 Adaptive Sound Field Control

- Adjust sound level

Detailed information can be found in Section 8.

3.5 Collective Awareness Platform

- Engage citizens in co-creation of smart city solutions
- Set up a Collective Awareness Platform (CAP)

Detailed information can be found in Section 10.

3.6 Visitor Experience

- Event Information
    - Get event information
    - Give event feedback
    - Evaluate event

Detailed information can be found in Section 9.

3.7 MONICA Tools

- **Scalability/Replicability Matrix**

  The Scalability/Replicability Matrix is a tool identifying the components necessary to execute the different usage scenarios. Based on required functionality and selected usage scenario(s), the tool shows which high-level MONICA enablers to deploy in the solution. These high-level enablers in turn define the necessary components. Further details on how to use this tool can be found under Technical Information in Section 12.2.

- **Toolbox**

  The MONICA Toolbox contains Software Developer Tools, Generic Enablers and Third-Party Tools that allow developers to rapidly develop new applications to be deployed on the MONICA platform. The development platform consists of a toolbox and a set of tutorials and guidelines. The toolbox can be used to integrate various resources into the IoT Platform, and hides the complexity of the communication with IoT devices. Details can be found under Technical Information in Section 12.3.

4 Platform Architecture and Components

The MONICA IoT Platform features a cloud based, comprehensive and advanced, open IoT platform where networking technologies and cloud services dynamically integrate fixed and nomadic devices and mobile wearables in the physical world with automated closed-loop actuating functions. The platform also integrates humans in the loop, where appropriate, by providing situational awareness and dynamic decision support tools. A strong toolbox for security and trust management complements the platform.

The MONICA IoT Platform is built on several IoT physical world network infrastructures and a closed loop control system for each application. The components are connected via dedicated communication network and data repositories. The platform is able to support multiple IoT applications in a wide usage context focusing on the two most important challenges for organisers of large-scale concerts and cultural events in large cities: Unwanted noise in the surroundings and security of the audience.

The MONICA IoT platform consists of six different solutions; each of them providing different technical features:

The MONICA Sound Level Monitoring solution provides real-time monitoring of sound levels with accredited sound level meters enabled for use in IoT applications and also perform real-time sound analysis:

- Measures and stores historical sound level parameters measured within a specified time interval in steps of one second.
- Makes analysis of sound streams from outdoor events and estimates the contributions from concerts, audience, traffic, etc.
- Enables the computation of a sound density distribution (heat map) across a pre-defined area.
- Provides an interface to an Open Data environment or a standard Content Management System so that sound and noise data can be made available to the public.

The MONICA Adaptive Sound Field Control solution is an active sound control system that can optimise sound field in the audience area while reducing the sound levels in neighbouring areas with up to 10dB:

- Deploys additional loudspeakers pointing towards the area where noise reduction is needed thereby creating the sound level reductions.
- Uses accurate, adaptive sound propagation models for the venue based on measurements of sound levels, wind speeds and weather data, to control the secondary sources (loudspeakers).

The MONICA Crowd and Capacity Monitoring solution facilitates the collection of important information about crowd size, flow, object detection as well as early warning of security and safety threats:

- Interfaces to a wide variety of sensors and components which can be deployed for different purposes related to crowd behaviour, security and safety of visitors.
- Connects to CCTV cameras and advanced video analytics such as people counting, crowd density estimation, human and object detection, crowd flow.
- Connects to wearables (wristbands, smart glasses, GPS trackers) and IoT sensors (wind speed, noise and other environmental parameters)

The MONICA Crowd Management and Communication solution is a cloud-based, closed-loop management solution that provides a real-time operational picture with decision support and means for communication among staff members:

- Contains the Common Operational Picture (COP) as the main interface for providing human professional operators knowledge of the event performance.
- Contains the Decision Support System (DSS) that provides recommendations and proposes actions for the human operator intervention
- Facilitates real-time visual, audio and written communication between staff on-site and the control centre. Devices applied cover smart glasses, IoT staff wristbands and staff tracker.

The MONICA Collective Awareness Platform that displays noise related data and information for the citizens and facilitates co-creation of solutions:

- It can be integrated with any Content Management System such as WordPress, SiteCore, Joomla etc.

- It can also be integrated with Participatory Budgeting platform such as Consul

The MONICA Visitor Experience Apps consist of digital applications for greater enjoyment and quality of participating in events:

- Event apps can be customised to provide event-related information and can be integrated with the IoT wristband for location service and friend connect features.
- Can leverage on the wireless communication system that connects the wristband to create heat maps of crowd densities

4.1 Scenario descriptions

4.1.1 Challenges

MONICA addressed two very different challenges: the preservation and promotion of European culture and how to make IoT networks sufficiently developed to handle large-scale deployment.

A pinnacle in the European way of life and our whole society is precisely the love for culture; developed and refined over many centuries; effectively diffused to the most remote part of our continent; appreciated by all age groups; recognised in one form or the other by all citizens of Europe. The “European Culture” takes many forms and is expressed in millions of ways. MONICA focused on one of the key aspects of European Culture: The cultural performances in open-air settings, with special focus on musical expression. However, this arch-European cultural element is coming under pressure for the reason of safety or because of rising property costs in inner cities that made the neighbours less positive towards noise and congestion from open air concerts. On this background, the MONICA project has delivered a large-scale IoT platform with applications that fully supports all Smart Living themes and supports the preservation and promotion of European culture.

The Internet of Things is revolutionising the industrial ecosystems and the way industrial products and services are created and delivered and huge IoT sensor networks are deployed to manage and automate manufacturing plants and logistic processes. The Internet of Things is also increasingly being deployed to solve major societal challenges. However, most of the IoT and Smart City platforms are still insufficiently developed to handle really large-scale deployment. In response to this challenge, the MONICA platform is a resilient IoT platform and uniquely innovative since it demonstrates a large uptake of a multitude of IoT applications using low-cost wearables and apps with closed feedback loops to actuating networks and human interaction and intervention based on situational awareness and decision support.

4.1.2 Benefits

The MONICA IoT Platform features a number of benefits for developers and system integrators, who wish to develop an IoT network for advanced IoT solutions, e.g. for smart cities. The specific benefits are:

- A layered architecture with a substantial number of subsystems performing tasks.
- A high-level IoT network infrastructure which provides privacy and security for the information shared between the IoT devices, sensors and other IoT devices communicating with the network infrastructure.
- A middleware platform (the IoT Layer) simplifies the integration of a huge number of heterogeneous IoT devices and wearables considered in MONICA.
    - A SCRAL (Smart City Resource Adaption Layer) exposes interfaces for data coming from multiple gateways.
    - The LinkSmart middleware modules subscribe to data for further processing. LinkSmart provides IoT data storage, event forwarding, and directory services for locating the available IoT devices and IoT services.
- A semantic framework comprising conceptual data models focused on the semantic virtualization of both IoT resources and services employed in the project.
- An IoT-Resources-Ontology (IRO) where IoT Platform services, wearables & sensors etc. are exposed in semantic representation of functions, properties and categories. A Semantic Sensor Network Ontology (SSN developed by W3C group) is chosen for the IRO development because of its strong focus on addressing the issues of interoperability at sensor level within smart city contexts.

- A Cyber Security and Privacy Framework, enabling trust-based communication, policy management and technical support across all levels of the platform.

Availability of the MONICA Development Tool Box with Open Source components and Docker images of various representative solutions from the MONICA project.

4.2 Technical aspects

4.2.1 Technical concept

Conceptual Overview

The MONICA platform is a cloud based, advanced, open IoT platform with automated closed-loop actuating functions (see Figure 1). The platform dynamically integrates devices and mobile wearables in the physical world with automated closed-loop feedback functions. The platform also integrates humans in the loop by providing situational awareness and dynamic decision support tools. The platform supports multiple IoT applications in a wide usage context focusing on the two most important challenges for organisers of large-scale events in cities and urban: Unwanted noise in the surroundings and security of the audience.

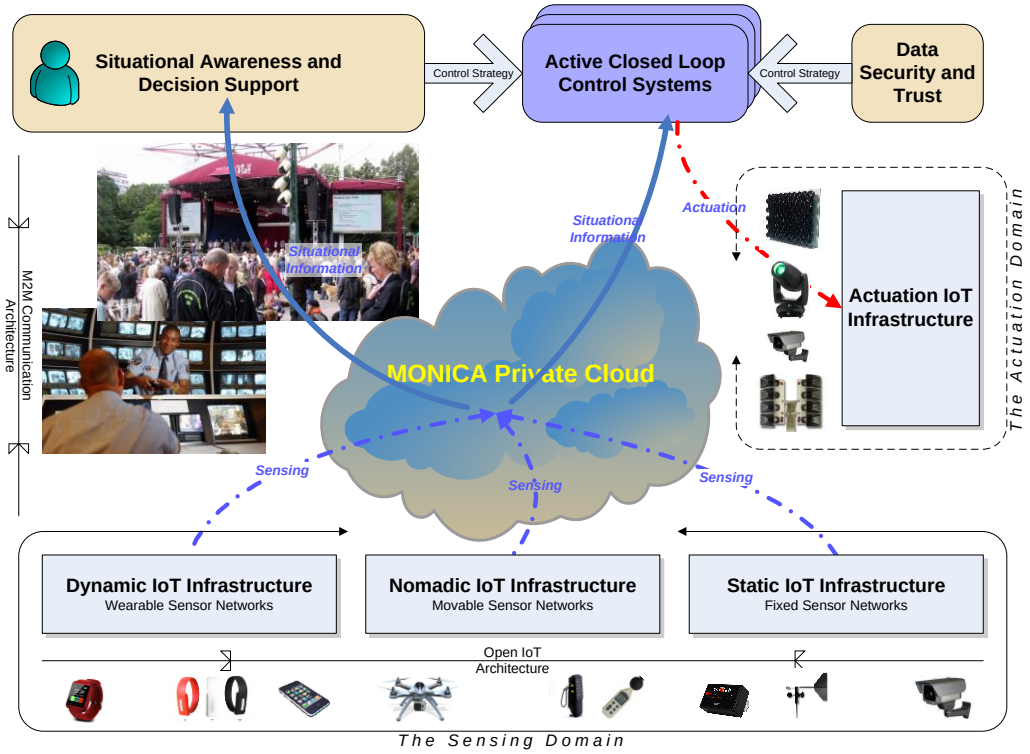

Figure 1: The MONICA platform

The MONICA platform is built on several IoT physical world network infrastructures and a closed loop control system for each application. The components are connected via dedicated communication network and data repositories. Some solutions cover with data capture from the physical world with analysis and transmission of information to the MONICA private cloud service. Other solutions deal with providing situational awareness from the information, decision support and feedback/actuation back to the physical world.

Functional View Architecture

The functional in **Error! Reference source not found.** view gives an overview of the architecture and its main c omponents, including main functionalities, interfaces and interactions. Taken all the components together, it demonstrates how the entire platform performs the functions needed by MONICA solutions and how it meets the related requirements.

The functional view is the result of the collection and categorization of technologies and software components provided by the MONICA partners and based on application requirements from the users.

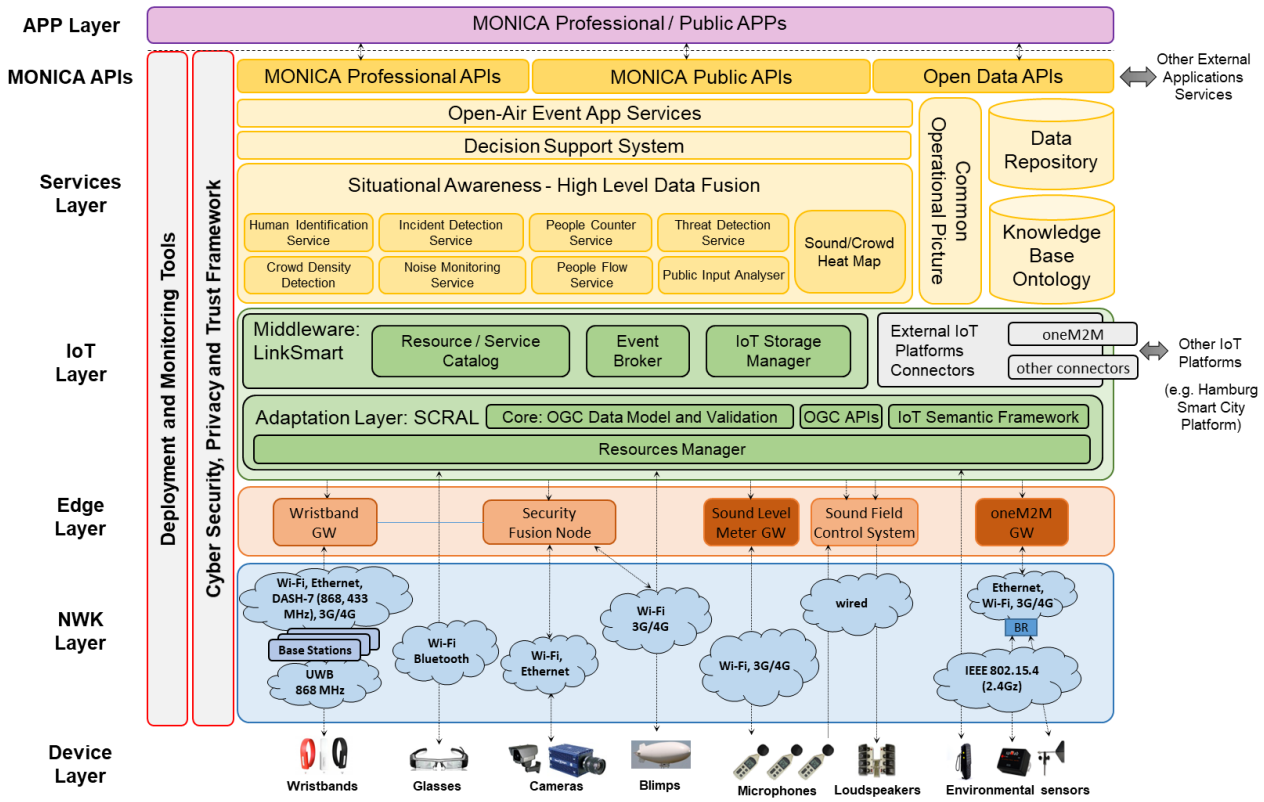

Figure 2: Functional View of the MONICA Platform Architecture

The architecture comprises the following subsystems, also called layers:

- The ***Device Layer*** includes all IoT wearables (*e.g.*, wristbands and glasses) and IoT sensors, which can be fixed (*e.g.*, sound level meters, loudspeakers, cameras, environmental sensors) or mobile (*e.g.*, wireless sound level meters, cameras installed in a Blimp).
- The ***Network Layer*** allows the effective communication between the heterogeneous IoT wearables, IoT devices and the IoT platform modules. This layer is responsible of forwarding data coming from the IoT wearables and IoT sensors as well as of responding to service requests coming from upper layers;
- The ***Edge Layer*** includes a set of processing modules (*e.g.*, the Wristband GW running localization algorithms, Processing Units executing video-based algorithms, the Sound Field Control System (SFCS) for managing the sound quality and noise reduction) that process real-time data directly from the *Device Layer*. To this purpose, these modules need to be deployed locally in the pilot site to avoid the latency introduced by the upper layers of the platform. Moreover, these modules require an efficient and scalable Network Infrastructure.
- The ***IoT Layer*** is composed of the following three subcomponents:
    - The *Adaptation Layer*, here represented by the SCRAL, providing technology independent management of physical resources and uniform mapping of data into standard representations that can be easily handled by the upper platform modules;
    - The *Middleware*, here represented by the LinkSmart, which offers storage and directory services for resources registered in the IoT platform;
    - The *External IoT Platform Connectors*, handling the communication with external IoT platforms and the integration of data coming from outside (*e.g.* from the Hamburg Smart City platform). In addition, MONICA integrates the oneM2M interface allowing the platform to expose the IoT data according to the oneM2M standard;
- The ***Services Layer***, where the intelligence of the platform is implemented and specific processing modules are integrated to provide technical solutions compliant with the application requirements. The services modules are combined together with knowledge base components and decision support

tools, whose aim is to propose a set of intervention strategies to assist human operators in gathering context-sensitive information and decision making;

- The ***MONICA APIs Layer***, which provides service access points for MONICA application developers and external application developers that want to access MONICA functionalities and information streaming from the platform;
- The **Cyber *Security and Privacy Framework***, enabling trust-based communication, policy management and technical support across all levels of the platform. More specifically, this framework ensures secure data flows and storage, protected information exchange and trusted federation mechanism to facilitate private information sharing;
- The ***Deployment and Monitoring Tools.*** These tools belong to a transversal framework able to make the platform deployment easy (*e.g.* modules belonging to the *Device* and *Network* layers) and used for checking the operational status of the devices, networks and overall system. Moreover, these tools are also used for measuring performance metrics and tracing pilot events.

The platform architecture has been defined based on the HLA developed by the Working Group 3 (WG3) of the AIOTI. The WG3 last updated the HLA in June 2017 (AIOTI HLA, 2017), which at the same time is described using the ISO/IEC/IEEE 42010 standard (ISO/IEC/IEEE 42010, 2011). Related documents to the HLA defined by the WG3 are available at https://aioti.eu/aioti-wg03-reports-on-iot-standards/. The MONICA functional architecture has been mapped to the HLA, which describes functions and interfaces (interactions) within the IoT domain.

Deployment View Architecture

The deployment view shown in Figure 3 describes how the MONICA platform is deployed on the field with concrete platforms (e.g., base stations, cameras, sound level meters, embedded systems running real-time processing algorithms, cloud Infrastructure) and concrete execution environments (e.g., SCRAL, LinkSmart, DSS).

The deployment view focuses on aspects of the system that are important after the system has been tested and is ready to go live. More specifically, this view defines the physical environment in which it is intended to run, including:

- required hardware environment (e.g. processing nodes, wristband GWs, network interconnections, etc.);
- technical environment requirements for each node;
- mapping of software elements to the runtime environment;
- third-party software requirements;
- network requirements.

The deployment view needs to document the required deployment environment of the MONICA platform, which depends on the pilot areas.

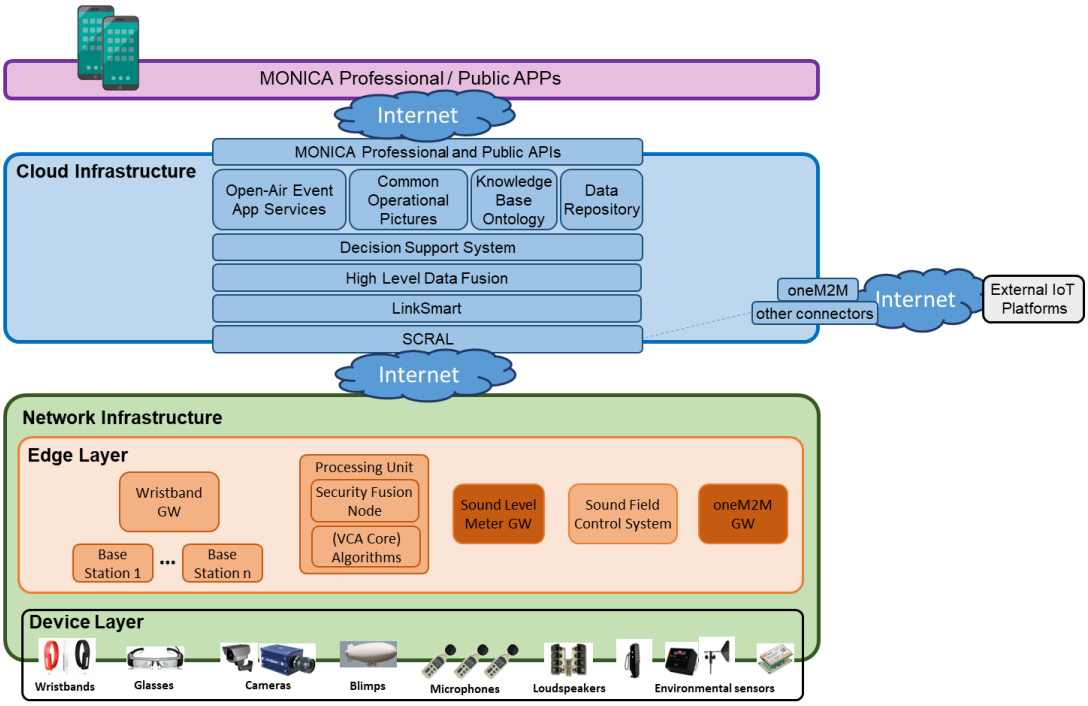

Figure 3: MONICA High-Level Deployment Architecture

Starting from the bottom, firstly, there are the wearables (i.e., wristbands and glasses), which are battery powered, running their intelligence in small and low power microcontrollers; then there are IoT devices, which can be fixed or mobile, such as cameras, blimp and microphones that are equipped their own processing module. Thanks to the Network Infrastructure, the IoT devices and wearables communicate their data to the Edge Layer, which includes some modules for further real-time data processing.

All the data processed in the Edge Layer are sent upward to the IoT Platform thanks to the Network Infrastructure. It is worth mentioning that the *SLM-GW* and the *oneM2M-GW* are not deployed in the pilot area because these are already deployed in their own cloud solutions managed by B&K and Telecom Italia, respectively.

The MONICA Cloud Infrastructure provided by Atos is hosting the IoT platform (composed of the SCRAL and LinkSmart middleware), the DSS, the HLDF, the Open-Air Event App Services, the Data Repository, the COP and the MONICA APIs.

4.2.2 Communication

The *High-Level Network Infrastructure* is made up of physical hardware, logical software and other peripheral resources of an entire network that provides network communication, connectivity, operations and management of an enterprise network. It provides secure communication paths and services between application service processes and internal or external networks through Intranet or Internet communication via virtual private network (VPN). It offers the same functionality as to any network infrastructure once it is deployed with the aim to provide connectivity and secure communication paths for all IoT wearables and IoT devices.

The MONICA IoT Platform addresses communication issues of scalability, reliability, interoperability, bandwidth/data rate and availability. The different types of IoT connectivity network topologies that can be handled by the MONICA architecture are the following.

1. A point-to-point network infrastructure is a simple form of network infrastructure. The network can be established directly between two sensors or a sensor and network node gateway which then connects to the internet.
2. A star network infrastructure is where every sensor node is connected to a single central hub which is also known as gateway node. The nodes are able to communicate with each other via the central hub. Thus, all other minor nodes may communicate with all others by receiving from and transmitting to the central hub.

3. A mesh/Hybrid network infrastructure is a network infrastructure where many sensor applications require a long range and broad area coverage. A mesh network infrastructure is deployed where all sensors are within the transmission range and can use any path to get to its destination without data loss.

The aim of the communication infrastructure is to provide a broad area network coverage for: (i) the low power low data rate IoT wearables, (ii) the high data rate IoT devices such as IP-cameras and (iii) the low data rate IoT sensors such as the Environmental Sensors.

The IoT wearable communication is ensured by the *Wearable Network Infrastructure* while the *High-Level Network Infrastructure* instead provides connectivity for the (i) high rate IoT devices, (ii) the Wearables GW and (iii) the GWs for the low data rate IoT sensors. The general deployment view of the overall network infrastructure topology is provided in Figure 4.

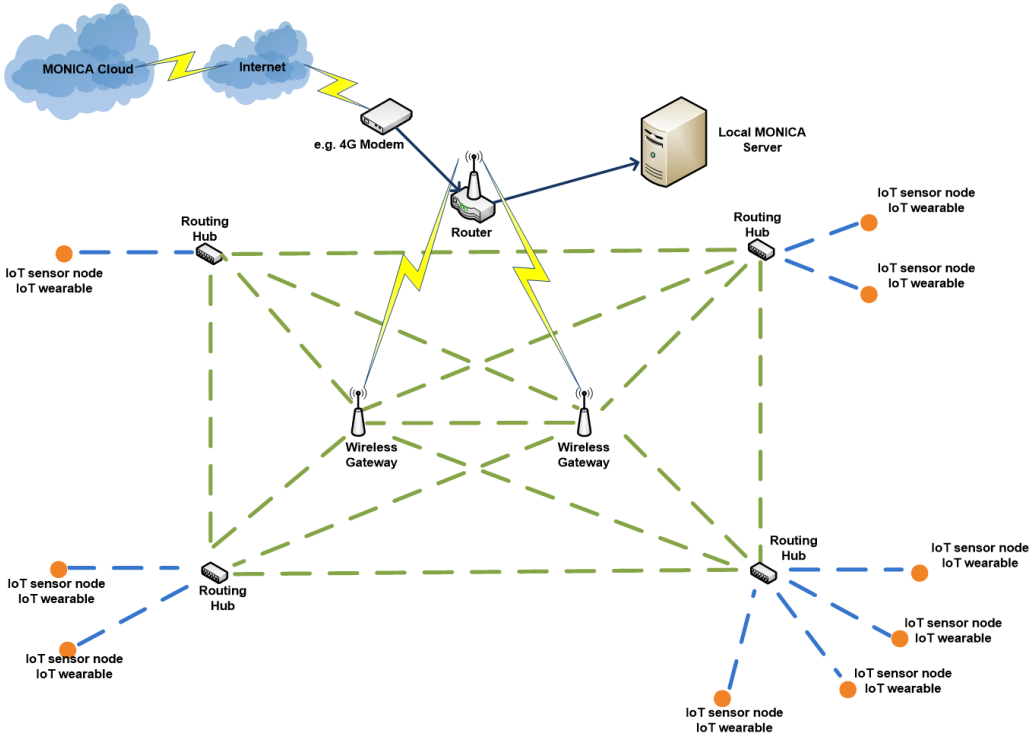

Figure 4: Generic View of the Overall Network Infrastructure Deployment

The blue dash lines in the figure show the communication paths between the IoT wearables/sensors and Routing Hubs devices, which have routing capability. These *Routing Hubs* connects also wireless SLMs and processing modules of the *Edge Layer* (e.g. *Wristband-GW*, *Processing Unit, SLMs*).

The green dash lines instead show the communication paths between the Routing Hubs and the Wireless Gateways. This part of the network corresponds to the High-Level Network Infrastructure. The Routing Hubs select the best path for the communication of the modules belonging to the Edge Layer modules with the IoT Platform deployed in the MONICA Cloud. The number and locations of the Wireless Gateways strongly depend on the specific pilot area. The wireless access points mainly rely on the Wi-Fi standards IEEE 802.11 (a, b and g) with frequency range between 2.4GHz and 5GHz. In addition, 4G modems might be required for the Internet connectivity in case a more reliable Internet service access is not available in the pilot site.

The communication among the different MONICA components in the Service Layer is enabled by means of the "*Event Broker*" sub-component offered by the LinkSmart framework. An Event Broker provides a message bus for efficient asynchronous communication of sensor data streams implementing the publish/subscribe communication pattern. The Message Queue Telemetry Transport (MQTT) protocol is recognized as the de-facto standard for Publish/Subscribe communication in the IoT messaging domain. As a Publish/Subscribe protocol, MQTT provides several features like topic wildcards, different level of quality of service, retained messages, last will and testament, and persistence sessions.

4.2.3 Integration

N/A

4.2.4 Scalability

N/A

4.2.5 Associated MONICA solutions

Associated MONICA solutions

The MONICA Platform Architecture and Components supports the following MONICA solutions:

- The MONICA Sound Level Monitoring
- The MONICA Adaptative Sound Field Control solution
- The MONICA Crowd and Capacity Monitoring solution
- The MONICA Crowd Management and Communication
- The MONICA Collective Awareness Platform
- The MONICA Visitor Experience App

4.3 Implementation

4.3.1 Installation

Preparation

The planning and preparation of the MONICA Platform Architecture and Components are done in connection with the planning of the installation of individual solutions. Please consult the applicable partner responsible for the solution.

Deployment

The deployment of the MONICA Platform Architecture and Components are done in connection with the planning of the installation of individual solutions. Please consult the applicable partner responsible for the solution.

Operation

MONICA deployment and monitoring tools are available to ease the platform deployment and may be used for checking the operational status of devices, networks and overall system behaviour. These tools are also used for measuring overall performance metrics.

The operation of the MONICA Platform Architecture and Components are done in connection with the planning of the installation of individual solutions. Please consult the applicable partner responsible for the solution.

4.3.2 Regulatory aspects

Technical regulations

The following IoT “horizontal standards” have been adopted in the MONICA IoT Platform:

Architecture

- ISO/IEC/IEEE 42010:2011

Device/NWK Layer

- Bluetooth BLE
- Wi-Fi – IEEE 802.11
- UWB – IEEE 802.15.4a
- ETSI EN 302 065-2 V2.1.1 for staff wristbands (UWB)
- ETSI EN 300 220-2 V3.1.1 for crowd wristbands (868MHz)
- IETF 6LoWPAN / IETF ROLL / IETF CoAP
- OASIS MQTT

Ontology

- ETSI SAREF

Security

- IETF Oauth / OASIS XACML

IoT Platforms

- oneM2M

Data format

- OGC SensorThings API

Other standards and norms have been adapted in the individual MONICA solutions.

Other local/national regulations

There are no specific national regulations related to the MONICA architecture itself. The regulations are related to the individual solutions running on the platform.

Ethics

There are no specific ethical considerations related to the MONICA architecture itself. The considerations are related to the individual solutions running on the platform.

4.4 Business aspects

4.4.1 Revenue models

The following information is solely provided as a guide to the expected business conditions that the MONICA Components might be provided at. Please contact the responsible partner for further, up-to-date details (see section 4.5.4).

Components	Type	Anticipated revenue model
MONICA Cloud Infrastructure	Cloud service	Can be replicated as a customised solution for other IoT applications with closed loop feedback functionalities. The Platform Core Enabler is available as a Platform as a Service (PaaS) solution, extended by integration services of the appropriated auxiliary enabler(s). Planning service is always required as an additional one-off charge.
MONICA Network Infrastructure	Network service	Can be replicated as a customised solution for other IoT with closed loop feedback functionalities.
MONICA Development Tool Box	Open Source Software	The MONICA Development Toolbox contains software developer tools, Generic enablers and third-party tools.

4.4.2 Business models

No business models have been created for the MONICA Architecture and Components itself. The MONICA solutions are the subjects of exploitation and the business models have been created for each solution only.

4.5 Potential for replication

4.5.1 Lessons learned

No lessons learned has been specifically collected for the MONICA Platform Architecture and Components.

4.5.2 Usability aspects

4.5.2.1 Acceptance of MONICA solutions

N/A

4.5.2.2 Effectiveness of MONICA solutions

N/A

4.5.3 Reproducibility

Reproducibility means that a MONICA solution (including data sets, software code, etc) can be made available to others for reproducing the same results.

Software components of the MONICA Platform are made available by the MONICA Development Toolbox (developed within WP7, D7.6) allowing developers to rapidly reproduce specific use cases and also develop new applications on top of the MONICA Platform. The Development Toolbox consists of a set of platform components and tools as well as a set of tutorials and guidelines.

Given a specific use case, the involved components are integrated and interconnected among them according to the defined MONICA Platform architecture. The toolbox can be used to integrate various resources into the IoT platform and hides the complexity of the communication with IoT devices.

In particular, data from the *Device Layer* can be sent to the IoT Platform by a tool called Replayer that replays real observations stored in databases from pilot events. Alternatively, some software emulators can be used like the Wristband Emulator that generates wristband positions and sends the wristband messages to the IoT platform. Other MONICA components and tools made available by the Toolbox are: the HLDF, the DSS, and the tools related to the COP, which allow the user to reproduce the COP and test the COP user interface, the COP APIs and the COP databases used for storing the state of the COP.

4.5.4 Contacts

The following partners are responsible for various components of the MONICA Collective Awareness Platform solution:

Solution	Responsible	Acronym	Details
MONICA Cloud Infrastructure	Atos	ATOS	ATOS can replicate the cloud infrastructure in the appropriate structure and provide the integration of the MONICA components (acting as the system integrator) and offer the best structure (SW and HW as the service or purchase of the equipment – contemporary installations).
MONICA Network Infrastructure	Rinicom	RINICOM	RINICOM can replicate some of the MONICA IoT network infrastructure components
MONICA Cloud Infrastructure	CNet Svenska AB	CNET	CNET can replicate some of the MONICA Cloud components
MONICA Development Tool Box	CNet Svenska AB	CNET	CNET can provide support for using the MONICA Development Tool Box
MONICA IoT Platform	LINKS	LINKS	LINKS can replicate some of the MONICA IoT Platform components

5 Crowd and Capacity Monitoring

The MONICA Crowd and Capacity Monitoring solution is used by Smart City organisers, event organisers, security staff and first responders to monitor crowd behaviour and manage security at large events, e.g. to mitigate security and safety risk or annoyance.

This MONICA solution complements the MONICA Crowd Management and Communication solution. Combined they represent a comprehensive, closed loop solution for gathering information on crowd behaviour and event risks in real-time and presenting such information in the relevant context as decision support for those entrusted with total management of large events.

The MONICA Crowd and Capacity Monitoring is an on-site solution consisting of a series of components which can be deployed for a variety of purposes using CCTV cameras, wearables and advanced video analytics. The solution hence collects important information about crowd size and flow (crowd counting), advanced object detection, including vehicle detection as well as early warning of security threats. Providing this information to the MONICA Crowd Management and Communication solution allows security staff to obtain enhanced, contextual real-time oversight and decision support for interventions.

The specific features of the MONICA Crowd and Capacity Monitoring solution are:

People counting: CCTV cameras incorporating advanced video analytics are used to accurately count the number of people entering and leaving a specific area through one or more gated entrances. It is primarily used to identify the potential risk of overcrowding, but can also be used for statistical purposes, timelines of crowding, etc.

Crowd density: Advanced video analytics is used to estimate crowd size and density from the CCTV footage and results are shown as a real-time heat map on the MONICA Common Operational Picture (COP) in the control room. The information can be used to locate high density areas, so that the event organiser can take precautionary measures to avoid unattainable crowd build-ups during the event. Crowd density can also be accomplished by having visitors wearing low-cost wristbands which allows for anonymous localisation of visitors in the event area.

Human and object detection: Computer based object detection algorithms are used to identify and detect more than 100 different kind of objects in real-time, including humans and vehicles. It can be used for intervention, elimination of security threats and/or redirection/elimination of potential, emerging security threats.

Crowd flow: Using the crowd density and object detection algorithms, early warning of security threats, such as overcrowded, high-risk queues, fights or health incidents, can be achieved and immediate actions can be initiated by the security staff and first responders e.g. using the MONICA Crowd Management and Communication solution. Interventions can be in the form of security or first responders' interventions or redirection of visitors to safer areas.

Staff tracking: The positions of stewards and other staff deployed in the event area can continuously be tracked and reported to the MONICA COP. Control room staff can then, at any moment, view the different positions of staff on the ground and obtain an overview of available resources in case of incidents or other interventions. Tracking can be performed with staff wristbands or with dedicated GPS tracking devices.

Mobile video and audio recordings: Smart Glasses, worn by the staff in the field, are able to record video and audio incidents directly from the scene and send them, in real-time, to the control room for decision support and intervention. The glasses have two-way communication capabilities.

5.1 Scenario Descriptions

Monitor crowds based on capacity:

This scenario enables the involved actors to successfully monitor crowd levels for the purpose of ensuring that the venue of the event does not have more visitors than the allowed capacity. The involved actors are Security staff and Control room staff.

Detect high-risk queues:

In this scenario, the system detects high-risk queues and the staff member is informed. An overview of the situation is shown in the COP in the control room.

Re-direct high-risk queues:

In this subsequent scenario, the staff member is advised by the Control room to re-direct the high-risk queue via text message, using their preferred MONICA-enabled device, e.g., staff wristbands or smart glasses.

Manage crowds based on capacity:

When visitors have to be redirected, the MONICA communication support applications simplify coordination between staff members and the control room for faster reaction to remedy the situation.

5.1.1 Type of Event

The MONICA Crowd and Capacity Monitoring solution can be used at any type of gated or non-gated open-air event, e.g., concerts, festivals or sport events.

- Musical events, outdoor concerts
- Street festivals, open-air markets
- Sporting events
- Restaurant and night-life areas
- Streets and areas with heavy traffic

It can be used for short term deployment (e.g. for a specific concert); for a recurrent event (monthly or seasonal) or for semi-permanent events (night life area, traffic).

5.1.2 Challenges

A smart city is a lively city; a cultural city; a city worth living in. A pinnacle in the European way of life and our whole society is precisely the love for *culture*; developed and refined over many centuries; effectively diffused to the most remote part of our continent; appreciated by all age groups; recognised in one form or the other by all citizens of Europe.

However, in the last two decades the need for enhanced security measures during the numerous city events is sadly increasing, due to the risk of terrorism; open air events are often attended by thousands of people, so crowd management and mitigation of annoyance is becoming a major challenge requiring advanced ICT tools.

The challenges of crowd monitoring in open-air events are mostly related to:

- monitoring and managing the crowd itself: Mass panic, overcrowded spaces, lost persons, unauthorised vehicle in the event area, bottlenecks with high-risk queues;
- lack of proper technology: Unreliable communication tools, limited or missing network and Internet access;
- the venue: Narrow access gates, complex street topology, poor lighting and visibility.

The MONICA Crowd and Capacity Monitoring solution provides a comprehensive tool for overcoming these challenges.

5.1.3 Benefits

The MONICA Crowd and Capacity Monitoring solution provides a comprehensive and cohesive set of tools to capture and store situational awareness information of crowds and staff. It will greatly help event organisers to manage crowds in real-time during the event and support post-event investigations. The specific benefits of MONICA Crowd and Capacity Monitoring solutions are:

- Provide full overview of the crowd levels in different areas
- Prevent exceeding capacity limits
- Predict critical situations and high crowd density
- Detect abnormalities within a crowd
- Report abnormalities instantly and accurately with images
- Identify and report objects such as vehicles
- Maintain all safety levels during and around the event including e.g. wind strength

- Facilitate safe and quick entry to and exit from the event area

5.1.4 Stakeholders for the MONICA Solutions

Event organiser: Person in charge of managing budget, logistics and external stakeholders that are part of the event. Responsible for assuring the success of the event at a practical level.

Cities: Cities (or municipalities) involved in monitoring facets of public life and interacting with their citizens.

Security staff: Personnel in charge of monitoring the event area and keep it safe. This may include local authorities, e.g., the police.

Control room staff: In charge of guiding security and emergency activities for the event, supporting the coordination and direction of activities to deal with incidents.

Solution developers: Persons responsible for adapting/integrating the selected MONICA solution(s).

Event volunteers: Volunteers are often first responders to visitors.

5.2 Technical Aspects

The MONICA Crowd and Capacity Monitoring solution uses commercially available CCTV cameras in combinations with specific, high performance algorithms and communication infrastructure developed by MONICA partners. The solution also uses commercially available wearables such as smart glasses, wristbands, GPS trackers, wind sensors and noise monitors to collect additional information about event crowds and environmental conditions. Although almost all IoT devices are commercially available off-the-shelf devices, they have been enhanced and additional features have been added by the MONICA partners.

5.2.1 Technical concept

The MONICA Crowd and Capacity Monitoring solution is built on several IoT capable network infrastructures. Some components are also connected via dedicated communication network and data repositories. The entire solution is embedded in a MONICA Private Cloud structure as described in the MONICA Platform Architecture and Components.

The MONICA IoT Infrastructure is capable of handling three different types of IoT devices: i) fixed sensors and fixed Cyber Physical Systems, ii) “nomadic” devices and iii) wearable devices.

- Fixed sensors and Cyber Physical Systems comprise devices mounted on fixed structures in and around the event area, e.g. cameras.
- “Nomadic” devices are quasi-mobile devices confined to the event area, such as IoT sound level meters and other sensors (e.g. temperature, wind, etc.). Cameras can also be nomadic, when mounted on controllable airships.
- Wearable devices include wristbands, glasses and mobile phone apps. Crowd wristbands are worn mainly by the spectators while staff wristbands and smart glasses are intended for the staff.

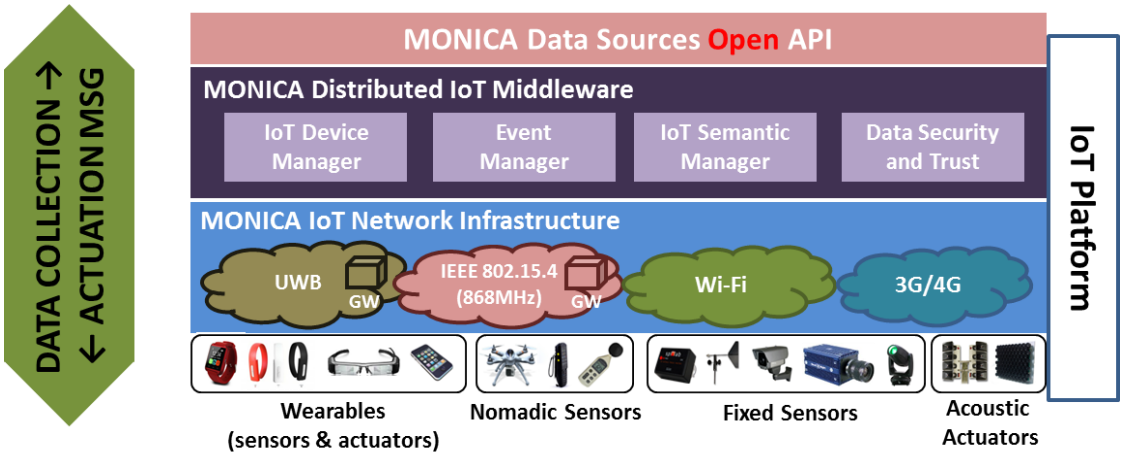

Figure 5: The MONICA IoT Platform

The MONICA Crowd and Capacity Monitoring solution uses commercially available CCTV cameras in combinations with specific, high performance algorithms and communication infrastructure developed by MONICA partners. The solution also uses commercially available wearables such as smart glasses, wristbands, GPS trackers, wind sensors and noise monitors to collect additional information about event crowds and environmental conditions.

Although almost all IoT devices are commercially available off-the-shelf devices, they have been enhanced and additional features have been added by the MONICA partners.

The technical concepts in the *video part* of the MONICA Crowd and Capacity Monitoring solution consists of: a) video capture with CCTV cameras b) one or more embedded algorithms for feature analysis and c) server communication management tools.

Camera processing: Cameras are used for analysing crowd behaviour and density in real-time. Standard CCTV cameras are equipped with embedded analytics in two main modalities: monocular (regular CCTV cameras), and time-of-flight. Each camera type offers a range of video analytics with varying accuracies. This core camera framework (VCAcore) pre-dates the MONICA project, but it has been extended as part of the project to allow analytics developed by other partners as well as integration with the MONICA cloud layer. The MONICA version of the framework comprises the camera platform, the various algorithms that perform analysis, and software (Security Fusing Node - SFN) that manages data from VCAcore to the cloud.

The specific *analysis and detection features* implemented in the MONICA Crowd and Capacity Monitoring solution are:

Crowd density estimation: Crowd density estimation focuses on providing a single crowd count for a scene, avoiding the complications of localization and identification of individual persons. This count is based on the ability to estimate the size of groups of people and then summing those detected groups to return a final count. This strategy allows for better handling of occlusions and low resolution that is often present in surveillance camera data. It is usually achieved by summing over the map to provide the final count.

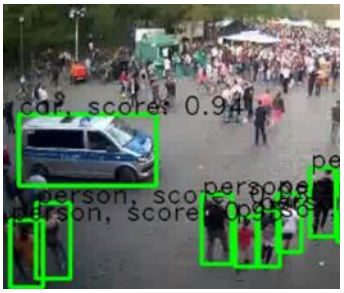

Figure 6: Human detection

Human and object detection: The human and object detection framework is based on feature extraction using a type of neural network called Convolutional Neural Network (CNN). In machine learning, a convolutional neural network is a class of deep, feed-forward artificial neural networks that has successfully been applied to analysing visual imagery. The CNN is followed by region proposal and region of interest (RoI) classification. The entire system is a single, unified network for object detection. Using “attention” mechanisms, a Region Proposal Network module tells the neural network where to look for objects of interest.

People counting: VCA provides a more general-purpose people counting analytic that functions on standard CCTV footage. This analytic is available as a commercial product and also as a pre-integrated analytic in VCA’s video processing framework. This people counting analytics can process video data from regular monocular cameras and can thus be applied to sites where the cameras are already installed.

Fight detection: The aim of this algorithm is to provide means for the real-time detection of fighting events in video streams. A fast detection algorithm has been implemented for human tracking, which used the detections of the previous component (human detection) in order to initiate new tracks and validate/rectify existing ones. A range of approaches were implemented for actual event recognition, each one composed of a different combination of feature extraction processes and classification schemes.

In addition to the features provided by cameras and video processing, the MONICA platform contains a number of wearable devices that can be used, either as standalone crowd or personal monitoring devices, or in connection with two-way communication means between control room, staff and visitors.

The technical concepts in *the wearables part* of the MONICA Crowd and Capacity Monitoring solution consists of: a) Wristband for staff localisation and communication, b) wristbands for anonymous. mass localisation of visitors, c) Smart Glasses for mobile video and audio capture and d) GPS tracking devices for staff localisation.

Staff wristbands: Sendrato staff wristbands provided by DEXELS are used for two-way communication between control room and the stewards in the field. The wristbands use Ultra-Wideband (UWB) two-way communication and incorporate a LED screen for user interaction. UWB-based geometrical localization is used

for positioning. The infrastructure is comprised of anchors, tags, a network router, a network switch and a server running the location engine and configuration software. A browser is used to setup and monitor the system which can run on anything from a PC, a tablet to a smartphone.

Figure 7: Staff wristband

Crowd wristbands: Low-cost Sendrato wristbands provided by DEXELS are used for location of wearers in defined spaces. The wristbands are equipped with LED displays and narrow-band radio (868/900MHz) technologies. Base stations are placed around the venue and used to determine location to be displayed on a heatmap. The button can be used to collect user input from the visitors ("Likes", voting or "Friend-Connect"). The material could be a leather bracelet, a textile wristband or a silicon wearable.

Figure 8: Smart glasses

Smart glasses: The Smart Glasses from OPTINVENT are used in MONICA. They have been tailored with an app (Monicora) in order to facilitate communication with the MONICA COP and present the user feedback for the person wearing the Smart Glasses. The app provides real time exchange between the COP and other stewards in the field to improve security interventions and report incidents. A user interface is superimposed on the glass itself with a menu of actions that can be performed with a Bluetooth joystick. The glasses can send and receive video files, take pictures and record audio, and display messages from the COP.

GPS staff tracking devices: Location information (Longitude and latitude) of a steward, volunteer or other staff is continually collected using a MONICA GPS tracking module. The tracking devices upload the data via a LoRa communication network. The data is stored in an OGC Sensorthing server. The data model follows the OGC Sensorthings specification (Version 1). Once the database user has the knowledge of the device then corresponding "Thing" can be located, followed by corresponding "Data stream" which points to the observations.

The technical concepts in *environmental sensors* of the MONICA Crowd and Capacity Monitoring solution consists of: a) IoT enabled Sound Level Meters, b) wind sensors for detection strong winds during events.

Sound Level Meters: IoT enabled accredited sound level meters provides real-time monitoring of sound levels at discrete outdoor locations. They are enabled for use in Internet of Things and is easy to deploy. They collect data in real-time and sends them directly to cloud storage. They can also perform real-time sound analysis so that sound contribution levels from different sources can be separated. More details are provided in the MONICA Sound Level Monitoring solution.

Environmental Sensors: Sensors are used for measuring weather (wind, temperature and humidity) needed in the MONICA Adaptive Sound Field Control solution. Single wind sensors (anemometers) are used to detect wind speed for increased safety of roller coasters, scene gear, and event infrastructures. Sensor nodes could easily be integrated with the MONICA cloud standard interfaces – e.g. the SCRAL middleware and the One M2M gateway – using open standard IoT technologies, protocols and software. The sensors transmit sensor data to the MONICA Cloud and on the MONICA COP.

5.2.2 Communication

The MONICA Crowd Capacity and Monitoring solution uses a broad range of communication network infrastructures and protocols, each suited to a specific part of the internal and external communication infrastructure.

Cameras: CCTV cameras include in the MONICA cloud layer framework which facilitates integration of video sensor analytics into the MONICA cloud layer. The cameras use Ethernet (PoE) LAN networks to connect to the control room. The cameras can send video and alerts in a range of formats such as HTTP, TCP, SMTP for integration into other layers of the MONICA platform. Video is streamed in a range of formats including MJPEG over HTTP and H.264 over RTSP/RTP.

The Short Range Communication (SRC) devices use a variety of different protocols:

Smart glasses: Use WiFi b, g, and n protocol @ 2.4GHz for communication, Bluetooth 4.0 Low Energy for user handling, and µUSBS 2.0 for charging, data exchange and transporting mono audio to an audio headset accessory.

Staff wristbands: Use UWB (Ultra-Wide Band) communication for positioning and communication.

Crowd wristbands: Use 868Mhz networks and proprietary communication protocols for positioning and communication and RFID for contacts. TCP/IP based communication, both Ethernet and WiFi, as well as several low-bandwidth wireless communication technologies are supported. Altogether this creates a highly fault-tolerant communication channel between the base stations.

Live Positioning Information System (LiPS): GPS trackers uses LoRa (Long Range) communication infrastructures. LoRa uses license-exempt sub-gigahertz radio frequency bands like 433 MHz, 868 MHz (Europe) and enables long-range transmissions (more than 10 km in rural areas) with low power consumption. LoRa is available from telco operators in most countries. The communication channel is encrypted with a secure key for every device. Time, location, ID and packet counter is transmitted.

Other IoT devices: The IoT Sound Level Meters may use standard 3G/4G network for data communication, but can also use standard Wi-Fi, if available.

Environmental devices: Wind sensors use Wi-Fi communication.

M2M Network Service Capabilities Layer (NSCL): TIM has developed a OneM2M compliant gateway for External Platform connectivity of MONICA services. The ETSI compliant M2M platform is accessible in the cloud and will be deployed as PaaS (Platform as a Service).

5.2.3 Integration

The MONICA Crowd and Capacity Monitoring solution is a complex solution that relies on both external components and technologies, enablers and tools from the MONICA project partners. Please contact the responsible partner listed below for more information.

Interfaces to the MONICA Cloud services

The MONICA Data Sources API functions as interface layer between the MONICA IoT Platform and the MONICA Cloud services as described in the MONICA Platform Architecture and Components. The following subsystems are installed:

- The ***Device Layer*** includes all IoT wearables (*e.g.*, wristbands and glasses) and IoT sensors, which can be fixed (*e.g.*, sound level meters, loudspeakers, cameras, environmental sensors) or mobile;
- The ***Network Layer*** that allows the effective communication between the heterogeneous IoT wearables, IoT devices and the IoT platform modules. This layer is responsible of forwarding data coming from the IoT wearables and IoT sensors as well as of responding to service requests coming from upper layers;
- The ***Edge Layer*** includes a set of processing modules (*e.g.*, the Wearables GW running localization algorithms, Processing Units executing video-based algorithms, the MONICA Adaptive Sound Field Control solution (ASFC) for managing the sound quality and noise reduction) that process real-time data directly from the Device Layer.

IoT devices

In the MONICA Crowd and Capacity Monitoring can be complemented with any combination of IoT sensors which suites the need to provide contextual information for crowd monitoring for a specific event. The flexibility has been demonstrated in a large number of MONICA demonstrations as listed below. The IoT sensors used for these demonstrations comprise:

- Cameras
  - CCTV cameras
  - 3rd party image analysing algorithms
  - Blimps, airships and balloons for airborne “nomadic” cameras
- Wearables
  - Staff wristbands for staff
  - Crowd IoT wristbands for visitors
  - Smart glasses
  - GPS trackers for staff
- Other IoT devices
  - Environmental sensors (wind, humidity, temperature)
  - Sound Level Meters

External technologies required

The MONICA Crowd and Capacity Monitoring solutions are built on commercial products that can be sourced directly from the manufacturer:

- CCTV Cameras are commercially available from a range of manufactures
- Original VCAcore algorithms (crowd density algorithm, gate counting algorithm) for the cameras are available from VCA Technology Ltd.
- The Blimps are available from DigiSky S.r.l.
- Sendrato Staff Wristbands are available from Dexels BV
- Sendrato Crowd Wristbands are available from Dexels BV
- ORA-2 Smart Glasses are available from Optinvent S.A.
- Sound Level Monitors are available from Brüel & Kjær A/S

Internal MONICA enablers and tools required

The remaining components are available from the MONICA partners as listed below

- MONICA Platform Core Enabler
- MONICA Crowd Monitoring Enabler
- MONICA Crowd Control Enabler
- MONICA Security Enabler
- MONICA Crowd Flow Algorithm
- MONICA Human & Object Detection Algorithm
- MONICA Fight Detection Algorithm
- MONICA Staff Wristband and Applications
- MONICA Crowd Wristbands and Applications
- MONICA Monicora Smart Glass Applications
- Live Positioning Information System (LiPS)
- MONICA Environmental Sensors for measuring weather conditions
- SCRAL layer middleware and OneM2M compliant gateways

5.2.4 Scalability

The following scalability issues should be considered:

Scalability of the IoT platform: The IoT platform has been adopted for crowd monitoring applications using cameras (in several pilot demonstrations) and crowd wristbands (in three demonstrations). Before going to the real large-scale demonstration with the crowd wristbands solution, the IoT platform has been intensively tested and improved in terms of scalability thanks to a wristbands emulator that is able to generate localization messages form a configurable number of wristbands. Using this emulator, the overall IoT platform has been able to support a flow of positioning data from 10.000 wristbands that send a position update every 30 seconds. In principle, more wristbands could be supported by the IoT platform, without overloading it, if we can relax the update periodicity parameter. During the Woodstower Festival 2019, a total of 6.230 crowd wristbands were used by visitors and the IoT platform performed very well without introducing any delay or interruption of the services.

Scalability of the Security Fusion Node: The SFN along with VCAcore are designed to be scalable and capable to handle multiple cameras and algorithms simultaneously. For a single site there would be one instance of the SFN and VCAcore with the algorithms running on a processing node. If required, more processing nodes running instances of VCAcore with the algorithms can be added to handle additional cameras. All instances of VCAcore would point to the single instance of the SFN.

Scalability of the staff wristband network Infrastructure: The staff wristband, based on the UWB technology, uses a network of base stations, called anchors. Each anchor must be able to communicate with a nearby master anchor. The master anchor is responsible for collecting ranging and user data from normal anchors. In addition, the master anchor must be able to offload its data to a LAN. The number of anchors and master anchors is only limited by the 3 bytes that are used to identify an anchor. Hence, in theory, the network can scale to large amounts of anchors. In practice the largest networks that have been used in practice consisted of 100s of anchors. In principle, the total number of staff (UWB) tags is also only limited by the 3

bytes that identify a tag. However, there is only a limited number of time slots available to communicate ranging data; currently this limit is 1.000.

Scalability of the crowd wristbands: The crowd wristband protocol uses four parallel time frames allowing a large number of wristbands to connect to the infrastructure and exchange messages. In more details, four radio channels are simultaneously used by a cluster of 16 base stations. In order to avoid interference, within a single radio channel, wristbands can send messages using a TDMA protocol. In particular, the wristband protocol relies on a tight clock-synchronisation with a frame duration of 250 ms. A total of 96 base stations can be deployed in an event area, this results in a maximum reporting throughput of almost 6.400 messages per second. The total number of wristbands supported by the infrastructure depends on the network address size of the wristband, which is currently set to 18 bits. Thus, currently the maximum number of wristbands can be 262.144 that can be updated at least every 40,96 seconds (i.e. 262.144 / 6.400). To sum up, the maximum number of wristbands can be increased if the network address size is increased.

Scalability of the crowd base stations: The coverage area of the crowd wristband infrastructure, which is composed of base stations, scales with the number of base stations up to a certain limit. Given that the maximum safe range between a wristband and a base station is about 75 m, this implies that a wristband must always be at maximum 75 m away from a base station in order to have coverage. This characteristic can be used to design and setup the base station infrastructure for a specific venue. Since there is a limit to the number of base stations (96), there is a limit to the maximum area that can be covered. However, thanks to the large coverage area of the wristband infrastructure, the crowd density information can be estimated in an area much larger than the coverage area provided by CTTV cameras. Over the course of an event, millions of messages are being collected by the GW that estimates the wristbands' locations and sends the result to the MONICA cloud infrastructure.

Scalability of the smart glasses: Up to 10 devices were used in Leeds in the Rugby – Varsity (October 2019) and the IoT platform showed good performance. Considering that the message update from glasses is similar to GPS trackers, a larger number of devices could be supported without overloading the platform.

5.2.5 Associated MONICA solutions

The MONICA Crowd and Capacity Monitoring solution is closely related to and have been demonstrated together with these additional MONICA solutions:

- MONICA Crowd Management and Communication
- MONICA Sound Level Monitoring.
- MONICA Adaptive Sound Field Control

5.3 Implementation

5.3.1 Installation

The MONICA Crowd and Capacity Monitoring solution can also be implemented as a customer specific solution independent of other MONICA solutions.

Preparation

The following information should be investigated and prepared before implementation is commenced:

Communication: Wireless LAN communication: A stable WiFi network is required to avoid data loss and a high bandwidth for advanced functionalities requiring audio recording such as source contribution identification. whereas the

Cameras: The location of visitors is measured by the cameras and used to calculate a crowd density. The resolution of this discrete density field is typically 5 m x 5 m. Preparation for using the camera solutions include:

- Determine camera requirements and needed accessories. Possible requirements to be considered for the selection of the cameras: Required accuracy, availability of mounting locations, Illumination constraints, color/B&W video required, area to be covered, density of people to be measured, budget available, etc.
- Investigate installation details. The most suitable mounting height / angle of attack for Time-of-Flight cameras in the locations is identified for each position of the cameras

- Identify the supporting infrastructure including cable harnesses, availability of power, availability of reliable internet access, space requirements for processing equipment in the control room,
- Identify the required network infrastructure (wired or wireless) including capability of streaming real-time video from the cameras to the processing nodes.
- Investigate PC requirements: 1 Processing unit in situ in the server should be available. It can be the processing node, 16 channels, but a regular PC can be used as well. The processing node runs some algorithms for crowd size estimation. A common PC (as in 2020) with modern CPU and GPU e.g. Intel i7 CPU, 64GB RAM, NVIDIA RTX2080 GPU, will suffice to process all algorithm on two video channels.
- Consider data storage requirements such as a) constraints (e.g. video data must not be stored, can be stored if does not contain personal data, etc.); b) expected duration of the event and the amount of data; c) a detailed map of the area and the event (including metadata/info e.g. camera locations, security personnel locations, etc.)
- The algorithms need to be trained for the actual location. Training of the system can take a long time and should be done prior to the installation. Performance of the system will be directly linked with the availability of training data.
- The CCTV cameras can be mounted not only on fixed structures, but also on Unmanned Aircraft Systems such as Blimps and Balloons. Blimps can be positioned accurately above the event area and are able to communicate with the MONICA IoT platform by means of either Wi-Fi or ad-hoc radio link. Such ventures require special planning and the MONICA point of contact should be involved as soon as possible.

Staff wristbands: The layout and placement of the anchors that communicate with the staff wristbands via UWB must be carefully planned and the following limitations need to be considered:

- All anchors need to be in range with the UWB master in order to correctly calculate the anchors' coordinates
- Anchors should be mounted on a stable structure at a height of 3-4 meters above the ground.
- The anchors should be shielded against water.

Crowd wristbands: The crowd wristbands need a dedicated infrastructure of base stations that communicate with each other and with the wristbands.

- The maximum safe range between a wristband and a base station is 75 m. This implies that a wristband must always be at maximum 75 m away from a base station in order to have coverage.
- Same is applicable to the base stations as for the anchors above.

Live Positioning Information System (LiPS): The GPS tracking units have a limited battery life, and re-charging should be taken into account during events with long duration:

- Battery lifetime: about 16 hours
- Charging: about 7 hours from empty to full

Deployment

The following information is provided for the organiser of the event for the deployment of the solution:

- Installation of cameras and wiring can be performed by local technicians once the layout has been approved by the responsible for the installation.
- For gate counting the cameras should have an inclination of 90°.
- Network and power shall be provided by the organiser.
- The Processing Node is remotely accessible. It shall be active by the local organiser as soon as possible before the event allowing able time for adjustment and final training of the system.
- The organiser shall provide the rule on capacity as soon as possible for the Decision Support System (e.g. Area: 30m^2, less than 2 person/ m^2 → ok/green, 2-3 person/m^2 → warning/orange, more than 3 person/m^2 → alarm/red)

Operation

- Monitoring of accuracy of counts is needed.

Remote support by the solution provider during the event is normally adequate for correct operation. For the most part, the system is operating autonomous.

5.3.2 Regulatory aspects

Technical regulations

- All devices of the MONICA solutions making use of radio frequency spectrum must adhere to the various European regulatory provisions as laid forth by CEPT/ECC including some relevant EU Decisions/Directives. For further information see D12.5 Report on Standards, Regulations, and Policies for IoT Platforms.
- All devices of the MONICA solutions making use of radio frequency spectrum, must comply with the Radio Equipment Directive 2014/53/EU (RED), and be duly CE-marked..
- The staff wristbands comply with ETSI EN 302 065-2 V 2.1.1(Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 2: Requirements for UWB location tracking and further comply with the EU Commission Implementing Decision 2014/702/EU, (Amending Decision 2007/131/EC on allowing the use of the radio spectrum for equipment using ultra-wideband technology in a harmonised manner in the Community".
- The UWB communication protocol is compliant with the IEEE802.15.4-2015, the protocol and compatible interconnection for data communication devices using low-data-rate, low-power, and low-complexity short-range radio frequency (RF) transmissions in a wireless personal area network (WPAN).
- The crowd wristbands are built to comply with ETSI EN 300 220-2 V 3.1.1 (2017-02) (Short Range Devices (SRD) operating in the frequency range 25 MHz to 1 000 MHz; Part 2: Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU for non-specific radio equipment , and later updated by EN 300 220-2 V3.2.1 (2018-06).
- The hardware must comply with the Waste Electrical and Electronic Equipment Directive (WEEE 2012/19/EU).
- The hardware must be marked with the WEEE mark.
- The CCTV cameras and other hardware sensors are an electronic equipment and the supplier and the organiser must agree on the proper take-back procedure for the used hardware.
- The hardware must comply with the Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive (RoHS 2011/65/EU).

Other local/national regulations

With regard to the collection and processing of personal data, the GDPR, (EU) 2016/679, allows Member States to enact national provisions on certain issues as stipulated by the National Data Protection Authority. For example, Member States will have discretion to enact national provisions imposing further requirements regarding the appointment of Data Protection Officers.

- Internal procedures must be developed to protect personal data
- Internal procedures to protect the rights of data subjects must be implemented
- The event organiser is identified as the “Data Controller”
- The MONICA provider is identified as a "Data processor”
- A Data Processor Agreement must be drafted and signed by these two parties
- Data Processor Agreements with third parties must be in place if relevant
- A Data Protection Officer can be designated by the Data Controller

- A Data Management Plan is required which establishes the intended processing of personal data and the purpose of such processing
- A Data Protection Impact Assessment must be carried out based on the Data Management Plan and special areas of vulnerabilities towards protection of personal data must be identified and resolved
- Formal permission to install CCTV cameras must be granted and cameras should only record those areas that need to be surveyed for the purpose of the solution
- Standard CCTV signs must be placed by the cameras following the applicable rules for CCTV signage including the following information in a concise language:
    - That you are in or about to enter into an area where video surveillance is taking place;
    - Why the recording is taking place (i.e. the controller's justification for installing a CCTV or other video system);
    - The identity of the controller (or its representative) responsible for the video system;
    - The rights that the data subject can avail themselves of in respect to such processing of their personal data;
    - The contact details of a data protection officer or, where one is not appointed, whichever individual would be responsible for the footage being recorded, who would ideally be the same individual whom the data subjects would be able to contact to exercise their rights as mentioned in point 4 above;
    - Where the data subject can find further information regarding the processing of their personal data.

Figure 9: Example of GDPR compliant CCTV notice poster © In-JeT ApS

Ethics

The following specific ethical considerations shall be made:

- As a rule of thumb, video recordings with people should always be assumed to be personally identifiable data (location of identifiable persons is specifically mentioned in the GDPR regulation)
- Note, that CCTV footage may be used to implement vehicle recognition technology and thus record personal information.

- Proper graphic displays with CCTV warnings must be planned and implemented.
- Proper procedures for end-of-life of video recordings must be defined and meticulously implemented.
- Sound procedures for allowing individuals access to CCTV footage where they feature must be in place, including guidelines for how to verify the individual's identity, identify the individual in the footage and anonymise all other individuals in the footage.
- The COP should be placed in a secure room with controlled access to prevent any form of misuse of the collected and displayed data.

The solution may raise public concerns about increased surveillance practices and how these affect citizens' rights to privacy. Event organisers should define the legitimate reasons for implementing the solution. It may be useful to carry out a Legitimate Interests Assessment (LIA).

5.4 Business Aspects

5.4.1 Revenue models

The choice of business model and pricing schemes is entirely up to the partner that have commercialised the solutions. Hence, the following information is solely provided as a guide to the expected business conditions that the solutions might be provided at. Please contact the responsible partner for further, up-to-date details.

Components	Type	Anticipated revenue model
Camera platform VCAcore	Hardware, Firmware	VCA framework with 3rd party plugin wrapper is available as commercial hardware with embedded firmware. Optional planning services are available at a cost.
Security Fusion Node	Firmware	The Security Fusion node is available as a tailored solution including hardware and firmware at a one-off cost. If required, installation, integration, update and consultation are subject to further fees.
MONICA Platform Core Enabler	Cloud service	The cloud services is available as a Platform as a Service (PaaS) service. Planning service is always required as an additional one-off charge. The Platform Core Enabler is available as a Platform as a Service (PaaS) solution, extended by integration services of the appropriated auxiliary enabler(s). Planning service is always required as an additional one-off charge.
MONICA cloud integration enablers	Firmware	The cloud integration component consists of the MONICA Platform Core Enabler combined with the MONICA Crowd Loop Enablers are provided as one-off license fees per camera.
Crowd density, optical flow and object detection algorithms	Algorithm	Firmware one-off license per camera for all algorithms1. If required, installation, integration, update and consultation are subject to further fees. Optical flow algorithm is licensed under Apache License, version 2.0, crowd density and object detection algorithms under MIT license.
Human and object detection	Algorithm	Firmware one-off license per camera for human and object detection algorithms.
People gate counting algorithms	Algorithm	Firmware one-off license for per camera people counting algorithms.
Fight detection	Algorithm	Firmware one-off license per camera for fight detection algorithms.
Staff wristband	Hardware, Network, Infrastructure	The wristbands are available as commercial hardware with embedded firmware. MONICA firmware is available as one-off license per solution. Planning service is always required as a one-off charge.
Crowd wristbands	Hardware, Network, Infrastructure	The crowd wristband solution is available as a complete event solution including hardware, network, operation and data analysis.

Smart glasses	Hardware, Firmware	The Smart Glasses are available as commercial hardware with embedded firmware. Monicora firmware is available as a one-off license per solution.
Live Positioning Information System (LiPS)	Hardware, Firmware	The Live Positioning Information System (LiPS) solution is available as a complete event solution including hardware, network, operation and data analysis.
OneM2M compliant gateway	PaaS	The external M2M gateway is offered as a Platform-as-a-Service solution.

5.4.2 Business Models

The Business Model Canvas is used to give a high-level overview of the contents in the value configuration and in the customer group side related to a specific value proposition. This tool is used to map out all details of the MONICA business models based on the value proposition, target groups, the partner constellations, and revenue models outlined in this chapter.

Table 1: Business Model Crowd and Capacity Monitoring

<table>
<tr>
<td rowspan="2"> 
Key Partners

<u>MONICA partners</u>
• VCA Technology Ltd
• Kingston University, Computer Science & Mathematics
• CERTH Information Technologies Institute
• Dexels BV
• Optinvent
• Fraunhofer FIT
• Telecom Italia
• Digsky s.r.l.

<u>External partners</u>
• Hardware (cameras etc.)
• Network components
• On-site Installation
• Sound equipment</td>
<td> 
Key Activities
• Cloud operation
• Algorithm training
• Software development
• Firmware development
• Wristband design
• Network protocols
• Blimps operation</td>
<td rowspan="2"> 
Value Proposition
A cloud-based IoT platform supporting components that can be used to monitor, record & analyse the environment and detect emerging episodes
Options for video analytics, wearables, wind speed, noise.
Capable of collecting information about crowd size, flow, object detection as well as early warning of security and safety threats.
Used for variety of purposes related to crowd behaviour, security and safety of visitors.</td>
<td>Customer Relationship
• Provide information about crowd size, density and flow in real-time
• Detect abnormalities and report objects
• Facilitate safe and quick entry to and exit from the event area</td>
<td rowspan="2">Customer Segments
• Organisers of musical events, outdoor concerts
• Organisers of street festivals, open-air markets
• Organisers of sporting events
• City authorities for restaurant and night-life areas
• City authorities for streets and areas with heavy traffic
• City authorities responsible for noise control in the city</td>
</tr>
<tr>
<td> 
Key Resources
• Software developers
• Cloud operation
• Network specialists
• Image processing do.
• Hardware designers
• System integrators</td>
<td>Distribution Channels
• Direct event organisers
• DIrect city authorities
• Through system integrators</td>
</tr>
<tr>
<td colspan="2"> 
Cost Structure
• Standard cost of cloud services
• Cost of network services
• Cost of hardware
• Cost of development, customisation, training
• Cost of operation
• Cost of commissioning and de-commissioning
• Electricity and rental cost for long term installations</td>
<td colspan="2">• Cloud integration component and services as consultancy services
• Cost of hardware with embedded firmware.
• One off-licenses fees for software and firmware per installation
• Configuration, algorithms training, custom. services
• Installation and commissioning services</td>
<td> 
Revenue Streams</td>
</tr>
</table>

5.5 Potential for Replication

5.5.1 Lessons Learned

Lesson Learned have been collected throughout the deployment and demonstration phases of the MONICA project and the relevant Lesson Learned are provided here for reference. Please check with the responsible partner for the newest updates.

The following main Lesson Learned from the MONICA demonstrations and reference deployments are:

- Cameras should be installed and accessible through RTSP streaming protocol at least three days prior to actual event day.
- In crowded areas with narrow streets and lots of vehicles and human traffic, it is quite challenging to calibrate the cameras. A calibration mat can be handy to ease the process.
- Availability of the Internet connection in camera location is essential and should be investigated prior to the event.
- During notifications of national spectrum regulatory authorities in a Member State with regard to a planned demonstration/test of new and novel (not yet CE-marked) radio devices, it has proved useful to reference Art 9(2) of the 2014/53/EU (RED), where a MONICA supported event area is compared to a tech-exhibition or trade fair. It should be observed, that the event area must be gated, to prevent non-compliant equipment incidentally to pass through any exit gate, with the risk of causing harmful interference to other wireless services. Observe also, that Art 9(2) of said directive instructs that non-compliant devices shall be duly marked as “demonstration/not for sale”.

5.5.2 Usability Aspects

5.5.2.1 Acceptance of MONICA Solutions

- The ability to easily detect and report incidents whilst wearing the smart glasses, and the ease of use of the system, contributes to the overall acceptance of this MONICA solution.

5.5.2.2 Effectiveness of MONICA Solutions

- The security staff are assisted by the solutions to quickly and effectively complete their tasks, which helps to do their job more efficiently
- Detecting and reporting of incidents successfully ensures a safer public environment and enables security staff to quickly respond to incidents. It encourages a positive effect on quality of space, visitor experience and visitor safety
- Improves speed of communication
- Assists in completing general tasks more effectively.

5.5.3 Reproducibility Aspects

Following the reproducibility definition reported in section 4.5.3, the MONICA Crowd and Capacity Monitoring solution can be fully reproduced by using the Crowd and Capacity Monitoring Toolbox.

This Toolbox allows the user to demonstrate the Crowd and Capacity Monitoring use case by instantiating and running the involved MONICA components. In particular, the MONICA platform can use either anonymous stored data or emulated data.

In case stored data are used, the Replayer tool will be set to replay part of the crowd data based on cameras from the Rugby demonstration in Leeds (October 2019). Since the database is very large, for the demonstration of the toolbox only a small portion of it has been made available.

In case emulated data are used, the Wristband Emulator is executed generating wristbands positions in the event area. More specifically, the wristband emulator can generate a certain number of wristbands in four different regions of the pilot area according to a percentage vector (e.g. 30%, 20%, 40%, 10%) whose values refer to region 1, 2, 3 and 4, respectively. In each region the wristbands positions are generated according a 2D Gaussian distribution centred in a position and using a covariance matrix defined as parameters. The

Toolbox includes also the HLDF for generating the crowd density based on the wristband's positions, the DSS for generating the alerts and the COP for visualization purposes.

5.5.4 Contacts

The following partners are responsible for various components of the MONICA IoT SLM solution:

Solution	Responsible	Acronym	Details
Camera platform VCAcore	VCA Technology Ltd	VCA	VCA can provide CCTV cameras with build-in VCAcore framework
Security Fusion Node	Kingston University, Computer Science & Mathematics	KU	KU can provide the Security Fusion Node
MONICA Platform Core Enabler	Atos IT Solutions and Services	ATOS	ATOS can provide the MONICA Platform Core Enabler as a Platform as a Service (PaaS) and the system integration of the MONICA components (when using the cloud)
MONICA cloud integration enablers	VCA Technology Ltd	VCA	VCA can provide CCTV cloud communication firmware for the VCAcore framework cloud communication
Crowd density, optical flow and object detection algorithms	Kingston University, Computer Science & Mathematics	KU	KU can provide algorithms for the analysis of crowd density and objects. Types of events may be customised.
People gate counting algorithms	VCA Technology Ltd	VCA	VCA can provide algorithms for the analysis of crowd estimation, gate counting, etc.
Human and object detection algorithms	CERTH Information Technologies Institute	CERTH	CERTH can provide algorithms for image analysis and feature detection, e.g. humans and objects.
Fight detection algorithms	CERTH Information Technologies Institute	CERTH	CERTH can provide algorithms for fight detection.
Staff Wristband	Dexels BV	DEXELS	Dexels can provide the staff wristbands
Crowd Wristbands	Dexels BV	DEXELS	Dexels can provide the crowd wristbands
Smart Glasses	Optinvent	OPTIN	Optinvent can provide ides the Smart Glasses
Live Positioning Information System (LiPS)	Fraunhofer FIT	FIT	Fraunhofer FIT can provide the LiPS tracker and LoRa communication platform
OneM2M compliant gateway for External Platform Services	Telecom Italia	TIM	TIM can provide the M2M Network Service Capabilities Layer (NSCL) as a PaaS
BLIMP	Digsky s.r.l.	DIGISKY	Digisky can provide Blimp carriers for air-borne camera solutions.
IoT Enabled Sound Level Meters	Brüel & Kjær	B&K	Brüel & Kjær may offer accredited IoT Enabled Sound Level Meters

5.6 Reference Deployments, Demonstrations and Results

During the project period January 2017 to March 2020, the MONICA Crowd and Capacity Monitoring solution was deployed and tested in real-life situations during planned pilot events.

The activities conducted in these three years have been documented in several deliverables related to Pilot Preparation, Deployment and Execution (D8.1, D8.2, D8.3) as well as to Final Assessment and Validation Report of the MONICA IoT Platform (D9.2).

The aim of the following paragraphs is to summarise information collected in the above mentioned documents and provide an example and some guidelines to those that would like to replicate MONICA Solutions.

Moreover, articles related to MONICA Crowd and Capacity Monitoring demonstration have been collected in the following link - https://www.monica-project.eu/portfolio-items/crowd-and-capacity-monitoring/

5.6.1 Monitor Crowd Based on Capacity: Woodstower Festival

General description of the event

Woodstower[1] is an open-air festival that offers a large program of music with different influences, from electro to rap and reggae, which brings together both exciting artists, international icons but also the best of the local artists.

Woodstower takes place in the Grand Parc Miribel Jonage (a 22 000 hectares natural park located 15 minutes by car from Lyon, France) each summer since 2005. The 2019 edition took place from August 29th to September 1st and gathered more than 34 000 people in three evenings. The festival also offers non-musical activities such as a zip line.

Woodstower festival, with its 4 stages in an open air venue, was indeed an ideal event for large scale demonstration of the MONICA festival-goers' wristbands for crowd density estimation, wristband localization and to set up a wristband LED show.

A light functionality, in fact, has been added to the wristbands to facilitate their distribution to the festival-goers, improving their participation and acceptance of the test. It allowed the light engineer at one stage to manually light up all the wristbands, in such a way that the festival-goers could be part of the concert.

Figure 10: Woodstower festival 2019

Monitor Crowd Based on Capacity – deployment description

For this use case 15 base stations have been installed on site covering the complete event venue.

Wristband distribution: the aim was to distribute several thousands of wristbands, up to 10.000. The incentive was the light show provided by 2 LED blinking on the wristband accordingly to the instructions sent by the closest stage on the venue. On Friday night, more than 50% (around 3900 over 7000) of the party goers were

[1] https://woodstower.com/en/festival_en/

equipped with MONICA wristbands. More than 6000 wristbands were distributed in 2 nights and it was the largest amount of IoT devices handled during the MONICA project.

Wristband tracking: tracking information was sent and stored in database/MONICA cloud. However, there is still a huge progress to be made in terms of sampling frequency (only around 100 position in 10 hours in Woodstower) to reach actual real time experience on crowd heat map and more accurate results of noise exposure. For this reason the crowd density in the venue in terms of people number was shown, as in **Error! R eference source not found.**, after some post-processing.

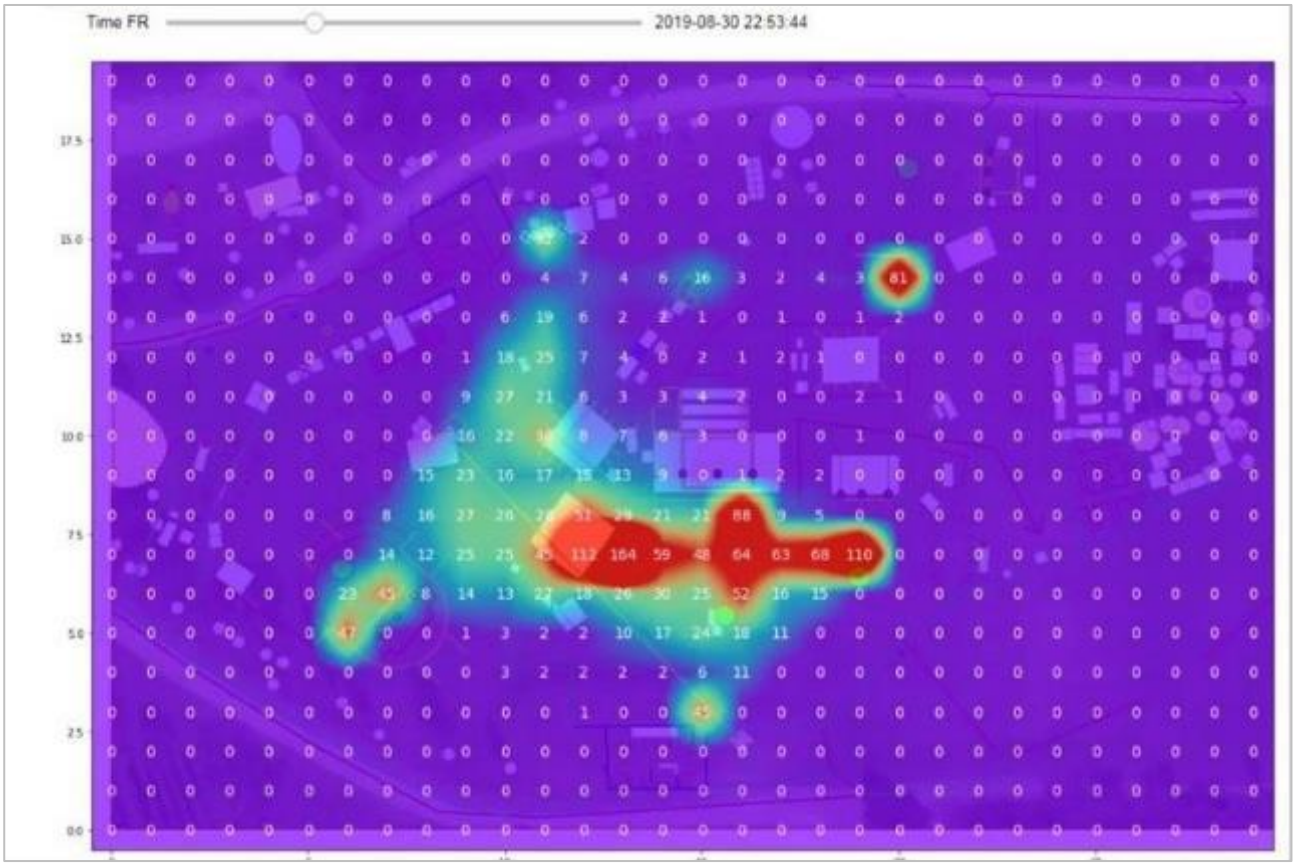

Figure 11: Display of the crowd density

Wristband light show: wristbands blinking worked being controlled by light console using DMX (Digital Multiplex) connection. Activation of the LED depended on the lighting engineer choice to use it or not during the music concert. The lighting engineer should design the show before the event (or at least during the setup) together with the artists and taking into account the level of the stage lights. In this way, the light output could be increased to the level of the stage lights or be controlled and adapted by the lighting engineer and the effectiveness of the light show could have improved.

Challenges faced using MONICA solutions

One of the main aspects to consider before replicating “Monitor crowd based on capacity use case” is the existence/status of pre-existing infrastructures (e.g. lights, electricity, and internet connection) in the venue. The set-up of infrastructure needs to be done specifically with a dedicated external staff to be engaged on purpose before the event. During the Woodstower event, electricity and internet connection for MONICA Solution deployment were provided by the organisers of the event that made available to the MONICA staff their suppliers. MONICA technical staff had some teleconferences before the event with the connectivity providers to share with them the requirements to let the MONICA solutions work. In particular such providers supported our staff for the deployment of Ethernet cables that brought connectivity to MONICA base stations.

Another aspect to consider before replicate use cases involving wearable devices, is the goers’ engagement in wearing the wristbands. During the festival, the incentive was the light show accordingly to the instructions sent by the closest stage on the venue. During the Woodstower festival no other functionalities were associated to wristbands (e.g. cashless payments) and MONICA staff, during the wristband distribution, gave people a very good explanation of functionalities, aims and privacy policy to clarify doubts and questions related to

wearing a device that can potentially trace them during the event. This communication actions helped to reach a large number of adopters during the event.

5.6.2 Monitor Crowd based on Capacity - Fête des Lumières 2018 - 2019

General description of the event

Fête des Lumières[2] is a free cultural event hosted by the city of Lyon every year around the 8th of December. For four nights, a variety of different artists light up buildings, streets, squares and parks. Since 2016, to prevent terrorism-related risks, it has been held for the most part on a perimeter closed to traffic, on the peninsula of Lyon, between the Rhône and Saône rivers, as depicted in Figure 12. Only the metro service remains accessible within the perimeter and safety controls are carried out at the accesses of the metro stations. Pedestrian accesses are possible on the whole perimeter. The area size of the event is over one square per meter. For the 2019 edition, 36 light performances took place, sometimes with sound playing. One major installation is the light show on the cathedral façade of Place Saint-Jean (Figure 13). The timeslots were from 7 pm to 11 pm or from 8 pm to midnight depending on the days. The site welcomed approximately 1.8 million visitors[3].

Figure 12: Perimeter of Fête des Lumières 2019

[2] http://www.fetedeslumieres.lyon.fr/en
[3] https://www.fetedeslumieres.lyon.fr/en/news/2019-festival-lights-facts-and-figures

Figure 13: Light show on the Cathedral facade of Place-Saint Jean

Monitor Crowd Based on Capacity – deployment description

The Crowd and Capacity Monitoring use case was deployed because the Fête des Lumières organisers wanted to improve the efficiency of crowd density monitoring. In particular the objectives of the deployment were:

- Count the number of entrances and exits using gate counting
- Estimate the number of spectators on the event
- Count the number of spectators on the square on real time
- Analyse the density and the number of spectators on the seven areas of interest
- Send an alert if the density is over three persons per square meter

For this purpose, seven cameras were used to produce crowd density maps as well as supply spectator counting at the entrance and the exit of Place Saint-Jean. The CCTV cameras (Low-Light High-Resolution RGB cameras) were installed around Place Saint-Jean in 2018 demonstration and, since one year later they were still active, the same configuration has been repeated in 2019.

CCTV cameras available commercially lack processing power to count and track people in crowded scenes. For this reason, a processing unit was provided and configured by ACOUCITE and the CCTV department. As a result, the additional power, from clouds and IoT hybrid processing models, in comparison to commercial cameras, enable more advanced algorithms to be developed, achieving high performance for tracking and counting in both crowded and uncrowded scenarios

MONICA partners KU and VCA had remote control of the Processing node to test and deploy three functionalities enabled by three algorithms: the counting estimation, density estimation and object detection.

The difference between entrance and exit counting provides an estimate of the overall density of the square. The event managers were able to follow the status in the MONICA COP and when the crowd limit was reached, notifications to organisers and security staff were generated.

The Processing node, former central unit provided by the City of Lyon, was in the same COP room, near the City Hall of Lyon. **Error! Reference source not found.** shows the real-time Crowd Counting estimation on the C OP CROWD tab.

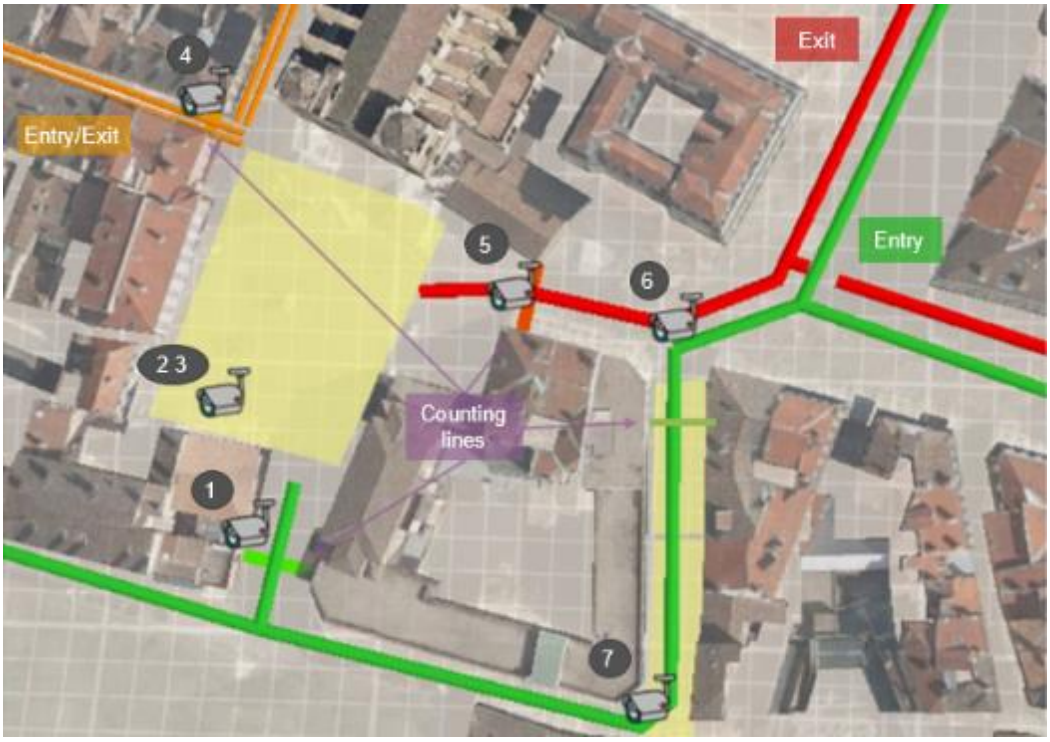

Figure 14: Crowd and Capacity Monitoring scenario for Place Saint-Jean

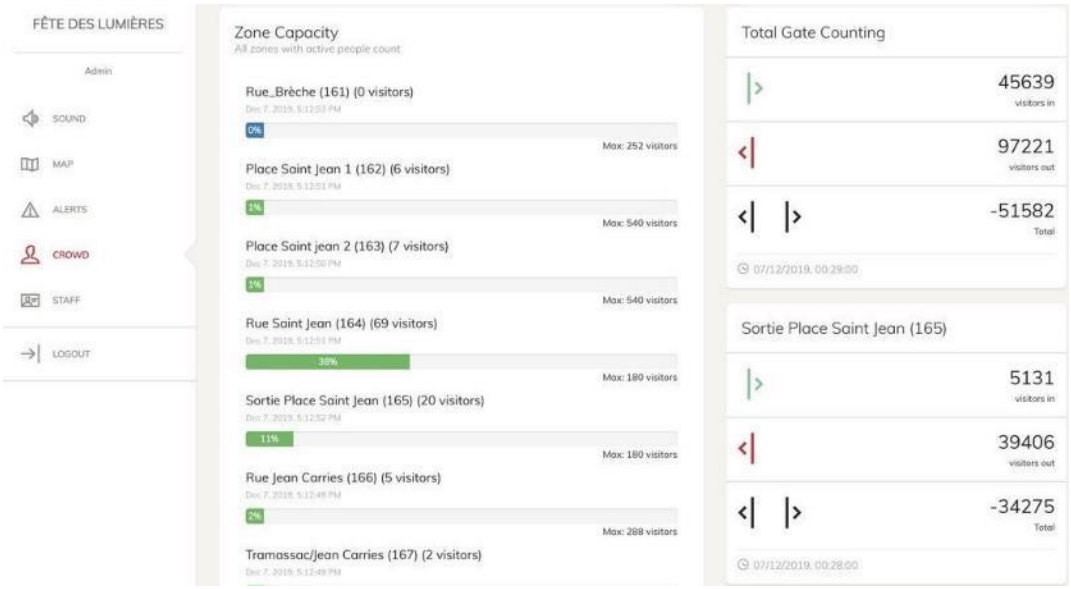

Figure 15: Real-time Crowd Counting estimation on the COP

In addition to estimating the real-time density and counting of Place Saint-Jean, it was also tested to estimate the total count of people going to Place Saint-Jean for the three evenings of the event. It was indeed a valuable information for the organisers to communicate after the event.

The results of Crowd Counting estimation were feeding the DSS and alerts were forwarded to the COP. The alert threshold was set to four persons per square meter as decided during the setup.

Moreover, ACOUCITE post-processed the results (in Python), which allowed to correlate the exit counting and sound level fluctuations with the light show schedule, as shown in Figure 16.

Figure 16: Correlation between exit counting, sound level fluctuations and the light show timeframe

Challenges faced using MONICA solutions

One of the main aspects to consider before replicating the Monitor crowd based on capacity use case, according to the experience of Fête des Lumières demonstration, is the installation in advance of the hardware and software components, as well as the check on Wi-Fi network access.

Some software was required to be installed on Processing Node and, since at the time of the demonstration, an installation package was not available, the technical team spent time for this work.

The organization of the event has to take into account this aspect, to set and test all the components few days before the event, to avoid to waste time during the event.

6 Crowd Management and Communication

Crowd management and response is greatly facilitated by the MONICA Crowd Management and Communication solution. This solution gives a perfect overview of event activities in real time as well as means for feed-back to and communication with security and first-responder staff in the field.

This solution complements the MONICA Crowd and Capacity Monitoring solution. The solution also complements the MONICA Sound Level Monitoring solution. Combined they represent a total, closed loop solution for gathering real-time event information and presenting this information for decision support.

The MONICA Crowd Management and Communication solution is a MONICA Cloud based solution that receives information from the MONICA IoT platform. The IoT platform collects, records, and analyses the environment and behaviour of crowds and event performance. All information is passed on to the MONICA Cloud.

During the event, security and first responder personnel at the control centre can monitor the situation on large display screens using the MONICA Common Operational Picture (COP). The MONICA Decision Support System (DSS) facilitates a better understanding of the event and improved coordination of intervention.

The COP provides real-time overview, quantitative data about crowds and crowd behaviour, and advanced detection of incidents and events. Two-way communication allows on-site personnel to report incidents to the control centre by sending live video stream and images, Staff wristbands and GPS staff trackers communicates with the COP in real time as decision support for control room staff.

The MONICA Crowd Management and Communication solution is a cloud-based, closed-loop management solution that provides a real-time operational picture with overview, decision support and intervention strategies for event organisers and security and first responder teams during large scale events. It also allows staff to exchange information in a reliable and timely manner to improve the handling of critical incidents during events.

The core of the MONICA Crowd Management and Communication solution is the MONICA Common Operational Picture (COP), a professional user interface that creates overview and understanding of the different aspects of crowd management during an event. The COP can be used to monitor, record and analyse the environment and detect emerging episodes at an early stage. It can assist security and first responder staff with decision support for intervention strategies. The COP relies on situational data and context provided by the multitude of IoT sensors connected through an IoT sensor platform such as the MONICA Crowd and Capacity Monitoring solution.

The MONICA Crowd Management and Communication solution can be used in any type of open- air, gated and non-gated event. It can be used for short term deployment (e.g. for a specific concert); for a recurrent event (monthly or seasonal) or for semi-permanent events (night life area, traffic). It is made to be compliant to professional standards and it can operate on WiFi or 3G/4G wireless internet:

- It can be used to visualise data on a dedicated dashboard - the MONICA COP in the control room
- It can be used with a decision support system like the MONICA DSS
- It enables safety and security teams to evaluate emerging incidents
- It can issue alerts of potentially critical situations related to crowd management and control
- It can be used to document incidents and incident handling
- It can support on-site staff communication, coordination and management
- It can support security personnel in the reporting of health, safety and security incidents
- It can be used with a variety of devices such as smart glasses, staff trackers, crowd wristbands and CCTV cameras.

The core of the MONICA Crowd Management and Communication solution is a dashboard such as the MONICA COP and at least one application, which allows event personnel to send and receive vital event organisation information.

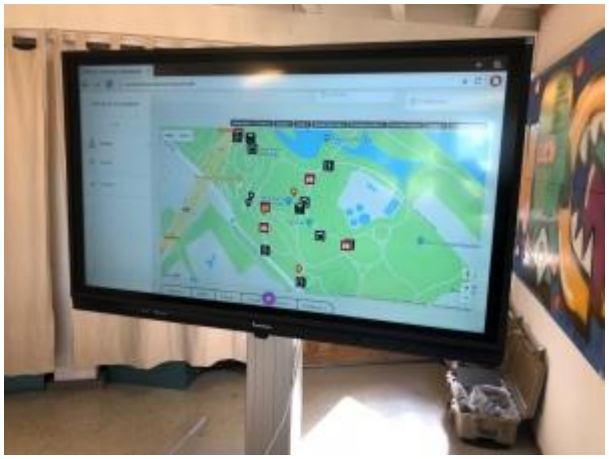

Figure 17: COP in use during Rhein-in-Flammen 2018

Common Operational Picture (COP): The COP is the main interface for providing human professional operators knowledge on the event in order to take informed decisions on environment and crowd control. The COP can combine crowd monitoring with sound monitoring to give event managers a complete overview of the situation. It can be connected to any number of large-screen displays in the control room. Working as a webserver solution, it can be combined with most existing types of control room monitoring infrastructure.

Decision Support System (DSS): Provides recommendations and proposes actions for the human operator based on camera and Sound Level Meters' data as well as from input from other IoT devices such as wristbands. The DSS can solve problems and make interactive decisions by analysing massive streams of data in real-time. The DSS supports security use cases such as to crowd incidents, sound management (sound limits, sound contribution, annoyance level), missing persons and locating security personnel. The DSS can also handle sound management, such as sound limits compliance and sound contribution analysis.

Two-way communication between staff: The staff wearable wristbands contains a UWB radio that provides a reliable communication channel relatively insensitive to interference compared to narrow- or broadband alternatives. A MONICA protocol supports bi-directional communication with other staff wearables.

Alerts: The MONICA Crowd Management and Communication solution simplifies coordination between staff members and the control room for faster reaction to remedy any situation in the field. High-risk queues or other crowd incidents detected by the MONICA Crow and Capacity Monitoring are reported via the COP and the DSS to control room personnel. The control room staff can then direct on-site personnel to proper intervention and send selected information from the COP to support the interventions. Further, on-site staff can via the two-way communication network acknowledge the commands and send reports back to the control room on the situation as it unfolds.

Staff communication: As an extension to the COP, the MONICA Crowd Management and Communication solution facilitates real-time visual, audio and written communication between staff on-site and the control centre. Devices applied cover smart glasses, IoT staff wristbands and staff tracker. Onsite personnel can report the incident to the control centre by sending live video stream and images, staff wristbands and

Staff wristbands: Staff wristbands makes it possible to locate and communicate to staff members in real time If there is an incident, the staff can press a button on the wristband to ask for assistance and thereby automatically call upon the nearest available colleague. A LCD screen, 3 buttons, vibrator and buzzer can be programmed for input and output. The UWB radio infrastructure captures the position of the wristbands using triangulation techniques and it is possible to view all staff locations on a map layer on the COP.

Smart glasses: On-site safety and security stewards can use smart glasses to report incidents to the control centre. They can send live video stream and images to support the team in evaluating the situation and whether additional security personnel should be despatched to the scene. GPS coordinates are automatically captured by the smart glasses to show the exact position of the reporting steward on the COP.

Figure 18: Steward testing the smart glasses

Live Positioning Information System (LiPS): Resilient GPS staff trackers using LoRa communication networks make it possible to locate and track staff members in real time in large areas for a better coordination of interventions. The positions can be shown on the COP as a digital map overlay.

6.1 Scenario Descriptions

Inform staff:

If crowds are approaching the capacity limit or if it is necessary to redirect queues, alerts are sent to the preferred device/method of the involved staff members.

Inform visitors:

The MONICA app for visitors allows the users to discover shorter queues at, e.g., bars, rides and other attractions by way of receiving real-time data/information updates from the COP.

Guide people to exits:

The MONICA app for visitors receives real-time information from the COP, informing the users where the closest exits or the fastest routes are.

Missing person (Locate staff member):

This scenario enables the involved actors to successfully locate the staff members (such as Organisers, fire brigade, police, public order officers, emergency rescue crews) in a venue and communicate with them based on needs. In addition, this helps the staff to provide important notifications to the control room, whenever necessary.

Security incidents (Detecting, reporting, handling a security incident):

The MONICA solution simplifies the detecting, reporting and handling of security incidents. The solution enables the user to detect abnormalities within a crowd. Where an incident arises and must be reported to the event control room, this can be done via the solution. It improves accuracy and speed of communication from the control room to the security ground staff/incident responders. It facilitates the deployment of the closest responder, such as a first aider or a firefighter.

Health incidents (Detecting, reporting, handling a health incident):

The MONICA solution enables more accurate reporting of health incidents, leading to the deployment of the appropriate response, e.g., immediate call for emergency/specialist support.

Safety incident (Precautions at unsafe wind speeds):

The MONICA solution allows the detection, reporting and handling of safety incidents caused by high wind speeds. The solution enables the user to monitor wind speeds at the event site in real time. If wind speeds exceed a predefined threshold the MONICA DSS will trigger an alarm in the COP to inform the staff (e.g. event organiser) what measure need to be taken, i.e. which rides or stalls need to be closed. Overall, the solution improves the safety of visitors.

6.1.1 Type of Event

The MONICA Crowd and Capacity Monitoring solution can be used at any type of gated or non-gated open-air event, e.g., concerts, festivals or sport events.

- Musical events, outdoor concerts
- Street festivals, open-air markets
- Sporting events
- Both small and large area, gated and non-gated events can be covered

It can be used for short term deployment (e.g. for a specific concert); for a recurrent event (monthly or seasonal) or for semi-permanent events (night life area, traffic). It is made to professional standards and it can operate on WiFi or 3G/4G wireless internet

6.1.2 Challenges

All large events need to have adequate safety and security measures in place. In the last two decades the need for enhanced security measures during the numerous city events is sadly increasing, due to the risk of terrorism; open air events are often attended by thousands of people, so crowd management and mitigation of annoyance is becoming a major challenge requiring advanced ICT tools.

On this background, onsite security personnel play a crucial role in ensuring that the event runs smoothly and without major incidents. One of the main challenges for managing security and safety at large events and crowds in venues is to ensure that security staff can communicate efficiently and accurately.

The challenges of crowd management in open-air events are mostly related to:

- getting a full overview of the situation in the field and the behaviour of crowds;
- identifying the precise nature and location of an incident including context such as video;
- providing timely response to incidents;
- tracking the location of on-site security personnel;
- coordinating on-site security personnel in responding to an incident;
- sharing of relevant information between the control room and other on-site personnel.

The MONICA Crowd Management and Communication solution provides a comprehensive tool for overcoming these challenges.

6.1.3 Benefits

The MONICA Crowd Management and Communication solution provides the event organisers with a reliable overview platform and a tailored communication system that supports efficient and timely management of incidents during large events. Control room overview combined with efficient staff communication is a crucial factor in handling critical incidents.

Safety and security responsible teams can benefit from improved support in detecting potential critical incidents, as well as in handling and reporting such incidents.

From the control room, security staff can inform on-site personnel of an emerging situation and coordinate the response. Being able to share information with team members, will improve the assessment of a situation and therefore improve the efficacy and speed of the intervention required at the site. Such timely support can help security personnel prevent a situation from escalating.

- *The benefits for event organisers are:* being able to support on-site safety and security personnel to detect, report and handle incidents in a timely manner. By combining different applications and devices to collect and transmit relevant data to the COP, the DSS can help to detect potentially dangerous situations. The control room can use the COP to locate on-site personnel and be better able to coordinate a response team to handle incidents.
- *The benefits for on-site safety and security personnel are:* improved support from the control room as their location is constantly known and they can send images, live video and audio to get support from team members in assessing the situation. Should an incident occur, other team members can arrive in a timely fashion to support the handling of the incident and potentially preventing it from escalating.

Ultimately, the safety and security of event visitors and staff is improved.

6.1.4 Stakeholders

Event organiser: Person in charge of managing budget, logistics and external stakeholders that are part of the event. Responsible for assuring the success of the event at a practical level.

Cities: Cities (or municipalities) involved in monitoring facets of public life and interacting with their citizens.

Security staff: Personnel in charge of monitoring the event area and keep it safe. This may include local authorities, e.g., the police.

Control room staff: In charge of guiding security and emergency activities for the event, supporting the coordination and direction of activities to deal with incidents.

Solution developers: Persons responsible for adapting/integrating the selected MONICA solution(s).

Event volunteers: Volunteers are often first responders to visitors.

6.2 Technical aspects

The MONICA Crowd Management and Communication solution uses commercially available hardware components in combinations with specific, MONICA developed, display applications and decision support functions. For communication, MONICA relies on standardised communication networks such as wide-area 3G/4G/5G telecommunication infrastructure, UWB low latency network, WiFi networks and LoRa wide area IoT networks. Communication protocols have in many cases been enhanced with additional plugins developed by MONICA partners. The MONICA cloud solution is based on standard cloud server infrastructure such as the ATOS Managed Public Cloud.

6.2.1 Technical concept

The MONICA Crowd Management and Communication solution is based on a user interaction platform, the MONICA COP (Common Operational Picture), which visualises situational data captured by MONICA IoT sensors. The COP is enhanced with the MONICA DSS (Decision Support System) for automatic assessment of potential critical situations and is connected to various MONICA feed-back solutions for two-way communication with field staff such as stewards, police, security staff, emergency responders, etc.

The MONICA Crowd and Capacity Monitoring solution provides data from cameras with different analytics algorithms, and from crowd wristbands, staff wristbands, smart glasses, and GPS staff trackers in order to support the communication between staff members and teams. Also sound and noise management can be performed (even simultaneously with the crowd management) using the COP showing data from the MONICA Sound Level Monitoring solution and the MONICA Adaptive Sound Field Control solution.

The entire solution is embedded in the MONICA Cloud as described in the MONICA Platform Architecture and Components. The cloud solution is based on standard cloud server infrastructure such as the Atos Managed Public Cloud.

The MONICA Crowd Management and Control solution consist of the following components:

MONICA Common Operational Picture (COP): The MONICA Common Operational Picture (COP) control room solution aggregates all the information from the area under surveillance and displays it in real-time and incorporates the interactive Decision Support solution for the control room staff. It includes live heatmaps of crowd density and capacity, sound and noise.

It also shows the position of varies types of staff on the ground and existence of detected objects or incidents.

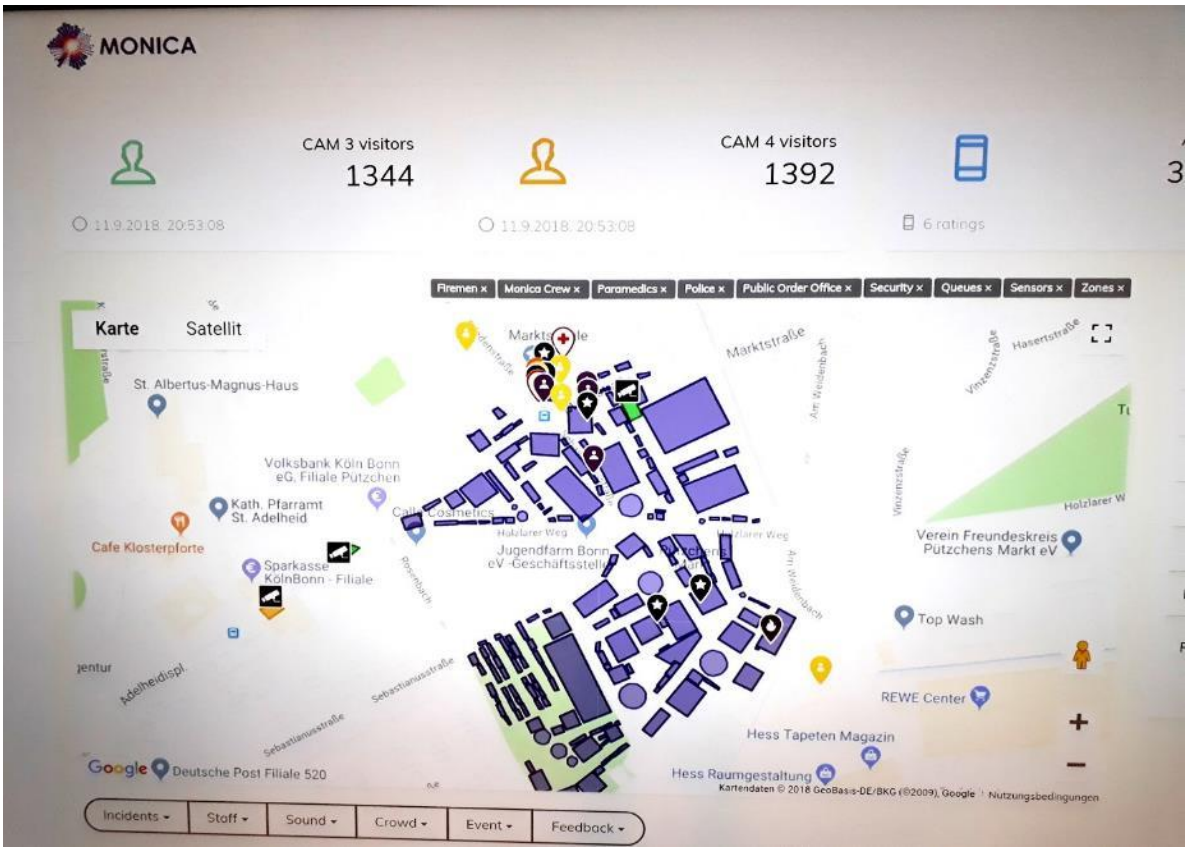

Figure 19: The COP displaying crowd data and visitor counts from Pützchens Markt event 2019 in Bonn

The COP consists of a database representing the current status at the event and a user interface. The data in the COP Data Base is exposed to other MONICA components through a service layer with an API. The DSS can be integrated into the COP and used to issue alerts related to e.g. crowd capacity levels, crowd movements and sound levels based on data collected and processed from deployed MONICA devices, e.g. CCTV cameras and crowd wristbands. The processed data will be visualised as e.g. heat maps superimposed on the map of the event site.

The COP enables the control room staff to make decisions on emerging issues and take preventative or responsive action based on accurate, real-time information. The COP also communicates these decisions to advanced wearable devices that allow security and first responder personnel in the field to be notified, in real-time, of incidents such as fights or high-risk queues.

MONICA Decision Support System (DSS): The DSS component offers recommendations and proposes actions for the human operator based on data from CCTV cameras, Sound Level Meters, wristbands as well as input from other IoT devices. It is based on a decision tree that combines fuzzy rules and expert knowledge.

The DSS is customized to the needs of end users; it parses information directly from the database, depending on user needs and the type of decision that must be made.

The core of the Decision Support System is rule-based and consists mainly of actions, conditions and rules, the final result of which is affected by the credibility factor. Each of them forms a separate class:

Actions: The “Actions” class, returns the description of each action and its degree of fulfilment.

Conditions: The “Conditions” class receives the condition parameters as an input, calculates the membership function and then returns a fulfilment pair that includes the fulfilment degree and the description of a condition.

Rules: The "Rule" class first calculates the mean of all preconditions. Then, the precondition's mean is multiplied with that rule's credibility factor in order to determine the rule's degree of fulfilment. Information of all actions, conditions and rules is contained in the *input* JSON file and is parsed during the setup phase of the application.

Security, Privacy and Trust Framework: The aim of cyber security, privacy and trust framework is to address the privacy and security of technical issues within the MONICA IoT infrastructure, which is expected to share critical information with components involved in the pilot sites.

Staff wristbands edge layer: Staff wristbands are used for two-way communication between control room and the stewards in the field. The wristbands use Ultra-Wideband (UWB) two-way communication and incorporate a LED screen for use interaction. UWB-based geometrical localization is used for positioning. The infrastructure is comprised of anchors, tags, a network router, a network switch and a server running the location engine and configuration software.

Figure 20: Crowd wristband, Woodstower 2019

Crowd wristbands edge layer: The low-cost crowd wristbands are equipped with LEDs and a user interaction button that can be used to collect user input from the visitors ("Likes", voting, etc). Crowd density can be accomplished by having visitors wearing crowd wristbands which provides anonymous localisation of visitors in the event area. The crowd wristbands were used during the Friday Rock concert (Tivoli, Copenhagen) in April 2018, in the IoT Week 2019 and Woodstower (Lyon) in 2019. LED were used to create synchronised lightshows with the concert goers.

Smart glasses edge layer: The MONICA Crowd Management and Communication solution uses the Optinvent ORA-2 smart glasses which have a built-in camera and communication means to send images and live video feeds to the control room, to receive texts and alerts and to send acknowledgements. The smart glasses are operated by either a handheld joystick or using a touch pad on the side of the glasses. The smart glasses have transparent display and is a fully standalone Android device that can run any other Android application.

Live Positioning Information System (LiPS): GPS LoRa staff trackers allow the control room to track the location of staff for a better coordination of team response actions to incidents on-site. The tracker updates the location every 5 seconds allowing the control room staff to view the on-site staff's positions on the COP map in real time. An Open Source program that displays GPS positions with coordinates from MQTT messages on a map is available at GitHub here: https://github.com/MONICA-Project/lora-map.

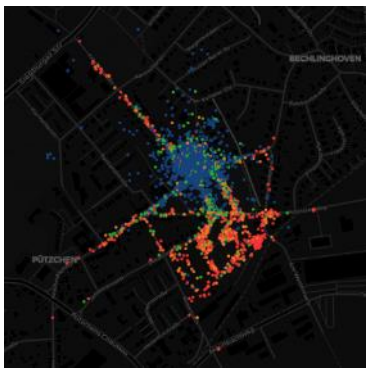

Figure 21: The COP displaying GPS staff tracking positions (signal strength) during Pützchens Markt event 2019

6.2.2 Communication

The MONICA Crowd Management and Communication solution uses a broad range of communication network infrastructures and protocols, each suited to a specific part of the internal and external communication infrastructure. Communication protocols have in many cases been enhanced with additional plugins developed by MONICA partners.

WAN communication: MONICA relies on standardised communication networks such as wide-area 3G/4G/5G telecommunication infrastructure, The MONICA COP requires a fast cloud Internet connection for minimum latency. Some devices, such as the SLM, may use 3G/4G network communication. GPS trackers uses LoRa communication infrastructures.

Wireless LAN communication: A stable Wi-Fi network is required to avoid data loss and a high bandwidth for advanced functionalities requiring audio recording such as source contribution identification. The Sendrato wristbands uses UWB (Ultra-Wide Band) communication whereas the Sendrato crowd wristbands use 868Mhz networks and proprietary communication protocols.

Wired LAN communication: CCTV cameras uses Ethernet with PoE (Power over Ethernet) LAN networks.

The security and privacy features are ensured by the MONICA Cyber Security, Privacy and Trust Framework.

6.2.3 Integration

The MONICA Crowd Management and Communication solution is a complex solution that relies on both external components and technologies as well as components, enablers and tools from the MONICA project partners. Please contact the responsible partner listed below for more information.

The entire solution is embedded in a MONICA Private Cloud structure as described in the MONICA Platform Architecture and Components.

MONICA Private cloud services

The MONICA architecture comprises the following subsystems, also called layers, as described in the MONICA Platform Architecture and Components.

- The ***IoT Layer*** is composed of three subcomponents: a) The *Adaptation Layer* providing technology independent management of physical resources and uniform mapping of data into standard representations, b) the *Middleware* offering storage and directory services for resources registered in the IoT platform; and c) the *External IoT Platform Connectors*, handling the communication with external IoT platforms and the integration of data coming from outside e.g. through the OneM2M Network Service Capabilities Layer (NSCL);
- The ***Services Layer***, where the intelligence of the platform is implemented and specific processing modules are integrated to provide technical solutions compliant with the application requirements;
- The ***MONICA APIs Layer***, which provides service access points for MONICA application developers and external application developers that want to access MONICA functionalities and information streaming from the platform;
- The **Cyber *Security and Privacy Framework***, enabling trust-based communication, policy management and technical support across all levels of the platform. More specifically, this framework ensures secure data flows and storage, protected information exchange and trusted federation mechanism to facilitate private information sharing;
- The ***Deployment and Monitoring Tools.*** These tools belong to a transversal framework able to simplify the platform deployment (*e.g.* modules belonging to the *Device* and *Network* layers) and used for checking the operational status of the devices, networks and overall system.

MONICA Private cloud integration

In the MONICA IoT Platform, Data Sources API functions as interface layer between the MONICA IoT Platform and the MONICA Cloud services as described in the MONICA Platform Architecture and Components. The following layers are described in the MONICA Crowd and Capacity Monitoring solutions:

- The **Device Layer** includes all IoT wearables
- The **Network Layer** allows effective communication between IoT devices and the IoT Platform
- The **Edge Layer** includes a set of modules for real-time data processing

The MONICA Platform Architecture and Components provides further details about the behaviour of each system's component and related subcomponents, including architectural elements that deliver the system's functionality.

External technologies required

The cloud solution is based on standard cloud server infrastructure such as the Atos Managed Public Cloud.

Internal MONICA enablers and tools required

- MONICA Common Operational Picture (COP)
- MONICA Decision Support System (DSS)
- MONICA Cyber Security Privacy and Trust Framework
- MONICA Private cloud services

6.2.4 Scalability

The following scalability issues should be considered:

Scalability of the MONICA COP: The MONICA COP requires a fast internet connection for minimum latency. The Smart Glasses Monicora app is different from apps on mobile phones, since it executes on an extremely small processor embedded in the glasses. Although the app can be customised, it is limited in terms of features that can be implemented. Hence, it requires a more powerful platform such as the COP to provide advanced features. One COP is able to control several Smart Glasses at the same time

Scalability of the high-level network infrastructure: The theoretical assumption is that the *High-Level Network Infrastructure* scales up to a thousand nodes or more for large-scale IoT deployment. However, for MONICA deployment, the network might scale to just hundreds of nodes in a single network for large-scale deployment linked together via an 802.11 backbone due to data rate and duty cycle requirements of a typical application. To achieve better scalability, the coverage area of the access points within the MONICA pilot is the key parameter.

Scalability of the cloud infrastructure: To Scale Vertically (or Scale-Up): this type of scalability can work with any application to a limited degree. To scale vertically means to add resources to a single node in a system, typically involving the addition of processors or memory to a single computer. Such vertical scaling of existing systems also enables them to use virtualization technology more effectively, as it provides more resources for the hosted set of operating system and application modules to share. An example of taking advantage of such shared resources is by increasing the number of Apache daemon processes running. To Scale Horizontally (or Scale-out): scaling a system by adding hardware resources horizontally and then dividing the load between them. Horizontal scaling is similar to elasticity; it allows the reallocation of resources between applications by provisioning, or by claiming back virtual machines. Horizontal scaling uses the infrastructure elasticity, but the application needs to be able to scale by adding more nodes and by distributing the load. To scale horizontally means to add more nodes to a system, such as adding a new computer to a distributed software application. An example might be scaling out from one web-server system to a system with three web-servers.

6.2.5 Associated MONICA solutions

- The MONICA Crowd Management and Communication solution: is closely related to and have been demonstrated together with the MONICA Crowd and Capacity Monitoring solution for a complete IoT enabled, closed-loop security solution. But despite this, the two solutions may be used independently.
- The MONICA Crowd Management and Communication solution have also been demonstrated with the MONICA Sound Level Monitoring solution for providing heat maps of sound levels during concerts. It is also closely associated with the MONICA Active Sound Field Control System solution providing environmental and sound monitoring data.

6.3 Implementation

6.3.1 Installation

The MONICA Crowd Management and Communication can be implemented as a customer specific solution independent of other MONICA solutions.

Preparation
The following information should be investigated and prepared before implementation is commenced:

Control room: The availability of the following assets should be investigated and planned before implementation is commenced: Availability of network/power, availability of high-speed internet connection, general control room facilities such as tables and chairs, display screens.

Event location: A map of the venue should be provided in order to plan the position and the amount of the equipment to be installed. Also, the availability of, and access to, elevated places to mount wristband anchors and LoRa antennas should be identified. Finally, the availability of power and internet access should be investigated for each equipment and mapped.

Wristband infrastructure: The staff wristbands operate at a high frequency so buildings/walls/trees can negatively influence this. Generally, the venue should be a large indoor or outdoor open space with low complexity: an indoor venue with many rooms or an outdoor space inside a city centre are not feasible. Ten anchors can cover app. 2.500m^2. At least one Ethernet connection is required for the master anchor.

Deployment

Wristband infrastructure: It is strongly advisable that DEXEL (or another partner that has been properly trained) is hired to supervise the installation. The COP should be set up in a control room where qualified control room operators can monitor the incoming data.

Operation

The supplier of the MONICA Crowd Management and Communication should be at hand during the event to support the event organiser. The support can be delivered remotely.

The DEXEL (or another partner that has been properly trained) should be hired to supervise operation of the wristband infrastructure.

6.3.2 Regulatory aspects

Technical regulations

Interoperability in MONICA is achieved also thanks to the adoption of several open standards. The standards adopted by the MONICA platform are the following.

Device/NWK Layer

- Bluetooth BLE / DASH7 / Wi-Fi – IEEE 802.11
- UWB – ETSI EN 302 065-2 V 2.1.1 - EU Commission Implementing Decision 2014/702/EU, and IEEE 802.15.4a
- ETSI EN 302 065-2 V2.1.1 for UWB staff wristbands
- ETSI EN 300 220-2 V3.1.1 crowd wristbands
- IETF (Internet Engineering Task Force) 6LoWPAN (an acronym of IPv6 over Low -Power Wireless Personal Area Networks). / IETF ROLL (Routing Over Low power and Lossy networks) / IETF CoAP (The Constrained Application Protocol)
- OASIS (The Organization for the Advancement of Structured Information Standards) MQTT (Message Queuing Telemetry Transport) Protocol
- **Ontology**
- ETSI SAREF (Smart Applications REFerence ontology). https://saref.etsi.org/saref/latest/saref.html
- **Security**
- IETF Oauth 2.0 (Open-standard authorization internet protocol) / OASIS XACML (eXtensible Access Control Markup Language), an architecture, and a processing model describing how to evaluate access requests according to the rules defined in policies.

IoT Platforms

- oneM2M Network Service Capability Layer / GW

Data format / API

- OGC (Open Geospatial Consortium) SensorThings API (The OGC SensorThings API provides an open, geospatial-enabled and unified way to interconnect Internet of Things (IoT) devices, data, and applications)

Architecture Design and Documentation

- ISO/IEC/IEEE 42010:2011 (ISO/IEC/IEEE 42010:2011, a standard addressing the creation, analysis and sustainment of architectures of systems, through the use of architecture descriptions.
- AIOTI HLA (Alliance for Internet of Things Innovation) https://aioti.eu/wp-content/uploads/2017/06/AIOTI-HLA-R3-June-2017.pdf
- The staff wristbands should be compliant with ETSI EN 302 065-2 V 2.1.1 https://www.etsi.org/standards-search#page=1&search=EN300%20392&title=1&etsiNumber=1&content=1&version=0&onApproval=1&published=1&historical=1&startDate=1988-01-15&endDate=2016-10-10&harmonized=0&keyword=&TB=&stdType=&frequency=&mandate=&collection=&sort=1

- The staff wristbands should be compliant with EU Commission provisions 2014/702/EU https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014D0702
- The crowd wristbands should be built to comply with ETSI EN 300 220-2 V 3.1.1 https://www.etsi.org/standards-search#page=1&search=EN300%20392&title=1&etsiNumber=1&content=1&version=0&onApproval=1&published=1&historical=1&startDate=1988-01-15&endDate=2016-10-10&harmonized=0&keyword=&TB=&stdType=&frequency=&mandate=&collection=&sort=1
- The UWB communication should be compliant with the IEEE802.15.4-2011 standard.
- The hardware must comply with the Waste Electrical and Electronic Equipment Directive (WEEE 2012/19/EU).
- The CCTV cameras and other hardware sensors are an electronic equipment and the supplier and the organiser must agree on the proper take-back procedure for the used hardware.
- The hardware must comply with the Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive (RoHS 2011/65/EU).
- The hardware must be marked with the WEEE mark.

The IoT elements of the MONICA Crowd Management and Communication solutions making use of radio frequency spectrum must adhere to the various European regulatory provisions as laid forth by CEPT/ECC in conjunction with some relevant EU Decisions. For further information see D12.5 Report on Standards, Regulations, and Policies for IoT Platforms.

Other local/national regulations

With regard to the collection and processing of personal data, the GDPR allows Member States to enact national provisions on certain issues as stipulated by the National Data Protection Authority. For example, Member States will have discretion to enact national provisions imposing further requirements regarding the appointment of Data Protection Officers.

When MONICA solutions are used to collect and/or process personal data, the following general topics need to be considered to be GDPR compliant:

- Processing data based on consent must be unambiguous and involve a clear affirmative action (an opt in)
- Internal procedures must be developed to protect personal data
- Internal procedures to protect the rights of data subjects must be implemented
- Informed consent procedures and forms must be designed and collected
- The event organiser is identified as the “Data Controller”
- The MONICA provider is identified as a "Data processor”
- A Data Processor Agreement must be drafted and signed by these two parties
- Data Processor Agreements with third parties must be in place if relevant
- A Data Protection Officer can be designated by the Data Controller
- A Data Management Plan is required which established the intended processing of personal data and the purpose of such processing
- A Data Protection Impact Assessment must be carried out based on the Data Management Plan and special areas of vulnerabilities towards protection of personal data must be identified and resolved.

Ethics

The following specific ethical considerations shall be made:

- The COP should be placed in a secure room with controlled access to prevent any form of misuse of the displayed data (location of staff, pictures, videos etc.).

- If informed consent from staff (see below) needs to be collected, this should be done voluntarily and in due time prior to the deployment of the solution to allow staff sufficient time to make an informed decision.
- If the COP is used to display the location of security personnel, the involved personnel need to be informed and have provided explicit consent on an informed consent form.
- If staff wearables are used, staff need to be given detailed information of the purpose and use of the wearable and sign an informed consent form.
- If smart glasses are used, data files stored internally in the smart glasses must be deleted at the time they are no longer needed, e.g. when the event is finished. Internal procedures stating who is responsible for doing so and how the action needs to be documented should be place.
- If smart glasses are used, ways of alerting those who may be recorded should be considered. For example, a clearly visible badge could be worn.
- If the LoRa staff tracker is used, it is necessary to download an app on a mobile device (e.g. phone). Staff members cannot be expected to use their personal mobile phones for this purpose and should therefore be supplied with a suitable mobile device for this purpose. This is not valid for the LiPS solution.

- The solution may raise concerns about increased surveillance practices and how these affect citizens' rights to privacy. Event organisers should define the legitimate reasons for implementing the solution. It may be useful to carry out a Legitimate Interests Assessment (LIA).

6.4 Business Aspects

6.4.1 Revenue models

The choice of business model and pricing schemes is entirely up to the partner that have commercialised the solutions. Hence, the following information is solely provided as a guide to the expected business conditions that the solutions might be provided at. Please contact the responsible partner for further, up-to-date details. A list of relevant contacts is provided in section **Error! Reference source not found.**.

Components	Type	Anticipated revenue model
Common Operational Picture (COP)	Software, cloud solution	The COP software can be provided as an up-front design, development and installation charge combined with recurrent software licenses. The cloud hosting is provided at standard cloud solution costs.
Decision Support System (DSS)	Software	The DSS software can be provided as an up-front design, development and installation charge combined with recurrent software licenses.
Security privacy and trust framework	Software, cloud solution	The Security privacy and trust framework will be sold as a recurrent software license plus one-off configuration charges. The cloud hosting is provided at standard cloud solution costs.
Staff wristband edge layer	Hardware, firmware, software	The wristband components are offered at a commercial one-off cost per wristband. The firmware is included in the cost. The infrastructure is either provided as one-off costs or is offered as a complete rental including design, installation and operation during the event. The software for MONICA COP integration is offered at a one-off license per installation.
Smart glasses edge layer	Hardware, firmware, software	The smart glasses components are offered at a commercial one-off cost per glass. The firmware is included in the cost. The software for MONICA COP integration is offered at a one-off license per installation.
Staff real-time positioning edge layer	Hardware, firmware, software	The positioning devices and LoRa interfaces are offered at a commercial one-off cost per user. The firmware is included in the cost. The use of LoRa is offered by the network provider. The software for MONICA COP integration is offered at a one-off license per installation.

6.4.2 Business Models

The Business Model Canvas is used to give a high-level overview of the contents in the value configuration and in the customer group side related to a specific value proposition. This tool is used to map out all details of the MONICA business models based on the value proposition, target groups, the partner constellations, and revenue models outlined in this chapter.

Table 2: Business Model Crowd Management and Communication

<table>
<tr>
<td rowspan="2"> 
Key Partners

<u>MONICA partners</u>
• LINKS
• CNet Svenska AB
• Atos
• VCA Technology Ltd
• Dexels BV
• Optinvent
• Fraunhofer FIT

<u>External partners</u>
• Hardware
• Network components
• On-site Installation</td>
<td> 
Key Activities
• Cloud operation
• Cloud systems
• Software development
• Firmware development
• Network protocols
• Cybersecurity analysis and mitigation</td>
<td rowspan="2"> 
Value Proposition
A Private Cloud structure including the MONICA Common Operational Picture (COP) the MONICA Decision Support System (DSS)
Visualise data in the control room and provide an overview of crowd’s position, movements, and behaviour
Decisions support system to make the right decisions at the right time
Two-way communication supports onsite staff, coordination and management</td>
<td>Customer Relationship
 
• Provide overview of crowd size, density and flow in real-time
• Detect abnormalities and objects for interventions
• Enhance communcation with on-site staff</td>
<td rowspan="2">Customer Segments
 
• Organisers of musical events, outdoor concerts
• Owners of venues for large events such as stadiums, concert arenas
• City authorities for safety of large events
• City authorities responsible for noise control in the city
• Organisers of sporting events</td>
</tr>
<tr>
<td> 
Key Resources
• Software developers
• Cloud operation
• Network specialists
• System integrators
• Cybersecurity experts</td>
<td>Distribution Channels
 
• B2B event organisers
• B2B city authorities
• Through system integrators
• Through cloud operators</td>
</tr>
<tr>
<td colspan="2"> 
Cost Structure
• Standard cost of cloud services
• Cost of network services
• Cost of hardware
• Cost of development, customisation, training
• Cost of operation
• Cost of commissioning and de-commissioning</td>
<td colspan="2">• COP and DSS provided as an up-front customization and installation charge plus recurrent software licenses
• Cloud integration component and services as consultancy services
• Security framework as a recurrent license plus one-off configuration charge
• Configuration, installation commissioning service costs</td>
<td> 
Revenue Streams</td>
</tr>
</table>

6.5 Potential for Replication

6.5.1 Lessons Learned

Lesson Learned has been collected throughout the deployment and demonstration phases of the MONICA project and the relevant Lesson Learned are provided here for reference. Please check with the responsible partner for the newest updates.

The following main Lesson Learned from the MONICA demonstrations and reference deployments are:

- Smart glasses may interfere with the uniforms, e.g. hats or caps, of the on-site security staff. The glasses should therefore be tested by staff in full uniform before deployment.
- LoRaWAN based trackers are a suitable alternative to overcome problems and limitations (or non-existence) of WiFi or cellular networks in low data rate scenarios.
- LoRaWAN based trackers are primarily suitable for outdoor events.
- As the RIOT-OS based GPS trackers utilize the LoRaWAN infrastructure of TheThingsNetwork it is vital to have at least one LoRaWAN gateway within range of the event site (venue).
- The use of iPhone to create ‘hot spots’ is an effective back up for areas where Wi-Fi is poor/ unavailable.
- Hardware should be installed 2-4 days prior to the event and tests should be carried out.
- During notifications of national spectrum regulatory authorities in a Member State with regard to a planned demonstration/test of new and novel (not yet CE-marked) radio devices, it has proved useful to reference Art 9(2) of the 2014/53/EU (RED), where a MONICA supported event area is compared to a tech-exhibition or trade fair. It should be observed, that the event area must be gated, to prevent non-compliant equipment incidentally to pass through any exit gate, with the risk of causing harmful interference to other wireless services. Observe also, that Art 9(2) of said directive instructs, that non-compliant devices shall be duly marked as "demonstration/not for sale"

6.5.2 Usability Aspects

6.5.2.1 Acceptance of MONICA Solutions

- The COP requires accurate results for the user to be able to use solution as intended. This information is to be presented in an organised and readable manor on the COP. This, as well as assisting the user to make appropriate decisions, contributes to the overall acceptance of the MONICA solution.

6.5.2.2 Effectiveness of MONICA Solutions

- Assists with decision making as the COP produces event information and enables the user to make informed decisions at the event.
- Training of COP is required for users to ensure COP can be used in the most effective way.
- Data provided by the COP can be used to ensure a safer environment, in relation to crowd monitoring, crowd safety and security etc. A quicker intervention of incidents helps to ensure a safer environment for all.

6.5.3 Reproducibility Aspects

Part of the Crowd Management and Communication use case can be demonstrated and reproduced thanks to the Staff Management Toolbox. Anyone with the docker supported computer can run the demonstration following the instruction specified in the toolbox tutorial.

This toolbox instantiates different components of the MONICA toolchain as docker containers, namely SCRAL, OGC Sensorthings storage and Common Operational Picture. The entire setup can be verified with the help of a docker container called gpsfaker. Once the data is populated, different components can be validated with the help of corresponding endpoints as mentioned in the README file of the toolbox.

6.5.4 Contacts

The following partners are responsible for various components of the MONICA Crowd Management and Communication solution for detecting and reporting critical incidents:

Solution	Responsible	Acronym	Details
MONICA Private cloud services	Atos	ATOS	ATOS can provide the cloud infrastructure and the system integration.
MONICA Common Operational Picture (COP)	CNet Svenska AB	CNET	CNET can provide the software for the COP
MONICA Decision Support System (DSS)	CERTH Information Technologies Institute	CERTH	CERTH can provide the software for the DSS
MONICA Security privacy and trust framework	Atos	ATOS	ATOS can provide the cyber security privacy and trust framework
MONICA IoT and edge layers	LINKS	LINKS	LINKS can provide the MONICA IoT integration components
Staff and crowd wristbands interfaces for COP	Dexels/Sendrato	DEXELS	Sendrato can provide the hardware wristbands. DEXELS can provide the firmware and the communication infrastructure
Smart glasses interfaces for COP	Optinvent S.A.	OPTIN	OPTIN can provide the hardware and the firmware for the wristbands.
Staff real-time positioning interfaces for COP	Fraunhofer FIT	FIT	FIT can provide the GPS location devices with LoRa communication interfaces.

6.6 Reference Deployments, Demonstrations and Results

6.6.1 Security Incident – Leeds Rhinos – Rugby – October 2019

General description of the event

Emerald Headingley Stadium (EHS), in Leeds, is home to MONICA pilot partners Leeds Rugby (LR) and Yorkshire County Cricket Club (YCCC) and hosts both men's and women's cricket and rugby union and super league matches, including international fixtures. Sky TV is often present and broadcasts games around the world. EHS provides match day services including bars and food outlets, entertainers and souvenir stalls. In May 2019 a £50m stadium infrastructure development was completed securing the future of the Stadium as an international sporting venue for the foreseeable future. The crowd capacity for rugby is 19,544 and a mix of seats and standing. The crowd capacity for cricket is 18,350 and is all seating. During 2017 and early 2018 extensive consultation took place with key stakeholder groups, including Ground Safety Officers for Leeds Rugby and YCCC, G4S Security Services, the Safety Advisory Group, and Fire and Police Emergency Services. Following this a safety and security needs analysis for Rugby and Cricket was undertaken to identify the main match day challenges/ issues which were: queues at services and gates leading to overcrowding; and speed and accuracy of incident detection. It was also felt that event information could be improved, particularly for first time visitors. Consequently, security incident use case was deployed in Emerald Headingley Stadium (EHS), both in 2018 and 2019. The Leeds Rugby Varsity Game held in October 2019 is the event we will describe and we refer to as an example to take into consideration in case of replication.

Figure 22: EHS Stadium in Leeds

Security incident - deployment description

The Use Cases selected for the focus of the demonstrations reflect the main issues and challenges faced by EHS, and the IoT Devices and Solutions provided by the MONICA Platform seek to demonstrate effective ways of addressing these challenges maintaining a safe, secure and enjoyable environment for visitors.

After the demonstration held in 2018, the smart glasses were found to be a valuable source of information if able to provide real time images of an incident to attending fire crews, but may have limited use in smoke filled rooms and if worn with fire safety equipment.

In 2019 the MONICA demonstration event, deploying Security incident use case, was the Leeds Rugby Varsity Game held in October. This event attracted 8,617 visitors.

Prior to the demonstration, stewards from the stadium and firemen from West Yorkshire Fire and Rescue Service were recruited to participate in testing the glasses. They were selected so that the MONICA team could analyse how different event users could effectively use the smart glasses for their specialist roles.

The aim of deploying this solution was to use the smart glasses to help with general stadium security, such as reporting and detecting incidents and observing general crowd and individual behaviour. The smart glasses were used in various different ways. For example, one steward detected and reported the use of a flare in the away visitor section of the crowd. The steward had the ability to film the incident on the glasses and report back to the COP. The glasses also helped with bag searches, prior to gaining entry to the stadium. The stewards wore the glasses for the duration of the bag searches but did not record.

Taking into account the lessons learned from the previous demonstrations, the Wi-Fi network was upgraded to support the Smart Glasses and a comprehensive connectivity survey undertaken by MONICA partner Rinicom indicated it fully suitable for the planned tests. Due to the improvements, ten pairs of smart glasses were prepared for the tests with the West Yorkshire Police Officers on duty at the event. Eight officers were recruited and briefed on the Project and their roles.

Improved incident detection, as well as the improved incident information sent to the control room was successfully demonstrated. The increase in speed of communication and communication options between control room staff and stewards were also successfully demonstrated.

Challenges faced using MONICA solutions

One of the main aspects to take into consideration before replicating security incident use case, is the organization of connectivity tests before the event. Such tests avoid problems during the event. During the deployment stages at Emerald Headingley Stadium in 2018, technical partners faced difficulties with remote connectivity. By using other technologies, such as TigerVNC, this issue can be resolved as it will improve remote connectivity.

During the test of the smart glasses, the wi-fi would occasionally drop out, which meant features of the smart glasses could not be used. To help with this, the MONICA team provided their phones with a hotspot as a

solution, which meant the glasses were connected at all times. This instigated the upgrade of the wi-fi in preparation for the October (Varsity) demonstration.

Another aspects to consider is related to conditions of use of the smart glasses. In fact, the smart glasses may have limited use in smoke filled rooms and if worn with fire safety equipment. During some MONICA tests, it was discovered that the smart glasses could interfere with the officer's uniform (hats, earpieces etc.) and testing of the Glasses prior to the live demonstration is critical to ensure they can be safely worn with the relevant emergency services uniform as these differ across Europe.

Smart glasses would be a valuable source of information if able to provide real time images of an incident to attending fire crews, as well as video recorded and streamed by them.

Testing these features, MONICA team and security staff noticed that the over-use of the video feature could drain the battery and cause some issues with overloading the COP with images. For these reasons during the deployment in 2019, the staff was trained to use the video mode judiciously.

6.6.2 Safety Incident – Winter DOM

The Hamburger DOM is Northern Germany's biggest funfair with 7-10 million annual visitors during the 91 DOM days.[4]

In the 1930s, the original wintertime market was expanded with a spring market in an effort to help local merchants through the economic crisis. After the end of World War II, a summer market was added as well. With its three recurring festivals in spring, summer, and winter the DOM is today the largest fair in Northern Germany, and the longest running fair in the whole of Germany.

The funfair takes place in the premises of the Heiligengeistfeld with a total of around 251 attractions[5].

Heiligengeistfeld is an event area in the St. Pauli residential quarter right next to the Millerntor-Stadion[6], in central Hamburg.

Since 1893, the funfair Hamburger DOM has been held here. When this area is not used for exhibitions, circuses or for the DOM, it is a car park. A building from German Telekom, a swimming complex, Millerntor-Stadion, a school, a patrol station, a historic defensive tower (Flakturm IV) and a shopping mall are fixed structures on the field.

From roller coasters, haunted houses and bumper cars to an old-fashioned game of duck fishing: in total, there are around 251 attractions (it depends on the season). There are also around 60 food stalls.

Safety incident use case – deployment description

Figure 23: Deployment of environmental sensors with wind speed meter

This use case was chosen by event organisers to track health and security incidents, in order to measure the wind speed and to be alarmed in case of high values. For this scope wind speed sensors along with two environmental sensors (temperature and air humidity) were implemented to detect hazardous weather conditions at the DOM site.

The sensors were put on 7 m - 7,5m high poles which can be seen in Figure 23.

They were positioned at the northern and southern parts of the DOM.

The visualisations and information displayed in the COP were evaluated before the event in a workshop with the stakeholders. The results were used for all demonstrations (Spring DOM and Winter DOM).

[4] 2017 Edition: March 24 - April 23 2017, July 28 - August 27 2017, November 3 - December 3 2017
2018 Edition: March 23 – April 22 2018; 27 July - 26 August 2018, November 9 - December 9 2018
2019 Edition: March 22 – April 22 2019; 26 July - 25 August 2019, November 8 - December 8 2019
[5] http://www.hamburg.de/dom/
[6] It's a stadium mainly used for football matches and it's the home stadium of FC St. Pauli.

The COP used a colour scale to show the different wind speeds. The rules linked to values were taken from the DWD[7], the German meteorological service.

Some stalls have to take specific measures when a wind speed is reached to ensure the safety of the visitors. A list of 20 stalls and their wind speed limit and the actions to be taken was provided by the event organiser.

The COP interface allowed the event organizer to have a summarized overview about all the activities regarding safety incidents, weather conditions and visitor count on the fairground in one dashboard and to have a spatial overview about the weather activities in a map.

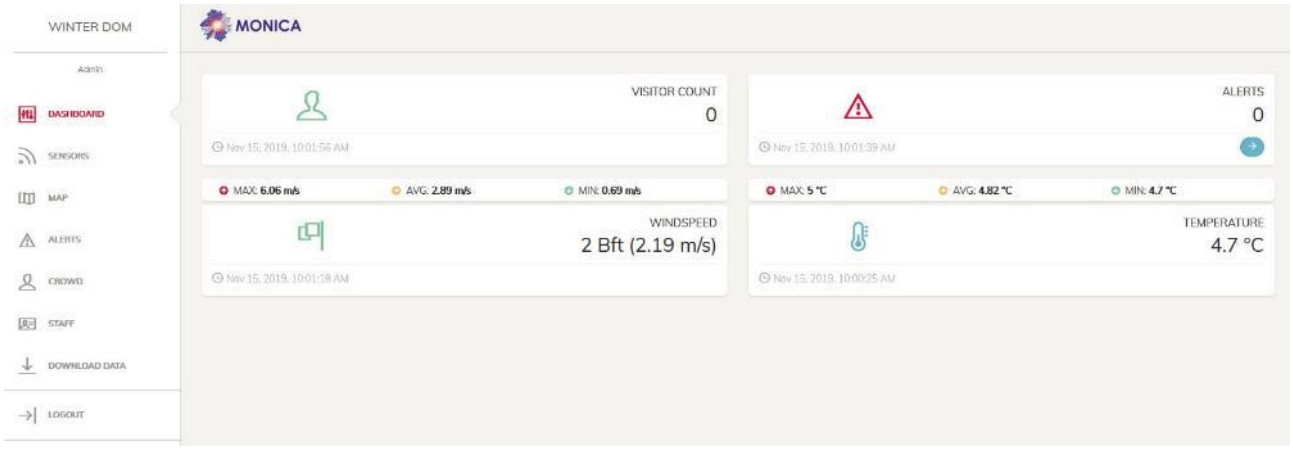

Figure 24: COP dashboard with safety incidents, current average wind speed and temperature

Figure 25: COP sensor portal at the MONICA COP for wind speed (real time, historical data) and temperature (real time, historical data)

Moreover, there were historical functions implemented, which allow the event organiser to not only monitor the current situation on the fairground but also the weather conditions of the preceding hours. This supported the decision-making process to push the appropriate measures for the current situation, e.g. if the wind is gusty or stormy. Another feature was the data download service which enabled the event organiser to download sensor data for a predefined period of time for each stall and sensor. Therefore, the data accessibility was enhanced if there were further questions regarding the weather situation at the fair ground if there were any incidents or accidents.

[7] https://www.dwd.de/DE/Home/home_node.html

Challenges faced using MONICA solutions

Challenges faced by MONICA staff were related to the integration of data into the cloud and reliable transfer to the COP. There were some problems during the first demonstration and they were solved before the 2019 deployment.

Thanks to the collaboration among the event stakeholders and the MONICA staff, the COP interface was improved. Moreover, event organisers used iPad (instead of mobile phones) and these two aspects enhanced visualizations and user experience.

6.6.3 Missing Person – Locate staff – Pützchens Markts 2019

General description of the event

Pützchens Markt is a historic street festival that has taken place in Pützchen, Beuel near Bonn every year for more than 650 years. Placed in an area with many narrow streets and houses, the organisers are deploying MONICA's crowd, capacity and staff monitoring tools to handle congestion and incidents.

The history of Pützchens Markt, known locally as the fair of the well, goes back to the worship of the German Abbess Adelaide (970 – 1015) who conjured up a well by throwing her crosier into the ground.

The village was named after the well, attracting pilgrims to its healing water. Soon traders started to put up tents and stalls to sell their goods. Gradually, a fair developed which continued to expand and Pützchens Markt was born.

Today, the festival takes place the second week of September and offers all kinds of attractions from traditional merry-go-rounds to more than 550 commercial stalls. The five-day event attracts around 1,4 million visitors of all ages who can enjoy the festival for free.

Pützchens Markt is located in a residential area in Pützchen, Beuel, near Bonn. The area is 4.5 km long, covering 80,000 m^2. There are six entrances and four main roads that lead to the main attractions.

Missing person – locate staff – deployment description

By equipping the staff with GPS trackers, the event organisers can locate them via the COP dashboard and thereby have an overview of the work force at all times. The purpose is to coordinate tasks effectively and improve response time in the case of incidents, since they can now also be detected by the system.

During the first year of Pützchens Markt, the localisation was run inside the COP dashboard deployed in the MONICA cloud. However, this first deployment revealed that a stable internet connection could not always be relied upon. For this reason, for the second year a digital location map was deployed independent from the MONICA cloud. The location of the forces was implemented via GPS trackers using the LoRa technology for the transmission. As a gateway, a Raspberry Pi with a LoRa extension was used.

In 2019, 45 devices were handed out to public order, fire brigade, police, first aid, security. The transmission worked very well in both years, only suffering from lower accuracy inside the command centre.

Following the feedback from 2018 that the GPS devices were too big, the devices were decreased in size for 2019. Also, an emergency button in order to call for backup was desired in 2018 and implemented in 2019.

Figure 26: First (top) and second generation of LiPS GPS trackers (bottom)

Real-time localization of staff is a part of improving the communication during health and security incidents, together with a fight detection algorithm developed by CERTH.

7 Sound Level Monitoring

When assessing sound levels, for instance in public urban areas, it's important that the measured sound levels are reliable, accurate and traceable. Therefore, it is required to use a type-approved, accredited and calibrated Sound Level Meter, which measures correctly under changing environmental conditions like temperature, humidity, and wind speed. Such installations are often bulky, complicated to install and difficult to collect real-time data from. The MONICA IoT Enabled Sound Level Meter is a practical, easy to use answer to this problem.

The MONICA IoT Sound Level Meter (SLM) solution provides real-time monitoring (measuring and displaying) of sound levels at discrete outdoor locations in the city. It is enabled for use in Internet of Things applications and is easy to deploy in the urban space. It collects data in real-time and sends them directly to backend databases. It can also perform real-time sound analysis so that sound contribution levels from different sources can be separated and pre-defined sound events can be detected.

The MONICA solution uses professional Brüel & Kjær IoT Sound Level Meters to measure instantaneous broadband sound levels (several acoustic parameters such as LAeq or LCeq), 5-minute average sound level (LAeq) and 1/3 octave spectrum. In addition, the SLM can provide GPS positioning and source contribution analysing. Data are exposed on a gateway and may be transmitted to cloud servers or the user's proprietary servers or CMS (Content Management System) platforms.

This MONICA solution complements the MONICA Adaptive Sound Field Control System solution. Combined they represent a total, closed loop sound monitoring and control solution for event and concert organisers during large open-air events. The solution also complements the MONICA Crowd and Capacity Monitoring solution where it is combined with crowd monitoring IoT devices. All together they provide a comprehensive solution for monitoring and managing sound and noise during large scale events.

The MONICA IoT SLM can be used in any type of open- air, gated and non-gated event. It can be used for short term deployment (e.g. for a specific concert); for a recurrent event (monthly or seasonal) or for semi-permanent events (night life area, traffic).

The MONICA IoT SLM solution solves many of issues related to professional sound monitoring in cities:

- It is made to professional standards and may be used for compliance measurements
- It provides real-time monitoring
- It is light-weight and easy to install by electricians
- It can operate on WiFi or 3G/4G wireless internet
- It can operate on battery (up to 14 hours) and on permanent power (if available)
- It will measure a range of useful technical sound level parameters

The SLM Gateway contains processing capabilities, which enable services that uses input data from several Sound Level Meters and which can further reduce the data, before transferred to the MONICA Cloud. The SLM Gateway provides the following additional features:

- It may detect pre-defined sound patterns such as gun shots, screams, braking noise, etc.
- It exposes data for other applications through simple web services
- It may be interfaced to the city's Open Data platform

Sound levels: Historical Sound Level parameters measured at the location of the Sound Level Meter(s) can be retrieved within a specified time interval. Intervals can be specified in steps of one second. The Sound Level Meter can measure basic acoustic parameters with up to two simultaneous frequency weightings (available weightings: A, B, C and Z). It can measure with up to three simultaneous time weightings (Fast, Slow and Impulsive) for the exponential averaging. ©

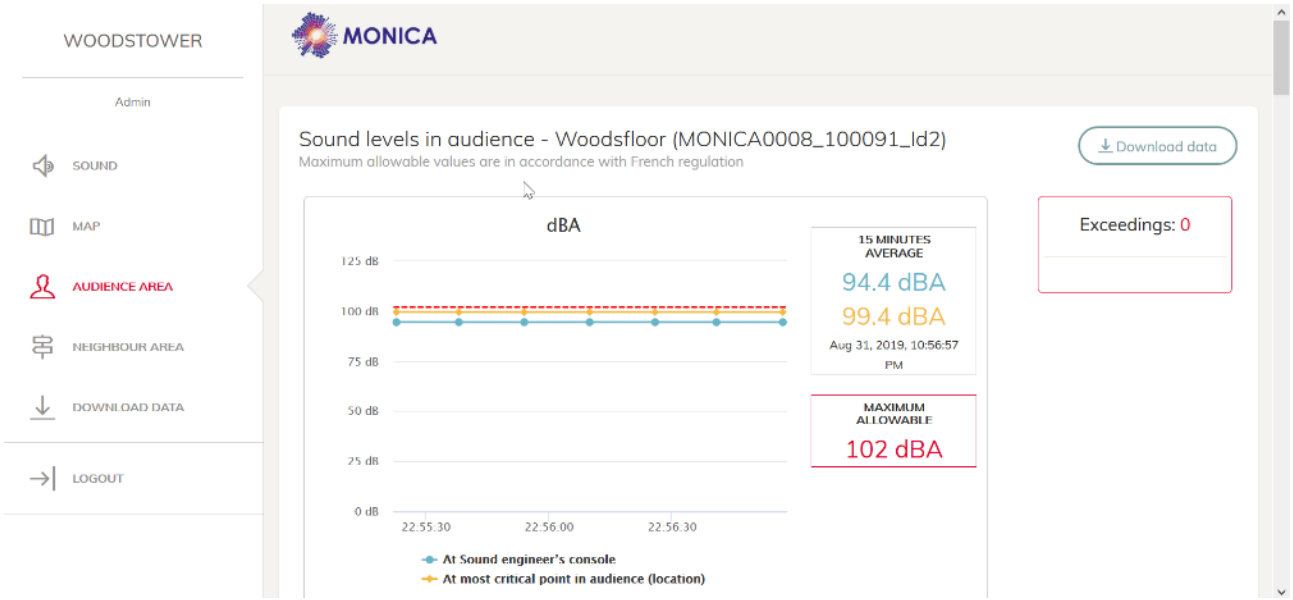

Figure 27: Assessing sound level regulation compliance during Woodstower 2019

Sound contribution analysis: Measuring the sound level in the vicinity of an outdoor event like a concert will also include the sound from other sources, like cars driving by. By placing one or more Sound Level Meters close to the concert, this service enables that the contribution from that concert can be separated at any other location where a Sound Level Meter is placed, and the sound level caused by the concert at that location estimated.

Sound heat map: A simple module has been developed using LAeq measurements of the MONICA IoT SLMs to compute a 2D map of noise density across a pre-defined area. The map covers the area of the venue and the surrounding neighbourhoods, giving an overview of the levels during the concert. The signal from the MONICA Adaptive Sound Field Control System solution can also be combined to reflect its impact on the sound levels.

CAP data platform: A simple WordPress plugin has been developed so that data can be displayed on e.g. a city's CAP (Collective Awareness Platform) or standard website. The plugin collects data obtained directly from one or more MONICA IoT SLMs and send to a CMS platform. The plugin displays the time series and the geographical location of each of the SLMs. The MONICA IoT SLM was demonstrated at the Copenhagen Municipality CAP during the replication event "Istedgade".

Figure 28: SLM places in Istedgade 2019 © In-JeT ApS

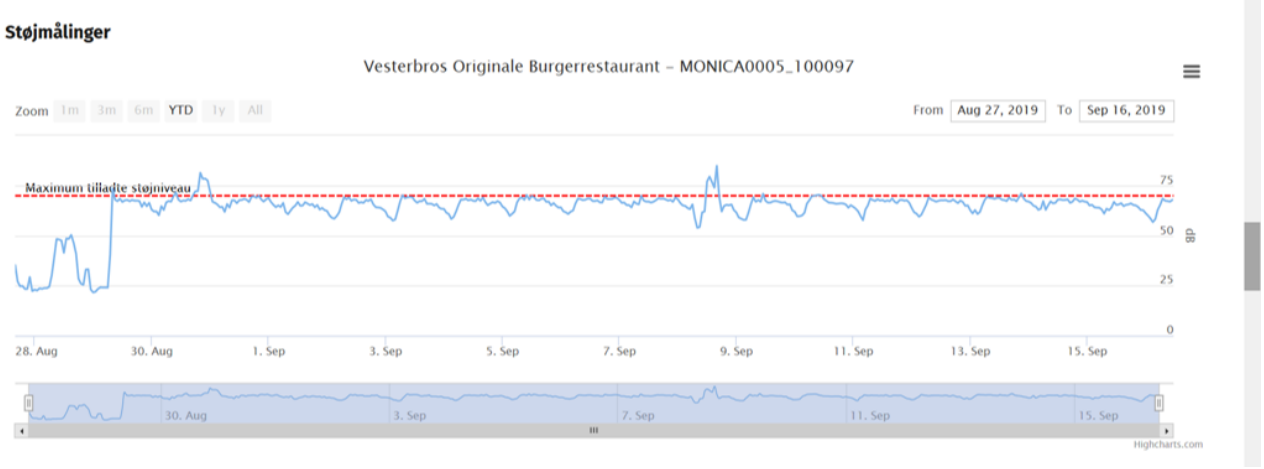

Figure 29: Measurements on the CAP in Istedgade from a MONICA IoT SLM

7.1 Scenario Descriptions

Monitor sound level:

In this scenario, the system monitors in real-time the sound level with measuring devices at a remote place from the display according to the reference units (dBA and dBC), and indexes (LAeq and LCeq) and with a sufficient precision to have professionals relying on it.

7.1.1 Type of Event

The solutions for monitoring sound level may be used at any type of gated or non-gated open-air event, e.g., concerts, festivals or sport events.

- Musical events, outdoor concerts
- Street festivals, open-air markets
- Sporting events
- Restaurant and night-life areas

- Streets and areas with traffic
- Building and construction sites

It can be used for short term deployment (e.g. for a specific concert); for a recurrent event (monthly or seasonal) or for semi-permanent events (night life area, traffic).

7.1.2 Challenges

Noise pollution poses a threat to both our health as well as the attractiveness of a city. Notable health issues that can be caused by noise pollution include stress, weakened mental acuity, and elevated blood pressure and heart rates. All major cities and larger urban areas have to cope with various sources of noise:

- Compliance of sound level ordinances for musical events, outdoor concerts in inner-cities
- Ad-hoc analysis of sound levels from street festivals and open-air markets in inhabited areas
- Sporting events compliance with area regulations and noise limits
- Restaurant and night-life areas respecting needs of neighbours
- Ad-hoc monitoring of streets and areas with heavy traffic for noise pollution monitoring
- Ad-hoc monitoring of temporary building and construction sites

Moreover, the city often has an interest in understanding the impact of sound in the city i.e. noise for neighbours during event set-up, during the event (music and crowd) and noise during decommissioning including noise from trucks and construction gears. The city may define noise level limits which external event or venue organisers must comply with in order to obtain the city's permission to organise an event. In this case, it is important for both the city and the event organiser that the sound level can be measured accurately to verify compliance. For the city, keeping a good relationship with neighbours in the proximity of major events or restaurant areas is very important.

The MONICA Sound Level Monitoring solution provides a comprehensive tool for overcoming these challenges.

7.1.3 Benefits

When assessing sound levels in urban areas, it's important that the measured sound levels are accurate to draw the right conclusions. If a venue is under a sound level regulation, authorities must make sure that measured sound levels are accurate before approaching the venue organizers. For that purpose, it is necessary to use a type-approved Sound Level Meter, which is calibrated, and which measures correctly under changing environmental conditions like temperature, humidity and wind speed.

The MONICA IoT SLM solutions help to establish the sound map of an event from three perspectives: regulation (confirm adherence to established noise limits), objective contribution (define noise sources and their contribution) and information (inform about sound levels and analyse components of sound).

- *The benefits for Smart City Operators are:* being able to monitoring noise in various spots in the city will enable municipalities and Smart City Operators to get precise information about street noise. By clustering the sound levels with crowd data, they can identify patterns on which to act upon and build new strategies of crowd management.
- *The benefits for event organisers are:* being able to estimate the impact of sound emissions in audience and neighbour areas, and to better manage complaints from the neighbours.

Performing processional sound level monitoring is often a complicated issue involving bulky and expensive professional equipment and highly skilled professional staff to install and interpret the measurements. This task is made easy with affordable, easy to arrange professional MONICA IoT Sound Level Meters and data can easily be send to monitoring platforms (like the MONICA COP), to own databases or CMS (like the MONICA CAP) or to the Smart City's Open Data platform.

7.1.4 Stakeholders for the MONICA Solutions

Event organiser: Person in charge of managing budget, logistics and external stakeholders that are part of the event. Responsible for assuring the success of the event at a practical level. Benefits for this stakeholder is to

have an overview on the sound levels in the audience and in the neighbouring area, as well as the assessment of the compliance with regulatory limits.

Event visitor: Person enjoying the event as an entertainment experience. Benefit for this stakeholder is to be informed on the sound levels in the audience and the compliance with regulatory thresholds.

Neighbour: Person living near the event. Benefits for this stakeholder are to be informed of the sound levels in neighbouring area, to assess the impact of the event (compliance with regulations) and minimise the sound impact of the event (noise induced annoyance, sleep disturbance) on his/her everyday life by the action of the ASFC.

Sound engineer: Person in charge of managing all the sound aspects before, during and after an event, dealing with the technical staff and the event organiser. Benefits for this stakeholder is to monitor sound levels in audience (at sound engineers console) to ensure compliance with regulations.

Local authority: Representative of the Public Administration departments interested in the health and safety of the event. With MONICA, this stakeholder can ascertain compliance with regulations (maximum sound levels allowed) while maintaining cultural events in the city.

7.2 Technical Aspects

The MONICA IoT SLM solution uses accredited Brüel & Kjær IoT Sound Level Meters to measure instantaneous broadband sound levels. In comparison to other accredited sound level meters, the MONICA IoT SLM is enabled for the Internet of Things using mobile or fixed data networks for communication and battery operation for ease of use.

7.2.1 Technical concept

The MONICA IoT SLM prototype uses accredited Brüel & Kjær IoT Sound Level Meters to measure instantaneous broadband sound levels. In comparison to other accredited sound level meters, the MONICA IoT SLM is enabled for the Internet of Things using mobile or fixed data networks for communication and battery operation for ease of use.

The basic components in MONICA Sound Level Monitoring solution are the Sound Level Meters, which measure sound levels and record sound. Collected data are transmitted to a SLM Gateway which takes care of local buffering, and data analysis/reduction. Data can be pulled from the SLM Gateway to the MONICA cloud or directly to an external cloud-based application, for example an organisation’s CMS. The concept is illustrated in the figure below:

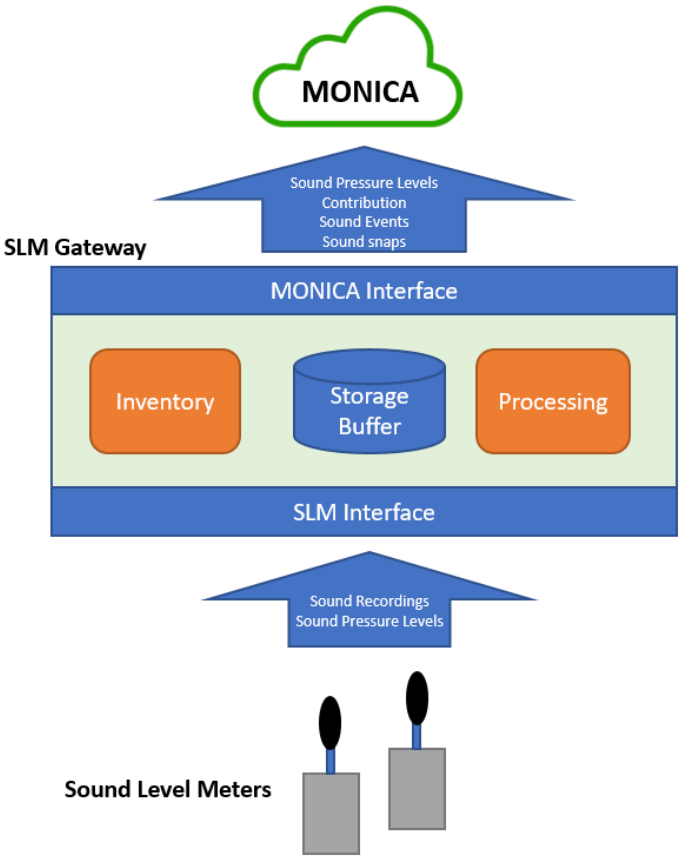

Figure 30: IoT Sound Level Monitor concept

The Sound Level Meter itself contains 3 elements:

1. The Sound Level Meter device itself which includes the microphone
2. A mobile phone, which in this first version will take care of the communication between the Sound Level Meter and the SLM Gateway.
3. A Power Bank which will supply both the Sound Level Meter device and the mobile phone enabling at least 8 hours of battery operation. Main power can be supplied for longer operational time.

Sound Level Meter: The Sound Level Meter is by itself an autonomous device, which do not depend on an infrastructure. It will record the sound; do the data analysis and data reduction and transfer the results to the SLM Gateway. The Sound Level Meter incorporate a GPS Receiver which enables information of the location of the Sound Level Meter to be read, but also to time stamp data from the Sound Level Meter, which enable time alignment of data from several devices.

SLM Gateway: Since the data collected from the Sound Level Meters are very high, a data reduction must be performed, which is done in the SLM Gateway. The Sound Level Meter will automatically connect to the SLM Gateway when either WiFi or 3G/4G networks are available. The needed bandwidth depends on the mode of operation. Most demanding scenarios are those which require sound recording (around 2 Mbit/sec). The compressed data are streamed to the owner's cloud server.

Event detection: Sound event detection algorithms can be developed to identify pre-defined sound events in real-time and publish a message from the cloud server. The security and control room staff can subscribe to these messages.

7.2.2 Communication

The MONICA IoT SLM will automatically start streaming the type of data which they are configured for to the SLM Gateway. The data will go to storage and potentially processing if configured. Communication from the MONICA IoT SLM to the MONICA cloud is provided by using a RESTful API. The data model contains

elements that allows user to build a hierarchy of devices within an organisation based on locations and directly address each device within the hierarchy. Uses can then extract various types of data sequences (e.g. Leq or octaves) with date-time stamps and GPS. The SLM Gateway also maintains an inventory of available devices and their physical and logical (sites) locations.

7.2.3 Integration

The MONICA IoT SLM is a relatively complex solution that relies on both external components and technologies and technologies, enablers and tools from the MONICA project partners. Please contact the responsible partner listed below for more information.

External technologies required

- Commercial Brüel & Kjaer Sound Level Meters.
- A stable WiFi or 3G/4G network is required to avoid data loss and a high bandwidth for advanced functionalities requiring audio recording such as source contribution identification. For one SLM, the required data rate is between 200 b/s and 2 Mb/s depending on the configuration.

Internal MONICA enablers and tools required

- Brüel & Kjaer SLM Gateway platform.
- MONICA Platform Core Enabler
- Sound Control Enabler
- Sound Monitoring Enabler

7.2.4 Scalability

- The MONICA IoT SLM system is scalable in terms of data types. It can handle several data streams simultaneously: base values, spectra and audio.
- The MONICA IoT SLM refresh rate is sufficiently high to allow the technical operator to react fast, in case an issue is detected (music too loud, noise levels exceeded, event detected).
- Data transfer and storage are only limited by the capacity of the organisations network connections and the capacity of its servers.
- The MONICA IoT platform has been demonstrated with integration of a maximum up to 10 SLMs retrieving sound measurements (e.g. LAeq, LCeq and spectrum data) from the SLM Gateway periodically every 15 seconds. In these pilot scenarios, the IoT platform has been performed smoothly without any delay and interruption. Potentially, a larger number of SLMs could be integrated, for instance, by increasing the periodicity of the sound data retrieval.

7.2.5 Associated MONICA solutions

The MONICA IoT SLM is closely related to and have been demonstrated together with these additional MONICA solutions:

- MONICA Adaptive Sound Field Control
- MONICA Crowd and Capacity Monitoring
- MONICA Crowd Management and Communication (including cloud server and COP)
- MONICA Collective Awareness Platform
- Noise Maps using Electrical Bikes Sensors

The MONICA IoT SLM can also be implemented as a customer specific solution independent of other MONICA solutions.

7.3 Implementation

7.3.1 Installation

Preparation

The following information must be investigated and prepared before implementation is commenced:

- Possible positions for mounting the MONICA IoT SLM should be identified and carefully investigated in terms of sound monitoring topography, expected performance, reflections, background noise, accessibility, aesthetic considerations, safety, etc.
- The need for permissions for installation and connections must be identified, from whom permissions shall be obtained, and the conditions and procedures for obtaining the permissions. This can be a lengthy process (private properties, access rights, etc.)
- The MONICA IoT SLM uses 230V AC for continuous operation. The right power plugs and adapters should be assessed depending on the type of power available onsite.
- For shorter term use and when no power is available, the battery power pack can be used, but the lifetime should be considered. The MONICA IoT SLM will have 14 hours of battery operation.
- A stable WiFi or 3G/4G network is required. If 3G/4G is preferred, a local SIM card is needed for each Sound Level Meter.
- MONICA IoT SLMs have a local storage in order to avoid any data loss, since mobile network transmission is sometimes unreliable (e.g. a large number of cell phones during an event is causing network traffic congestion).

Deployment

The solution can be deployed freely to any locations. See Preparation section above for limitations.

Operation

The devices can be operated unattended but need to be secured from unexpected touches/operations done by visitors. The noise information provided by the system will be delivered as decision support to authorities as well as event sound engineers, depending on the option.

7.3.2 Regulatory aspects

Technical regulations

- The analysis in the MONICA IoT Sound Level Meter conforms to the international standard IEC 61672-1 (Class 1) and has implemented frequency and time weightings as specified in the standard.
- The MONICA IoT Sound Level Meter conforms to the international standard IEC 61260-1 and has implemented 1/1-octave and 1/3-octave frequency analyses as specified in the standard.
- Sound Level Meters and Gateways comply with the Radio Equipment Directive 2014/53/EU (RED).
- Authentication for data transfer is enabled using OAuth 2.0, the industry standard protocol for authorization.
- The hardware must comply with the Waste Electrical and Electronic Equipment Directive (WEEE 2012/19/EU).
- The hardware must be marked with the WEEE mark.
- The hardware contains electronic equipment and the supplier and the organiser must agree on the proper take-back procedure for the used hardware.
- The hardware must comply with the Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive (RoHS 2011/65/EU).

Other local/national regulations

- The use of the SLM that only measures sound pressure levels is handling personal data. However, each implementation should be analysed against the GDPR requirements.

Ethics

- The MONICA IoT SLMs may pick up conversation and although this is not the purpose of the solution, it is advisable to post signs informing the public that sound data is being collected. The signs should be placed by the SLMs and be clearly visible and containing operator/contact information (similar to how to CCTV is marked be signs).

- The solution may raise concerns about increased surveillance practices and how these affect citizens' rights to privacy, particularly if also CCTVs are in operation enabling audio to be coupled with video.
- The solution may reveal facts about actual sound levels which may require the city to inform citizens hereof and take action.

7.4 Business Aspects

7.4.1 Business Models

7.4.1.1 Revenue models

The choice of revenue model and pricing scheme is entirely up to the partner that have commercialised the solutions. Hence, the following information is solely provided as a guide to the expected business conditions that the solutions might be provided at. Please contact the responsible partner for further, up-to-date details.

Components	Type	Anticipated revenue model
IoT SLM and SLM Gateway	Hardware, Service	SLM: Provided as a one-off commercial product Gateway: Provided as a one-off service fee
Contribution Analysis	Algorithm	May be provided at a recurrent license fee, but not decided at the time of writing
Noise Heat Map	Service	May be provided as a recurrent cloud service fee, but not decided at the time of writing
CAP Data Platform	Hardware, Service	SLM: Provided as a one-off commercial product WP plugin: Provided at a recurrent license fee

7.4.1.2 Business Models

The Business Model Canvas is used to give a high-level overview of the contents in the value configuration and in the customer group side related to a specific value proposition. This tool is used to map out all details of the MONICA business models based on the value proposition, target groups, the partner constellations, and revenue models outlined in this chapter.

Table 3 Business Model Sound Level Monitoring

<table>
<tr>
<td rowspan="2"> 
Key Partners

<u>MONICA partners</u>
• B&K
• DTU
• ATOS
• CNET
• CERTH

<u>External partners</u>
• Hardware
• Network components
• On-site Installation</td>
<td> 
Key Activities
• Cloud operation
• Cloud systems
• Software development
• Firmware development
• Network protocols
• Cybersecurity analysis and mitigation</td>
<td rowspan="2"> 
Value Proposition
Manage noise levels and compliance during events
Provide sound monitoring platform for the Adaptive Sound Field Control solution
Monitor noise levels in restaurant and nightlife areas
Map city noise levels in traffic zones & work areas
Send accredited noise data directly to the city database for later analysis</td>
<td>Customer Relationship
 
• Organisations responsible for regulatory compliance during concerts
• Departments analysing noise data in the city
• Sound engineers with concert operators</td>
<td rowspan="2">Customer Segments
 
• Organisers of musical events, outdoor concerts
• Owners of venues for large events such as stadiums, concert arenas
• City authorities for noise from large events
• City authorities responsible for noise control in the city</td>
</tr>
<tr>
<td> 
Key Resources
• Software developers
• Cloud operation
• Network specialists
• System integrators
• Cybersecurity experts</td>
<td>Distribution Channels
 
• B2B event organisers
• B2B sound engineers
• B2B city authorities
• B2B system integrators</td>
</tr>
<tr>
<td colspan="2"> 
Cost Structure
• Cost of hardware
• Cost of development, customisation, training
• Cost of operation
• Cost of commissioning and de-commissioning</td>
<td colspan="2">• Sound Level Meter provided as a one-off commercial product
• Contribution analysis provided at a recurrent license fee
• CAP integration provided at a recurrent license fee
• Configuration, installation, service costs</td>
<td> 
Revenue Streams</td>
</tr>
</table>

7.5 Potential for Replication

7.5.1 Lessons Learned

Lessons Learned has been collected throughout the deployment and demonstration phases of the MONICA project and the relevant Lessons Learned are provided here for reference. Please note, that a number of the experienced issues have been corrected in the final MONICA products so please check with the responsible partner for the newest updates.

The following main Lessons Learned from the MONICA demonstrations and reference deployments are:

- Remote configuration for SLMs is useful for managing the MONICA IoT SLM and should be supported.
- Hardware (sensors, computers etc.) needs to be installed in advance: at least a few days before the pilot demonstration in order to check if everything is working correctly (network, power supply, data transmission etc.) and perform preliminary measurement if needed.
- For configurations which requires high data rate transmission, a high bandwidth 4G network is important.

7.5.2 Usability Aspects

7.5.2.1 Acceptance of MONICA Solutions

(input from *D9.2 Final Assessment and Validation Report of the MONICA IoT Platform*)

- The ability to easily monitor and control the sound levels at an event contributes to the overall acceptance of this MONICA solution
- Solution which provides accurate results; functional solution which does what it says it should
- Easy to use; clear organisation of information on the screen
- User should be able to easily recover if they make a mistake.

7.5.2.2 Effectiveness of MONICA Solutions

- Effectively comply with regulations with regards to sound levels
- Sufficient, organised and clear information provided by the solutions to assist in decision making by necessary staff.

7.5.3 Reproducibility Aspects

Following the reproducibility definition reported in section **Error! Reference source not found.**, the MONICA Sound Level Monitoring solution can be fully reproduced by using the Sound Monitoring Toolbox[8].

This Toolbox allows the user to demonstrate the Sound Monitoring use case by instantiating and running the involved MONICA components. The Replayer tool will be used to replay part sound data from the Woodstower festival (August 2019). Since the database is very large, for the demonstration of the toolbox only a small portion of it has been made available. The Toolbox includes also the DSS module for generating the alerts and the COP for visualization purposes.

7.5.4 Contacts

The following partners are responsible for various components of the MONICA Sound Level Monitoring solution.

Solution	Responsible	Acronym	Details
IoT SLM and SLM Gateway	Brüel & Kjær	B&K	The Sound Level Meter described in this material is today a commercial product and can be purchased at Brüel & Kjær. The rest of the solution is at prototype level

[8] The link to the Sound Monitoring Toolbox is in D7.6 The MONICA Development Toolbox 2

			and may never be released as commercial products or in a different form than is described here.
Contribution Analysis	Brüel & Kjær	B&K	B&K provides algorithms for the analysis and sound event detection. Types of events may be customised.
Noise Heat Map	Technical University of Denmark	DTU	DTU provides algorithms for calculating the Sound Heat Map. This requires the MONICA Cloud solution.
CAP Data Platform	In-JeT ApS	IN-JET	IN-JET provides integration to CAP or website based on WordPress. A data repository with readings from the SLM Gateway and a WP plugin to display the data is available.

7.6 Reference Deployments, Demonstrations and Results

7.6.1 Sound Monitoring – Kappa FuturFestival

General description of the event

Kappa FuturFestival (KFF) is the first dance Italian daytime summer festival. Dedicated to techno and house music, it takes place every year with two full days of concerts from midday to midnight in Torino, in Parco Dora, a public park in a densely populated neighbourhood.

The park restored an area of 450 thousands square metres that was exploited for decades by factories, making it polluted and inaccessible creating a space for sports, entertainment and relax. The park, however, keeps alive the memory of the industrial past of this part of the city, maintaining some of the pre-existing structures (pools, steel pillars, smokestacks).

Concerts take place over 4 stages in a “fenced” area of about 60 thousands square metres surrounded by residential buildings. Even though the park ground is some meters lower than the road level the sound coming from the festival hits directly the houses. In addition going farer from the source the sound of the different stages blends and becomes an indistinguishable noise.

Movement Entertainment decided to join the MONICA project to look for innovative solutions to the problems raised by Kappa FuturFestival.

Monitor Sound Level - deployment description

For this use case nine fixed Sound Level Meters (SLMs) have been deployed by B&K as shown in Figure 31 (SLMs are represented by blue circles). As it can be observed, four SLMs have been deployed in the audience area of each stage while five SLMs outside the venue to monitor the level of noise in the dwellings. One of these is “redundant” and it has been installed in the same apartment but collecting different sound data.

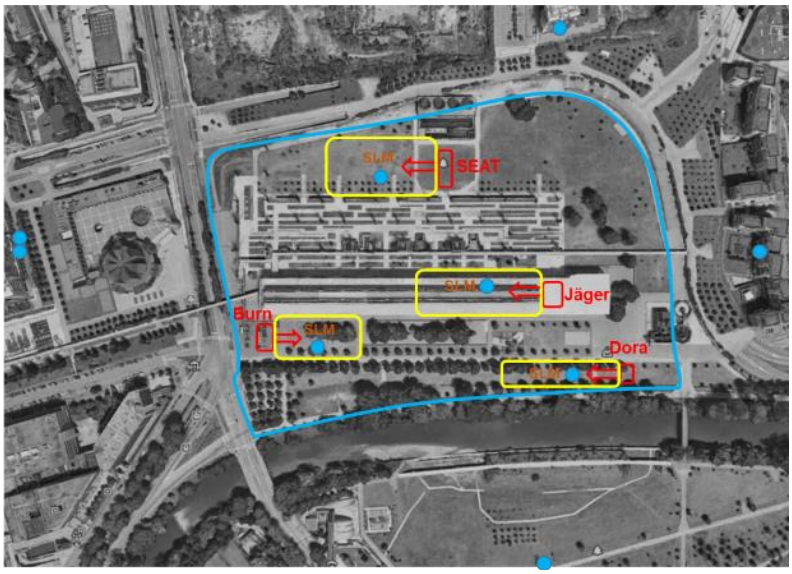

Figure 31: Map of the KFF Venue showing also the positions of the four stages

Each SLM, excepts the “redundant” one, provides sound pressure data (e.g. LA_{eq}, LC_{eq} and spectra) every one second to the SLM-GW (deployed on the B&K cloud). For this type of message, each SLM requires a data rate approximately equal to 10 Mbyte/day (i.e. on average corresponding to 926 bit/sec). Differently, the “redundant” SLM records audio signal useful to estimate the “contribution” value generated by a specific stage to the neighbourhood. We remark that this calculation is performed by the SLM-GW. This type of SLM configuration requires a much higher data rate than the others, approximately equals to 1 Mbit/sec. In addition to the fixed SLMs, two mobile SLMs have been programmed to record audio signal, useful for the DTU team to calibrate the Sound Field Control System (SFCS).

In order to send sound data to the SLM-GW, the SLMs require Internet connectivity, preferably using Wi-Fi. Alternatively, the 4G modem integrated in the SLM can be used.

Regarding the four SLMs deployed inside the venue, it has been used the Wi-Fi connectivity that has been provided by RINICOM. Regarding the five SLMs deployed in the neighbourhood, it has been used the internal 4G modem. Unfortunately, the two mobile SLMs dedicated to DTU could not send sound data efficiently because a high data rate Internet connection was not available outside the KFF venue.

All SLMs and the SLM-GW have been configured by B&K. The configuration of the SLMs took about 1.5 hour for all SLMs, and the installation started two days before the event (access to the private apartments, installation on consoles in front of each stage).

The SLMs require to be powered by electricity from the grid. If this is not available, the SLM can be powered by using an internal battery that lasts about 8 to 9 hours.

The four SLMs inside the venue have been installed in the control room (i.e. the light console), where the electricity was available. Regarding the SLMs installed in the neighbourhood, the electricity was provided by the apartments.

The four SLMs inside the venue have been installed on Thursday (i.e. two days before the event) along with the Wi-Fi network. These SLMs worked very well on Saturday (i.e. the first day of the event), while on Sunday, just two SLMs had a relatively high amount of losses in the message transmission to the SLM-GW. The SLMs outside the park in dwellings worked very well.

The sound data collected by the SLM-GW are sent to the IoT platform every 15 seconds for each SLM. In turn the IoT platform models the data according to the OGC Sensor Things standard, stores the observations in a data base, then the Decision Support System (DSS) processes them and rises alerts on the basis of some specific thresholds/rules, finally, the MONICA dashboard, named Common Operational Picture (COP), shows both sound data and alerts as depicted in Figure 16. The IoT Platform, DSS and COP modules have been deployed by the MONICA Team on the cloud infrastructure.

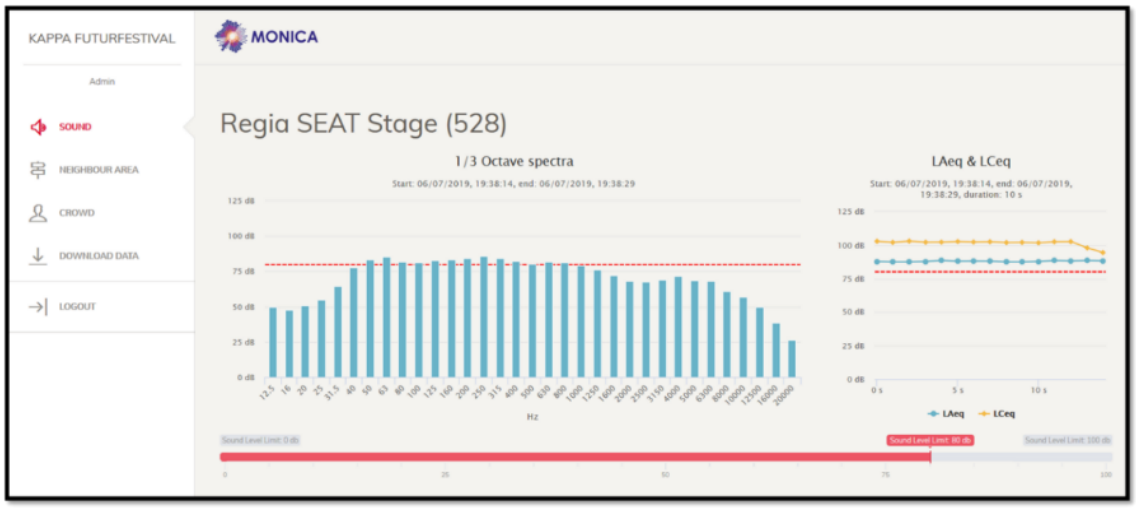

Figure 32: Screenshot of the COP showing the sound monitoring section

Challenges faced using MONICA solutions

One of the main issues to consider is the absence of pre-existing infrastructures (lights, electricity, internet connection) in the park meaning that everything has to be set up specifically. It is technically quite difficult to deploy cables on the ground or install components on height in order not to create obstacles in the flow of people. Finally costs for deployment may grow significantly.

Another challenge is the fact the park is surrounded by residential buildings hence the configuration of instruments should run at the same time of the festival rehearsal because the allowed timeframe is limited and monitored by authorities.

Moreover KFF takes place only once a year in an area normally open to the public, hence the set-up is limited as well by authorities (about 10 days prior the event and 5 after it) and it's not possible to replicate the same conditions during the rest of the year rather than with mathematical models.

Last but not least all the material used or stocked in the venue during the show must be the EC marked to comply with local safety and security rules hence the use of prototypes is subjected to the authorities upon the presentation of a specific dossier.

7.6.2 Sound Monitoring – Woodstower

General description of the event – ref. sez. 3.7.1.

The acoustic impact assessment of the festival has been a request from the organisers since 2017. The significant wind effect on sound propagation also made this pilot site very special from an acoustic point of view.

Monitoring Sound Level - deployment description

The first objective of the sound monitoring was to assess the acoustic impact of the festival with regards to the requirements of the new French decree, in terms of sound exposure of festival-goers and sound impact in the neighbourhood. Eight IoT SLMs were deployed for the demonstration: four inside the venue at each stage near the sound engineer console, four outside the venue in municipalities where the impact of wind could be assessed easier.

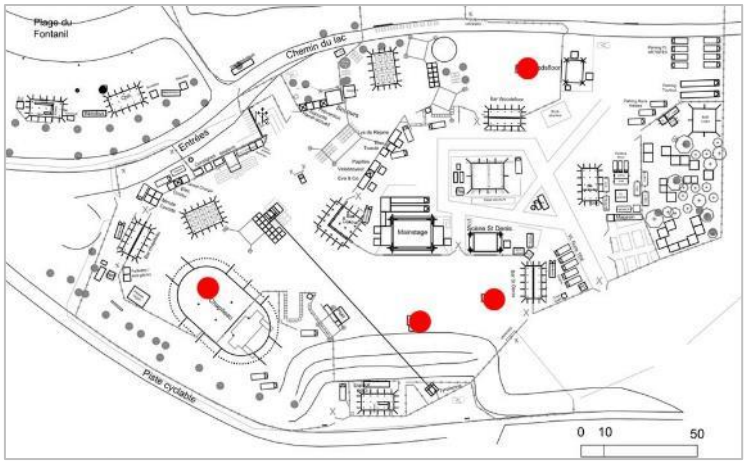

Figure 33: Sound monitoring points location in the venue

Due to the wind, the impacted neighbourhood was in fact around 2 km away. Simultaneously measurements in front of each stage (inside the venue) and at receiver points in neighbour area (outside the venue) provides information about sound levels at those locations, but it also allow deeper analysis for estimating the contribution of sound emissions from festival to the total sound measured in surrounding populated zones. Furthermore, one environmental sensor was tested on the ground by DIGISKY to collect wind speed and then explain any sound levels that may be increased by the wind.

Figure 34: Sound monitoring points location in the neighbourhood

The second objective of the sound monitoring was to assess the festival-goers' and the neighbours' perception of the festival through surveys. The festival-goers' survey was sent to them with the online "*thank you letter*" of Woodstower after the festival. It was focused on their opinions on the sound quality of the festival, their hearing protection habits and their opinions about the festival-goers' wristbands. The surveys were mentioned via several media channels (cities' websites and halls, local newspaper, social networks, festival's newsletters). The questionnaire aimed towards the neighbours was focused on the type of annoyance perceived from their homes, the type of noises perceived and their impacts on their day-to-day life.

Beside the achievement of these two objectives, a Sound Heat Map considering the directivity and the schedule of the four stages has been developed and was displayed successfully on the COP.

Figure 35: Display of the Sound Heat Map on the COP

The DSS was deployed to the MONICA cloud throughout the duration of the pilot. Prior to the event, pilot-specific configuration was set up, such as SLM names and locations as well as transfer functions. In collaboration with ACOUCITÉ and CNET, several subsystems were improved, including, for example, Neighbour sound limits, dynamically adjusted based on the time of the event, critical point calculation.

During Woodstower, the DSS' output (Stage sound limits, Neighbour sound limits, Critical point, LA_{eq} 15-minutes average for both stage and neighbor SLMs, LC_{eq} 15-minutes average for stage SLMs) was validated by ACOUCITÉ and was determined to be accurate.

The COP displayed data coming from IoT SLM, data streams from DSS and Sound Heatmap.

Challenges faced using MONICA solutions

One of the main aspect to take into account is the risk of data loss during the event.

It is very important identify the sources of data loss (i.e. monitoring the Wi-Fi network with a second device "sniffing" to determine if anomalies are coming from network or from transmitter in IoT SLM).

Moreover, a local save system like a SD card will also help to avoid any data loss since the network transmission is sometimes difficult (e.g. lots of mobile phones in a festival in the countryside) and that no buffer is used as a failsafe is the network is down.

8 Adaptive Sound Field Control

Improving visitor's sound experience during musical events venue while at the same time reducing the noise annoyance for the neighbours seems to be a contradiction. But it is not.

The MONICA Adaptive Sound Field Control solution is an advanced sound control system that can impact the sound field outside the scene layout through the active and adaptive sound field control.

The system can provide an optimised sound field in the audience area (bright zone) while reducing the sound levels in neighbouring areas (dark zones) with up to 10dB at low frequencies.

In other words, the music can be louder for a better concert experience at the front of the stage, whereas sound levels can be reduced outside the concert area for less annoyance. To this end, the sound levels are dynamically controlled adjusting for changes in weather or audience, which impacts the propagation of sound waves. The system can work in any kind of environment, open air or closed space or urban area.

Low frequencies (less than 100Hz) are the most critical frequencies in the noise. Sound waves at these frequencies are less attenuated in the air, less prone to reflections from boundaries, and less impacted by the buildings. The MONICA Adaptive Sound Field Control solution actually offers a better reduction of these low-frequency components in the music sound field. Consequently, concerts, festivals with rhythmic music (rock, techno, jazz, etc.) with a high content of low-frequency components are the most likely beneficiaries of the MONICA Adaptive Sound Field Control solution.

Further reading: https://backend.orbit.dtu.dk/ws/portalfiles/portal/194650956/ICA_2019_JBR_paper_final.pdf

The working principle of the MONICA Adaptive Sound Field Control solution is to install extra loudspeakers around the concert venue and optimize the sound radiation from them in such a way, that the sum of sound pressures directly from the performers (primary sources) and from the additional loudspeakers (secondary sources) add together in any observation point in the dark zone and thereby effectively reduces the total sound pressure level in the that an observation point.

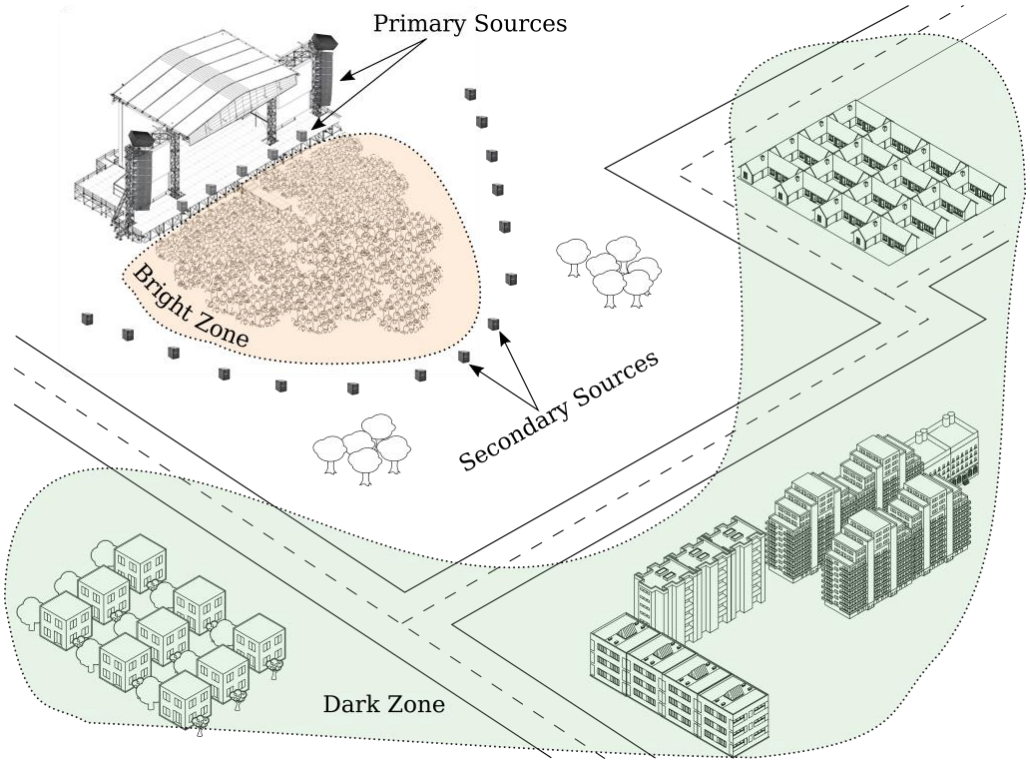

Figure 36: Basic principle of the MONICA Adaptive Sound Field Control solution

The MONICA Adaptive Sound Field Control solution provides the following features that help concert organisers cope with noise problems:

Sound level reduction: The ASFC depends on additional loudspeakers pointing towards the area where noise reduction is needed. This part is integrated with the venue's overall sound (PA) system. The ASFC enables a high sound pressure level in the bright zone relative to the sound pressure level in the dark zone

thereby creating the impact of sound level reductions. Moreover, the additional loudspeakers to control the sound in the dark zone do not negatively impact the sound experience in the audience area, the bright zone. The software for sound field optimization algorithm and sound propagation model is configured and tuned specifically for each venue.

Figure 37: Secondary sources consist of large loudspeaker arrays pointing towards the dark zone. Examples from Kappa FuturFestival 2018 (left) and Tivoli Fredagsrock 2018 (right)

Adaptable sound field control: Two important prerequisites for the ASFC system to perform well in a practical situation are: 1) obtaining an accurate sound propagation model for the venue and 2) providing a suitable controlling signal through the secondary sources (loudspeakers).

1. The propagation model can be obtained using various environmental sensors and microphones in and around the concert area. Sensors for wind speed, humidity and temperature provide data for the propagation models and “heat maps” for the venue areas.
2. The control signal is obtained by converting the entire PA system output to a control signal for the secondary sources. The control signals have been modified in order for the desired effect to take place in each observation point in the dark zone. The modification takes place in fast computer algorithms based on so-called “forward models” that models the sound propagation through atmospheric air from the secondary loudspeakers to the observation point in the dark zone. The forward model is continuously updated using input from the environmental sensors in order to adapt to changes in atmospheric/weather conditions during the concert.

Figure 38: Quite Zone, Tivoli 2018

Sound Level Meters: The Sound Level Meters (SLM) should be type-approved, accredited and calibrated Sound Level Meters, which measures correctly under changing environmental conditions like temperature and humidity. They are enabled for use in the IoT networks and are easy to install and move around the convert venues as necessary in order to provide proper input for the adaptive algorithms. Sound level data needs to be collected in real-time and send directly to the ASFC with minimum latency.

Quiet Zone: A Quiet Zone is a noise barrier that allows staff on the field to have a small physical space where they can speak without the overwhelming sound from the concert performance. The Quiet Zone principle is to make use of active elements (ASFC) to cancel out low frequencies and passive elements (sound blocking screens) to block higher frequencies using a passive noise barrier. The aim is to obtain the highest possible attenuation of sound level across the entire listening spectrum without disturbing the sound field from the primary sources. The Quiet Zone system can be installed independently from the ASFC but also can work together.

8.1 Scenario Descriptions

Adjust sound level:

In this scenario, the system can be used to adjusts the sound level in areas of the venue defined by the organisers to manage sound exposure of the audience and/or reduce the noise annoyance of the neighbours.

8.1.1 Type of Event

The solution is tailored to the precise needs of the client. It can be used in any type of open-air, gated and non-gated event. However, due to the complexity and magnitude of the installation, it is at the moment not suitable for short term deployment (e.g. for a single concert). The most likely targets are recurrent events (monthly or seasonal) or in permanent installations.

- Musical events, outdoor concerts
- Street festivals with loud music
- Sporting events with loud music

8.1.2 Challenges

Urban spaces are growing fast and cities are becoming denser and denser, so the issue of the perception of sound emissions outside a venue is increasingly challenging. Organisers of concerts want to give their performers and audiences the best music experience but they also wish to comply with local regulations on environmental sound exposure.

This produces a two-sided dilemma when you talk about outdoor concerts in residential areas: Since high sound pressure levels are necessary for optimal concert sound, there is a risk of the audience becoming disappointed and artists turning down invitations to perform if regulations say you have to turn down the volume. And even if you comply with the regulations, you might still have to deal with residents living next to the venue who complain about the noise coming from the concerts, and that it is affecting their quality of life.

A typical example, where the MONICA Adaptive Sound Field Control solution can make a difference, is the Tivoli Gardens Entertainment Park in Copenhagen. Tivoli organises rock concerts every Friday during the summer season and is struggling with emissions of noise to the neighbourhood, in particular from the outdoor music performances as well as general noise from the amusement park. The neighbours are regularly filing complaints about the sound levels with the Municipality resulting in caps being put on the total sound levels that can be emitted. The capping means that international artists have refused to play at the outdoor stage at reduced audio levels. Also, the music audience complains about low sound volume during concerts.

8.1.3 Benefits

The MONICA Adaptive Sound Field Control solution can be seamlessly integrated with sensors and actuators using the MONICA Crowd and Capacity Monitoring solutions and the MONICA Cloud in the MONICA Crowd Management and Communication solution. The total solution can have a benefit in monitoring and managing the sound before and during a performance. The main feature of the MONICA Adaptive Sound Field Control solution is to provide an IoT solution with closed-loop feedback that addresses noise challenges during concerts and musical events.

To this end, the MONICA Adaptive Sound Field Control solution offers a multitude of innovative benefits related to the execution of open-air music performances in the public space.

Benefits for the performers and organisers:

- The sound experience can be optimised with respect to both the performers and the concert audience in terms of loudness, directionality, and quality. At the same time, the ASFC system can perform dynamic adjustment of the secondary source loudspeakers so that neighbours of the concert venue can enjoy up to 10dB attenuating of the sound levels in their neighbourhood, where it is unwanted and annoying.
- High sound levels can be dangerous to the health of concertgoers; some will prefer to have a lower sound level at the expense of the ultimate artistic quality. For these spectators, the application will make it possible for the organisers to offer different classes of sound levels (maybe at different prices).
- Quiet zones can be created close to the audience area (“Silence Showers”). These spots can be used for security personnel and the organizers’ staff. They can in principle also be created for other people a distance away from the primary audience area (e.g. restaurants, ticket offices, etc.). The number, size, and location of the Quiet Zones are specific to each concert and can be moved for different venue layouts.

Citizen Engagement widgets can be developed that can be installed on public authorities' websites and display e.g. real-time and cumulative data on noise levels and crowd sizes obtained from the city's Open Data repositories. This can be part of a cooperation and co-creation activity launched by the city.

8.1.4 Stakeholders

Event organiser: Person in charge of managing budget, logistics and external stakeholders that are part of the event. Responsible for assuring the success of the event at a practical level. Benefits for this stakeholder is to have an overview on the sound levels in the audience and in the neighbouring area, as well as the assessment of the compliance with regulatory limits.

Event visitor: Person enjoying the event as an entertainment experience.

Neighbour: Person living near the event. Benefits for this stakeholder is mainly to minimise the sound impact of the event (noise induced annoyance, sleep disturbance) on his/her everyday life by the action of the ASFC.

Sound engineer: Person in charge of managing all the sound aspects before, during and after an event, dealing with the technical staff and the event organiser. Benefits for this stakeholder is to monitor sound levels in audience (at sound engineers console) to ensure compliance with regulations.

Local authority: Representative of the Public Administration departments interested in the health and safety of the event. With MONICA, this stakeholder can ascertain compliance with regulations (maximum sound levels allowed) while maintaining cultural events in the city.

8.2 Technical aspects

8.2.1 Technical concept

Most modern sound reinforcement systems used for concerts are based on the line array principle, which allows for the control of directivity of the sound radiation of high and mid frequencies. However, the radiation of low frequencies cannot be as easily controlled, as sound waves at these frequencies are less attenuated by air and reflections from boundaries and are damped the least by the structures of residential buildings. Low frequencies are therefore the most critical frequencies in the noise problem of outdoor concerts.

The MONICA Adaptive Sound Field Control solution is designed to control the sound field restricted to low frequencies over large areas with a feasible number of loudspeakers. As such, the solution leverages on the principles of IoT sensor networks provided by the MONICA Crowd and Capacity Monitoring solution as well as the MONICA Cloud server with decision support and feedback communication tools provided by the MONICA Crowd Management and Communication solution. It may further be augmented with the MONICA Collective Awareness Platform for interaction with citizens and neighbours.

The ASFC system interacts with the other MONICA solutions in two ways:

1. The MONICA Crowd and Capacity Monitoring solution provides various collected sensor data (e.g. weather condition and sound pressure) to the ASFC system upon requests. These data are used to update the sound propagation model and estimate the sound propagation in and around the venue.
2. The sound propagation model supplies information on the sound condition in and around the venue to the MONICA Crowd Management and Communication solution in the form of a Sound Heat Map.

The figure below shows a schematic of the information flow in the acoustic closed loop system. Compared to a traditional sound reinforcement chain, a *Sound Field Controller* is inserted as a processing unit between the mixer and the loudspeaker system. IoT enabled microphones and weather sensors distributed throughout the venue and the control areas continuously measure the sound pressure field created by the ASFC and current weather conditions. These data are made available to the *Sound Propagation Module* via the IoT platform. The *Sound Propagation Module* uses the data to estimate the transfer-functions between sound sources and the control areas, which are needed by the *Sound Field Controller*'s optimization routine.

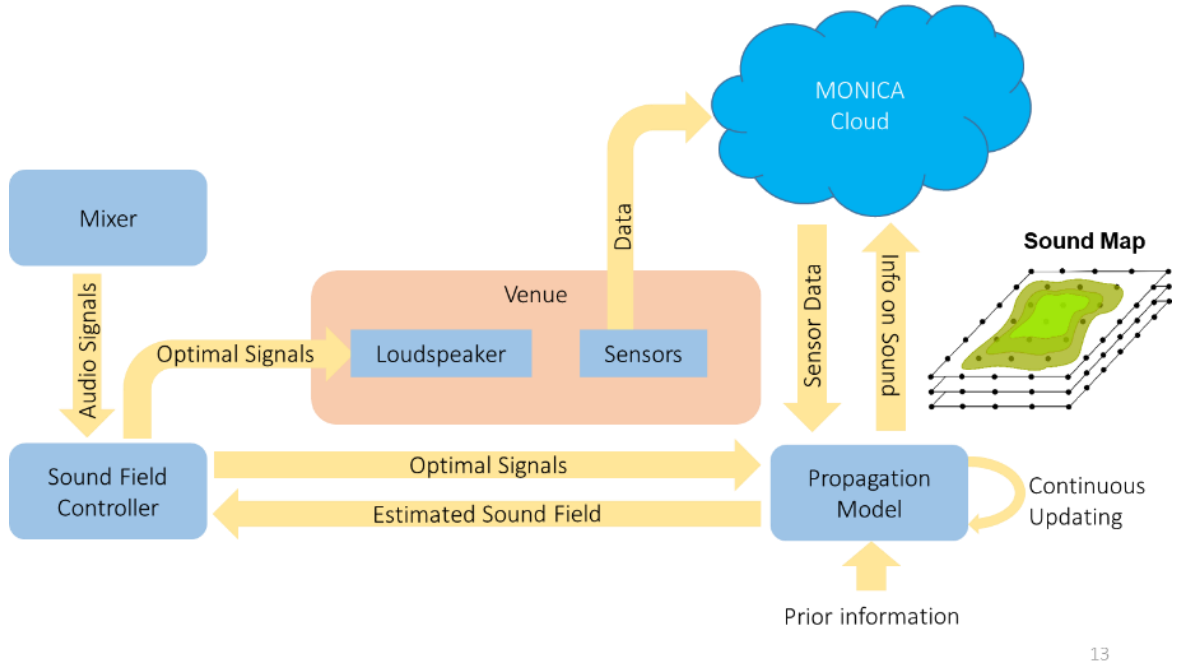

Figure 39 Concept of the ASFC (Adaptive Sound Field Control) system

The MONICA Adaptive Sound Field Control solution can be divided into six parts:

- The *Adaptive Sound Field Controller* drives the secondary source loudspeaker array by feeding the organizer's Public Address (PA) system into an acoustic closed loop system.
- A *Sound Propagation Module* uses environmental data to estimate the transfer-functions between sound sources and the control areas, which are needed by the Adaptive Sound Field Controller's optimization routine.
- The *Sound Heat Map* calculates an estimation of how the sound is propagating through a concert venue. A Sound Heat Map can be a coarser prediction for visual inspection or informative assessment.
- *Sound Level Meters* are used to measure sound levels at strategic locations and send the information to the Sound Heat Map as well as to sound technicians and possible to external stakeholders such as public authorities, the audience, and the neighbourhood.
- A secondary source *Loudspeaker Array System* is placed behind the audience between the primary sources and the neighbouring region in which the sound from the event should be reduced (dark zone).
- A *Quiet Zone* is a small localised noise barrier, which creates the highest possible attenuation of noise across the whole listening spectrum so that event staff can speak together in the middle of the concert area.

Adaptive Sound Field Controller: The ASFC system receives audio signals from the concert's PA console or from behind the PA's power amplifiers. The latter would be the primary choice because the standard PA system incorporates signal processing units into the power amplification stage. For example, devices such as limiters cause nonlinear components which will decrease the performance of the *Adaptive Sound Field Controller*. The audio signals, that are needed to feed to an *Adaptive Sound Field Controller* algorithm, will be the "reference" signal. In all the pilot demonstrations, reference signals were either obtained from the console (mixer) or from a signal "sniffer" device (inserted between power amplifier and speaker channel). Good results were obtained with both methods.

The infrastructure of the *Adaptive Sound Field Controller* consists of signal gateway/router (signal monitoring and control of main PA system), hub (audio interface), ASFC Core (Digital Signal Processor - DSP), and loudspeaker system (multichannel amplifier and loudspeakers). The ASFC Core calculates the optimal solution based on a sound propagation model estimation. Multichannel signal rendering (filtering) may be processed using a general desktop PC but can be developed as a stand-alone DSP for more efficient computing.

A well performing ASFC system will enable a high sound pressure level (SPL) in the bright zone relative to the sound pressure level in the dark zone. A performance indicator for this reduction in SPL is the *insertion loss*

(IL), i.e. the reduction in decibels provided by the ASFC system within the dark zone compared to the bright zone. With the MONICA Adaptive Sound Field Control solution, the demonstration pilots have obtained up to 10dB reduction in the low frequency band at the various demonstration sites.

Sound propagation model: Sound field control in outdoor spaces requires accurate estimates of the transfer functions between source and receiver. Feedforward approaches are based on direct measurements of the transfer functions in a dense grid of points. However, this makes them intractable for large-scale situations. Hence there is a need for propagation models to characterize the sound field in large areas and provide the ASFC system with such proper transfer functions.

During the first year, the MONICA project investigated the adequateness of Nord2000. The Nord2000 specifies a calculation method for the prediction of the attenuation of sound during propagation outdoors. However, it turned out to have severe limitations when modelling sound propagation at low frequencies and titled to further research and development of alternatives.

During the second year, a new model based on spherical harmonics was successfully tested under controlled conditions in the anechoic chamber for a scaled setup of 2 x 5 m. The acoustic contrast produced when using this model is very similar to the one that can be obtained using a dense grid of microphones.

In the next phase, a novel Source Separation/Contribution technique was introduced in order to improve the estimation capability of the sound propagation model. The aim of this technique is to estimate the amount of noise contribution (in sound pressure level in dB over time, or similar) that originates from the actual concert in the presence of background noise created from other noise sources (such as traffic noise, people talking, etc.). The technique thus answers the question: Is the noise coming from the concert or from other sources, and if this is coming from the venue, what is the contribution from the venue. The Contribution technique was successfully demonstrated at the Sound2019 in Roskilde and may be used for future sound propagation models.

Sound Heat Map: The *Sound Heat Map* provides an estimate of the SPL at other positions than the one being measured by a Sound Level Meter. The forward sound propagation model calculates an estimation of how the sound is propagating throughout a well-defined area. The forward sound propagation model can be used the calculation of the EU noise indicators Lden and Lnight, in addition to the production of *Sound Heat Maps*.

The. *Sound Heat Map* can be used as a stan-alone solution or as part of the ASFC system. The difference is that the ASFC needs very precise predictions on how the sound propagates, while the *Sound Heat Map* can provide coarser prediction to be used for visual inspection or informative assessment.

Sound Level Meters: The transfer-function measurements can be been conducted with standard wired microphones. However, at the concert venues, where the dark zones are far away from the stage and ASFC system, it is recommended to use the MONICA IoT enabled Sound Level Meters described in the MONICA Crowd and Capacity Monitoring solution.

Loudspeaker Array Systems: The PA amplifier output signal is fed into the ASFC system as a reference signal. For real-time application, the music signal, or “sniffer output”, has to be convolved in real-time with the Finite Impulse Response (FIR) filters for each control loudspeaker. A sniffer device for converting the loudspeaker amplifier output signal to line levels has been developed. The loudspeaker systems (secondary sources) are extended by the use of additional low-frequency loudspeakers. The secondary source loudspeakers are placed behind the audience between the primary sources and the neighbouring region where the event sound should be reduced (dark zone). It is important, that the secondary source loudspeakers do not negatively impact the sound experience in the bright zone. This restriction must be taken into account in the loudspeaker configuration by using either directive loudspeakers facing away from the bright zone or in the formulation of the loudspeaker signal optimization problem.

Quiet Zone: The principle of the *Quiet Zone* is to make use of a) the ASFC to cancel out low frequencies and passive elements (sound blocking screens) and b) to block higher frequencies using a passive noise barrier. The aim is to obtain the highest possible attenuation of sound level across the entire listening spectrum without disturbing the sound field from the primary sources. The active part of the *Quiet Zone* system consists of arrays of loudspeakers that synthesize the cancelling sound-field to cancel out the noise-field in the desired zone. In simulations, different aspects of the design of the *Quiet Zone* system have been investigated.

A *Quiet Zone*, which is quiet in a defined area but introduces noise into the surrounding, lacks meaning. The design is constrained by practicalities, costs and its impact on the surroundings, which means that unwanted acoustic energy could be emitted by the *Quiet Zone* system itself.

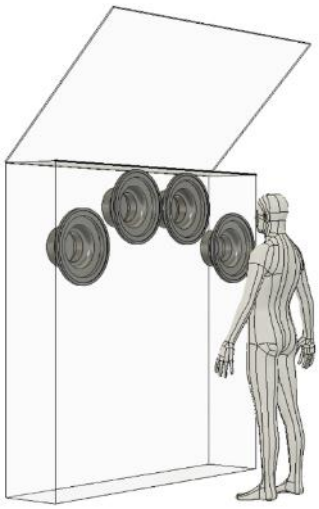

Figure 40: Quiet Zone

The positioning of the secondary sources is e.g. limited by the dimensions of the speakers – which means they can't be put very close to each other. On the other hand, having them far away from each other would just be impractical. The number of speakers and microphones should be as low as possible in order to minimize the costs. As a result of the simulations, the following can be recommended:

- A distance of about 1.5 to 2m to the secondary sources is recommended, which is also practical for the physical implementation of the system.
- The optimal distance between the secondary source speakers is about 1-1.2m. A deviation from this optimum does not have a big impact on the attenuation.

The number of secondary sources has a big impact on the costs of a quiet zone system. The number of speakers also depends on the frequency range of interest. For frequencies up to 200 Hz more than three speakers do not have a significant impact. For frequencies up to 500 Hz more than 5 speakers only result in a marginal increase of attenuation.

A passive noise barrier is added in front of the secondary source loudspeaker to block higher frequencies. However, the existence of the passive element might introduce problems into the active part.

8.2.2 Communication

ASFC communication: The ASFC Core does not require the connection to MONICA Cloud. It can function as a stand-alone system. However, single or multiple PCs computing the sound propagation model and the sound field optimization algorithm, and rendering multi-channel signal outputs require good, stable communication connections within the system. It necessitates a stable network that can transfer a relatively high rate of data (minimum 1 Mbit/sec is required).

SLM communication: A stable connection to the 10-15 SLM in the area is crucial for the performance of the ASFC system. The most stable solution is the use of a cabled connection to all SLMs. However, this requires massive cabling throughout the venue, which can be costly and unsafe. A WiFi or 3G/4G network can be a substitute method but high stability is required to avoid data loss and high bandwidth for advanced functionalities. For the IoT SLM, WiFi-connection mode has been updated with special firmware, which dramatically improves the connectivity. Another possible issue could be the clock synchronization between the SLM and the ASFC system's D/A converters. To ensure accurate transfer-function measurements, future SLMs will feature an alternative protocol that can perform time synchronisation over long distances. However, limitations may arise depending on general WiFi network traffic at the site. SLMs can also use 4G where there is no WiFi available.

8.2.3 Integration

The MONICA Adaptive Sound Field Control solution is a complex solution that relies on both external components and technologies as well as components, enablers, and tools from the MONICA project partners. Please contact the responsible partners listed in section **Error! Reference source not found.** for more i nformation.

The ASFC system interacts with the MONICA IoT platform in two ways:

- The MONICA platform provides various collected sensor data (e.g. weather conditions and sound pressure) to the ASFC system upon requests, which is used to update the sound propagation model and estimate the sound propagation in and around the venue.
- The sound propagation model supplies information on the sound condition in and around the venue to the MONICA Cloud in the form of a Sound Heat Map.

External technologies required

Additional to the venue's sound-system the following major equipment is needed in order to run the Adaptive Sound Field Controller:

Secondary source loudspeaker system: High power multiple loudspeaker, Amplifier system (type/brand should match the venues system), multi-channel DAC (RME M-32 DA (x2) or equivalent), cabling and rigging equipment.

Sound monitor system: Monitors the signal output of venue's PA system (RME MADI Router or equivalent), multi-channel ADC (RME M-32 AD or equivalent).

Internal MONICA enablers and tools required

None

8.2.4 Scalability

Scalability is an issue. Control over large areas needs considerate amount of control loudspeakers and microphones. Every installation is different and scalability issues will be determined in the initial site-survey and feasibility study.

8.2.5 Associated MONICA solutions

The MONICA Adaptive Sound Field Control is closely related to and have been demonstrated together with these additional MONICA solutions:

- MONICA Sound Level Monitoring
- MONICA Crowd and Capacity Monitoring
- MONICA Crowd Management and Communication (including cloud server and COP)

The MONICA Adaptive Sound Field Control cannot be implemented as a customer-specific solution independent of other MONICA solutions.

8.3 Implementation

8.3.1 Installation

Preparation

For the best performance of the ASFC system, the following preparations should be carefully executed and venue specific information needs to be communicated with ASFC specialists.

Information required:

- Detailed geometrical plans or drawings of the venue and its surroundings for the sound propagation model. Preferred in digital format. Information about surface materials can also be used. Elevation of the terrain (Digital Elevation Models).
- It is necessary to choose possible positions for microphones, weather sensors, additional speakers.
- The signal chain of a venue's PA system with EQ, delay line information, loudspeaker configuration.
- Definition from the client of the most critical areas in the neighbourhood and the less important ones, so to tune the system to reduce the sound in the problematic areas.
- The following roles should be contacted in the preparation phase: responsible for sound from the venue, sound engineers of bands playing, responsible for band booking, renting/equipment company.

Deployment

The MONICA partner can provide a system integration package including site survey, design and planning, installation, test, and operational support during the event.

Before the event: The venue's model needs to be integrated into the sound propagation model and the development of possible setups regarding the placement of loudspeakers and sensors needs to be done.

The final primary and secondary sound system design is developed together with a sound system designer/engineer of the venue.

During the event setup: Installation/Setup and conventional tuning of PA system: This tuning presents the fall-back state (if something goes wrong) and cannot be changed without impacting the tuning of the ASFC

system. Tuning/Initialization of ASFC system: This will involve the measurement of transfer-functions between the single channels of the PA and the control areas (listening area and neighbouring area). It also involves doing measurements to estimate the 'static' model parameters.

Operation

The functionality should be continuously checked during the concert by measurements and/or human listening.

The operational status of the system can only be evaluated indirectly. The active noise controller is running under heavy computational cost and robust performance is needed to avoid audible dropout. The calculation of the performance measure insertion loss (IL) in real-time and on the same machine would have added the risk of dropouts.

The performance can otherwise be roughly evaluated through the real-time metering of the sound pressure levels in the error microphones. This is a rough estimate because the sound level meters show a broadband signal, while the active noise controller acts on low frequencies only. A quantitative estimate of the performance in real-time is the insertion loss suggested. IL is directly related to the amount of sound pressure per frequency that is attenuated by the system. Such a measure could be estimated on a parallel computer and presented as a time-varying frequency spectrum on a screen or sent to the COP.

8.3.2 Regulatory aspects

Technical regulations

- The analysis in the MONICA IoT Sound Level Meter conforms to the international standard IEC 61672-1 (Class 1) and has implemented frequency and time weightings as specified in the standard.
- The MONICA IoT Sound Level Meter conforms to the international standard IEC 61260-1 and has implemented 1/1-octave and 1/3-octave frequency analyses as specified in the standard.
- Sound Level Meters and Gateways comply with the Radio Equipment Directive 2014/53/EU (RED).
- Authentication for data transfer is enabled using OAuth 2.0, the industry-standard protocol for authorization.
- The hardware must comply with the Waste Electrical and Electronic Equipment Directive (WEEE 2012/19/EU).
- The hardware must be marked with the WEEE mark.
- The hardware contains electronic equipment and the supplier and the organiser must agree on the proper take-back procedure for the used hardware.
- The hardware must comply with the Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive (RoHS 2011/65/EU).

Other local/national regulations

There are no personal data captured or handled in the MONICA Adaptive Sound Field solution. Hence, the GDPR regulation does not apply to this solution.

Ethics

There are no ethical concerns associated with the use of the MONICA Adaptive Sound Field Solution. However, the use of CCTV cameras for determining the density of the audience (as used in the propagation models) may raise concerns about increased surveillance practices and how these affect citizens' rights to privacy.

8.4 Business aspects

8.4.1 Revenue models

The choice of revenue model and pricing scheme is entirely up to the partner that have commercialised the solutions. Hence, the following information is solely provided as a guide to the expected business conditions that the solutions might be provided at. Please contact the responsible partner for further, up-to-date details.

Components	Type	Anticipated revenue model
Adaptive Sound Field Controller	Software, Hardware, Services, Customisation	Provided as a system integration package including site survey, design and planning, installation, test and operational support during the event
Sound propagation model	Software, Algorithms	Supplied as a single use license for each customised version of the model (i.e. for each event)
Sound Heat Map	Software, Algorithms	Supplied as a single use license for each customised version of the model (i.e. for each event)
Loudspeaker Array System	Hardware	Provided as rental or purchase of loudspeakers and necessary cabling
Quiet Zone	Hardware, Software, Services	Provided as a system integration package including site survey, design and planning, installation, test and operational support during the event

8.4.2 Business models

The Business Model Canvas is used to give a high-level overview of the contents in the value configuration and in the customer group side related to a specific value proposition. This tool is used to map out all details of the MONICA business models based on the value proposition, target groups, the partner constellations, and revenue models outlined in the chapter.

Table 4: Business Model Adaptive Sound Field Control

<table>
<tr>
<td rowspan="2"> 
Key Partners

<u>MONICA partners</u>
• DTU
• B&K

<u>External partners</u>
• Hardware
• Loudspeakers
• Network components
• On-site Installation</td>
<td> 
Key Activities
• Propagation model optimisation
• Software development
• System integration development
• Sound field analysis</td>
<td rowspan="2"> 
Value Proposition
Manage noise levels and compliance during events
Provide Adaptive Sound Field Control
Establish Quiet Zone for event staff</td>
<td>Customer Relationship
 
• Organisations responsible sound quality during events
• Sound engineers with concert operators
• Concert venue owners</td>
<td rowspan="2">Customer Segments
 
• Organisers of musical events, outdoor concerts
• Owners of venues for large events such as stadiums, concert arenas
• City authorities for noise from large events</td>
</tr>
<tr>
<td> 
Key Resources
• Acoustics
• Software developers
• System integrators</td>
<td>Distribution Channels
 
• B2B event organisers
• B2B sound engineers
• B2B city authorities
• B2B system integrators</td>
</tr>
<tr>
<td colspan="3"> 
Cost Structure
• Cost of hardware
• Cost of propagation model optimization
• Cost of development, customisation, training
• Cost of operation
• Cost of commissioning and de-commissioning</td>
<td colspan="2">• System integration package including site survey, design and planning, installation, test and operational support during the event
• Single use license for each customised version of the model (i.e. for each event)
• Rental or sale of loudspeakers and necessary cabling</td>
<td> 
Revenue Streams</td>
</tr>
</table>

8.5 Potential for replication

8.5.1 Lessons learned

Lesson Learned has been collected throughout the deployment and demonstration phases of the MONICA project and the relevant Lesson Learned are provided here for reference. Please check with the responsible partner for the newest updates.

The following main Lesson Learned from the MONICA demonstrations and reference deployments are:

- The AFSC system works well in open terrain, but cannot be expected to give similar reductions in a city environment.
- For thorough and complete testing of the ASFC system, it is essential to have a dedicated 4-hours timeslot without interruptions
- The system must be calibrated prior to the event to establish references values.

Weather conditions may impact measurements. For instance, the wind might propagate noise very far from a venue. The reference values will help to discriminate against other sound sources during the event, calculate the weather effect, set up the sound system according to the local regulations and prepare the tuning of the ASFC system.

8.5.2 Usability aspects

8.5.2.1 Acceptance of MONICA Solutions

- Neighbours will find the sound (in the dark zones) is much better than previous events without the ASFC system
- Visitors will have a more improved experience because of the better sound quality at the event

8.5.2.2 Effectiveness of MONICA Solutions

- The system can provide an optimised sound field in the audience area
- The system will reduce the sound levels in neighbouring areas with up to 10dB
- Provide a better sound quality for those at the event

8.5.3 Reproducibility

No data set are available for reproducibility.

8.5.4 Contacts

The following partners are responsible for various components of the MONICA Adaptive Sound Field Control solution:

Solution	Responsible	Acronym	Details
Adaptive Sound Field Controller	Technical University of Denmark	DTU	DTU offers a total system integration package including site survey, design and planning, installation, test and operational support during the event
Sound propagation model	Technical University of Denmark	DTU	DTU offers to deliver, customise and train the sound propagation model for the ASFC system
Sound Heat Map	Technical University of Denmark	DTU	DTU offers to deliver, customise and adapt the noise heat map for the ASFC system
Sound Level Meters	Brüel & Kjær	B&K	B&K can supply a variety of accredited SLM

Solution	Responsible	Acronym	Details
Loudspeaker Array System	Technical University of Denmark	DTU	DTU offers advice on the purchase or rental of loudspeakers for the ASFC system
Quiet Zone	Technical University of Denmark	DTU	DTU offers to deliver, customise and test the Quiet Zone for use with an existing ASFC system

8.6 Reference Deployments, Demonstrations and Results

8.6.1 Sound Control – Sound Summit Roskilde 2019

General description of the event

Roskilde SOUND2019 is an annual Music Festival held by Roskilde Festival Højskole, which is a modern college in a new creative district, based on the ideals of the famous Roskilde Festival. The event is known as a meeting place for the Danish music and festival culture. It is mainly held indoors, but for the MONICA ASFC test, SOUND2019 had arranged a special outdoor stage at Søjlepladsen which is a large outdoor event venue near the area.

Figure 41: Scenes from the Roskilde SOUND19

The main purpose of the demonstration was to test the adaptive algorithm in the ASFC. The SOUND2019 test showed that the ASFC can run with few microphones and achieve good performance. Two adaptive algorithms were tested and both worked well. The possibility of using few control microphones makes the system much easier to deploy. The minimum number of microphones required is closely related to the “openness” of the venue. The venue of the SOUND2019 was a quite open space, and it is expected that applying various strategies in predicting the accurate propagation model in space would delimit this “openness” constraint. The use of a few control microphones makes the ASFC more usable and replicable in many real outdoor events.

Overall the ASFC worked well and achieved 10-12 dB of attenuation in the dark zone.

Challenges faced using MONICA solutions

Since the Roskilde Sound 2019 was the first time MONICA team ran the fully adaptive algorithm, they reserved five days for preparation for the ASFC to be setup to work properly (especially for validation and tuning of the system).

This preparation time, after this successful experience and the support technical material available for replication, should be reduced to less than one day.

9 Collective Awareness Platform

The MONICA Collective Awareness Platform (CAP) is an online citizen-oriented platform that promotes collective awareness about societal challenges by gathering and displaying all related data and information for the citizens. The challenge for the cities is to find solutions that can bridge the gap between cultural attractiveness and community nuisance when organising events in the inner city next to residential areas. The starting point is creating common awareness of the challenges based on facts and on this background, engage the stakeholders in identifying and developing sustainable solutions.

To this end, MONICA has established a citizen engagement platform at the city level that provides factual information about sound and/or security in the city based on various MONICA sensor data. This knowledge is then used to stimulate a collaborative co-creativity process engaging citizens and other stakeholders.

The platform typically consists of two layers: an awareness layer and an engagement or co-creation layer. The former provides factual information, the latter is used to invite people to interact and/or participate. In some cases, crowd funding and donations are also part of the platform.

The awareness layer outlines a particular challenge by presenting factual information and data. Based on this, participation is encouraged either through the platform functionality or in separate forums. Awareness is created through the display of open data, made available by the city's users and presented in a way that is understandable to a wider, general public. Based on this informed knowledge, the CAP invites or unites people in creating solutions which can help improve the situation. As such, the co-creation of value takes place in collaboration with the city's users as collectors of data.

Two MONICA CAP, which have been launched during the project, exemplifies the features. Both of the CAP websites are available in the local language as well as in English:

The Copenhagen City CAP: The primary focus is on the impact of sound/noise, e.g., by investigating correlations between sound and noise data, but other open data areas such as air quality are also going to be considered for more CAP functionalities. The CAP for Copenhagen City can be found here: https://copenhagen.monica-project.eu.

Figure 42: The data section of the CAP: sound measurement and presentation of the city bicycle initiative

The goal of the Copenhagen CAP is to collect audio data with the help of citizens renting the electric bicycles from the City Bicycle in Copenhagen.

During the spring of 2019, the MONICA City Bike installed sound sensors on a number of electric bikes for the purpose of gathering information on sound levels in the city. the plan is to provide comprehensive information about the environmental areas and the impact it has on citizens. Information was provided by partners in the MONICA project as well as experts from the City of Copenhagen's Technical and Environmental

Administration. An invitation to download apps or use measurement tools is also provided, motivating the user to act:

The Torino City CAP: is focused on the impact of nightlife in urban spaces. It presents factual information and data to the citizens thus strongly supporting the user engagement strategies and co-creation phase. The purpose is to create awareness about urban night-life in Torino and its impact, and has been supporting a hackathon organised by the city. The CAP for Città di Torino can be found here: https://torino.monica-project.eu.

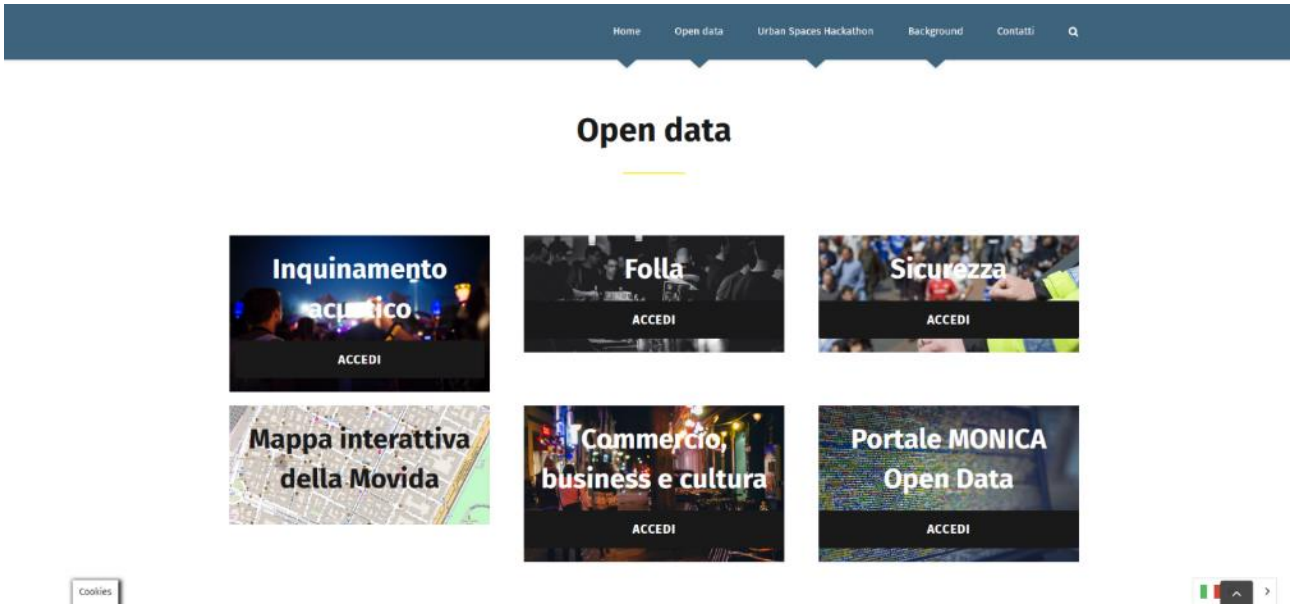

Figure 43: The Open data section of the CAP contains nose data, security data, general Open Data and context maps

The reader is immediately invited to explore the open data coming from the city's own data sources and data generated by a MONICA installation. The Open Data section contains different boxes depending on the types of data: The boxes *Inquinamento acustico* (Noise), *Folla* (Crowd) and *Sicurezza* (Security) will contain existing historical information and data from the city's portal. Other box will be added containing already published, public information on businesses in the area and scheduled events.

To visualise data, boxes like *Mappa interattiva della Movida* (Interactive Map of Movida) will provide interactive user interfaces to display the public data, such as sound and crowd numbers, in the form of heat maps, crowd counting numbers in real-time, etc. (Movida is the term for the night-life evolving in certain sections of the city dominated by restaurants and bars).

9.1 Scenario Description

Engage citizens in co-creation of smart city solutions:

In this scenario, the system provide important information to users about events and get their feedback. The user experience is also increased with value adding features using smart wristbands.

Set up a Collective Awareness Platform:

In this scenario, the system sets up a CAP – Collective Awareness Platform for sustainability and social innovation. The aim is to find new models on how to create awareness of emerging sustainability challenges and ease them through collective actions.

9.1.1 Challenges

In current years, cities' population have been growing, increasing pressure on urban services and infrastructure. Although the city is growing fast, people still expect a city that is a good place to live, and not least fun, clean, sustainable and climate-friendly. This means that the municipalities need to develop new solutions that can optimise and enhance the operation of the city in order to improve the quality of life of the citizens.

Moreover, for many years, public administrations have faced the issue of citizen participation and involvement in addressing public problems as an experience of democracy and the formation of civic virtues. Nowadays the cities can implement a bottom-up approach that opens the way to democracy through direct and binding mechanisms, thus bringing citizens closer to the decisions taken by city administration and allowing them to choose and indicate the priorities on which the municipality must intervene. The objective is to provide citizens with Open Government and e-Participation tools through which people can actively participate in the decision-making processes, have greater transparency on administrative activity and obtain factual information related to these initiatives.

The MONICA CAP makes data meaningful by presenting them in a context that is relevant to many citizens, engaging them in the creation of value and in developing new solutions to city challenges.

9.1.2 Benefits

The benefit of the CAP is its ability to integrated Open Data from the physical environment in the city with a co-creation platform for discussion and collaboration of citizens with the city administration about sustainable solutions. The solution also represents clear benefits for the stakeholders:

- *The benefits for Smart City Operators are:* being able to engage citizens in co-creation activities. The benefits for Smart City Operators are that they are able to engage citizens in co-creation activities with real, factual information. This gives unique opportunities for in-project assessment purposes, but also for longer term involvement in sustainable societal solutions.
- The benefits for citizens are that they are able to benefit from online, relevant information and data and are able to take that information in to co-creation activities and to make better, informed decisions about the city's environment, economy, infrastructure and consumption. Moreover, this makes citizens' voice heard, and makes the city's ICT portals more inclusive.

9.1.3 Stakeholders

Cities: Cities (or municipalities) involved in monitoring facets of public life and interacting with their citizens.

Citizens: The citizens are able to be better informed on decisions taken by the city and to have an additional tool to interact with the municipality.

9.2 Technical aspects

9.2.1 Technical concept

The concept of the MONICA CAP is visible from the two examples, which have been launched during the project. The CAP can be integrated with any Content Management System such as WordPress, SiteCor, Joomla etc. It can also be integrated with Participatory Budgeting platform such as Consul. Both of the CAP websites are available in the local language as well as in English:

The Copenhagen City CAP

The CAP for Copenhagen City can be found here: https://copenhagen.monica-project.eu.

The Municipality of Copenhagen is looking at the environmental impact that sound and noise has on city life. In terms of citizen engagement, the Copenhagen CAP is an example of direct interaction involving citizens in the value creation by being collectors of data. Hence, the Copenhagen CAP looks at the whole city. The concept is to create awareness about environmental issues in the city in a new way, for example by mounting sensors on electric city bikes and visualise the results in the CAP.

Noise Open Data: Flexible but accurate noise monitoring have been achieved with different noise measuring devices (Sound Level Meters). Some of these are supplied as part of the MONICA Crowd and Density monitoring solution; some are available as secondary solutions. Data can be used in various ways including the MONICA Common Operational Picture (COP), which is part of the MONICA Crowd Management and Communication solution. Other types of sound level meters can be integrated with the CAP and displayed directly on the customers own websites.

In the Copenhagen CAP, sound level data have been collected from three IoT enabled Sound Level Meters. Data were collected across a defined geographical area and the CAP simultaneously displayed location, and

data streams from the locations of the sound level meters. More information is found here: MONICA Sound Level Monitoring.

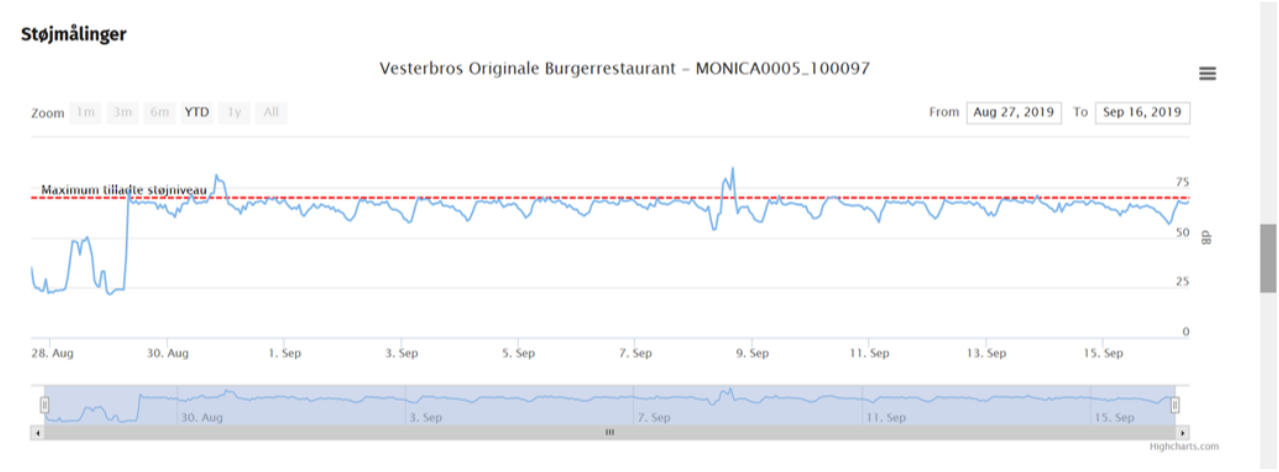

Figure 44: Example of a sound level sensor mounted during a street festival

The CAP can also use dynamically captured noised data from electric bicycles that are crisscrossing the city area. In the Copenhagen CAP, a mobile sensor gateway was used to dynamically make measurements in real time on the streets of Copenhagen. The data-capturing device consists of a small mobile sensor with gateway that can be mounted on a bicycle or other powered vehicle such as an electric car. The gateway consists of a Raspberry PI processor board equipped with a noise capture sensor. The gateway is flexible and open, so different types of sensors can be attached such as sound sensors or air quality sensors for NO_2 and atmospheric particulate matters such as $PM_{2.5}$, PM_{10}

The gateway is equipped with a GPS/Galileo receiver to simultaneously obtain the location of the measurements. The gateway continuously transmits the measurements to the MONICA Cloud for storage, processing and analysis. The raw data consists of longitudinal measurements of noise following the bicycles trajectory across the city. The COP can map the measurements into geographical areas so that a noise heatmap can be generated from all the bicycles that traversed the defined area.

General Open Data: The Copenhagen CAP also provides access to Open Data sources provided by the City of Copenhagen (https://data.kk.dk, https://kbhkort.kk.dk, and http://miljoegis.mim.dk) for noise and air quality. The main idea is to complement the existing Open Data sources, which are based on measurements made in a few places in the city, with dynamically generated mass-data from sensors mounted on bicycles and other moving vehicles.

The Torino City CAP

The Cittá di Torino administration is focused on the impact of nightlife in urban spaces. The CAP concept is aimed to create awareness about urban nightlife and its impact. The city already operates a number of citizen engagement platforms for collecting proposals from citizens and for participatory budgeting. The MONICA CAP can easily be integrated with such applications. The CAP for Città di Torino can be found here: https://torino.monica-project.eu.

Figure 45: The introductory section of the Torino City CAP

Noise Open Data: The Torino CAP collects real-time or near real-time data on sound from sound measuring sensors. MONICA IoT Enabled Sound Level Meters have been permanently mounted in the San Salvario district of Torino for measuring sound levels (noise). In the future, the Contribution Analysis algorithms may be deployed to distinguish between the sound from music and the noise from the crowd.

The data can then be displayed in heat maps.

Figure 46: Noise measurements in the San Salvario district in Torino

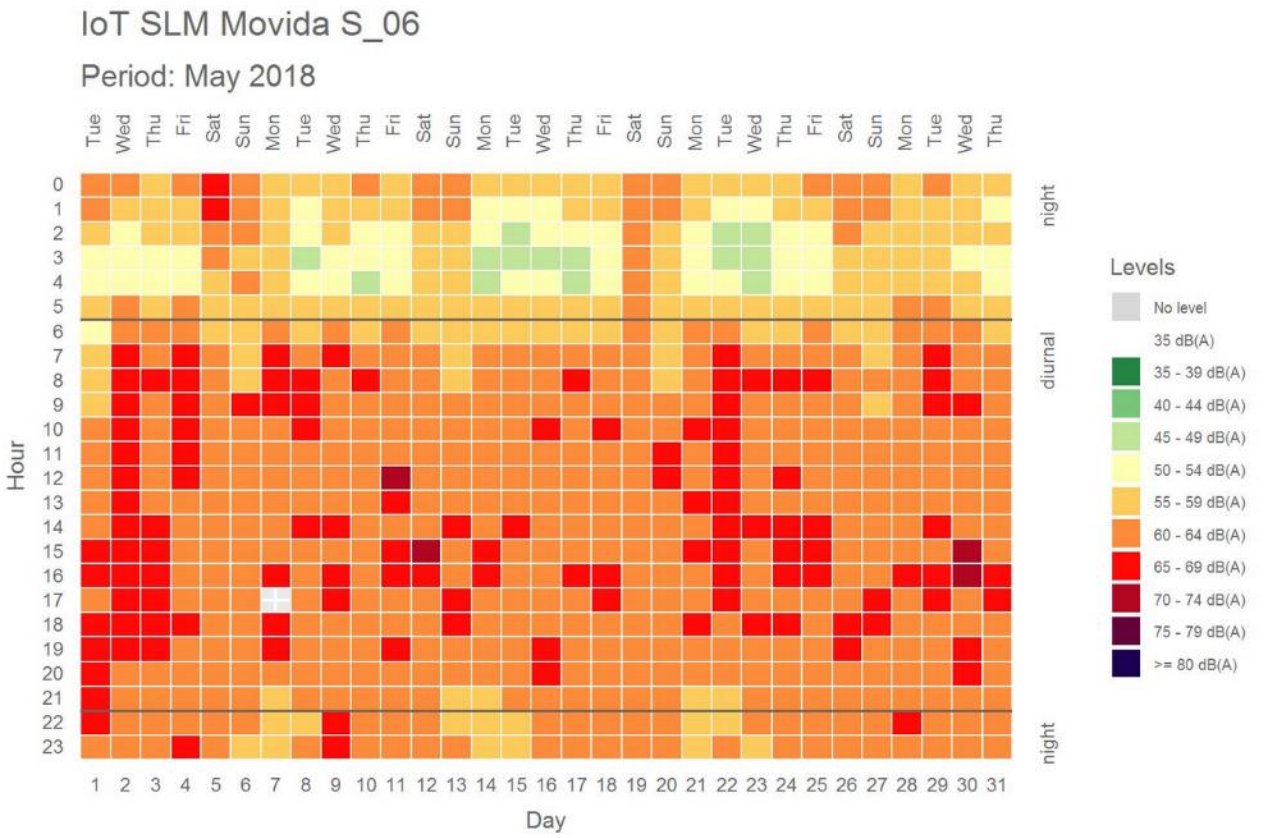

Figure 47: Noise monitoring from the San Salvario restaurant district for May 2018

The collected data have been organised according to date and hour and displayed in terms of noise levels in dB(A) average over one hour. The user can select the month from which to display data. In the dataset from May it is clear that sound levels are high (>60dB) every Saturday and Sunday nights between 00:00 and 02:00. Some nights (5-6 May and 19 May 2018) the noise continues until the early morning.

Crowd Monitoring: The Torino CAP has been set up to display real-time or near real-time data on crowd numbers coming from cameras in the San Salvario district of Torino. This work has not been completed at the time of writing. Please contact the contact point for more information.

Interactive Data Display: The collected data will, in the future, be organised in city maps with noise and crowd density maps.

9.2.2 Communication

The MONICA Collective Awareness Platform itself does not rely on separate communication networks. The CAP is cloud based and retrieves data through the city's Open Data platform.

For sensor communication, please refer to the MONICA Crowd and Density Monitoring solution.

9.2.3 Integration

N/A

9.2.4 Scalability

N/A

9.2.5 Associated MONICA solutions

The MONICA Collective Awareness Platform is related to and have been demonstrated together with these additional MONICA solutions:

- MONICA Crowd and Capacity Monitoring

- MONICA Sound Level Monitoring
- MONICA Crowd Management and Communication (the COP)
- City Noise Maps using Electrical Bikes Sensors
- Sound Composition Analysis

9.3 Implementation

9.3.1 Installation

The MONICA Collective Awareness Platform can be implemented as a customer specific solution independent of other MONICA solutions.

Preparation

No special technical preparation is necessary for the MONICA Collective Awareness Platform.

Deployment

The solution can be deployed freely to any locations.

Operation

The MONICA Collective Awareness Platform can be operated by the city's own ICT department or as a Platform as a Service (PaaS) or fully operated by a third-party vendor.

9.3.2 Regulatory aspects

Technical regulations

There are no specific technical regulations related to the MONICA Collective Awareness Platform

Other local/national regulations

The data and information collected at the MONICA Collective Awareness Platform from user interaction may be of personal nature.

Ethics

With regard to the collection and processing of personal data, the GDPR allows Member States to enact national provisions on certain issues as stipulated by the National Data Protection Authority. For example, Member States will have discretion to enact national provisions imposing further requirements regarding the appointment of Data Protection Officers.

- Internal procedures must be developed to protect personal data
- Internal procedures to protect the rights of data subjects must be implemented
- The CAP owner is identified as the "Data Controller"
- The CAP operator is identified as a "Data processor"
- A Data Processor Agreement must be drafted and signed by these two parties
- Data Processor Agreements with third parties must be in place if relevant.
- A Data Protection Officer can be designated by the Data Controller
- A Data Management Plan is required which established the intended processing of personal data and the purpose of such processing
- A Data Protection Impact Assessment must be carried out based on the Data Management Plan.

9.4 Business aspects

9.4.1 Revenue models

The choice of business model and pricing schemes is entirely up to the partner that have commercialised the solutions. Hence, the following information is solely provided as a guide to the expected business conditions that the solutions might be provided at. Please contact the responsible partner for further, up-to-date details.

Components	Type	Anticipated revenue model
CAP Platform	Cloud service	Can be provided to the city's own ICT department as consultancy costs. Or as a Platform as a Service (PaaS) or fully operated by a third-party vendor against recurrent service charges.
Sound Level Meters	Hardware	Can be provided at initial costs for hardware and design, configuration costs for installation.

9.4.2 Business models

The Business Model Canvas is used to give a high-level overview of the contents in the value configuration and in the customer group side related to a specific value proposition. This tool is used to map out all details of the MONICA business models based on the value proposition, target groups, the partner constellations, and revenue models outlined in the chapter.

Table 5: Business Model Collective Awareness Platform

<table>
<tr>
<td rowspan="2"> 
Key Partners

<u>MONICA partners</u>
• IN-JET
• CNET

<u>External partners</u>
• Hardware
• Cloud solutions
• Open Data
• On-site Installation</td>
<td> 
Key Activities
• Cloud operation
• Cloud systems
• Software development
• Cybersecurity analysis and mitigation
• Citizen engagement</td>
<td rowspan="2"> 
Value Proposition
Provide a co-creation collaboration platform where different actors can develop new solutions together using Open Data
Integrated with any Content Management System such as WordPress, SiteCore, Joomla etc. and Participatory Budgeting platform such as Consul
Used with the MONICA Sound Level Monitoring to create Open Data with sound levels from streets and areas with heavy traffic, temporary building and construction sites</td>
<td>Customer Relationship
 
• Departments involved in citizen engagement
• Political members of city councils
• Department responsible for infrastructure and the environment</td>
<td rowspan="2">Customer Segments
 
• Smart City Operators
• City authorities responsible for engaging citizens
• City authorities responsible for city infrastructure and urban living</td>
</tr>
<tr>
<td> 
Key Resources
• Software developers
• Cloud operation
• System integrators
• Social science experts
• Communication experts</td>
<td>Distribution Channels
 
• B2B city authorities
• Corporation with system integrators and smart city solution providers</td>
</tr>
<tr>
<td colspan="2"> 
Cost Structure
• Cost of development, customisation, training
• Cost of operation
• Cost of commissioning</td>
<td colspan="2">• CAP integration provided at a recurrent license fee
• Configuration, installation, service at costs</td>
<td> 
Revenue Streams</td>
</tr>
</table>

9.5 Potential for replication

9.5.1 Lessons learned

No lessons learned has been collected for this solution.

9.5.2 Usability aspects

9.5.2.1 Acceptance of MONICA Solutions

- Achieve accurate data from the SLMs.
- Produce relevant information that is accessible for all citizens.

9.5.2.2 Effectiveness of MONICA Solutions

- Citizens have the opportunity to engage in the creation of value and are able to contribute to the development of new solutions to challenges that occur in cities.
- This solution is an opportunity to access real-time data.

9.5.3 Reproducibility

No reproducibility data sets are available for the MONICA Collective Awareness Platform solution.

9.5.4 Contacts

The following partner is responsible for various components of the MONICA Collective Awareness Platform solution:

Solution	Responsible	Acronym	Details
CAP Platform	In-JeT ApS	IN-JET	IN-JET will provide the CAP, data repository and other websites for the CAP.
Sound Level Meters	In-JeT ApS	IN-JET	IN-JET will provide Sound Level Meters for noise measurements.
Bicycle Noise Sensors	CNet Svenska AB	CNET	CNET will provide the noise and environmental sensors for mounting on electric bicycles and cars.

10 Visitor Experience

Enhancing the visitor's experience of an event is an important requirement for event organisers and cities wanting to innovate and stay competitive.

The MONICA Visitor Experience solution consist of two digital applications for greater enjoyment and quality: 1) an event app, enabling visitors to access and negotiate the event more easily and 2) a Smart IoT wristband solution, interacting with users through concert lightshows at festivals or at events with features like polls, attention notifications and connecting through social media.

The MONICA Visitor Experience solution can work as a stand-alone solution, but can also be combined with the MONICA Crowd and Capacity Monitoring with components which can be deployed for a variety of purposes (CCTV cameras and wristbands) and with the MONICA Crowd Management and Communication solution which allows contextual real-time oversight and feedback directly to the visitors wristbands.

- **Event App:** The event app is customised to the specific event and provides event-related information and guidance, enables communication of important happenings or security situations with the choice of offering exclusive content and feedback-options. It can be integrated with the IoT wristband for location service and friend connect features.
- The **IoT wristband** can be used in various settings, applying several features that fit the event, with and without the use of the app.
- **Light shows:** The two RGB LEDs on the crowd wristband can be controlled by a management console available for operators wishing to synchronise the LEDs with the music from the stage.
- **LED alerts:** The two RGB LEDs on the crowd wristband can be used to guide people based on colour codes. A venue can have “coloured exits”. The LEDs of the wristbands can be controlled by individual base stations. A wristband will give priority to LEDs command from the base station that is nearest; based on this proximity characteristic the wristbands can be guided to the nearest exists indicated by a colour command of the LEDs.
- **Crowd density:** leveraging the bi-directional 100 m range radio that is integrated in the wristband. The crowd monitoring feature can be used to create heat maps of the crowd, showing visitor densities.
- **Location Service:** Since there is an approximate location for every wristband in near real time, every few minutes, this feature can be leveraged to implement a Location Service for visitors. In case a visitor needs to be found, the last known location can be queried from the COP in the MONICA cloud.
- **Friend-Connect:** A friend is connected by exchanging personal information (which is enabled during registration) by holding the button for 2 s until the LEDs light up blue. By holding the wristbands in close proximity of each other, the LEDs flash green and a connection is made (in the cloud database).
- **Conference-Like:** When the button on the wristband is pushed for a moment, the location and time will be registered.

10.1 Scenario Descriptions

Event information:

An app that can be downloaded by visitors of events, which features event important information, such as maps, fixtures, live updates, exclusive content etc. It is a solution to improve the overall visitor experience and satisfaction of the event.

Get event information:

In this scenario, the system provides:

1. Overall event schedules with listed event highlights
2. General information about the event and the history
3. General information about tips, rules and hints in relating the event
4. Detailed information about the attractions/highlights
5. General information about the project and data protection

6. Public transport information
7. Location of different stalls, rides and other basic and special infrastructure (first aid points, toilets, parking space, etc.)
8. Event map
9. Direct navigation option
10. Weather warnings
11. Advertisements
12. Feedback option

Give event feedback:

In this scenario, the system lets the visitors give feedbacks about the app. There is the option to ask the visitors about the whole event or only the app.

Evaluate event:

In this scenario, the system lets the event organizers evaluate the visitor experience with the app to optimise the app and adapt the user needs in future versions. With a full questionnaire which also polls the opinions of the visitors to the overall event the organizers can use the app for the overall evaluation with visitor's satisfaction, neighbours' complaints, sound levels, etc.

10.1.1 Type of Event

The MONICA User Experience solution can be used at any type of gated or non-gated open-air event, e.g., concerts, festivals or sporting events. It can also be used for indoor conference or convention events. It leverages on cost-efficient wearables and existing smartphones and mobile technology with a high visitor reach.

Event Information may be used at any type of gated or non-gated open-air event, e.g., concerts, festivals or sport events.

- Sport stadiums
- Street festivals
- Outdoor concert events
- Indoor conferences and conventions

10.1.2 Challenges

In an increasingly competitive event and tourism landscape, the demand today is for events that stand out and offer unique and personalised user experiences. This does not only include providing the frame for an enhanced experience of the actual performances, sports game or event content but also for an overall good experience of the event. Typical visitor experience challenges for event organisers are:

- Providing a smooth entry and exit to events (public transport, traffic, parking)
- Informing visitors about the event (time schedules, facilities, emergency services)
- Communicating security related information. The lack of technology to communicate creates security risks, as communication can become slower, more unclear and less people can be communicated with simultaneously.
- Adding value to the concert, festival or sports experience by offering exclusive, interactive or VIP content

10.1.3 Benefits

Providing an event app and an IoT wristband can help to improve the quality of the event and to boost visitor engagement and interest. The aim is to create a positive visitor experience before, during and after an event by preparing the visitor of the visit and by enhancing the event atmosphere through exclusive content or fun interaction between artist and audience and between audiences. Improving the entire visitor journey can improve the overall positive experience of the event and motivate the visitor to return or spread the word.

Additionally, the organiser can communicate important information about an event, gain insights into crowd behaviour and needs that help optimise content and procedures and thereby make the event fun and safe.

Benefits for the visitor:

- Updated, clear and complete information about the event, weather, infrastructure and facilities for easy, stress-free navigation to the target destinations
- Background stories and history of the event
- Interactive and exclusive content

Benefits for the organiser / city:

- Reach a greater number of people
- Interact and engage with visitors
- Receive feedback from visitors
- Relief of emergency services (police, fire brigade, regulatory office, paramedics) by referring inquiring visitors to the app
- Possibility of marketing and generating additional revenue by recruiting sponsors
- Optimal use of infrastructure such as parking lots, shops and toilet areas by displaying and navigating to the nearest location
- Stand operators have the option of self-promotion, by the description and mention in the app
- Enhance the visitor experience of the event and the city and thereby improving the wellbeing, safety and security of the visitor

10.1.4 Stakeholders for the MONICA Solutions

Event organiser: Person in charge of managing budget, logistics and external stakeholders that are part of the event. Responsible for assuring the success of the event at a practical level.

Cities: Cities (or municipalities) involved in monitoring facets of public life and interacting with their citizens.

Solution developers: Persons responsible for adapting/integrating the selected MONICA solution(s).

Event visitor: Person who visits the event

Event authorities: Police, Fire Brigade, First Aiders, Regulatory Representatives

10.2 Technical Aspects

10.2.1 Technical concept

Figure 48: Crowd Wristband in MONICA design

The MONICA User Experience solution is built on several IoT physical world network infrastructures. The components are connected via dedicated communication network and data repositories. The entire solution is embedded in a MONICA Private Cloud structure as described in the MONICA Platform Architecture and Components.

The IoT wristband; The IoT wristband is a wristband connected to base stations via wireless communication. It contains an integrated radio and microcontroller, battery, two bright LEDs, RFID chip, clock, button, and antennas. Connecting the wristbands to the cloud data base is performed through base stations using sub-GHz radios. The wristband can appear in multiple bracelet incarnations, leather, textile or silicon.

The wristband can be handed out to the event audience and will, by means of its coloured LEDs, be able to send simple messages to the wearer and send simple uplink messages to the event organiser using the small button on the wristband.

Over the course of an event millions of messages are being collected. These messages are stored in a highly scalable distributed Mongo database. The database contains information of all the visitors. It is completely up to the festival organiser to determine which kind of registration information is mandatory or optional. This data can be imported from the ticketing database or, depending on the capabilities of the ticketing database, automatically synchronised. The visitor database is replicated in real time to cloud instances.

The app: The app is customisable with respect to a map layout, displayed properties with their icons, event schedules and timings. This makes it possible to reuse the core of the app for other events.

10.2.2 Communication

The crowd wristbands need a dedicated infrastructure of base stations that communicate with each other and with the wristbands. A wristband must always be at maximum 75 m away from a base station in order to have coverage. This characteristic can be used to design and setup the base station infrastructure for a specific venue.

The base stations themselves are joined together in a software cluster. A unique redundant-communication protocol has been developed that enables the use of multiple physical communication layers between the base stations.

The server infrastructure is partly deployed locally on the festival premises and partly in the MONICA cloud. This setup enables the mobile apps that are running on the visitor's smartphones to interact with the system. The messages that are received from the wristband are used to perform real-time triangulation to drive the crowd monitoring system, heat map visualisation and individual wristband tracking.

10.2.3 Integration

The MONICA Visitor Experience solution is a complex solution that relies on both external components and technologies and technologies, enablers and tools from the MONICA project partners. Please contact the responsible partner listed below for more information.

External technologies required

- Android and iOS app markets

Internal MONICA enablers and tools required

- Smart IoT crowd wristbands and base stations supplied by Dexels BV / Sendrato
- MONICA Platform Core Enabler
- Professional APP Enabler
- Public APP Enabler

10.2.4 Scalability

The following scalability issues should be considered:

- The visitor app enables large amount of downloads
- The visitor app must allow visitors to access the app at the same time without slowing down, force quitting etc.

10.2.5 Associated MONICA solutions

The MONICA Visitor Experience solution is closely related to and have been demonstrated together with these additional MONICA solutions:

- The MONICA Crowd Management and Communication solution, in particular the Common Operational Picture (COP). The app is built upon the COP API which has been factorised so that the efforts to adapt the different apps to other events can be minimised, thus increasing the reusability.

- The MONICA Crowd and Capacity Monitoring solution including data and analytics results from other IoT frameworks including the MONICA Sound Level Monitoring solution and the MONICA Crowd and Capacity Monitoring solution.

10.3 Implementation

10.3.1 Installation

The MONICA Visitor Experience solution can also be implemented as a customer specific solution independent of other MONICA solutions.

Preparation

The following information must be investigated and prepared before implementation is commenced:

- Ensure proper internet connection near and inside the event venue.
- Promote the app beforehand to the appropriate target audience. Make the app available to download prior to the event.
- Perform a site visit to establish number of base stations needed to cover the venue and network setup. Identify sufficient spots to mount base stations at least 4 m high and identify suitable production office space.
- Hire professional installation company for mounting and establishment of ethernet (PoE) network between base stations.
- Ship wristbands well ahead of time and ensure proper storage space is at hand at the venue.

Deployment

The app can be further generalised to adopt to other events in different locations and languages. It can be produced in any environment where providing visitors with event information at a large scale is difficult and any event where the distribution of information is necessary.

The IoT wristband can be customised according to the profile of the event (indoor, outdoor, music festival to conference event).

Operation

Install base stations and wristband network, establishing Ethernet (PoE) network between base stations. The maximum safe range between a wristband and a base station is 75 m. Test the network connection thoroughly.

Make sure to have extra batteries for replacement.

10.3.2 Regulatory aspects

Technical regulations

- The Smart IoT crowd wristband must be CE-market that it complies with ETSI EN 300 220-2 V3.2.1 (2018-06) Short Range Devices (SRD) operating in the frequency range 25 MHz to 1 000 MHz; Part 2: Harmonised Standard for access to radio spectrum for non-specific radio equipment.
- The wristband is an electronic equipment and the supplier and the organiser must agree on the proper take-back procedure for the used wristbands.
- The wristband must comply with the Waste Electrical and Electronic Equipment Directive (WEEE 2012/19/EU).
- The wristband must comply with the Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive (RoHS 2011/65/EU).
- The wristband must be marked with the WEEE mark.

Other local/national regulations

- Location data is collected through the app the user has downloaded it on to his/her phone. In this instance, the user will have to agree to the terms of use for tracking of his/her location to be activated.

- Location data is collected through the MONICA crowd wristband anonymously.
- Only when registering the wristband e.g. to exchange his/her profile with others, the user will have to agree to the terms of use i.e. exchange of person-related details.

Ethics

- The festival organiser should consider if there is a legitimate reason for requesting visitors to register when using the wristbands. If so, only personal data directly relevant to the use and purpose of the wristband should be collected.
- If personal data is collected for the registration, internal procedures for protection of personal data and data subjects' rights must be in place (GDPR requirement)
- The term and conditions for downloading the app must be in concise language and contain a clear affirmative action (an opt in).
- Information about the wristband and its functionalities should be described prior to the festival, e.g. on a related website, to enhance visitors' awareness and basis for opting in.

10.4 Business Aspects

10.4.1 Revenue models

The choice of business model and pricing schemes is entirely up to the partner that have commercialised the solutions. Hence, the following information is solely provided as a guide to the expected business conditions that the solutions might be provided at. Please contact the responsible partner for further, up-to-date details.

Components	Type	Anticipated revenue model
Event app	Software	Provided as a customized commercial product with a fixed cost.
IoT wristband	Hardware, software, service	Hardware (wristbands, antenna anchors) is provided at a fixed cost. The use of the wristband software and event database is provided at a recurrent charge. Localisation design of wristbands is provided as an add-on on-off service and hardware cost. Installation and operation is provided at a fixed service cost.

10.4.2 Business Models

The Business Model Canvas is used to give a high-level overview of the contents in the value configuration and in the customer group side related to a specific value proposition. This tool is used to map out all details of the MONICA business models based on the value proposition, target groups, the partner constellations, and revenue models outlined in the chapter.

Table 6: Business Model Visitor Experience

<table>
<tr>
<td rowspan="2"> 
Key Partners

<u>MONICA partners</u>
• Dexels BV
• IN-JET
• CNET

<u>External partners</u>
• Hardware
• Network components
• On-site Installation</td>
<td> 
Key Activities
• Wristband design
• Network protocols
• Cloud operation
• App development
• Software development
• Firmware development</td>
<td rowspan="2"> 
Value Proposition
Create lightshow effects at festivals or at events using wristbands with features like polls, attention notifications and connecting through social media
Enable visitors to access the event offerings and real-time data more easily.
Enhanced visitor experience during and after the event and create connections and likes using the wristbands</td>
<td>Customer Relationship
 
• Provide information about event organisation
• Provide enhanced visitor experience</td>
<td rowspan="2">Customer Segments
 
• Organisers of musical events, outdoor concerts
• Organisers of street festivals, open-air markets
• Organisers of sporting events</td>
</tr>
<tr>
<td> 
Key Resources
• Software developers
• Cloud operation
• Network specialists
• Hardware designers
• System integrators</td>
<td>Distribution Channels
 
• B2B event organisers
• Through system integrators</td>
</tr>
<tr>
<td colspan="2"> 
Cost Structure
• Standard cost of cloud services
• Cost of network services
• Cost of hardware
• Cost of development, customisation, training
• Cost of operation
• Cost of commissioning and de-commissioning
• Electricity and rental cost for long term installations</td>
<td colspan="2">• Cloud integration component and services as consultancy services
• Cost of hardware with embedded firmware.
• One off-licenses fees for software and firmware per installation
• Configuration, algorithms training, custom. services
• Installation and commissioning services</td>
<td> 
Revenue Streams</td>
</tr>
</table>

10.5 Potential for Replication

10.5.1 Lessons Learned

Lessons Learned have been collected throughout the deployment and demonstration phases of the MONICA project and the relevant Lessons Learned are provided here for reference. Please note, that a number of the experienced issues have been corrected in the final MONICA products so please check with the responsible partner for the newest updates.

The following main Lessons Learned from the MONICA demonstrations and reference deployments are:

Event app

- Timely completion of the app, considering language versions, age restrictions and data information
- Ensure app availability in different app markets (Android and iOS)
- Ensure proper internet connection near and inside the event venue because of extensive mobile usage
- Ensure the app is available to download prior to the event, to publicise and promote the app effectively and boost user engagement
- The app must be promoted effectively to the appropriate target audience

IoT wristband

- Ensure communication about the wristband and distribution of the wristband beforehand to make the wristband better known, thereby ensuring better acceptance and adoption
- Add several user features to the wristband to create high user value
- Consider the environmental impact of the wristband making it attractive as a souvenir or making it reusable/recyclable

10.5.2 Usability Aspects

10.5.2.1 Acceptance of MONICA Solutions

- Users (visitors) are able to find important aspects of the event quickly. Using these functions, such as maps and event information, leads to a high acceptance with users
- Targeted messages increases satisfaction with the app
- Including exclusive content entices visitors to use the app for the event
- Having access to information which is otherwise difficult to find elsewhere at an event makes the user want to use the solution
- Ease of use increases user acceptance
- App must be functional i.e. do what the user wants/expects it to do, such as show them event information
- Aesthetically pleasing app which makes users want to download.
- Opportunity to provide feedback improves future design and delivery

10.5.2.2 Effectiveness of MONICA Solutions

- The ability to produce a solution that can provide further event information for visitors, such as key amenities, e.g., toilets and first aid points, helps to improve the quality of the event and boosts visitor engagement and interest
- The solution can encourage visitors to attend the event(s) again in the future
- Encourage positive visitor behaviour.

10.5.3 Reproducibility Aspects

No specific reproducibility data sets are available for the MONICA Collective Awareness Platform solution, However, the visitor app can be generalised to adopt other events with different location and language support. The app can be reproduced in any environment where the distribution of information (fixtures, live updates, street closure, amenity locations) is necessary.

The Replayer module, that replays OGC observations stored by GOST servers in Postgres databases during pilot events, can be used to test and demonstrate app-events.

10.5.4 Contacts

The following partners are responsible for various components of the MONICA Visitor Experience solution:

Solution	Responsible	Acronym	Details
Event app	CNet Svenska	CNET	CNET will develop a customised app for your event possible in cooperation with your existing app developer.
IoT wristband	DEXELS BV / Sendrato	DEXELS	DEXELS / Sendrato will design and supply the wristbands in the needed quantities. DEXELS will also provide the anchors and communication infrastructure and may install and operate the entire system during your event.

10.6 Reference Deployments, Demonstrations and Results

10.6.1 Event Information – Leeds-Rugby Varsity Match, October 2019

General description of the event

Leeds Varsity is an annual and massive sports competition between the two universities: Leeds Beckett University and University of Leeds. Over 60 fixtures across 25 different sports are played in one day, culminating with the traditional Rugby Finale at Emerald Headingley Stadium with more than 10,000 students cheering on their team.

Event information use case – deployment description

The purpose of the app, developed by CNET, was to enable the students to access and negotiate the event more easily and to provide exclusive content for greater enjoyment.

Figure 49: Varsity App

Visitors were able to safely enter and exit the ground using the interactive map detailing crowded areas. They were able to access ground safety rules and codes of conduct and view a safety message from the Police Superintendent of Operations.

Popular app features were the continuous updates of fixtures and live scores, as well as exclusive content such as match day images.

Almost 90 % of the survey respondents answered that the app improved their Varsity experience. Suggestions for improvement included expanding the live score function to include live streaming of other matches, including the women's rugby final to add interest and raise the profile of the less popular sports.

Challenges faced using MONICA solutions

Two main challenges were faced testing the MONICA visitors' app:

- Improving user Varsity experience
- Provide a potential impact on security measures

In previous years scores were communicated only by hearsay or Social Media. Students, using the MONICA app, liked the fact they could look at the upcoming fixtures and past fixtures for both men and women. One suggestion, brought up during the App evaluation process, was to allow sorting by sports, i.e. just football fixtures or just netball fixtures. The conception of the app was also to help raise awareness for other sports which aren't often advertised. 89% of the users that provided feedback stated that the APP improved their Varsity experience. 64% said they would be more likely to return next year if it was available. All stakeholders involved in the event e.g. Universities, Security, emergency services and Rugby unanimously agreed that it was a much better, safer event, with less incidents, compared to previous years. As a result of the overwhelmingly positive feedback the Varsity organisers are considering how they can develop the APP for Varsity 2020 implementation.

Even though visitor experience was the main driving force for the Varsity app, it might also prove promising in terms of supporting ground safety and security due to its information about these matters.

– "Evaluation of this year's event has shown fewer incidents and need to sanction on behaviour grounds. In general, students used the correct entrances for their universities and queues for entry were less busy than in the past. Some of the information contained in the app may have contributed to this positive outcome", explains Dr Helen Whitrod Brown, Project Co-ordinator, Yorkshire County Cricket Club and Leeds Rugby Ltd.

10.6.2 Engage citizens in creation of smart city solutions – MOVIDA, Turin

General description of the event

Starting from the 90s, the nightlife grew in San Salvario district, in Turin – Italy, thanks to pubs, low-cost bars, restaurants, liquor stores and wine cellars, boutiques and multi-ethnic shops that have been opened. These venues stay open until late and have completely reshaped the map of city entertainment, known as "Movida"[9].

Since 2010, the Movida phenomenon has been increasing due to the amount of people that are in the streets every night.

The city district of San Salvario is located near the city centre of Turin. This residential area is characterized by the grid plan typical of the old neighbourhoods of Torino; with about 470 four/five floors buildings with an internal court; about 7300 people live in the area with a surface of 0,26 km2 . In the most crowded area, about 120 activities selling food and beverages are counted by the Economic Affair Dept of the City, together with about 10 discos and private clubs.

Engage citizens use case – deployment description

Event Information for a spontaneous event like Movida requires a special focus on strategies and messages. The purpose is not increasing the number of people joining the event, but suggesting a quieter and gentler way to behave in public space, in order to avoid part of the noise due to unaware noisy behaviour, trying to avoid both commanding or paternalistic approaches.

In 2019 three different strategies where developed:

1. empathy, based on gentle or ironic messages;
2. fun, through games and street art performances;
3. amazement, through dance, costumes and whispered songs.

The first strategy was developed by the MONICA Hackathon Winner Team within their project: the target are people in front of bars and pubs and messages flow on a screen, using a bot whose behaviour is related to the noise levels and the number of interaction with the neighbours.

[9] from Spanish: movement, happening

A first demo was performed in “Casa del Quartiere”, in order to give feedback to the noise in the courtyard. The solution is based on a web-app and a low-cost SLM.

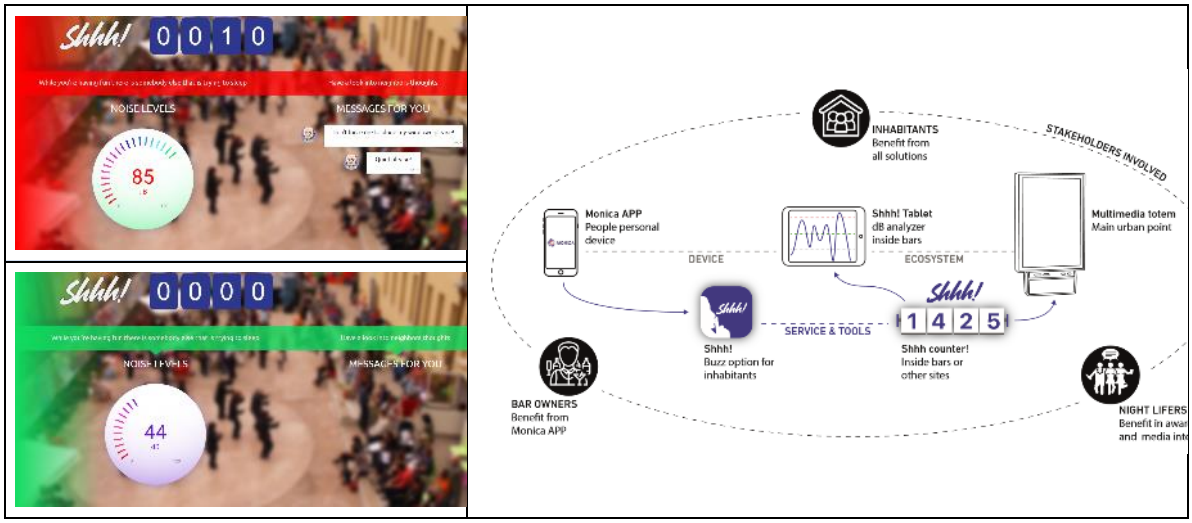

Figure 50: “Shhh!” project ecosystem and feedbacks, mixing colours and bot messages

The second strategy was developed in cooperation with the Local Health Department and was based on the artistic performances “VisibiLords” by Pindarica, mixing video projection, games and magic.

The purpose of the performance is making people aware of potential personal night life risk (alcohol, drugs, unprotected sex) and impact on public space (noise, rubbish, safety). The performance is an hook for a follow-up by professional educators, that offers more information and support (alcohol test, condoms, leaflets, etc.). The campaign of twelve nights launched #ladolcemovida hashtag, with the idea of building a communication campaign and an app managed by the Youth Department.

The third approach was tested one night, hosting “Les Pierrot de la Nuit” performers from Paris, as conclusion of a workshop about the impact of artistic performances in night life districts, sharing experience between Turin, Paris and Florence. Three dancers and singers played an elegant performance in Largo Saluzzo (Figure 45), mixing dance and songs whispered. An empiric observation showed a good reaction of Movida goers, whose conversation were suspended during the performances and the attention was oriented to silence and calm, in order to pay attention to the songs.

Figure 51: #ladolcemovida performances by Pierrots de la Nuit in Largo Saluzzo

Communication and event information in night life reflect all its complexity, but promising different approaches have been tested in Movida Pilot. Mixing technologies, arts and cultural events: this is one the added-value results of the project.

All lessons learnt will been capitalized in Movida Noise Action Plan, ready to be approved in 2020 by the Torino City Council after its publication and a good public debate.

11 General regulatory aspects

11.1 GDPR

The **General Data Protection Regulation (GDPR[10])** was put into effect on May 25, 2018. The GDPR lays down rules relating to the protection of natural persons with regard to the processing of personal data and rules relating to the free movement of personal data. Though it was drafted and passed by the European Union, it imposes obligations onto organisations anywhere, so long as they target or collect data related to people in the EU. The GDPR will levy harsh fines against those who violate its privacy and security standards.

For further details, the Guide to GDPR Compliance contains a library of information to help organisations achieve compliance, including checklists and customisable templates for the most common GDPR forms that companies need in order to be compliant. If you will be processing personal data, you must have a single valid lawful basis as outlined under GDPR.

The MONICA Cyber Security, Privacy and Trust Framework is built on Privacy by Design principles, and the basis for the MONICA solutions is a commitment to be in compliance with the regulation. However, organisations must be able to demonstrate that they have procedures and policies in place for dealing with their obligations to data subjects and that their data processing practices are transparent. Therefore, when MONICA solutions are used to collect and/or process personal data, the following topics need to be considered:

- Internal procedures to protect personal data
- Internal procedures to protect the rights of data subjects
- Informed consent procedures and forms
    - Processing data based on consent must be unambiguous and involve a clear affirmative action (an opt in)
- Identification of the Data Controller
- Identification of the Data processor
- A Data Protection Officer may have to be designated
- A Data Management Plan may be required
- A Data Protection Impact Assessment may be needed
- Data Processor Agreements with third parties must be in place.

11.2 Technical Regulations

All radio devices must comply with the Radio Equipment Directive 2014/53/EU (RED).

For the MONICA solutions, this typically involves

- IoT Wearables and connected Base Stations (Gateways)
  For the MONICA demonstrations, Smart IoT wristbands, IoT Ultra-Wide Band Short Range Tracking Devices and 800 MHz Staff Tracking Devices were used.
- Cameras (wireless)
- Unmanned Aircraft Systems (UAS, also called drones)
- Blimps (wire-tethered soft-balloon airships)
- Smart glasses and Monicora Gateway
- Sound Level Meters and Gateways
- Environmental sensors and OneM2M Gateway
- GPS Tracker and Tracker Gateway

For further details, see *D12.5 Report on Standards, Regulations, and Policies for IoT Platforms*, available from the MONICA website[11].

[10] https://gdpr.eu/what-is-gdpr/
[11] www.monica-project.eu

11.3 National/Local Regulations

With regard to the collection and processing of personal data, the GDPR allows Member States to enact national provisions on certain issues as stipulated by the National Data Protection Authority. For example, Member States will have discretion to enact national provisions imposing further requirements regarding the appointment of Data Protection Officers.

Until technical and operational EU regulations of Remotely Piloted Aircraft Systems or Unmanned Aircraft Systems are harmonised, regulations for “drones” are entirely at the national level and very different from Member State to Member State.

12 Technical Information

The ensuing sections contain detailed information on the composition of the MONICA solutions at component level, a guide to using the MONICA Scalability/Replicability Matrix and an overview of the MONICA Software Developer Tools, Generic Enablers and Third-Party Tools.

12.1 Components of the MONICA Solutions

12.1.1 MONICA Solutions

The solutions consist of the **MONICA Platform Core Enabler**, combined with one or more of the three types of MONICA Platform Auxiliary Enablers: the **MONICA Sound Loop Enablers**, the **MONICA Crowd Loop Enablers** and the **MONICA Event Information Enablers**.

The MONICA Sound Loop Enablers are the Monitor Sound Level Enabler and the Adjust Sound Level Enabler.

The MONICA Crowd Loop Enablers are the and Capacity Monitor Enabler, the Management and Communication Enabler.

The MONICA Event Information Enablers are the Professional APP Enabler and the Public APP Enabler.

Except for the Platform Core Enabler, each enabler consists of two parts:

- Technologies/modules deployed in the cloud
- Technologies/modules/devices deployed on site (typically wearables/cameras and technologies related to video analysing and processing).

If applicable, two optional services may be provided:

- **Local Processing Unit Rental** - if the event organiser does not have appropriate computing resources to run the on-site components of enablers, this may be supplied by the MONICA provider
- **External Platform Connectors** - connection of the MONICA ecosystem to the existing external platform.

12.1.2 MONICA Enablers

General descriptions of the MONICA Enablers are provided in Table 7. It is worth noting that the two “Control” enablers include the associated monitoring functionalities. To control something, it must be monitored first.

Table 7: Description of MONICA Enablers

MONICA Name	Description
Platform Core Enabler	The basic set of technologies as a cloud foundation which provides functionalities across all modules: Infrastructure (computation, storage, cloud networking, containerisation), Middleware, web services, database services, Authentication and Authorisation, Infrastructure monitoring. This enabler must be used as a foundation for any other enabler to run on top of it
Monitor Sound Level Enabler	A block of technologies/modules used to cover requirements of Sound monitoring and Control Use Case Group: for Monitor sound level
Adjust Sound Level Enabler	A block of technologies/modules used to cover requirements of Sound monitoring and Control Use Case Group: for Adjust sound level
Crowd and Capacity Monitor Enabler	A block of technologies/modules used to cover the monitoring requirements of Crowd and Capacity Monitoring Use Case Group: for Monitor crowd based on capacity, Detect/Re-direct high-risk queues (Detecting an incident)
Crowd Management and Communication Enabler	A block of technologies/modules used to cover the control requirements of Crowd and Capacity Monitoring Use Case Group: for Inform staff, Inform visitors, Guide people to exits, Missing person (Locate staff member), Security/Health incidents (Detecting, reporting, handling), Safety incidents (Precautions at unsafe wind speeds)

MONICA Name	Description
Professional APP Enabler	A block of technologies/modules used to cover requirements of Event Information Use Case Group and professional APPs
Public APP Enabler	A block of technologies/modules used to cover requirements of Event Information Use Case Group and public APPs

12.1.3 MONICA Components

Table 8 provides and overview of the cloud components and on-site components of the different MONICA Platform Auxiliary Enablers, similar to the Figure in the MONICA Enablers Matrix described in item 2) in Section 12.2.

Table 8: Enablers and Components

MONICA Enabler	Cloud Components	On-Site Components
Monitor Sound Level Enabler	Sound Monitoring Package	Sound Level Meter Devices and GWs
Adjust Sound Level Enabler	Sound Monitoring Package	Sound Field Control System, Loudspeakers
	Professional Sound APP	Sound Level Meter Devices and GWs
Crowd and Capacity Monitor Enabler	Monitor Crowds Based on Capacity Package	Security Fusion Node
		Devices and GWs
Crowd Management and Communication Enabler	Crowd and Capacity Monitor Enabler	Security Fusion Node
	Staff Management Package	Devices and GWs
Security Enabler	Safety Incidents Package	Devices and GWs
	Professional Security APP	
Professional APP Enabler	High Level Data Fusion	Devices and GWs
	Professional Sound APP	
	Professional Security APP	
Public APP Enabler	High Level Data Fusion	Devices and GWs
	Visitor APP	

12.1.4 MONICA Packages

Table 9 lists the components and sub-components making up the Packages referred to in Table 8.

Table 9: MONICA Packages

Package Name	Components	Remarks	Devices
Sound Monitoring Package	Observation Replay		Sound Level Meters (SLMs)
	GOST	Third-party	
	OGC Service Catalogue	Third-party	
	COP UI		

Package Name	Components	Remarks	Devices
	COP API		
	COP DB		
	COP Updater		
	SCRAL		
	Decision Support System		
	Sound Heatmap		
Staff Management Package	Observation Replay		Trackers
	GOST	Third-party	
	OGC Service Catalogue	Third-party	
	COP UI		
	COP API		
	COP DB		
	COP Updater		
	SCRAL		
	FIT COP		
	Tracker Emulator	For test purposes	
Monitor Crowd Based on Capacity Package	Observation Replay		Wristbands Crowd cameras Gate counting algorithm Vehicle detection algorithm
	GOST	Third-party	
	OGC Service Catalogue	Third-party	
	COP UI		
	COP API		
	COP DB		
	COP Updater		
	SCRAL		
	Decision Support System		
	Wristband Emulator	For test purposes	
	HLDFAD		
Safety Incidents Package	Observation Replay		Sensors
	GOST	Third-party	
	OGC Service Catalogue	Third-party	
	COP UI		

Package Name	Components	Remarks	Devices
	COP API		
	COP DB		
	COP Updater		
	SCRAL		
	Decision Support System		
	Tracker Emulator	For test purposes	

12.1.5 Details of Other Components

Localising Devices

Battery powered staff localising devices communicate to the control room wirelessly using a low power consumption technology. One or more stationary transceivers are deployed based on the size/geometry of the venue to receive the messages from the localising devices. One transceiver node can cover an area with a radius of 1 km.

The localisation is supported by the GNSS based (Global Navigation Satellite System). The system wakes up once a while to collect and transmit geo-location information. The sleep interval depends on the frequency at which the data needs to be sent to the control room. The tracking devices are also equipped with buttons and LED lights. The button is used for switch on and off functions. Additionally, a notification can be sent to the control room to draw attention to a situation near the staff member by pressing the button. LED light gives feedback about the state of the button.

The location information and the notifications are shown in the interactive map in the control room. This map can be rendered in different sizes of screens ranging from large displays to smaller tablets or mobile phones. This interactive map provides filtering and searching functionalities for the staff in the control room.

12.2 Using the Scalability/Replicability Matrix

The Scalability/Replicability Matrix can be used to identify the components necessary to execute the different Use Cases (also called usage scenarios).

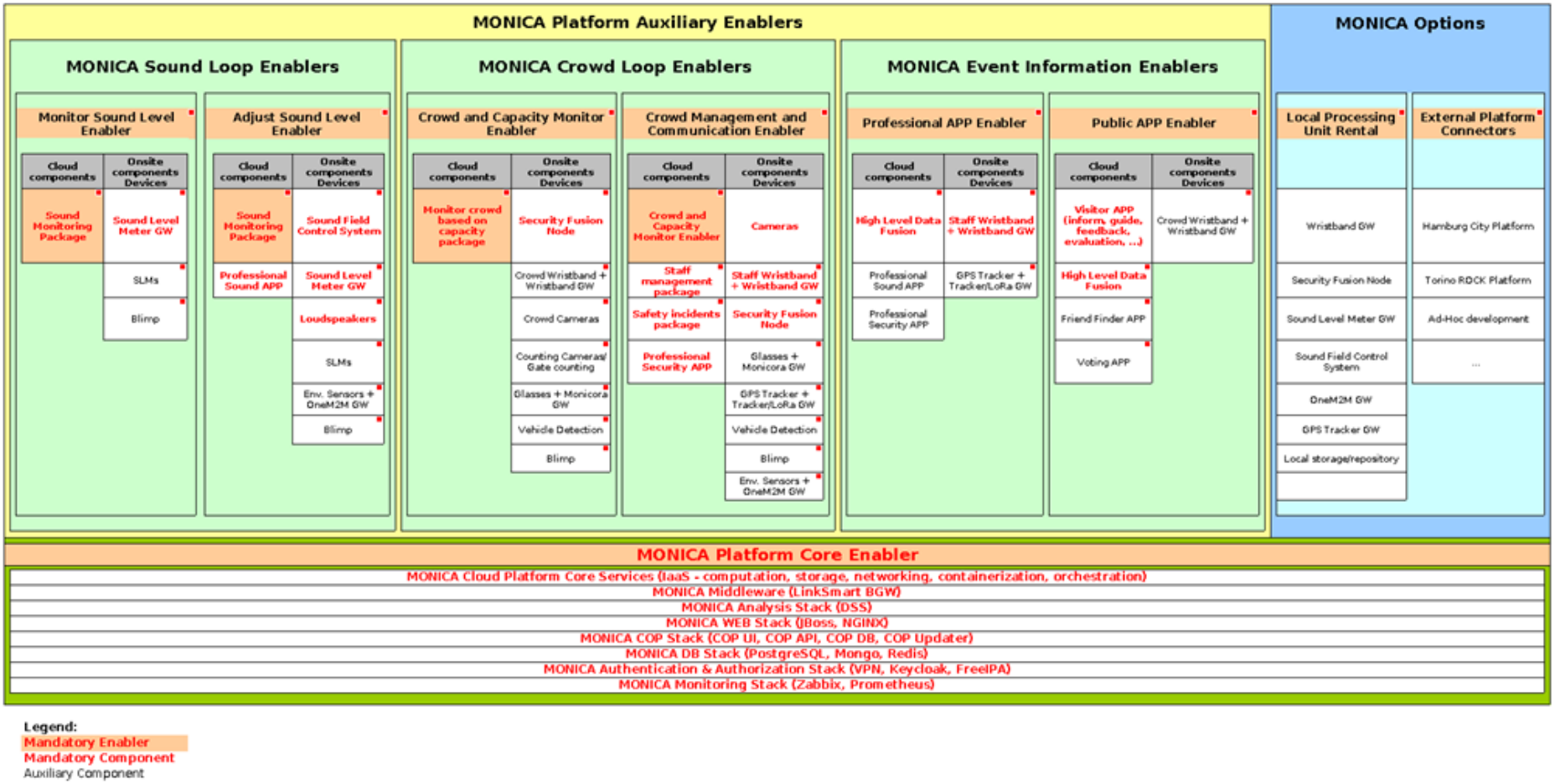

Figure 52: Scalability/Replicability Matrix

The tool is supplied as a file containing six spreadsheets:

1) Use Case/Components Matrix

   This sheet lists the Use Case Groups (Solutions/Functionalities) and individual Use Cases and combines these with the implicated entities, structured consistent with the different layers of the MONICA solution: Device Layer, Edge Layer, IoT Layer, Service Layer and Application Layer

2) MONICA Enablers Matrix

   This matrix provides an overview of the MONICA Platform Auxiliary Enablers and how these are combined with the MONICA Core Platform Enabler to achieve the desired functionality

3) MONICA Packages

   The MONICA Packages list the components and subcomponents required to support the different solutions, e.g., the Sound Monitoring Package and the Safety Incidents Package

4) MONICA Catalog Demonstrator

   This interactive demonstrator can be used to define which MONICA Enablers are required for a particular Use Case Group and Use Case

   For example, if you select Use Case Group 'Sound Monitoring and Control' and Use Case 'Adjust sound level' from the drop-down lists, the MONICA Platform Core Enabler and the Sound Control Enabler are required. You can then refer to the MONICA Enablers Matrix to see what that means in terms of components and subcomponents

5) MONICA Information Flow

   This chart illustrates the flow of information from the devices to the different applications

6) MONICA Deployment View

   This chart depicts the deployment view, with devices, network infrastructure, cloud infrastructure and professional and public applications, enveloped by the MONICA Cyber Security components.

ATOS is available to provide more information about the Scalability/Replicability Matrix.

12.3 The MONICA Toolbox

The MONICA Toolbox contains Software developer tools and Third-party tools as detailed below.

Details can be found in *D7.6 The MONICA Development Toolbox 2*, available from the Knowledge Centre on link to the MONICA website: https://github.com/MONICA-Project

12.3.1 Software Developer Tools

- IoT Monitoring Tool
- IoT Entity, Service and Resource Catalogues
- IoT Resource Management and Catalogue Tool
    - Smart City Resource Adaptation Layer

12.3.2 Third-Party Tools

- GOST Database
- PostgreSQL
- Mongo DB
- Redis
- Keycloak
- FreeIPA

- LinkSmart BGW
- OGC Service Catalogue
- Mosquitto
- RabbitMQ
- Zabbix
- Prometeus
- Grafana
- JBoss
- NGINX

13 Conclusion

This deliverable presents all the results and useful information collected in three years of testing and demonstrations performed by the MONICA consortium. It reports the six MONICA Solution Areas: Crowd and Capacity Monitoring, Crowd Management and Communication, Sound Level Monitoring, Adaptive Sound Field Control, Citizen Engagement using the Collective Awareness Platform, and Visitor Experience. The extensive description of the use cases and provided solutions point interested parties to areas of application that might be relevant for their dedicated scenario. Each section provides an overview of the typical use scenarios, technical, implementation and business aspects and details the potential for replication.

Next to the Solution Areas this deliverable presents two MONICA Tools. The first one is the Scalability and Replicability Matrix. This extensive tool elaborates a clear overview of MONICA solutions components and how they are interdependent. It aims to support the decision making process, when selecting an appropriate set of solutions. It clearly identifies which parts are mandatory and which parts or packages can be selected.

The second tool is the MONICA Toolbox. This open software repository is free and available to the interested community online: https://github.com/MONICA-Project. The aim of providing MONICA open licence software packages and data sets is to invite further spreading of the knowledge gained and in the long run enhanced event security, sound and visitor experience.

Potential customers are invited to replicate the MONICA solutions and further develop what has been created. All MONICA project partners and the Project Coordinator Fraunhofer Institute of Advanced Information Technologies (FIT) in Germany are keen to share more detailed information, to inform about follow up projects and their recent research activities.

14 Glossary

ASFCS: Adaptive Sound Field Control System. The ASFCS reduces the sound level in the dark zone considerably when using directly and densely measured transfer-functions between the loudspeakers and the control zones.

CAP: Collective Awareness Platform for Sustainability and Social Innovation. The aim is to find new models on how to create awareness of emerging sustainability challenges and ease them through collective action.

Contribution Analysis: Estimating the sound contribution of a concert, filtering away other sound sources.

COP: Common Operational Picture. A web based interface displaying information that gives you a full overview of a situation.

CCTV: Closed-circuit television/ video surveillance.

DSS: Decision Support System provides recommendations and proposes actions for a human operator based on contextual data and information from the IoT sensor networks.

GPS: Global Positioning System.

Hackathon: An event where computer programmers and software developers meet and code new software.

IoT: Internet of Things. Advanced wireless technologies connecting physical objects to the internet and making it possible to collect and exchange data and perform actions.

JSON: It's a text string containing data and parameters formatted for easy parsing. Often used when exchanging data between server and browser.

LAeq: A-weighted Sound Pressure Level.

LCeq: Equivalent continuous sound level.

PA: Public Address. A sound system including microphones, amplifiers, loudspeakers, and other related equipment.

Reproducibility: When an activity, process, or experiment cannot be fully replicated (e.g., because of a lack of time or resources) data sets, software code, etc. can be made available to others for reproducing the same results.

Scalability: The capability of a system, network, or process to handle a growing amount of work, or its potential to be enlarged to accommodate that growth.

SLM: The basic functionality of a sound level meter is to measure and calculate the sound level.

UWB: Ultra-Wide Band. A suite of broad wide wireless standards which apply very wide radio channel bandwidths.

15 List of figures and tables

15.1 Figures

15.2 Tables