WORKINGAGE

Smart Working Environments for All Ages

# D2.4 - Technical Requirements of the WA Tool

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# WP2 – User Centric Design

## D2.4– Technical Requirements

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# Executive Summary

The present deliverable presents the technical requirements of the WorkingAge project as these derived from analysing the user requirements as well as the selected architectures, both at system and at component level.

The objective of the tasks that contribute to this deliverable is to define the technical requirements of the WA Tool and to formulate its architecture taking into consideration: 1) the project's objectives as defined by the DoA, 2) the project's constraints identified in T2.1, 3) the sensing technologies ecosystem as this was designed in T2.2, 4) the Data Management Plan described in D2.3,5) the definition of the pilot tests as per T2.5 and 6) the interconnection among the various modules in the system.

Section 1 describes the WA Tool requirements, including its selected architecture, components and functions with regards to the project's theoretical background, project's objectives and limitations.

Section 2 proposes adequate scenarios for integrating WA Tool's systems regarding monitoring, location spotting, data security and privacy and human-machine interaction. For each of the aforementioned subsystems, the partners have considered the pros and cons to finally converge into an integrated proposed solution.

In section 3, the consortium draws the conclusions in terms of system architecture and outlines the WA Tool's specifications.

This document will be used as reference for the upcoming development phases. WA Tool system's specifications described in the document will be complemented with the feedback received in the context of Work Packages 4 and 5. The system's specification will also be enhanced in the next phase of the project for the system to have better data coverage at home environments.

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# Introduction

The WA Tool aims at monitoring working environments using IoT devices (sensors, interaction tools, wearables) to provide remote health surveillance capabilities. The WA Tool will gather the incoming information (i.e. analysis of the oculomotor functions, voice emotion, gestures, facial expressions, etc.) to provide as an outcome an indication of the user's overall status, accompanied by recommendations for relevant interventions if and where needed, always upon the consent of the user. The WA Tool relies on a user centric and design-driven approach and is respectful of all the existing privacy and security regulations. The tool assesses a range of factors, including Physical/Ergonomic, Psychological (including cognitive and emotional), and Lifestyle (food intake, physical activities, social engagement, etc.) parameters.

In the context of the WA project, the following three types of working environments will be monitored:

- **Working Offices**: The workplaces consist of a typical working office environment. The employees perform their work sat in front of desks, which are equipped with monitors and a keyboard. Typical office tasks are conducted, such as typing, filling in software templates with information, writing down on paper and speaking with customers/partners via telephone or web applications using a headset earphone. From a mental perspective, the work demands the usage of profession-specific, problem-solving, strategy-defining, negotiation and decision-making tasks. The tasks performed rely heavily on computer programs for reading, writing and verbal communication.
- **Professional Driving**: The workplace is a vehicle; thus, the working environment entails all the elements of a typical driving place, e.g. steering wheel, pedals, seat. Drivers have to perceive their environment, assess the current traffic situation and react respectively by making decisions and adjusting their own driving behaviour. This requires constant concentration and assessment of the situation while driving. In addition to mental stress, there is also physical stress caused by steering, using the pedals and the posture. Information that needs to be mentally processed comes usually in visual (watching the road, signalling, streets, monitoring traffic, other drivers, etc.), auditory (listening to noises, horns, etc.) or tactile (sensing road conditions through steering wheel, etc.) format.
- **Industrial plant**: The third working environment in which the WA Tool will be designed for and tested is manufacturing plants. Depending on the task performed in the industrial environment, a different working system is deployed; hence the use of different processes and pieces of equipment is required in each case. Working in an industrial plant entails all typical tasks related to a production line, such as conducting work with heavy machinery. An additional element that needs to be considered is the monotonicity of continuously repeated tasks. As a

result, this sort of working environments combines both physical and mental fatigue.

Within the WorkingAge project, some of the difficulties related to the aforementioned workplaces will be addressed. Through the WA Tool, workers will be equipped with sensors that are able to monitor their mental and physical strain at a (near) real-time basis, through a range of physical parameters, such as heartrate, blood pressure, body posture etc. If the measured strain indicators are too high, corresponding recommendations will be provided in order to lower the stress level of the employees. Moreover, environmental parameters, like illumination, vibration and air humidity, are captured aiming to gain valuable information regarding environmental conditions that could influence the workers' wellbeing.

The main challenges and limitations that the WA Tool will face are the following;

- **Mobility:** The WA Tool developed will need to be able to address the mobility of the users and the one related to the working environments. For instance, in the case of the driver, both the driver and the vehicle will be constantly on the move. The WA Tool must therefore foster a system wireless and embedded technologies to connect the users with the sensing ecosystem. Data collection and transfer should also be resilient to white spots with no Internet connection.
- **Flexibility**: Due to the diversity of use cases, the WA Tool should be flexible and modular. One should be able to choose among the set of sensors and services to be deployed. The system should require little maintenance and easily integrate new sensors and services.
- **Capacity:** The WA Tool's services will require high bitrate network and high storage and computing capacity for the transport and processing of data deriving from the IoT infrastructure.
- **Accuracy & Validity**: Some WA Tool's services will require low latency processing such as anomaly detection with automatic calls to 112. A way to reduce the latency is to process the data at the network edge close to its source. The working sites should also be remotely monitored. The data flow within the WA Tool may therefore require synchronisation procedures between local computing units and a remote cloud.
- **Resiliency:** In the foreseen deployment scenarios, Internet access may not be available at all times. This should not disturb the monitoring capacity of the WA Tool. Some of the WA Tool's services will need to operate offline, thus ensuring the resiliency of the system.
- **Scalability:** The WA Tool's architecture should be designed to be scalable, enabling the simultaneous monitoring of up to 90 workers.
- **Interoperability:** The system should be able to connect a large range and number of IoT devices. It should also be able to connect and interact with the local network of the working site.
- **Security**: The system should ensure secure communications and storage of this data with compliance with the GDPR regulation. Data should therefore be pseudonymised and anonymised at its source at the

network edge and stored in a central repository as per the WorkingAge Data Management Plan (D2.3).

- **Costs:** Having as an objective the development of a cost-efficient tool with high chances of becoming a successful product in the market, the WA Tool should rely on open-source and standardised off-the-shelf technologies and products, aiming at extending and integrating the tools that are already developed by partners.

# 1 The WA Tool

This section describes WA tool's architecture, main components and functions in response to the project's objectives and constraints described above and with regards to the theoretical background on cloud and networking systems.

## 1.1 System Architecture

### 1.1.1 Centralised vs Decentralised System Architecture

Edge computing is now quite well known, and many developed solutions have been tested in full scale. Edge Computing brings together the operator's vision with the MEC (Mobile Edge Computing), the vision of network equipment providers that corresponds to Fog Networking and finally a new vision, called 'Skin Networking', 'Mist Networking' or 'Home Computing', designed around femto-datacentres. Indeed, femto-datacentres are servers with quite a high power.

Over the past few decades, cloud computing has been significantly developed and implemented due to its high profitability and flexibility achieved through consolidation, in which the computing, storage and network management functions operate centrally. With the rapid development of mobile Internet and Internet of Things (IoT) applications, the existing centralised cloud computing architecture is facing serious problems. Mobile devices connected to remote centralised cloud servers are trying to obtain sophisticated applications, which impose additional burden on Radio Access Networks (RANs) and access networks, resulting in high latency. In addition, with the explosive growth of various access devices and the demands of end-users, IoT is driving a digital transformation in all aspects of modern-day life. Cisco estimates that the number of devices connected to IoT will reach 50 billion by the end of 2020. Emerging IoT introduces new challenges, such as strict latency, capacity constraints, resource-limited devices, uninterrupted services with intermittent connectivity, and enhanced security, which the centralised architecture of cloud computing does not allow to solve adequately. An advanced computing paradigm that transcends the centralised architecture and mitigates capacity and latency constraints is urgently needed to address these challenges.

IoT refers to the interaction and communication between billions of devices that produce and exchange data about real world objects. The IoT's capabilities, including the large-scale object network, device and network heterogeneity, and the large number of events generated by these elements constitute the development of diverse applications and services very difficult. These requirements are becoming increasingly difficult to be fulfilled in the cloud scenario. IoT applications generate huge amounts of data from IoT sensors. These data, which are counted in Giga and Tera bytes, are then analysed to determine the reactions to the events or to extract analyses or statistics. However, sending all data to the cloud requires extremely high network bandwidth. Recent research is examining ways to effectively leverage the capabilities at the edge of networks to support IoT and its needs. In edge computing, the large data generated by different types of IoT devices can be processed on the edge of the network instead of transmitting them to the centralised cloud infrastructure due to bandwidth and power consumption issues. Edge computing delivers services with faster response and better quality compared to cloud computing. Edge computing is more suitable for integration with IoT to provide efficient and secure services to a large number of end-users. Thus, an on-board computing architecture can be envisioned for future IoT infrastructure.

Recently, emerging technologies and applications are driving a trend in the computing and communications landscape that is shifting the function of centralised cloud computing to the peripheral devices of networks. Software-defined Networking (SDN) and the associated concept of Network Function Virtualisation (NFV) are proposed as emerging solutions for future networks. Ultra-low latency is identified as one of the key requirements of $5^{th}$ generation (5G) RAN networks. To reduce latency, operators are inclined to deploy the application and content to the edge of networks. At the same time, operators can open peripheral equipment to third-party partners, enabling them to rapidly deploy innovative applications and content for mobile subscribers, enterprises, and other vertical segments. While the computing capabilities of mobile watches, smart phones, and other IoT devices have been dramatically improved, they are still limited by fundamental challenges, such as memory size, battery life, and power dissipation. Mobile devices need to extend battery life by offsetting the calculation of applications that consume power at grid boundaries.

#### *1.1.1.1 Centralised Infrastructures*

Central cloud systems host all services in a remote server. Local sensors connect to the Internet using the operating network (2G, 3G, 4G), Satellite communications, IoT networks (Lora, Sigfox, LTE-M or NB-IoT)) or the Wi-Fi of the working place.

**Strengths:**

- One can access to the services from anywhere.
- Shared resources that can reduce cost of deployment.
- Cloud based systems provide large computing capacity.

**Weaknesses:**

- Accesses to the services rely on an Internet access. When communication stops, the monitoring services are down. Internet may not be available everywhere and at all times. For example, a vehicle may be driving through a city during rush hour when the 4G network is saturated by the large number of users, or in a rural area with white spots, or driving through a tunnel with no signal.
- Fixed subscription costs of the Cloud services can result high, especially when using video signals

#### 1.1.1.2 Decentralised Infrastructures

Decentralised infrastructures consist in using Edge and Fog computing, direct communications between people and things (device-to-device) and Mesh networks (multi-hops device-to-device communications).

**Strengths**:

- Decentralised infrastructure does not rely on Internet access. The local services are available at all times to the end-user.
- Fast processing of the data incoming generated at the edge and low latency in the response thanks to the short distance between the data source and the server where is hosted the service.
- High resiliency to density avoiding bottle neck of the global network.
- High resiliency to technical issues. If the edge server of one location is down, it will not impact the other sites.
- Energy saving of the overall system architecture by reducing the distance crossed by the bit of information.
- Privacy: the local information remains local and never leaves the office.

**Weaknesses**:

- Local data access for a remote administrator.
- Services are replicated on each site which may increase the cost of the solution.
- Decentralised systems require deploying additional devices in the field that may reduce system mobility.

#### 1.1.1.3 Conclusion

To cope with the use cases' constraints in terms of mobility, services availability as well as demand in both traffic and storage capacity, the WA Tool should use a mixed architecture combining edge computing capacity for the critical services with central cloud processing for advanced analytics and synchronisation procedures between the cloud and the edge.

### 1.1.2 The WA Tool Architecture

This section describes the selected architecture for the WA Tool that will comprise of both Edge and Central Cloud data processing and storage units, mixed with an innovative mobile network infrastructure in response to the use cases constraints.

The WA Tool infrastructure (Figure 1) will comprise of (from edge to cloud):

- **The Mobile IoT Infrastructure** consisting of:
    - User's sensors and devices -either fixed or wearable- connected to a mobile network infrastructure.

 - o The mobile network infrastructure aims at ensuring the connectivity for users and sensors in the three types of working environments (office, production site and professional vehicle).
 - o The Edge cloud which provides local storage and computing capacity. The edge cloud aims at hosting close to the end users the components of the WA services that need rapid, autonomous and secure processing.

- **The Central Decision Centre** which entails a set of server units hosting the additional components of the WA services to perform further processing of the data incoming from the edge cloud.
- **The WA Repository** is a central server where will be transferred the WA project data to long term secure storage.
- **Secure tunnelling** will enable each component of the WA Tool to synchronize data while preserving the confidentiality of the information.

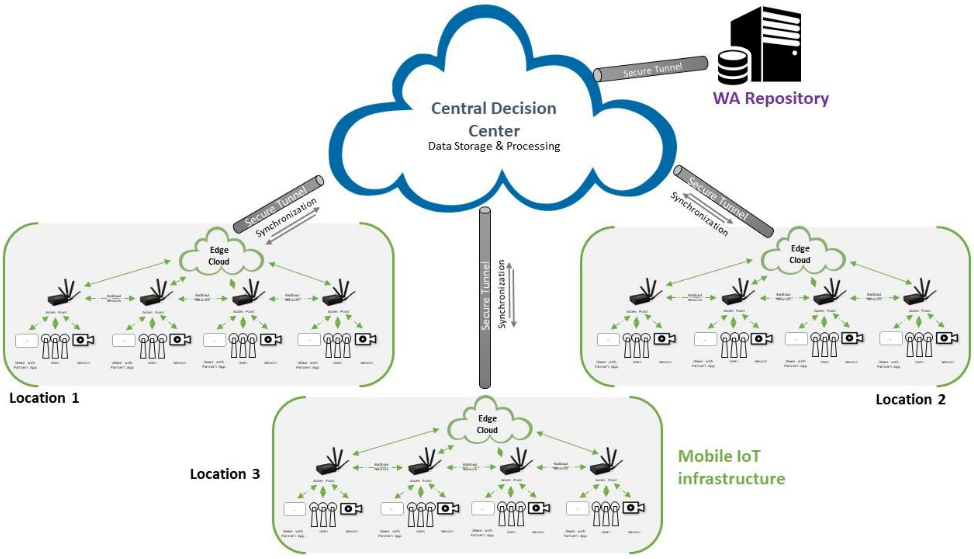


*Figure 1: The WA Tool Chosen Architecture*

The WA Tool will provide Human Computer Interaction via the following interfaces:

- **User Interfaces**:
 - o The Mobile IoT Infrastructure will provide a touchscreen interface where a user can interact with the WA System.
 - o The user will also be able to interact using gesture recognition services.
- **Administrator Interfaces:**
 - o An administrator will have access to the WA repository for secure identification.
 - o An administrator will also have access to the Mobile IoT Infrastructure's data using secure administrator credentials.

### 1.1.3 Data Flow

The expected data flow between the WA Tool components is represented by arrows in the Figure 2:

- **Raw data** incoming from sensors will be processed by the edge cloud.

- **Qualified data** will be sent to the central decision centre.
- **Regular requests, decisions and recommendations** constitute bidirectional data flowing between the decision centre and the Users/sensors.
- **Time-sensitive requests, decisions and recommendations** (such as alert triggering) are low latency and bidirectional data flows between the edge cloud and the user.

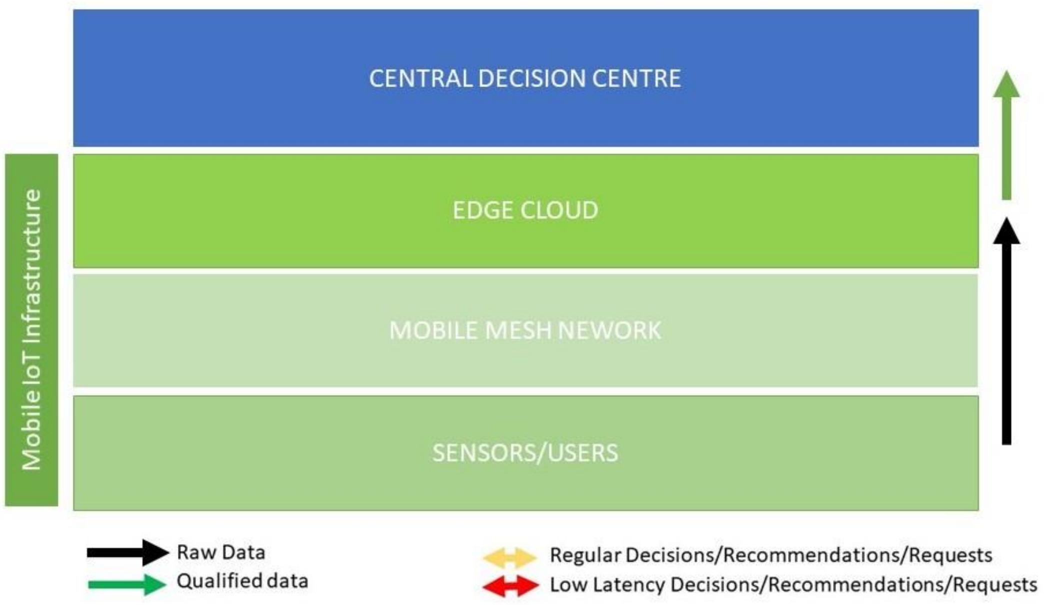


*Figure 2: WA Tool's Data Flow*

# 1.2 Main Components

## 1.2.1 Mobile Mesh Network

The IoT infrastructure as described in Figure 3 will be composed of embedded **Access Points** (AP) to be placed in the working environments described above (offices, vehicle, industrial plant). The APs aim at connecting the user's devices and sensors to the WA Tool using Wi-Fi and Bluetooth. WA's APs will be connected together directly and wirelessly using a **mesh network** technology to connect the WA Access Points (AP) together and to connect WA users and sensors. The local mesh network will be able to connect with the Central Decision Centre thanks to an **Internet gateway** which could be satellite, 3G or 4G, Ethernet or Wi-Fi, depending on the use case. Where a single gateway will be enough to provide an Internet access to all the APs of the mesh network in an office or a production site, each AP of a fleet of vehicle should be equipped with its own Internet gateway.

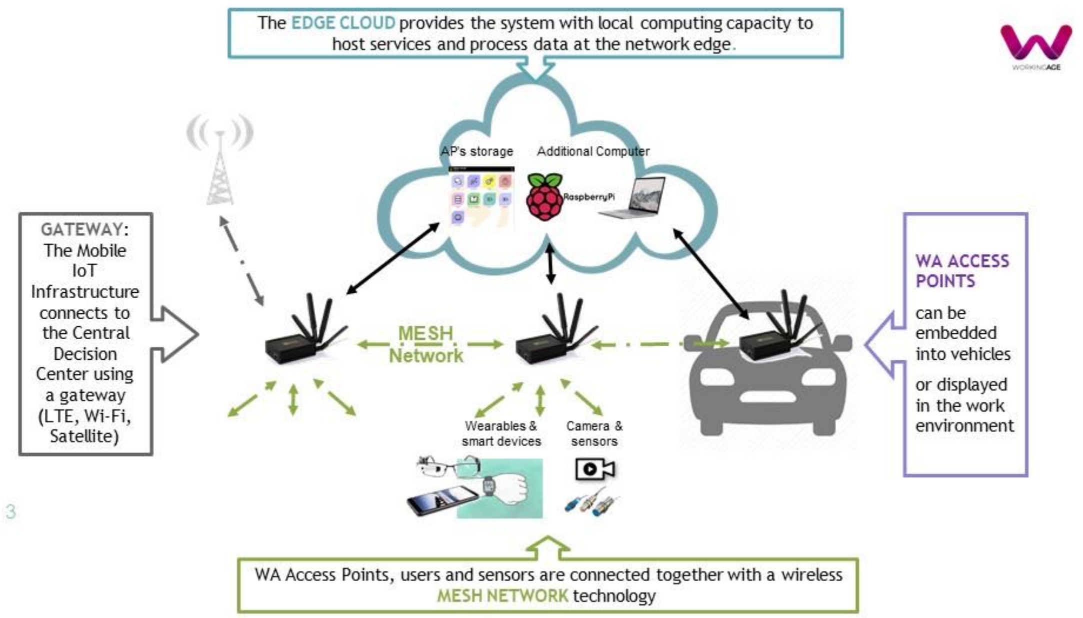


Figure 3: The Mobile IoT Infrastructure

## YOI: Wireless Mesh router of Green Communications

YOI is an embedded Linux router equipped with Green Communications' software (GreenSoft) for Mesh networking. Each router comes with 2 Wi-Fi interfaces: one to create a network with other YOI (mesh network), and another to provide access to smartphones, tablets, laptops, or any other Wi-Fi devices (Access Point). YOI features a web server, so that one can provide local content, services, and applications to the network. The user may also configure YOI as gateway to the Internet. In this case, local traffic stays local and global traffic is sent across the gateways to the Internet.

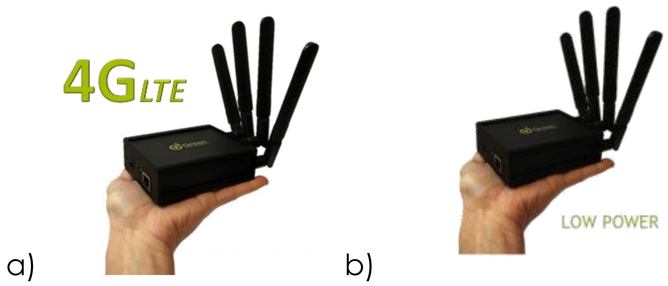


Figure 4: YOI Routers a) with 4G Gateway b) Regular

YOI's main functions:

- *Wi-Fi access network interface* (2.4 GHz and 5 GHz)
- *Possibility to integrate a Bluetooth interface*
- *Qolyester® Mesh routing protocol*
- *300 Mbit/s of wireless rate*
- *Ethernet, Wi-Fi or 4G Internet gateway*
- *Embedded TCP/IP*
- *Distributed DHCP*
- *CPU: Cortex-A9 800 MHz Dual Core*
- *RAM: 512 MB*

YOIs are tiny routers that can be easily embedded or worn. They consume less than 5W of energy and weight less than 400g each.

### 1.2.2 Edge Cloud Units

The mobile IoT infrastructure will feature an **Edge Cloud** to host services and process sensor's raw data locally. The Edge Cloud will combine the computing capacity of the mesh network's APs described above and of local computers (RPI, laptops) deployed in the working sites or into the vehicle.

The Edge Cloud is composed of the following components:

1) The YOI routers that host the IoT system platform (access to services, access interface, services description, service location)
2) A laptop to process the eye tracking, the cognitive and emotional states evaluation
3) Local servers to process the pose recognition, the facial expression, the gesture recognition, the emotion recognition, The voice analysis, the surrounding noise, the Illumination, the thermohygrometric and the $CO_2$ sensors

### 1.2.3 The Central Decision Centre

It consists of the devices used at the WA partner side where the access to the resources need an Internet Gateway. The WA Tool provides Internet Gateways through different interfaces: Wi-Fi, Ethernet or 4G. The Central Decision Centre will be composed of the following components:

1) A location server host by TPZ
2) A storage database host by BS

## 1.3 Main Functions

The WA Tool aims at providing a set of services to provide such as:

- Monitoring of the worker and of the working environment
- Emergency and location system
- Connection with External Networks
- Human computer interaction
- Data security and privacy

### 1.3.1 Monitoring of the User and of the Working Environment

**General Health Behaviour (heart rate, sleep duration and quality, step meter):** These measurements focus on the users' behaviour outside work. Sleeping behaviour consists of the data on the quality of sleep (deep/light sleep) and the duration of sleep, including time to bed behaviour, etc. The user's exercise habits are measured. And, the heart rate is a health indicator (apart from being used for sleep and exercise measurements). A smartband is used as sensor.

**Cognitive and Emotional States Evaluation:** This service aims at providing the neurometrics regarding the user's mental workload, stress and emotional state through a set of sensors that will allow to collect the user's neurophysiological signals and assessing its mental and emotional states while dealing with the working activities. The mental workload will be evaluated through the Electroencephalographic (EEG) signal. The stress level will be evaluated by analysing the combination of EEG, Galvanic Skin Response (GSR) and Electrocardiographic (ECG) signals. The emotional state will be evaluated through the combined analysis of the ECG and GSR signals. In particular, BS will use machine-learning algorithms for the online evaluation of the neurometrics during the users' regular working days and to try to extrapolate the parameters with less sensors. In addition, the results coming from the In-Lab tests will be used to identify the final set and configuration of the neurophysiological sensors with the aim to make the worker's cognitive and emotional states assessment easier, more comfortable, and high acceptable for daily-use.

**Eye Tracking:** Eye Tracking technology will be used to assess the user's mental workload. Various ocular measures have been investigated to measure mental workload in literature. One of the first was pupillary changes during mental activity, another index which has received consideration is the number of eye blinks during mental effort. Finally, the eye movements are associated with cognitive workload (J. Holmqvist, et al., 2011.). The goal is to develop a system that measures and evaluates the corresponding parameters in real-time to provide meaningful information regarding cognitive strain.

**Facial Affect Analysis:** The service is an image-based affect analysis module, which enables the robust detection of face and facial affect in challenging naturalistic settings, including work and home environments. It takes into consideration occlusion and variations in lighting conditions and head pose. This module will inform the overall system about the user expressions and affect to improve the quality of the interaction.

**Body Pose Recognition:** The goal of the system is to obtain 3D pose estimation of the user in real-world environment through a basic 2D RGB camera. Although this can be done very precisely using expensive 3D cameras and several configurations setups, the objective is to create an affordable product based on 2D camera that provides useful real-time information. The objective is to provide useful information for monitoring ergonomic habits.

**Voice Analysis:** The goal of voice analysis is inferring the emotional state of the user, by means of a Neural Network that leverages the acoustic characteristics of their speech and the words they used.

**Surrounding Noise:** Environmental acoustics can be analysed to infer surroundings' conditions such as noise level, quietness, bubble noise, etc. These variables can act as confounding variables that influence the stress/strain level.

**Illumination, Thermo-hygrometric, $CO_2$:** Workplace environmental conditions affect workers' wellbeing, health, productivity, and even satisfaction. Aiming at the assessment and the improvement of workplace environmental conditions, the WA Tool will monitor four key environmental variables: lighting, temperature, relative humidity and air quality ($CO_2$). Good lighting creates a visual environment that enables people to see, move about safely and perform visual tasks efficiently, accurately and safely without causing visual fatigue or discomfort. Adequate environment temperature has an obvious impact on comfort, but also on productivity, and can also provide health benefits or, on the contrary, aggravate certain medical conditions. Temperature values and its perception by the workers will not provide reliable information if measured alone, relative humidity must be taken into account, due to its impact on temperature perception and effects. Another key environmental variable is air quality. Poor air conditions may cause discomfort, poor concentration, stress, and even health issues. Air quality will be assessed by monitoring $CO_2$ concentration. The illumination, thermo-hygrometric and $CO_2$ measurement service will be based on non-intrusive and cost-effective devices that will perform workplace environmental condition measurements and assess them to provide the user and the system with periodical environment quality information. With the information provided by the system, the users may take actions to enhance lighting, temperature, humidity and air quality conditions as they change, and avoid the effects of poor workplace environmental conditions.

### 1.3.2 Location & Emergency System

The location system will provide the user location, inside buildings for the office and manufacture use cases, and outside for the driving use case. The user location will be exploited during an emergency call to 112 to advise the emergency services of the user's location so that he can be rescued. The user location can be associated to any other sensor data on request from other partners.

### 1.3.3 Connection with External Networks

The WA Tool will be connected to external stake holders.

**Enterprises Systems:** as input for data about working hours, machines operating, and/or other information considered of interest; to be determined with the collaborating companies. The company may include the following information:

- Structure of working time (e.g. regular daily working time, shift system, regular night working time, changing working times, weekend working time, frequency of working time changes, working schedule)
- Type of work task (mainly physical, mainly mental, combination of both)

**Occupational Safety & Health Systems (OSH) Integration:** contains company-specific information that can be integrated into the tool and already allows drawing conclusions about possible problem areas. The company may include the following information:

- Accidents at work (frequency, seriousness, type of injuries)
- Medical information for employees by the company doctor (with corresponding consents WA Tool could use this to improve personal advice to the employee)

The OSH responsible in the company may use the results of WA Tool to complement the mandatory Risk Assessment of the workplaces. WA Tool may provide on-line data that refines and complements the RA performed by the company. On the other hand, it may also provide information regarding the risk management measures that are effectively put in practice in the workplace (e.g. pauses, body position, etc).

**Social Integration:** In order to offer the WA-Tool users the possibility of exchange with other users and to keep informed about the WA project, the integration of certain social networks and forums is aimed at.

### 1.3.4 Human Computer Interaction

**User Interface:** The aim of the WA user interface (UI) is to provide appropriate user feedback according to the health and strain evaluation of the WA-Tool. The user should receive useful information, e.g. behavioural recommendations, while always complying with legal and medical regulations and rules. As the target group is over 50 years old, attention will be paid to age-related changes in information processing, which is why the user interface should be designed according to age.

**Augmented Reality:** The goal of the service is to show to the user ergonomic information under request, get ergonomic alarms about non-ergonomic postures, get generic information about the user status to give advice or information. The provision of continuous information of the user's position of the whole body in near real time is also foreseen, along with the virtual avatar to provide advice to the user.

**Gesture Recognition**: Working Age's Face Recognition & Gesture-based Interaction platform constitutes a module enabling its users 1) to be identified and authorised by the system and 2) to interact with the platform through simple hand gestures (e.g. enumeration), using a camera as an end device. It constitutes an HCI platform that can be embedded in any (user-sensitive) technology in need of user validation and gesture-based interaction. The platform comprises of two main components:

- The first component is responsible for face recognition and is mainly used for security purposes. Its goal is on one hand to ensure that only registered -and therefore validated- users can interact with the platform, and on the other hand, that any human activity or face irrelevant to the system's interest or access rights is not recorded. When registering with the WA Tool, the user uploads a 'selfie' picture via a supported interface (e.g. mobile application). The user's picture and details are uploaded and stored on the platform's cloud server in a GDPR-compliant way. After registering with the platform, the user becomes identifiable. When identified by an end device (camera) compatible or operated by the system the user becomes authorised to use the second component of the platform, i.e. to interact with it, through a set of pre-defined hand gestures.

- The second component is responsible for hand-gesture interaction with the system. Using any compatible, registered end-device (camera), and upon their consent, users can interact with the platform with hand gestures. This component relies on available datasets to train its gesture deep learning model and the selection of dataset depends on the system's requirements. At its current stage, the platform is based mainly upon simple, gesture-based communication codes (e.g. enumeration), but if required and after suitable training of the underlying Machine Learning (ML) algorithms, this can be adapted to the system's needs. There is a variety of training options for the ML component, depending on the intended use of the platform. More precisely, the system can be trained:
  1) by using specific users' gestures as a basis: this corresponds to a few days' worth of training per user
  2) by using available datasets to acquire a pre-trained ML model which is then tailored to each user: this is considered the most time-efficient way of training
  3) by pre-selecting typical categories (as per gesture behaviour) of people to pre-train the system and then map each user to a pre-defined category, of which the ML model will be used as a benchmark.

### 1.3.5 Data Security and Privacy

This service aims at ensuring user's privacy and security of the data through data pseudonymisation, anonymisation and secure storage. Each research data file will be named accordingly to his content to ease his identification with the project, following the pseudonymisation procedure described in D2.3. Each partner will keep this pseudo-ID on his side, in particular it will be stored by the Data Controller. BrainSigns, as Data Manager of the project, will receive only the anonymous data label containing the partner's pseudo-name and the participant's order. All research data produced during WorkingAge will be stored in dedicated hard drive and in separated Network Attached Storage (NAS), and for backup purpose. All the partners will transfer only pseudonymised data. Each transfer will be protected by end-to-end encryption. The data transfer support will be provided by the sharing platform called freeNAS, physically placed in BrainSigns and exposed through HyperText Transfer Protocol over Secure Socket Layer (HTTPS). All the data stored in the server will be encrypted. The software used for the encryption and decryption procedure will be GnuPG. Each partner will own the key to decrypt only the data that he acquired. BrainSigns will not have access to the other partner's datasets. If any partner needs to access other partner's research data, the data owner will encrypt the data and will provide the secondary decryption key only to the partner who needs the access.

# 2 Services Integration Scenarios

## 2.1 Monitoring Services

This section provides a technical description of WA Tool services, including integration scenarios of these services into the global system architecture.

### 2.1.1 General Health Behaviour

#### *2.1.1.1 Services Main Components*

The General Health Behaviour monitoring comprises information on sleep, exercise and heart rate. It is obtained from accelerometers, gyroscopes, heart pulse and temperature in a smartband.

General Health Behaviour will be determined by an Android Service integrated in the WorkingAge App developed by ITCL.

#### *2.1.1.2 Integration Scenario*

The expected data flow is as follows:

1) The user will wear the smartband all the time outside work. If no interferences with other equipment exist then it will also be worn at work. It will collect heartrate and movement data at regular intervals of time throughout the day.
2) The data collected by the smartband will be sent in real time to the mobile phone App via Bluetooth, an Android Service will receive them and process the data to calculate the hours and quality of sleep.
3) The Android Service will save the data on the mobile device and send it to the Ontology that will process it.
4) The user will be able to see in the mobile phone App the saved data, and graphics of these.

**Pros:** The smartband is a cheap and nonintrusive wearable device that provides continuous user behavioural and health data.

**Cons:** It does not really provide sleep data, it will be necessary to program an algorithm that processes the collected data (heartrate, movement ...) to obtain the information related to the sleep.

**Conclusion:** General Health Behaviour data is extremely relevant to integrate behavioural data of the users from outside the work environment, such as healthy sleeping and exercise habits. These are expected to have notable influence on the user's well-being at work.

Smartbands are relatively cheap devices, comfortable to wear, with long-lasting batteries, and with sensors capable of collecting multiple user health data. Note that the device will be given to the users as a compensation for participating in WorkingAge, a gadget that will surely motivate active use of the WA Tool.

### 2.1.2 Cognitive and Emotional States Evaluation

#### *2.1.2.1 Services Main Components*

Users' Electroencephalogram (EEG), Electrooculogram (EOG), Electro-cardiogram (ECG), Galvanic Skin Response (GSR), and Skin Temperature (ST) will be collected thanks to robust and non-invasive sensors. Nowadays, a great variety of wearable devices already on the market can provide these data such as:

- smart bracelets or bands,
- and video camera.

For the cognitive and emotional states evaluation BS will provide its application (Windows with Matlab and Python).

#### *2.1.2.2 Integration Scenario*

In the working system,

1) The signals will be collected by the wearable sensors connected to the mobile IoT infrastructure using wireless technologies (Bluetooth).
2) Sensors' raw data will be sent to an edge signal-processing module (a local PC or tablet also connected to the IoT infrastructure). The local computer will perform the neurometrics estimation without storing the data using BS application.
3) Mental and emotion state classified data will be sent through a secure tunnel to and stored in an encrypted server for backup purposes.

**Pros and cons:**

- Only the classification outcomes will be sent out
- No user's sensible data will be kept or stored.

**Conclusion:** The final solution should be portable and having enough power to sustain a daily acquisition session. In addition, some sensors may unplug from the users while dealing with works, therefore we should train the users to take it\them back on the right position.

### 2.1.3 Eye Tracking

#### *2.1.3.1 Service Main Components*

1) Remote Eye-Tracker Fovio FX3 (Eye Tracking Inc.)

- Established equipment at the Institute, can be used in addition to validate low-cost solution "Pupil Core"
- Measurable parameters: Pupil diameter, ICA, gaze, blinks
- Sensor: Infrared sensor with 60Hz sampling rate
- Software: Eyeworks™ software with Workload Module

2) Eye Tracking Glasses Pupil Core (Pupil Labs)

- Will be bought within the project
- Measurable parameters: Pupil diameter, gaze, blinks
- Sensor: eye-camera sensor with 200Hz

- Software: Pupil Mobile Open Source Software

3) Additional interface application (IA), consisting of an algorithm to calculate raw data in real-time and translate it to strain values for processing to the WA tool, and accuracy values. These data will be sent to the WA-Tool for further analysis.

#### *2.1.3.2 Integration Scenario*

1) Fovio™ remote eye tracker: The expected data flow is as follows: Eye tracking data will be captured by an infrared camera. The Eye-Tracker, connected to a laptop computer, running Eyeworks™ software will continuously send data with a sampling rate of 60Hz to the programmed IA.

2) Pupil Labs eye tracking glasses: Eye tracking data will be captured by the eye-camera. The Eye-Tracker, connected to a laptop computer, running Pupil mobile software will continuously send data with a sampling rate of 200Hz to the same programmed IA.

3) Interface Application: The IA can use a provided C# DLL file to receive the strain levels in real time. The file provides all functions necessary to connect to the server within the module and to receive the strain. It connects via TCP/IP to the Data Server hosted within the eye-tracking software to receive a real-time data stream. The IA consists of an algorithm to calculate the strain value and accuracy value in real-time. These values will be sent to the WA-Cloud for further analyses. Data is processed in real-time and do not have to be stored for calculation.

**Pros:** The main advantage of the system is the real-time analysis of the workers strain including an accuracy value, which evaluates the exactness of the recorded data. The eye-tracking glasses can be integrated in all of the three use cases.

**Cons:** The interface application has to be programmed. In addition, we need a powerful laptop to handle the data captured by the eye trackers.

**Conclusion:** The Eye tracking technology is very promising for cognitive strain research, and thus has high potential for use in the WorkingAge project. One disadvantage of the technology is high cost. By using different devices, it is ensured that valid data is generated and the low-cost eye-tracking system gets validated.

### 2.1.4 Body Pose Recognition

#### *2.1.4.1 Service Main Components*

- Sensors: RGB IP Camera
- Body pose estimation software: The software/service will run a trained Deep Learning network that will provide us with the estimated 3D position of the user.

- An additional module will provide ergonomic information from this pose estimation.
- Finally, this pose estimation in near real-time will be sent, on request, to the mobile application, where an avatar will be appearing to provide the user with ergonomic advice.

#### *2.1.4.2 Integration Scenario*

The working system will:

1) 2D cameras placed in the monitored environment and connected to the local IoT infrastructure that will send the images to a service hosted on a local machine.
2) These images will be processed on a local machine equipped with GPU processing. The result of the processing of the images will be the pose estimation; once the images have been processed the image will be removed from the system.
3) Only position tuples will be sent to the decision centre that will store the data for feeding other system elements:
    a. The ergonomic module
    b. The AR module in the mobile application.

Detailed data flow:

- The IP camera sends a video stream continuously to the edge cloud via the local Mesh network to the edge cloud.
- The edge cloud will host a service reading the video streaming. The Deep Learning algorithm will process the image to get a pose estimation.
- The image will be deleted.
- The pose estimation will be sent to the ergonomic module, also hosted on the edge cloud, including the position of the joints of the body of the user. The ergonomic module will provide ergonomic risk factors information.
- If an ergonomic risk factor is detected, an alert will be sent to the mobile application.
- The pose and ergonomic information will be sent to the decision support system (DSS).
- The system will store some previous poses in order to assess the repetition of the poses.
- If requested, the ergonomic module will send the pose, ergonomic information and video streaming to the mobile application. This information will be visible in the user mobile device.

**Pros and cons:** The main advantage of the system is to obtain the body pose and then the ergonomic information by using the 2D cameras which are low cost sensors in comparison with 3D cameras or devices. This approach could assume a lower accuracy in the measurements but enough for the ergonomics risk assessment.

**Conclusion:** At the development stage, which includes training, validation and test, the architecture should be able to store frames with ground truth information in a database with limited access. Only members of the WorkingAge consortium will be able to access these images, mainly ITCL but not limited to it. This information will be used only for the project development. The deep learning algorithm will be training by means of a synthetic dataset of images generated by using Augmented Reality tools, which will allow us to have enough images in order to train the algorithm (training stage). The validation stage will be performed with images (real) recorded at ITCL, simulating both actions or postures of the users and environments of the use cases (factory, office and vehicle). Finally, during the in-lab test, the server connected to the camera will have to store videos which later will be processed for validation and testing, and therefore the bottleneck will be the server storage capacity and not its processing capacity. Therefore, during, the development phase, images will be sent to a remote decision centre with sufficient storage capacity and secure access (vpn and / ssh) for processing and qualification.

### 2.1.5 Facial Expression

#### *2.1.5.1 Service Main Components*

The Facial Expression Analysis system consists of the following components:

- RGB Wi-Fi cameras:
    - One camera will be used to capture the frontal face, while a second camera will be potentially used to capture the face profile. The cameras are connected to access point of edge cloud via Wi-Fi.
- Edge server:
    - Equipped with powerful GPU for image/video processing
    - Required software/libraries: Pytorch, TensorFlow, CUDA, OpenCV, scikit-learn, SciPy (this list may get extended later on).
    - Running real-time face detection and facial expression analysis software
- Central decision centre:
    - Equipped with powerful GPU for training and testing
    - Required software/libraries: Pytorch, TensorFlow, CUDA, OpenCV, scikit-learn, SciPy.
    - Receiving pre-processed and anonymised image/video data (i.e. cropped face ROI for each frame) together with the analysis results (i.e. cropped face ROI with facial expression/affect/AU predictions)

#### *2.1.5.2 Integration Scenario*

The expected data flow is as follow:

1) Images and videos are fetched from cameras placed in the monitored environment that capture frontal face and profile face information. The

frame rate is 30fps and the minimum requirement of spatial resolution is 640x480 pixels, but we recommend 1280×720 pixels.

2) The cameras are connected to the edge server. Ideally OpenCV is used to read the raw image/video data and do pre-processing, such as cropping the images to keep only the facial region of interest (ROI). The minimum resolution requirement for the facial area is 96x96 pixels, for accurate facial expression analysis.
3) The facial expression analysis (expression/affect/AU prediction) is undertaken by the edge server. This is done by mainly utilising previously trained and tested Machine Learning/ Deep learning algorithms. The cropped face images are temporarily stored on the edge server together with the prediction results/labels. The data will be gathered as the batches (e.g. 5-minute time window – this needs to be determined experimentally) to be sent to the remote server (the central decision centre). The data is anonymised and encrypted (e.g. via GnuPG) before sending it to the central decision centre. After sending the data to the remote server, it gets deleted from the edge server.
4) The remote server receives the data sent by the edge server. The remote server constitutes the place where the data (facial ROI and prediction results) is stored. On the remote server, we can do long-term facial expression analysis for users, re-train/fine-tuning our model to improve the performance.

**Pros and cons** of performing facial expression analysis using the edge server:
Compared to a local desktop/PC, the edge server is more powerful for running deep learning models. Compared to the remote server, employing the edge server saves time for data encryption and transfer, which ensures the efficiency of the analysis. However, what remains to be clarified is how the edge server deals with multiple input devices/sources (i.e. images, voice, physiological sensors, etc.). Performing facial expression analysis on the edge server may require computational power that will affect other recording / processing / transfer tasks which needs to be accounted for in the same way.

**Conclusion:** The Facial Expression Analysis system uses Wi-Fi camera(s) to capture images/videos, and the edge server is utilised to process the captured images/frames and conduct facial expression and affect analysis. The outputs together with the processed images/videos will be stored in the remote server in an anonymised and encrypted manner.

### 2.1.6 Voice Analysis

#### *2.1.6.1 Service Main Components*

The Voice Analysis system is composed of the following modules:

- A wireless (Bluetooth) microphone, worn by the user and connected to the receiver;
- A Raspberry Pi 3, taking the role of microphone receiver (via Bluetooth) in charge of:

    - Performing Voice Activity Detection (VAD) on the microphone's input;
    - Transmitting each new voiced signal to the server through Wi-Fi connection;
- On-site server (a powerful, GPU-powered, machine is required), in charge of:
    - Running an Automatic Speech Recognition (ASR) program to transcribe speech to text;
    - Computing acoustic/textual features;
    - Running the Machine Learning algorithms (such as Neural Networks) to infer emotional state of the users.

#### *2.1.6.2 Integration Scenario*

The expected data flow is as follow (see Figure 13):

1) A Bluetooth microphone worn by the user (i.e., a headset) is connected to the on-site server, via a transceiver;
2) The Raspberry Pi 3 transceiver reads via Bluetooth the input from the microphone and runs a Voice Activity Detection (VAD) algorithm to separate speech from other acoustics. Then, after encrypting the speech segment, it sends the recording to the on-site server using the local, wireless, connection.
3) The server receives and decrypts the data sent by the Raspberry Pi, extracts the transcription, by the means of an Automatic Speech Recognition (ASR) system, and then runs the emotion recognition model to infer the emotional state. Recordings are discarded as soon as they're analysed.
4) We envision the WA Agent to generate the advice and send them to the user's User Interface (this last step is actually not part of the Voice Analysis and is provided just for reasons of completeness).

**Pros and cons**:

- Pro: working on an on-site, no sensible information is sent outside the company. We believe this is a crucial point.
- Pro: working on an on-site, no need of anonymisation/obfuscation. Data will be consumed at run-time.
- Pro: we can share the transceiver architecture and device with those employed for surrounding noise assessment.
- Con: we need to deploy, a powerful machine at the pilot site. This machine needs to be managed, remotely.
- Con: An internal network connection is needed all time (a "batch" approach could be used whenever a network connection is not available).
- Con: we need to build the Raspberry Pi transceiver software. This will require additional time and effort.

**Conclusion:** As audio might contain very sensible information, it is crucial to ensure that voice recordings and related transcriptions remain inside the company. For this reason, we argue that the approach we described above is the only one that has a chance to be approved by companies.

The commercial, stand-alone ASR application is not the best solution, as we will need to write code that could be error prone. Unfortunately, we do not see alternatives: using a cloud-based ASR is probably not possible due to the privacy concerns.

### 2.1.7 Surrounding Noise Assessment

#### *2.1.7.1 Service Main Components*

A Raspberry PI (RPI) module will be used to extract noise measures at real-time and send them to the on-site server. The device will be located near the users or attached to her clothes. The noise-level detector of RPI will be calibrated with a commercial noise-level meter which has a high accuracy.

#### *2.1.7.2 Integration Scenario*

1) Audio will be recorded continuously through the microphone of integrated on an RPI.
2) At real-time, acoustic measures such as "noise level" and "people talking" can be extracted through OpenSMILE[1] toolbox. The extracted measures do not have any speech content.
3) The results will be sent to the edge-server periodically.
4) The edge server will generate more statistics on the data (for example average hourly noise level) and uploads the data to the central decision centre.

**Pros and cons:**

- Pros: no speech is recorded, and the features are extracted in real-time without audio being stored anywhere. The results can be sent to the central decision centre periodically in a defined interval.
- Pros: the device is small, and only needs USB charger to run
- Cons: if the user moves a lot during the working period (for example in the manufacturing scenario), she needs also to take the device with herself.
    - If this case is happening a lot, then RPI should be supplied with a battery case

**Conclusion:** Using an RPI, real-time feature extraction and classification is performed to monitor acoustics in terms of its noise level, if human talking periods, etc. The results are sent to the edge-server, and from there, periodically to the remote server.

[1] A proprietary toolbox from audEERING to extract features from acoustics at real-time

### 2.1.8 Illumination, Thermo-hygrometric, $CO_2$

#### 2.1.8.1 Service Main Components

The illumination measurement service will be based on an environmental sensor device purposely designed for the WA Tool. This device will monitor four environmental variables:

- Lighting
- Temperature
- Relative humidity
- $CO_2$

These variables will be periodically monitored and the gathered values will be automatically sent to the Edge Cloud Server.

Based on an ARM 32 bit microcontroller, the environmental sensor device will feature bidirectional Wi-Fi communications to send sensors data to the Edge Cloud server and receive updates and commands trough the WA Access Points.

The sensor device will feature battery operation so that it is easy to place and its effects on the workplace available space are minimal.

#### 2.1.8.2 Integration Scenario

1) The user and sensor profiles will be configured and stored in the corresponding databases on the Central Decision Centre or the Edge Cloud. These profiles will contain information about sensor ID, user profile data (e.g. user age, scheduling, etc.), and case scenario (e.g. office, vehicle, factory, workplace conditions, etc.).
2) According to the configured profile data, the WA Tool will configure a set of rules and measurement thresholds for the sensor. As well as activate sensor periodic measurements as required.
3) The sensor will send periodically the measured data and device ID to Edge Cloud Server service via Wi-Fi.
4) The output data will then be synchronized with the Central Decision Centre and/or Edge Cloud system, where the data will be processed according to the corresponding profile and rules, and stored. This processing will allow the generation of notifications and warnings for the system and user.

**Pros and cons:** The illumination measurement system will only require a hardware sensor device and lightweight services, and will not produce large amount of data. Since the device will send the measurements periodically, there is no need for polling from the servers or WA Tool. The system will be able to operate even when connection with the Central Decision Centre is lost, if configuration profiles can be stored in the Edge Cloud.

The devices will be non-intrusive and portable, enhancing their ease of installation and placement. Furthermore, the use of Wi-Fi communications enables the use of a large group of devices, if needed, connected to the Access Points.

However, if configuration profiles and decision making (e.g. alarm triggering) are only made accessible through the Central Decision Centre, the main disadvantage of the workflow would be its dependency from Central Decision Centre connection with the Edge Cloud. The system would be able to retrieve sensor values with the last retrieved configurations until connection is restored, but configuration updates and alarms/warning triggering would not be possible until then.

Since device placement may affect the sensors measurements, there are potential constraints to be considered. In this sense, special attention should be paid to avoid sensor obstruction or blocking with objects, as well as placing the devices near heat sources or powerful light sources.

**Conclusion:** The illumination measurement system of the WA Tool will perform environmental workplace periodic measurements by means of a measurement device and provide illumination, temperature, relative humidity, and $CO_2$ information. Based on this environmental output values, The WA Tool will be able to generate the corresponding warnings or alarms for the user. The required services and data processing can be hosted on the Edge Cloud and/or Mesh Network devices.

## 2.2 Location & Emergency Service

### 2.2.1 Service Main Components

TPZ's developments in the frame of the WA project encapsulate two different services:

- The provision of the WA user location for both indoor and outdoor scenarios
- The call to emergency services and provision of the user location in case of an alert triggered by the WA Tool.

These two services are linked since the Emergency service requires inputs from the user location service.

Figure 5 provides a high-level architecture of the Location and Emergency service. This architecture will be described in details in the following sub-sections.

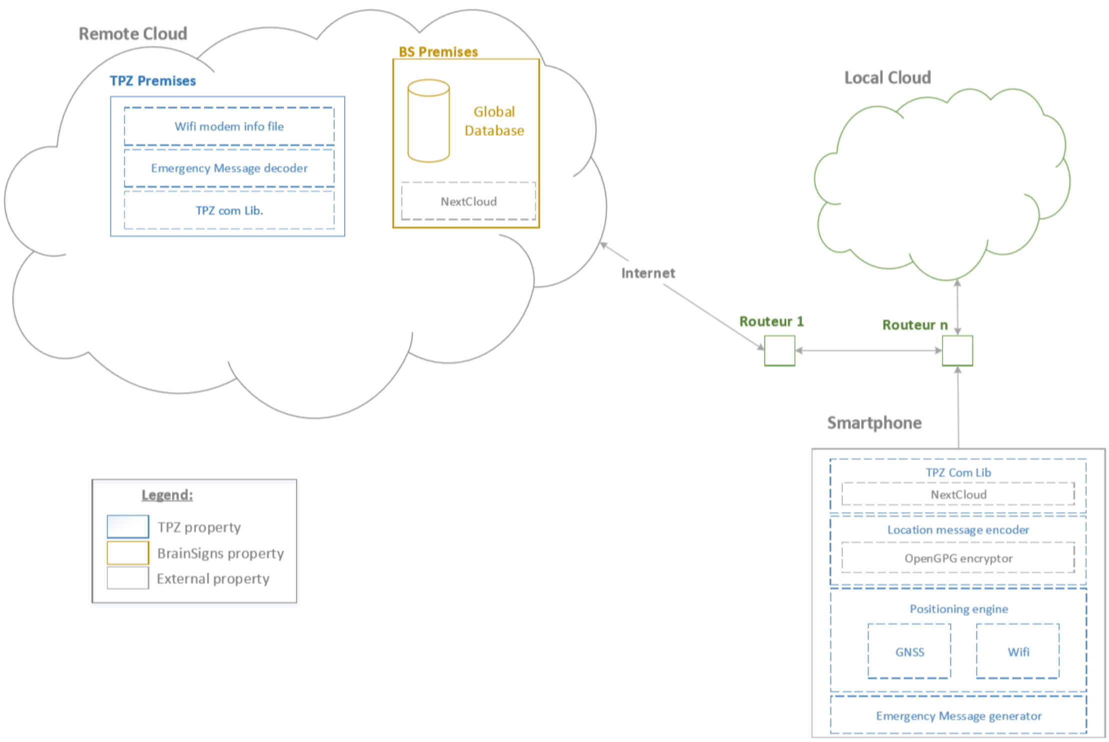


*Figure 5: Location & Emergency Service architecture*

### 2.2.1.1 User location service

The User location service aims at providing the WA user location for:

- Storage into the WA database.
- Provision to the emergency services in case of alert.

Since both indoor and outdoor use cases are considered in the scope of the project, the user location will be calculated in both indoor and outdoor environments.

The position data will be stored periodically in the WA database respecting GDPR constraints as described in the deliverable D2.3 Data Management Plan and can be retrieved on demand.

The current user's location will be encoded in the emergency message in case of alert.

### 2.2.1.2 E112 service

The E112 service of the WA tool aims at notifying the emergency services when the WA Tool detects a serious health problem on a user. The WA Tool monitors the health conditions of the WA users using the data collected from the various sensors and raises an alert based on a set of predefined conditions (e.g. a ruleset).

In a context of operational WA product, an automatic alert triggering would very probably not be acceptable by any Public Safety Answering Point (PSAP), therefore a "man-in-the-middle" architecture would be necessary. Indeed, PSAPs are operational emergency sites that follow strict regulations and thus, a mandatory supervisor would be in charge of validating/invalidating the alert. Only after validation, the WA tool would send a message (alert) to the PSAP responsible for answering calls for EMS / the 112 PSAP. The message contains information about the WA user, the location information as determined by the WA location service and any medical data that may assist the work of the EMS first responders.

The locations of the companies involved in the pilots were unknown at the time of the project proposal and a PSAP localized in the same area as the pilot companies is required so that it can receive and dispatch emergency services on the pilot site. For this reason, having a PSAP in the project consortium would have been complicated. A PSAP might have been added afterwards, but its participation to the project is actually not mandatory. A PSAP would be receiving and decoding the automated message sent by the WA tool, but we can emulate that in the context of the project, to prove the emergency message functionality.

To conclude, what will be implemented in the frame of WA project is:

- To validate the information (user position, type of emergency?, name and phone number of the user, etc) contained by the emergency message with the help of the emergency service network of the EENA. This will ensure the provision of pertinent information to a PSAP in our emergency message.
- To generate the emergency message in the WA tool in an already standardised format such as PEMEA or protocol such as CAP.
- To send the emergency message to the URL of a web server developed to simulate the message receipt by the system available at the PSAP, usually a Computer Aided Dispatch (CAD) system.

### 2.2.2 Integration Scenario

#### 2.2.2.1 User location service

The User location service architecture consist of:

- A service of the WA Tool Android application embedded on the user smartphone performing indoor and outdoor positioning
- Some Remote cloud server-based services, participating to the indoor position generation.

The WA positioning service will be running on the smartphone in background as a service of the main WA application detailed in section 3.3.2.

For outdoor positioning, the GNSS receiver embedded in the smartphone will provide the user's location. The location service will call for Android location service APIs functions to retrieve the GNSS location. The smartphone will be connected to the internet though one of the WA routers or through LTE, which will allow the collection of A-GNSS data.

For indoor positioning, a Wi-Fi-based localization service will be implemented. The WA Wi-Fi routers that are required in the WA Tool local architecture will be installed and positioned *a priori* on the user site. The routers' location will be stored together with their MAC address into a data file in TPZ Remote server.

Then, when using the WA Tool in indoor, the WA application will retrieve the MAC address of the router the smartphone is connected to and request the associated position from the TPZ remote server owning the file. The router position will be assimilated to the user indoor location.

Finally, a **location message encoder** will associate the PseudoID of the user (sent at boot by the WA Tool application) with the location data. Then, this dataset will be encrypted using OpenGPG APIs functions and stored in the WA database (hosted in BS premises) using NextCloud functions.

#### *2.2.2.2 E112 service*

The E112 service architecture consists of:

- A service jointly implemented with user Location service, aiming at receiving the alert from the WA Tool application activities and sending the user location to the simulated PSAP server. This service is called **Emergency message generator**.
- A Remote cloud server service simulating a PSAP, in charge of receiving, decoding and displaying the data sent by the message encoder. This service is called **Emergency message decoder**.

The Emergency message generator will receive an alert from the WA Tool together with potential additional data (name and phone number of the user[2], health data to be included in the emergency message will be defined in WP3).

Then, the application will get the user location and encode it with additional data according to standard message format. No firm decision has been taken regarding the emergency message format but the PEMEA standard is envisaged. Eventually, the message will be delivered to the Emergency message decoder hosted on remote TPZ server.

The remote TPZ server will receive the message, decode it and display the received data in a graphical interface for monitoring purposes. For instance, the location of the user will be displayed on a map. Moreover, an acknowledgment will be sent back to the application that could inform the user about the success of the sending.

[2] The name and phone number of the user will be taken from the user profile registered by the WA application on the smartphone.

## 2.3 Connection to Other Networks

### 2.3.1 Service Main Components

The members of the consortium have selected 3 different platforms to connect the WA Tool with. Their definition and scenario of implementation is described below.

Selected other networks to connect the WA Tool with:

1) Enterprises systems: data input from the WA Toom to the Enterprise's Systems, e.g. about working hours, machines operating.

2) Occupational Safety and Health systems (OSH): The OSH manager in the company keep records of risk assessments as well as preventive measures related to workplaces using specific software to keep the records. WA Tool may provide updates and data to complement these records. The employees' health records, rotation of workplaces and working hours information could be useful to improve work safety and provide personal advice to the employee.

3) Social Integration: integration of social networks like the users' web forum, Twitter or LinkedIn, to socialise, share thoughts and ideas in order to reduce psychosocial strain and, provide feedback on the WA Tool to WA project partners.

### 2.3.2 Integration Scenario

1) Connection of the WA tool with enterprise's ERP and OSH software.
2) Data input from the WA Tool to the enterprise's ERP System (working hours, machines operating, employees' health records, etc.)
3) Link on WA Tool's user interfaces to a forum and social networks groups on twitter and LinkedIn as well as to the forum within the WA webpage.

**Pros:**

- The data coming from the WA Tool need to be converted to OSH indicators which is simple.
- Providing social network groups like the users' forum, Twitter or LinkedIn, to socialise, share thoughts will provide a good extension of the WA tool to increase the exchange between users and reduce psychosocial strain. They will have the possibility of exchanging and archiving thoughts, opinions and experiences. In addition, anonymous and asynchronous communication enables flexible use.

**Cons:**

- The interpretation of medical data requires specific expertise and should only be done by qualified and authorised personnel.
- The WA Tool may provide information about the learning outcomes of users but the user data can be interpreted in a way which might be unfavourable for the employees. For example, in case it becomes apparent that some employees work slower than others. This is sensitive matter to be treated with the WA ethics committee.

**Conclusion:** With corresponding consents, the additional data and recommendations brought by the WA Tool could be very valuable for the company. These records may also help the company to demonstrate compliance with its OSH legal obligations. Care will be taken not to use user data that may be interpreted to the detriment of employees. Link to a forum and shortcut to groups on Twitter, Facebook and LinkedIn will be provided on the WA Tool user interfaces.

# 2.4 Human Computer Interaction (HCI)

## 2.4.1 User Interface

### *2.4.1.1 Design*

The WA-Tool will provide a central interface for the user, and a simple data summary interface for the company. Much of the literature has been devoted to identifying some good practices for HCI that are clear and consistent and provide action and feedback. These principles have general validity and can be used as a reference for the design of the interface to be developed in the WorkingAge project. Table 1 presents the most important principles:

*Table 1: European standards concerning ergonomic User Interface*

| DIN EN ISO 9241- | Topic |
|---|---|
| **Part 11** | Usability definition & concepts |
| **Part 12** | Information display |
| **Part 13** | User guidance |
| **Part 14** | Menu dialogues |
| **Part 110** | Dialogue principles |
| **Part 112** | Principles for information presentation |
| **Part 125** | Guidance on visual presentation of information |
| **Part 129** | Guidance for individualising software |
| **Part 210** | Human-centred design for interactive systems |

Particular attention is paid to age-related changes. The main changes in mental and physical conditions around the age of 50 years are changes in visual perception (e.g. colour perception, visual acuity), auditory perception (auditory acuity, frequency), perception of vibration, cognition (e.g. working memory, learning, reaction). The interface must be adapted to these needs. Table 2 represents the design principles for the user interface.

*Table 2: Design principles for User Interface: guidelines to the enhancement of users' perception and cognition capabilities*

| Perception | Cognition |
|---|---|
| **Colour scheme simplicity** | Information simplicity |
| **Use of images** | |
| **Showing trends** | |
| **Consistent visual and colour coding** | Consistency with the operator's mental model |
| **Spare use of motion and sound** | Functional separation |
| | Information hierarchy |
| | Grouping of data together |
| | Multi-language considerations |
| | Multi-letter acronyms and abbreviations |
| | Using analogue representations |
| | Feedback |

#### *2.4.1.2 Service Main Components*

- Mobile WA app
- Web server on the edge cloud for summarising data to company
- Secured Wi-Fi access to connect user device
- Android smartphone including web browser
- User forum on the internet

#### *2.4.1.3 Integration Scenario*

1. The project will provide the user with an Android smartphone
2. The user connects to the edge cloud with its device using Wi-Fi
3. He opens the mobile app.
4. Social interaction services (forum, social networks) will be opened in the web browser
5. The company accesses WA data through a local dashboard-like website
6. No person-specific data will be shown to the company, only summaries
7. No company sensitive data will leave the company's premises

**Pros**:

- For the user, the app will be a central place to interact with the WA Tool
- For the company, the web interface will be a central place to interact with the WA Tool providing a quick overview of data
- Both interfaces will guarantee the user's privacy and company's confidentiality
- The user is to keep the smartphone which is motivating to use the system

**Cons:**

- The user must carry the device with him all the time.
- Showing no person-specific data limits the company in its possibilities to improve this person's working conditions

**Conclusion:** The main user interface will be a mobile Android app for the user, and a web page hosted on the edge cloud to visualize the WA summaries to the company.

### 2.4.2 Augmented Reality

#### *2.4.2.1 Service Main Components*

- A smartphone ARCore compatible and has medium/high Graphic capabilities.
- The WA mobile application will include these modules related to AR/VR:
    - The 3D avatar will be present in the whole application in order to make it friendlier.
    - The AR pose estimation will be shown when the user places a request for it or when a bad posture gets detected.
    - A specific AR module (integrated in the same app) is foreseen for the Industrial environment in order to guide the user in a specific task (to be defined at the time of writing)

#### *2.4.2.2 Integration Scenario*

- Mobile APP: The Android App will receive notifications from the edge cloud or the central decision centre to show advices to the user. The information will be shown to the user through a normal interface or through the 3D avatar.
- Avatar and ergonomic: The expected data flow is highly related to pose estimation definition:
    - If requested, the ergonomic module in the edge cloud will send the pose, ergonomic information and video streaming, to the mobile application. This information will be visualised in the user mobile device.
    - AR to guide the user in a task in the factory environment: The AR application to guide the factory user in a specific task will be designed and developed for a specific case to be defined.
- The AR experience will not need any external information or sensor. Two types of visualisation will be available:
    - Integrated in the mobile App.
    - As a specific application in augmented reality grasses: HoloLens or Magic Leap.

The AR module will be integrated mainly in the mobile application and will gather information and alerts from the cloud to give advices to the user.

The 3D Avatar will help us to show the advices to the user in a more friendly way. A specific application with Augmented Reality developed for mobile phone and AR Glasses, to guide users in a specific task in the factory will also be developed.

**Pros and cons:** This approach allows us to give general feedback to the user with a few communication bandwidths in most of the services. We also focus the demanding tasks (rendering, AR computing…) in the mobile device. The specific application to guide the user in a task at the factory environment will be also developed for the mobile devices and for AR glasses and will only report general information to the cloud.

The only exception is the AR-related to ergonomic information in real-time that is demanding in bandwidth.

**Conclusion:** The proposed approach allows us to deploy different services and to interact with the users.

### 2.4.3 Gesture Recognition

#### *2.4.3.1 Service Main Components*

- User device (smartphone)
- An external camera
- The following image data processing services:
  - Face Detection
  - Body Detection
  - Hand Detection
  - Face Recognition
  - Hand Gesture Recognition

The image data processing services can be trained with one of the following methods:

- by using the (specific) users' first incoming data - might correspond to a few days' worth of training for each user.
- by spending a few days of collecting data from random users and generating a generic model which will be then re-trained/adjusted to each user. That means that via a ML method, the system will get better as the user uses it.
- by pre-selecting a few typical categories (as per gesture behaviour) of people and train the system with their data.

#### *2.4.3.2 Integration Scenario*

A typical use case of the gesture-based interaction platform is as follows: the user registers via his device (e.g. mobile phone), filling in their details and uploading a 'selfie' picture. This will be stored into the server. When the end-device (camera) starts recording, it only begins capturing frames, upon a registered user's permission/request. First, a face recognition phase takes place, confirming that the face of the user requesting to use the service matches the one stored in the server under the same user's dataset. From that point onwards, the gestures start being monitored. The continuous signal is then transferred, sampled and processed to be compared with an "average gesture signal" using ML algorithms until a match is identified. In case of matching, the signal is translated into its corresponding interpretation and the system acts as planned by the platform operator. For example, in the below use case, an AI engine sends alerts and recommendations as ordered by the user's gesture.

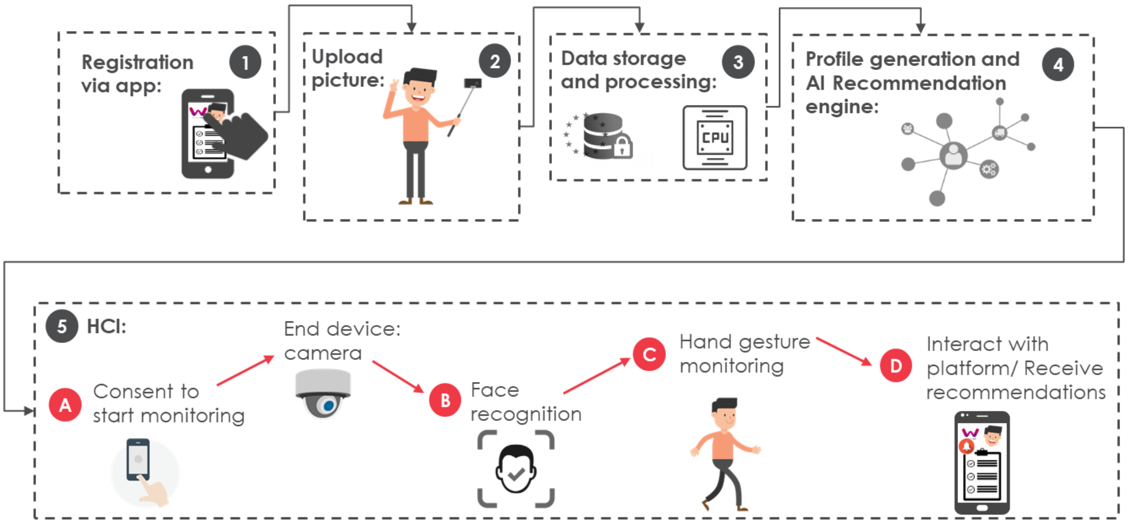


*Figure 6: The Face and Gesture Recognition Module*

**Expected data flow:**

- Camera devices (smartphone, external camera) will forward image data to the gesture recognition component in the format of byte arrays.
- The raw data will be sent to local server for pre-processing. The local server will ask for the existing stored data from remote(global) database and the output of pre-processing will be sent to the remote server.

**Pros:** The pretrained models for image detection and recognition will be fetched by local server. This is an advantage because these models are very large files and will be difficult to retrieve them from remote server.

**Cons:** In order to have a good accuracy in face and hand recognition we should have a good quality of communication (upload speed of Wi-Fi) between devices and software (gesture recognition component).

**Description:**

1) User registers via his mobile phone connected to the local platform using Wi-Fi by uploading a 'selfie' picture to the WorkingAge platform. A Web Application will be built as a first prototype and it will then be integrated into a mobile application.
2) The user's request/registration will be sent and stored into a remote server.
3) Upon the registered user's permission/request, the server gives a command to the camera to start recording.
4) Images are sent to a local machine, where a facial recognition phase is taking place, confirming that the face of the user requesting to use the service matches the one stored in the server under the same user ID.
5) From that point onwards, the gestures will start being captured. The real-time data processer used will be either Kafka or Apache Flink.
6) The signal will be then transferred on a remote server and processed until it reaches its final form, when it will be compared with an "average

gesture signal" corresponding to a profile that matches the characteristics of the user, or which corresponds to the user's history.

**Pros:** Fast data processing, as the models stored in the local file system are pre-trained.

**Cons:** Difficulties to handle many users' hand gestures at the same time.

**Conclusion:** We suggest that all the image pre-processing services take place on the local server. The local services will be then accessing the facial encoded images stored in the remote server in order to proceed to ID verification. Finally, the output of the local server in the form of notifications or alerts will be again sent to the remote server.

## 2.5 Data Security and Privacy

### 2.5.1 Service Main Components

- OpenGPG software for encryption/decryption software
- Server on BS site to store the encrypted data
- Nextcloud Interface to connect and access the data
- Secure IP tunnel between the edge cloud and BS's server

### 2.5.2 Integration Scenario

The data security procedure is in process of being designed. At the moment, BS will provide a server to store the pseudonymised and encrypted research data of the project. The consortium will interface with the server through the software Nextcloud. The consortium will use OpenGPG as encryption / decryption software. Ideally, the data should be encrypted at its source in the edge cloud and sent to BS server using secure IP tunnels.

# 3 Conclusion and Specifications

In the section above, the consortium has identified the technical requirements of the WA Tool in response to the WA objectives and constraints (sections 1), the state of the art (section 2.1) and, with regards to services' integration scenario (section 3).

The section below unveils the specifications of the WA Tool corresponding to the technical requirements in terms of hardware, content and services' architecture.

## 3.1 WA Tool Architecture

Following the technical requirement, the consortium has come to the conclusion that the WA Tool should comprise a mixed architecture leveraging computing capacity and low latency at the network edge (company side) as well as cloud-based computing and storage. The WA Tool should also leverage a mobile internet infrastructure called 'mobile mesh network' and involved embedded sensors to provide mobility to the system, and to connect users and things while on the move. The WA services should be easily available to the user through a mobile application, a web application and voice and gesture interactions. All the data of the project should be securely transferred and stored on a remote server. The figure below summarises the specifications of the global architecture of the WA Tool:

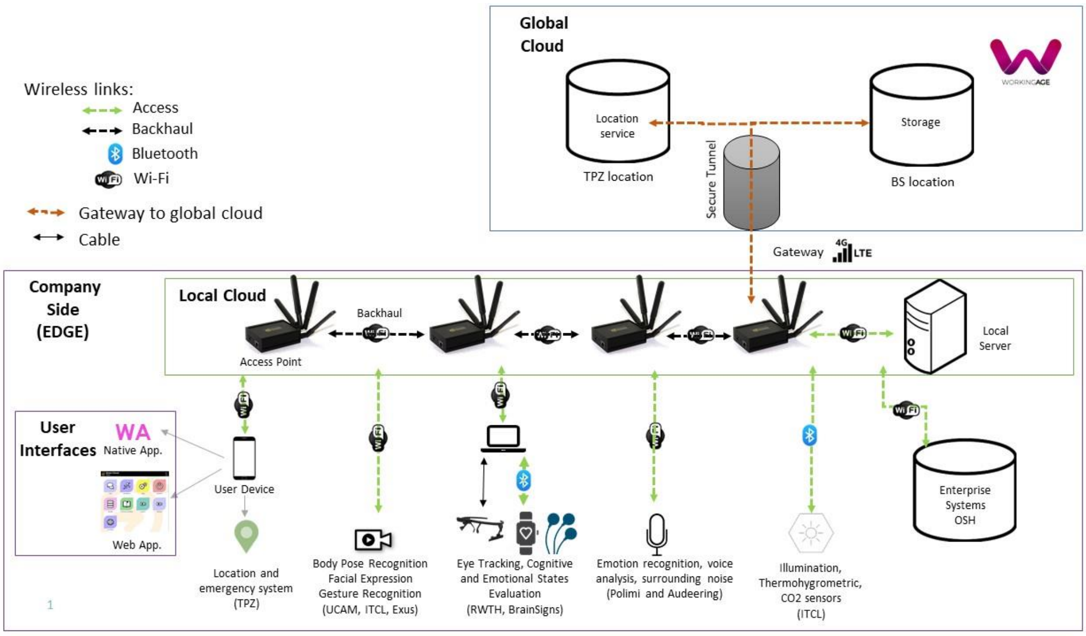


*Figure 7: Architecture of the WA Tool*

**Company side:**

- Mesh network: The working site will be equipped with a set of mesh routers. A router will connect with other routers using Wi-Fi to create a local wireless network. The number of routers per site should be adequate to provide connectivity to the group of users and sensors involved in the project's pilots. The routers should be equipped with Wi-Fi and Bluetooth in access to suit the different type of sensors. The router should be tiny enough to fit in a vehicle and battery powered. For the monitoring the driver, each vehicle should be equipped with one router. The table below describes the specifications of the mesh routers.

*Table 3: The mesh router specifications:*

| | |
|---|---|
| **Simultaneous connections** | <= 15 per router |
| **Wireless** | Access: Wi-Fi, Bluetooth and/or Ethernet<br>Backhaul: Wi-Fi<br>Gateway: 4G/LTE or Ethernet or Wi-Fi |
| **Enclosure** | handheld |
| **Power supply** | Battery and power plug |
| **Network size** | > 5 hops |
| **Bandwidth** | 300Mbps |

- Edge cloud: Mesh routers embed a distributed edge cloud capable of hosting applications and programs close to the end user. Due to the large volume of data processed at the edge, more computing capacity should be provided. Therefore, the partners will add a local server connected to the local mesh network. The combination of the computing capacity of the routers and of the local server will represent the Edge Cloud of the WA Tool.

*Table 4: Edge cloud technical specifications:*

| | **Mesh router's server** | **Additional server** |
|---|---|---|
| **OS** | Linux | Windows and Linux |
| **RAM** | 512MB | 32 GB |
| **DISK** | 32 GB | 1 TB |
| **CPU** | Cortex-A9 800 MHz Dual Core | Intel i7<br>ARM 450 MHz |
| **Other** | Web server<br>Xmpp server | 1 mic input<br>USB 2.0 port<br>GPU<br>Bluetooth 4 BLE or 5 |

- Sensors: The pilot site and monitored users, will be equipped with the following set of sensors:

*Table 5: Sensors of the WA Tool*

| **Name** | **Description** | **Device** |
|---|---|---|
| Working conditions | Questionnaires on work environment and working conditions | Smartphone Application |
| Psychosocial elements | Questionnaires on cognitive, emotional and social aspects | |
| Life habits & | Questionnaires on nutrition, sleep, | |

| | | |
|---|---|---|
| Health behaviour | exercise | |
| Ergonomics | Questionnaires on dynamic and kinesthetic characteristics of the task, etc. | |
| Social relations&well-being | Questionnaires on social interaction at work | |
| Location | Location for emergency calls | |
| Visualisation platform | Interface of mobile app | |
| E112 services | Emergency messages | |
| Eye movement | Eye gaze tracking | Eye Tracking Glasses |
| Pupil diameter | Pupil diameter | |
| Body Pose | Body Pose ergonomics | Camera |
| Facial expression | Facial expression/affect | |
| Gesture analysis | Arm gesture analysis | |
| Gestures | Hand/finger commands | |
| Temperature | Temperature | $CO_2$/T/RH Sensor |
| Humidity | Relative humidity | |
| $CO_2$ | Fresh air measurement | |
| EEG | Solid gel electrode to collect the EEG signal | Electrodes |
| ECG | PPG electrode to detect the HR | Wristband Empatica |
| GSR | Metal electrode to detect the GSR | |
| ST | Skin Temperature | |
| EMG | Electromyography | Electrodes |
| EOG | Electrooculogram: One solid gel electrode / IR camera | Electrodes / IR Camera |
| Interview | Interview | F2F interview |
| Illumination | Lux measurement | Lux meter |
| Voice analysis | Voice analysis: TTS & mood | Micro-phone |
| Noise | Acoustics (noise level, voice activity, voice overlap, speaker gender, laughter) | |
| Sleep | Sleep quality & length | Smart-band |
| Step meter | Exercise meter | |
| Heart rate | Pulse meter | |

- Gateway to the Internet: The local network should be connected to the internet through a gateway so that the local information can be transferred to remote servers. The WA Tool should be able to user several types of gateway to suit the equipment of the pilot site. Embedded 4G gateway is convenient in mobility. Ethernet or Wi-Fi gateway is convenient for the office and production pilots.

**Central Decision Centre / Global Cloud:**

The local Mesh network will be connected to two remote servers through secure IP tunnels: one connection to BS server and a second one to TPZ server. No connection to other remote servers is planned.

## 3.2 Content Architecture

Figure 8 shows the WA Tool architecture. Sensors communicate measurements through a local Mesh network, to the Sensor/Data Processing Server(s), deployed at the Company facility, where such measurements are elaborated and High-level Information is derived (for example, from voice recording, an *emotion* can be derived). This phase implies running multiple models (many of them are based on statistical classifiers) and thus powerful machines are needed.

Then, High-level Info about a given worker is sent to her/his Device (where the Ontology is stored), the DSS is executed, and the advices are generated and shown by the App. This phase is less computationally intensive, as we are going to use a logic-based approach for the DSS, and we are confident that an average-level smartphone could provide enough computational power (moreover, keep in mind that a very fast response time is not required, so the device has plenty of time for running the DSS reasoner).

The Rule Update Service periodically updates the rules that control the DSS reasoner, leveraging statistical analysis of the data collected by the system. We plan to start from a human-generated set of rules; then, each Rule Update Service will independently evolve such rules adapting them to the worker.

Finally, the Centralised Storage acts as a remote, encrypted backup for the Ontology.

In the WA Tool architecture, all the "reasoning" parts are deployed at the worker's device, while maintaining external servers for sensor data processing. In our opinion, this is the right balance between privacy (which would have required putting everything on workers' devices) and performance (which would have required to put everything on powerful servers).

In fact, in the current set up, each server works on a specific sensor and stores data for the (short) amount of time needed for computing the related High-level information. In this way, a breach in a server is likely to disclose a small amount of one data typology, about one or more workers. On the other hand, the worker's DSS needs to observe all the high-level information typologies, retaining them into the Ontology for a long time; so, a breach in the worker's device is likely to disclose all information, but is limited to that worker.

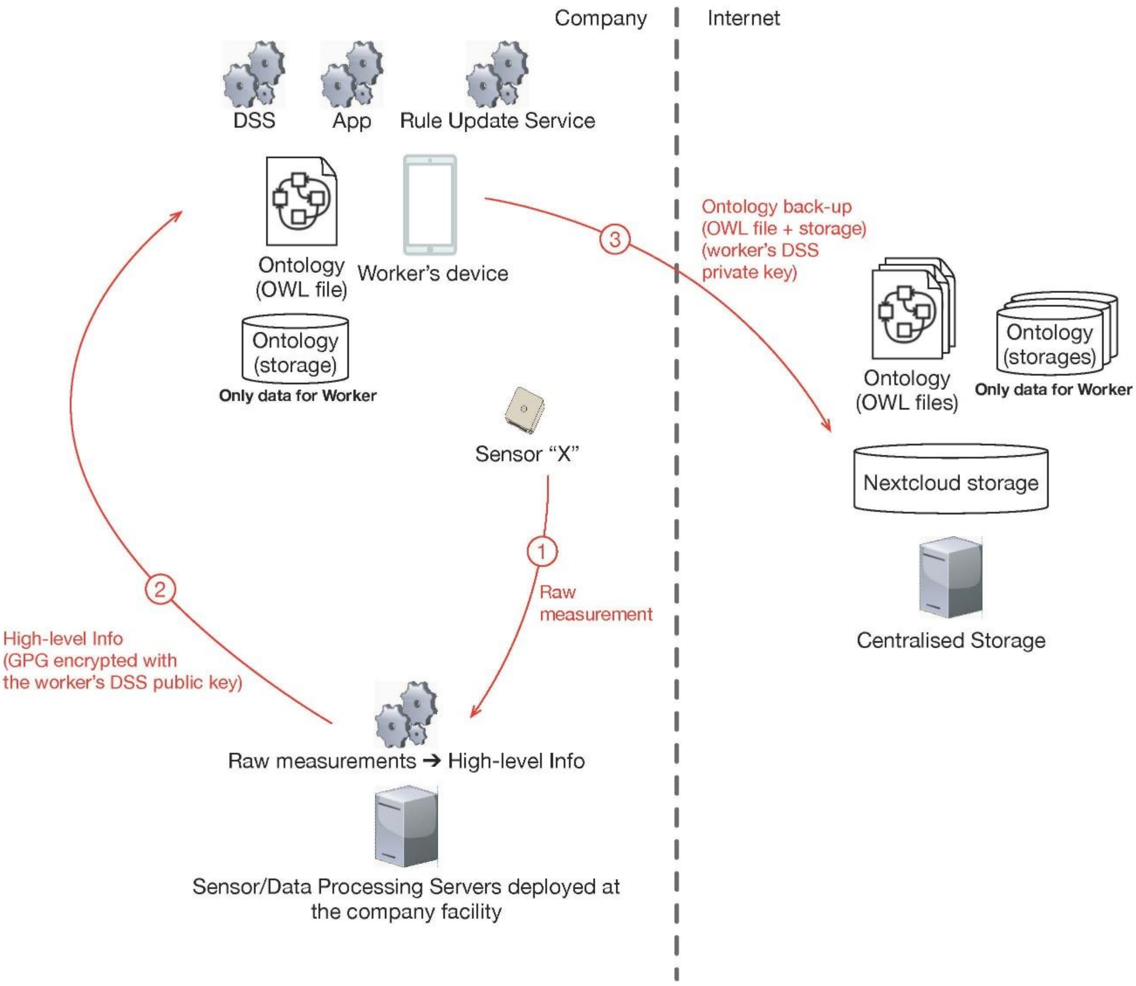


*Figure 8: WA Tool's Content Architecture*

## 3.3 Detailed Architecture per Service

### 3.3.1 Monitoring Services

#### *3.3.1.1 General Health Behaviour*

The smartband model foreseen to be integrated in the WA Tool is the Xiaomi Mi Band 4. Other models have been identified should if necessary for better technical integration (Xiaomi, Fitbit). The health behaviour of the user is monitored continuously at regular intervals (minutes). The data is sent to the mobile device via Bluetooth in real time, an Android Service integrated in the App both developed by ITCL will process them for sleep data, save them for later viewing in the App, and send them to the Ontology for processing (Figure 9).

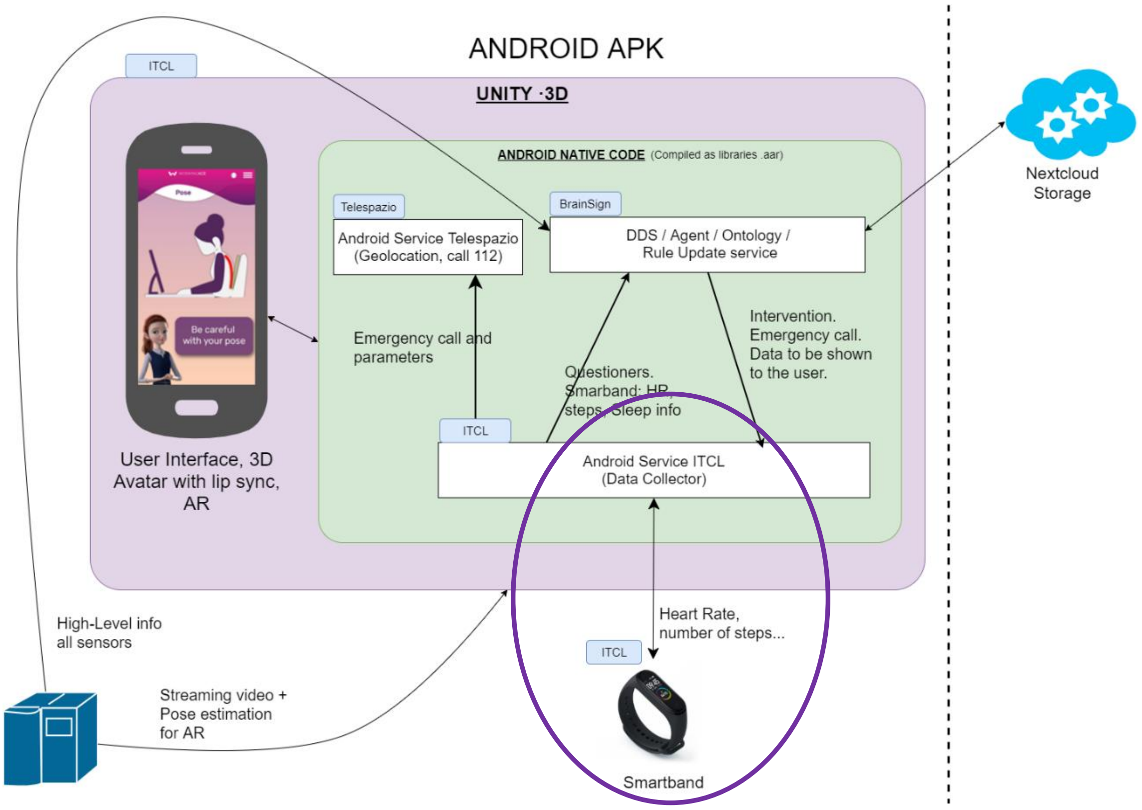


*Figure 9: Integration of General Health Behaviour in the Mobile App and WA Tool*

### *3.3.1.2 Cognitive and Emotional States Evaluation*

The passive-dry solid gel electrodes will be used for the EEG signal recording. The electrodes are wired to an EEG amplifier with Bluetooth module integrated. The EEG amplifier streams the data to PC Windows via Bluetooth interface.

The GSR signal will be collected through the Shimmer device: two AgCl electrodes will be used to collect the SCL component of the GSR signal. A photoplethysmogram (PPG) sensor will be used to collect the HRV component of the heart rate. The Shimmer streams the data collected via Bluetooth to a PC Windows.

### *3.3.1.3 Eye Tracking*

The eye tracking data will be captured by using the Pupil Core Eye Tracking Glasses. The Eye Tracking Glasses will be connected to a laptop computer, running the Pupil Core software and a programmed Interface Application (Strain-Level App). The IA receives the real-time data stream of the Eye Tracker with a sampling rate of 200Hz, containing all relevant eye values. These values are then processed into a strain level.

A C# DLL file will be provided, so that the WA Tool can connect to the IA to receive the computed strain level. Communication will be done via the TCP/IP protocol (Figure 10).

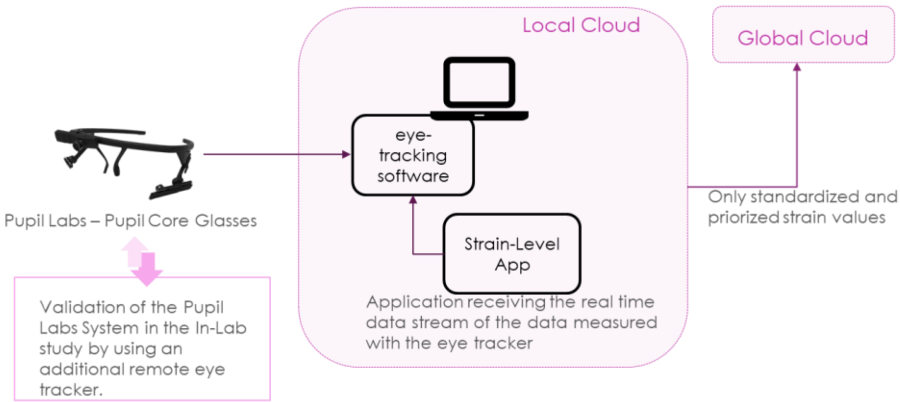


*Figure 10: Detailed Architecture of the Eye-Tracking System.*

### *3.3.1.4 Body Pose Recognition*

The posture of the users will be estimated by means of a monocular camera (focal length = 2.8mm, max resolution = 3MP) in order to perform an ergonomic assessment. Although the monocular camera provides 2d information, the posture estimation system will be able to obtain the position of each joint of the body in world coordinates (x, y, z) (3d).

The images captured by each camera will be sent to the Edge Cloud (Local Server) through the Mesh Network to be processed by the deep learning algorithm obtaining the posture of the users. A pre-processing has to be applied to the images in order to remove the distortions of the images. The pre-processed images are the input of the Convolutional Neural Network (CNN) previously trained, obtaining as the outcome the user´s posture estimated.

Once the posture of the users has been estimated, the images will be deleted by the system and the remaining information (posture and ergonomic information) will be anonymised and encrypted before to be sent to the Global Server. For instance, the posture estimated (for n joints) will be send with a format of an array of values (float) in millimetres with the following format:

| x_1 | y_1 | z_1 | … | x_n | y_n | z_n |
|---|---|---|---|---|---|---|
| 141.24 | 253.76 | 1744.00 | … | 1638.03 | 1335.35 | 3498.00 |

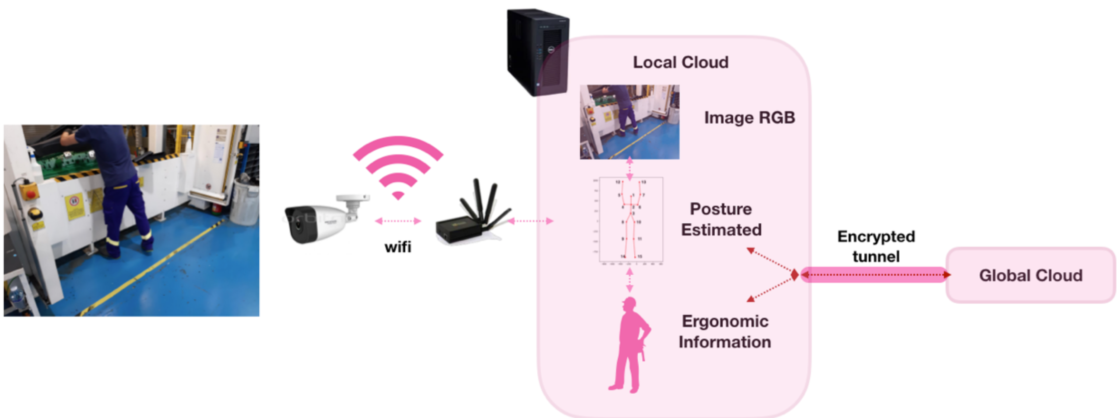


*Figure 11: Detailed Architecture of the Body Pose Recognition System*

### 3.3.1.5 Facial Expression

For facial affect analysis sub-system, one camera will be used to capture the frontal face, while a second camera will be potentially used to capture the face profile. The frame streams will be sent to Edge Cloud via Wi-Fi connection.

At Edge Cloud, the frames will be fed into the trained models for face detection and facial affect analysis. This requires software/libraries (i.e. Pytorch, TensorFlow, CUDA, OpenCV, scikit-learn, SciPy, etc.) to assist the analysis.

The analysis outcomes (facial ROI and prediction results) will be anonymised and encrypted. Then the data will be sent to the global server.

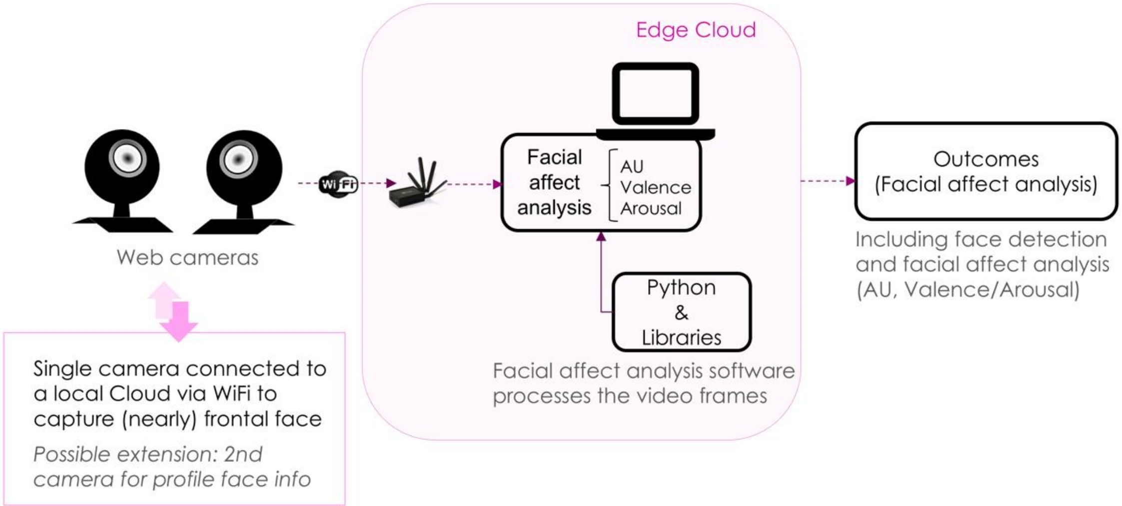


*Figure 12: WA Facial Affect Analysis Sub-system*

### 3.3.1.6 Voice Analysis

The voice analysis tool for emotion recognition leverages a Bluetooth microphone worn by the user to collect audio samples and send them to its receiver, a Raspberry Pi 3. The software running on the Raspberry will perform Voice Activity Detection (VAD) to isolate spoken segments of the audio signal (by the means of the openSMILE tool) and send them in encrypted form to server for elaboration. The code on the server will take care of:

- decrypt the recorded utterance;
- transcribe the utterance using a locally installed ASR;
- perform emotion classification.

This last task will be executed by a Neural Network developed with one of the available Python frameworks (related Python libraries and a CUDA compatible GPU are required to be installed on the server). Finally, the result of the analysis will be sent to user's device.

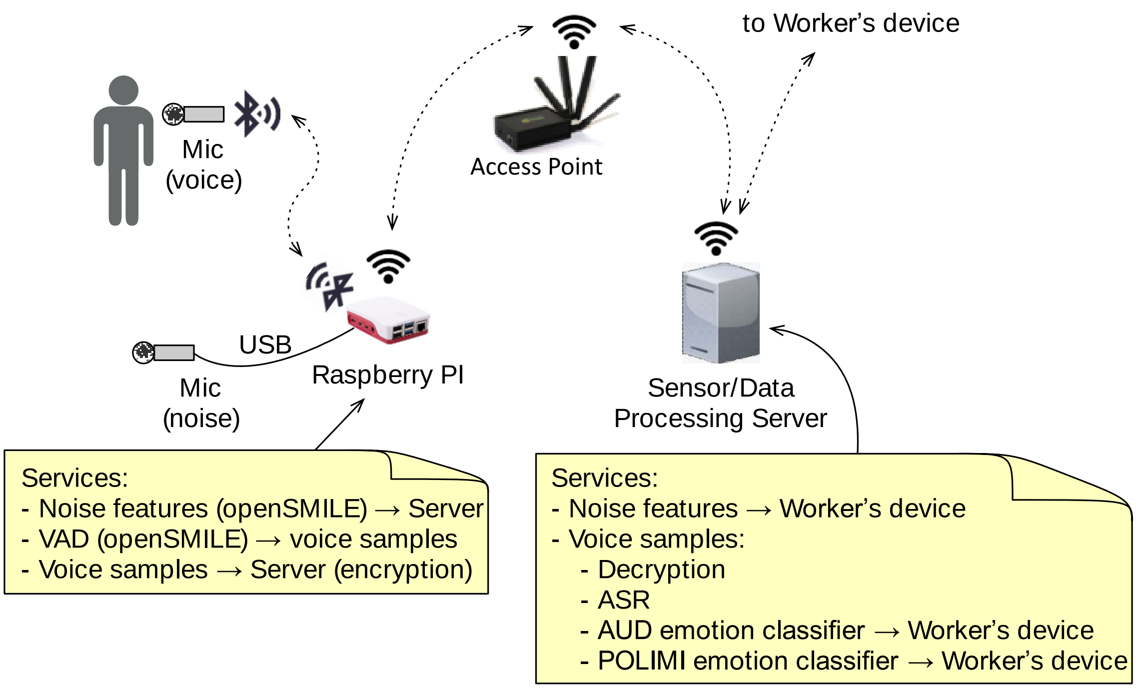


*Figure 13: WA Voice Analysis architecture*

### *3.3.1.7 Surrounding Noise Assessment*

A Raspberry Pi 3 (RPI) module will be located close to the user's working area or attached to her clothes. Inside the RPI, real-time processing of the acoustics will be carried out through using OpenSMILE software to extracts (every second) some acoustic parameters, such as noise level (dbA), voice activity, gender of the speaker, laughter detection. There will be two options:

1. This same module also computes some statistics out of them to provide a higher-level overview of the surrounding acoustics, and send them periodically to the decision centre (via Wi-Fi).
2. The RPI module sends the acoustic parameters to the edge-cloud, and there the statistics will be computed, and from there, they will be sent to the decision centre.

Since the computation of the statistics is not a high-resource demand, most probably the first option will be used.

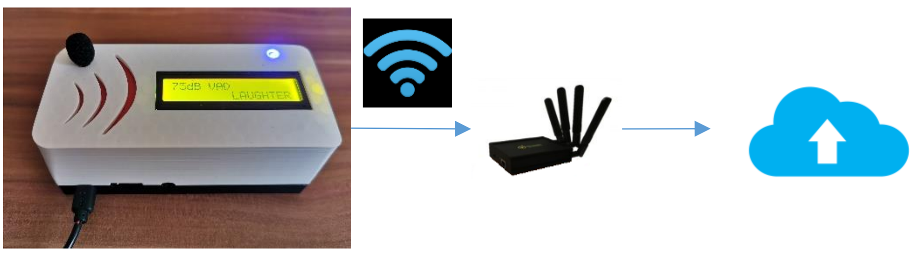

*Figure 14: Data flow of the noise sensor*

### *3.3.1.8 Illumination, Thermo-hygrometric, $CO_2$*

An environmental sensor device will be designed and used for workplace environmental monitoring, by means of evaluating the data obtained from illumination, temperature, relative humidity, and $CO_2$ sensors. The device will feature a 32-bit ARM microcontroller running a firmware that will manage sensor configuration and polling, signal conditioning and processing, Wi-Fi connection to the Access Points, and data communications with the Edge Cloud Server. Battery operation will be designed to provide a target autonomy of, at least, 8 hours.

The operating ranges of the sensors are described below:

- Illumination: 0 -6553 lux
- Temperature: 0 – 50 °C
- Relative Humidity: 0 – 100 %
- $CO_2$: 0- 5000 ppm

The sensor device will periodically poll the sensors and process the data to obtain illumination, temperature, humidity and $CO_2$ values. These values, together with the sensor ID and any other required information will be then sent to the Edge Cloud Server via Wi-Fi connection to the Edge Cloud Access Points.

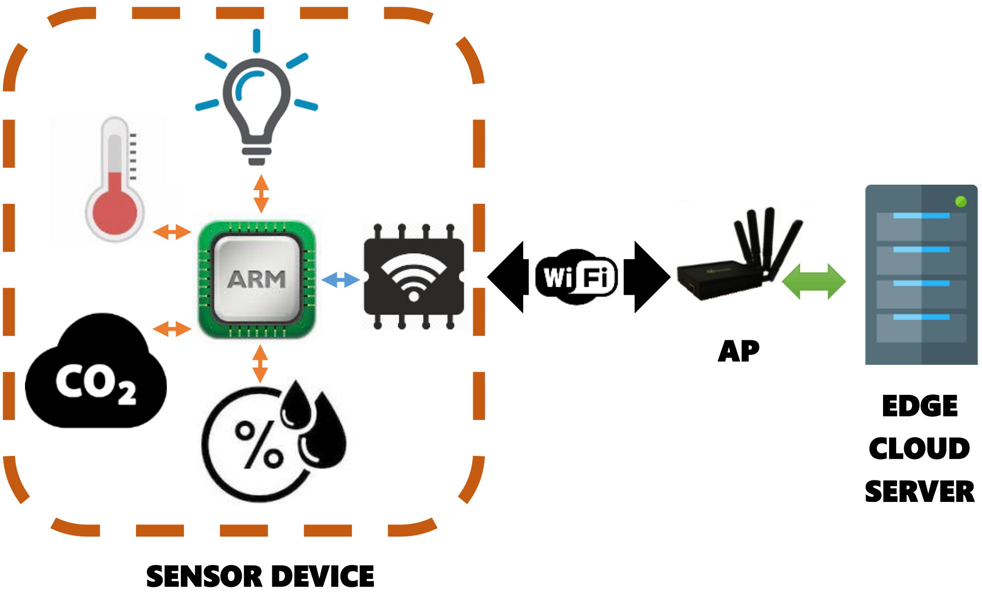


*Figure 15: Illumination, Thermo-Hygrometric and $CO_2$ Monitoring Architecture*

## 3.3.2 Location and Emergency Service

Figure 16 provides a synthesis of the Location & Emergency service components and high-level data exchange.

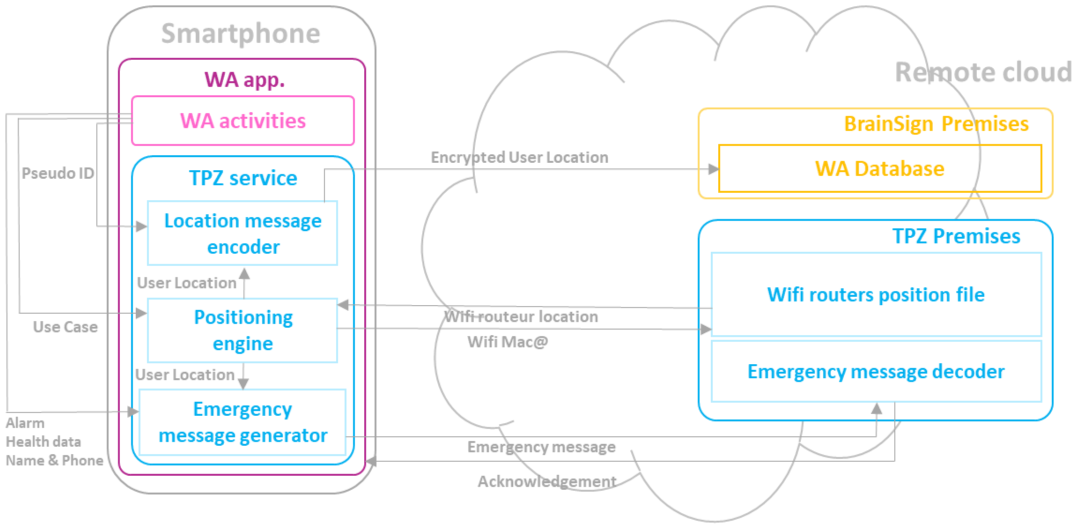


*Figure 16: Location & Emergency Service Components and Data Exchange*

The data exchanged by the different services are the following:

- Pseudo ID of the user, for GDPR compliance
- Current Use Case, for indoor or outdoor positioning lock by the positioning engine
- Alert coming from the WA tool in case of hazardous health condition of the user
- Health data to be send to the Emergency Services in case of alert.
- User location, to be encoded into the emergency message and the location message.
- The Wi-Fi router MAC address
- The Wi-Fi router location.

The following sub-section will provide details about each of this data as well as a high-level functional description of each block at stake in the Location and Emergency service shown in this figure.

## High-level functional description

### *3.3.2.1 Positioning engine*

The positioning engine block's inputs/outputs are presented in Figure 15.

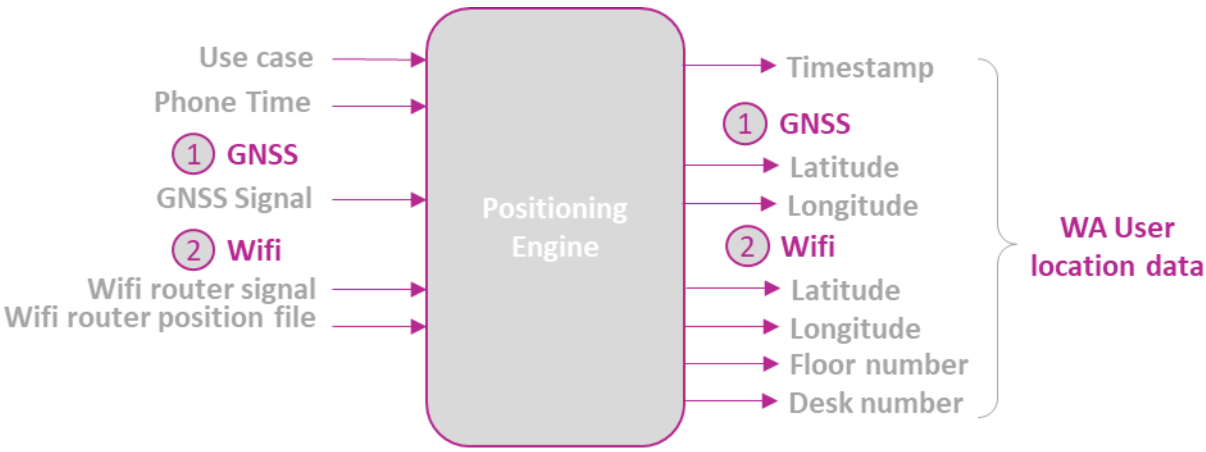


*Figure 17: Inputs/Outputs for Positioning Engine Block*

The knowledge a priori of the Use case is necessary to lock on the appropriate position technology: GNSS for outdoor and Wi-Fi-based for indoor.

**GNSS**

In case of GNSS positioning, the full computation is internally made by the GNSS receiver embedded in the smartphone. The GNSS position can then be retrieved using the Location Service Android API. This GNSS position consists of two parameters: the longitude and the latitude. Moreover, the position will be timestamped using the time provided by the smartphone. The positioning engine will provide the GNSS position every 5 seconds.

**Wi-Fi**

In case of Wi-Fi-based positioning, the user's position is computed in several steps:

1. The Location service gets the BSSID (Basic Service Set Identifier) of the router the smartphone is connected to. This BSSID corresponds to the MAC address.
2. A request containing this MAC address is sent to TPZ Remote Cloud to retrieve the associated position into the Wi-Fi router position file.
3. The TPZ Remote cloud server sends the associated position to the Location service on the smartphone.

These requests and communication will be made through functions described in section **Error! Reference source not found.**.

The routers will be positioned *a priori* with longitude and latitude data, as well as floor number and room number when applicable. Thus, the **Wi-Fi router position file** will be a table with the following columns:

- MAC address
- Latitude
- Longitude
- Floor number
- Desk Number

Each WA router will be uniquely defined in the table.

Once the positioning (GNSS or Wi-Fi) data retrieved, it will be timestamped using the time provided by the smartphone, and formatted as in the position frame presented in the next sub-section. The positioning engine provides the Wi-Fi-based position every 30 seconds.

### *3.3.2.2 Location message encoder*

The location message encoder block's inputs/outputs are presented in Figure 18.

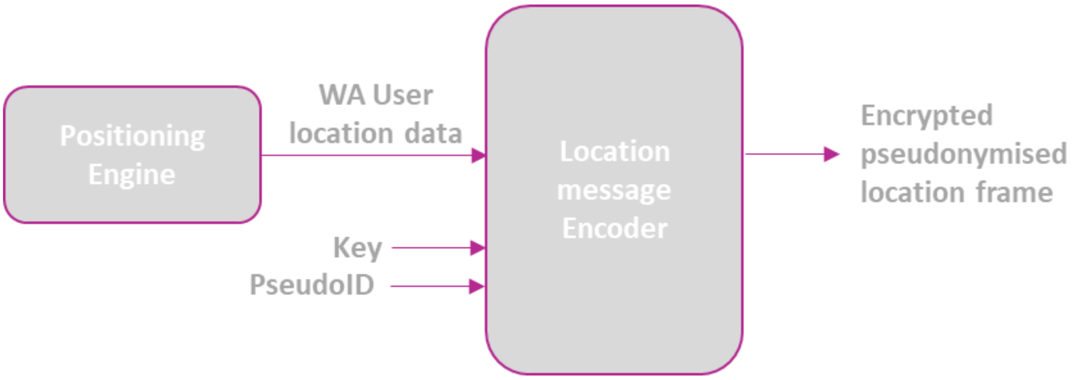


*Figure 18: Inputs/Outputs for Location Message Encoder Block*

The Location message encoder format the message that will be sent to the WA Database in a user's location data frame.

In order to fit all use cases, the user's location data frame will have the following structure:

- **Pseudo_ID**: Pseudonymised identifier of the user
- **Position_type**: Flag – 0 = GNSS, 1 = Wi-Fi
- **Timestamp** : YYMMDD – hh:ss format
- **Latitude**: [+-]DDD.DDDDD format where D indicates degrees
- **Longitude**: [+-]DDD.DDDDD format where D indicates degrees
- **Floor**: [+-] NN or 'NA' in case position_type equals 0 or it is not applicable to the concerned building.
- **Room**: 8 characters string to fit many room nomination or 'NA' in case position_type equals 0 or it is not applicable to the office organisation.

Then, the OpenGPG library functions are called to encrypt the location data frame with an encryption key owned by TPZ. The data is eventually sent to the BS storing server.

#### 3.3.2.3 *Emergency message*

The Emergency message service, made of Emergency message generator and Emergency message decoder manages inputs/outputs as presented in Figure 19.

This section presents both emergency message generator and decoder together for more clarity, as a client-server architecture.

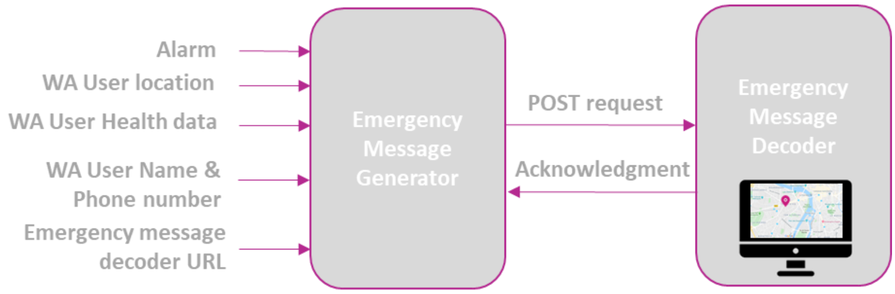


*Figure 19: Emergency Message Management Inputs/Outputs*

When an alert is sent by the WA application to the client (i.e. the emergency message generator), it will send a request to the server (i.e. the emergency message decoder) containing the emergency data and possibly asking for acknowledgment (not defined yet).

The web server will receive the request, get the data content and send an acknowledgment (data received or error). It will then process the received data and display the position on a map. In addition, the WA application could inform the user if the emergency message has been sent properly or not (using the Acknowledgment) through a pop-up message on the application. This way, the user could contact the emergency services himself in case of error or on the contrary know that he doesn't need to do it in case of success.

The data content of the request will have the following components:

- Part of the WA user location data (as defined in section 3.3.2.1 and containing at least latitude and longitude parameters)
- Additional health data coming from the WA application activity (to be defined in WP3 of the project)
- Potentially the user name and phone number (which could be stored inside the smartphone

The request will also take the URL of the web server as a mandatory input.

### 3.3.3 Connection to Other Networks

Connection to enterprise's systems and OSH software: One can set an HTTPS connection between the enterprise systems / OSH software and the local mesh routers to fetch the network information such as: who is connected when and where. One can also connect directly to the enterprise system with the local edge server to retrieve data incoming from the sensors. Traffic will be WPA2 encrypted when going through the mesh network. The company can add its own end-to-end security procedures. Enterprise systems / OSH software can be hosted on servers on the company side or in the cloud. The former case, traffic will go through the Internet gateway (Figure 7).

Social networks: In order to offer users the capacity of exchanging with other users, an online forum within the WorkingAge webpage (https://www.workingage.eu/) will be set up, in which they will be able to share their thoughts, opinions and experiences. To ensure, that comments are not seen by people outside the project, the users will have a password to login. The forum will get several administrators, so that upcoming questions can be answered as soon as possible. Beside the WorkingAge webpage and the included forum, the following websites are offered to users and to the general public within the WA Tool to get information and news:

- https://twitter.com/Workingage_EU
- https://www.linkedin.com/in/workingage-EU

To receive questions and feedback from the developers, the WA-Tool includes a contact form with the official WA email address:

- info@workingage.eu

### 3.3.4 Human Computer Interaction (HCI)

#### 3.3.4.1 User Interfaces

The WA App for Android smartphone will be developed in the objective of providing a user-friendly interface to interact with the WA Tool.

The main application will be developed under Unity3D because of the AR and the 3D avatar functionalities. Unity 3D is a graphic engine that allows the system to efficiently render 3D objects and AR/VR applications.

The main application will communicate and connect with other functional modules mainly by Android services compiled as libraries (.aar), notably the Location and Emergency service presented in section 3.3.2.

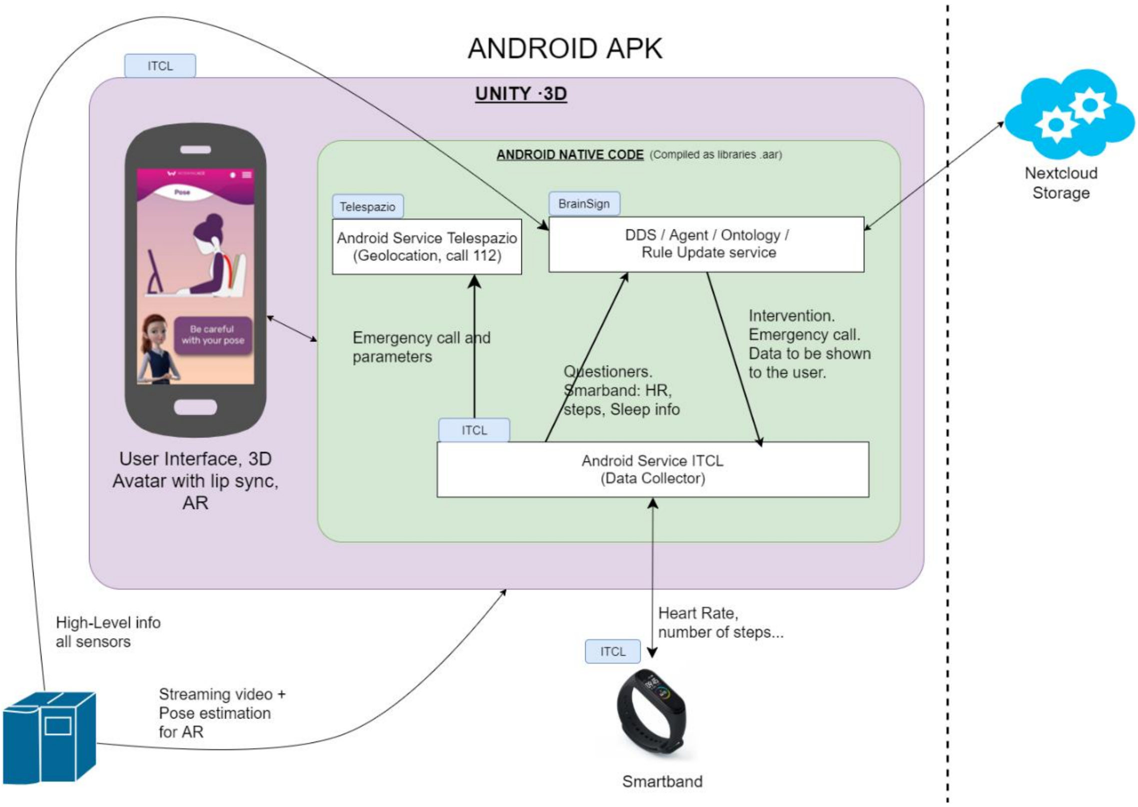


Figure 20: WA App Main Architecture

The app will be the main connection of the user with WA it should show important data about sensors, questionnaires and advice.

First design of the interface and avatar will be checked with real users to get their feedback.

Figure 21: Several 3D Avatar Options


Figure 22: Several UI Design

### 3.3.4.2 Augmented Reality

The Augmented Reality module will work mainly in three ways:

- Give advices, exercises or stretching to the user: If the user selects to see the advice in AR the APP thanks to the ARCore will activate the Smartphone camera. Look for a planar surface and the App will add the 3D avatar to the surface. All this process is done locally in the smartphone and does not need of additional information.
- Pose advice to the user: The Smartphone will receive, from the Edge Server, the image of the camera for pose estimation and the info related to pose and ergonomic. The info will be shown in the application in real-time.

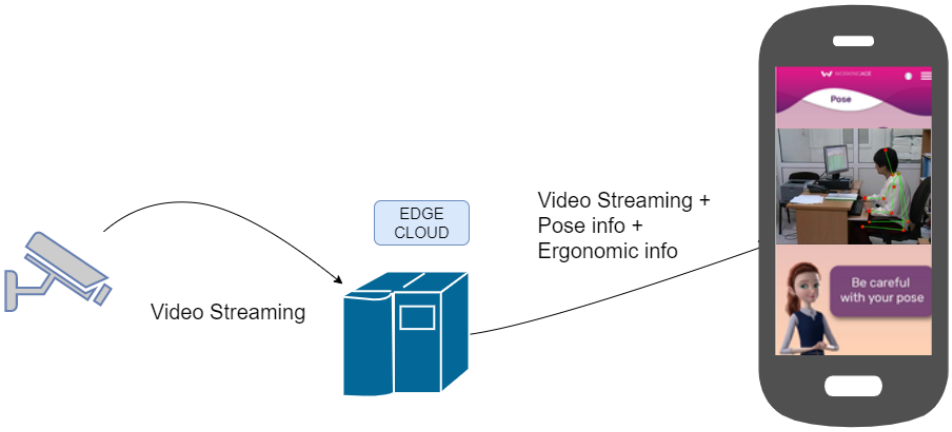


Figure 23: A Preview of the AR Module

Figure 24: AR for Pose Architecture and Samples

- Specific application for Factory: A specific application will be created for one of the working places of the GA RYA factory. The selected place is the Kitting XFB in which the users have to pick up several parts and, in some cases, assembly them before the distribution to the factory. This application will be specifically developed for the working place and need to have into account the needs of the user, the work to be done, interactions, etc. The preselected hardware is Hololens equipment that allows to recognise the environment or markers added to the environment and to visualize the AR info through the see-through display. The application will be installed only in the AR device and will report high-level info to the edge server.

#### *3.3.4.3 Gesture Recognition*

The goal of the developed module is to identify hand gestures in real time by streaming video from a webcam. The program will outline a hand within a given frame on the screen and then further determine the number of fingers, using Deep learning algorithms and more precisely convolutional neural networks (CNN). The possible hand gesture classes are as follows:

- 0 fingers
- 1 finger
- 2 fingers
- 3 fingers
- 4 fingers
- 5 fingers

The afore-described system can be expanded so as to receive feedback from the users via gestures (e.g. "OK", "thumps up", etc.) and translate it into a corresponding health (either physical or mental) status.

The main devices used for the gesture recognition module are the following:

- An external camera
- A server which locate the Gesture Recognition component

The main services developed in the context of the module are as follows:

- Real Time Face Verification Platform
- Real Time Gesture Recognition and Finger Enumeration component
- A Database schema containing:
    - A picture of the registered user
    - Deep learning pretrained models
    - 1000 images from each category for training purposes
    - 200 images from each category for testing and validation purposes

The model consists of 4 convoluted layers, each connected via a max-pooling layer to the next one. Following the implementation of the convolution, a fully-connected layer is deployed, and finally the output layer is generated. All input images are of the dimensions: 128x128x3mm (RGB 3 channels).

The face and hand recognition will be implemented in Python using the following libraries:

- Tensorflow
- Keras
- Scipy
- Numpy

Several image pre-processing techniques will be used such us:

- Image resizing
- Image filtering and transforming methods
- Image segmentation / background subtraction

For the face verification aspect of this component, pretrained neural networks such as FaceNet are being used. The hand recognition will, in turn, rely on fine-tuned deep learning models that will be developed by EXUS.

### 3.3.5 Data Security and Privacy

A server has been structured for backup purposes. Each data transfer, between each partner and the backup server, will be protected by end-to-end encryption. The data transfer support will be provided by the sharing platform called freeNAS, physically placed in Rome and exposed through HyperText Transfer Protocol over Secure Socket Layer (HTTPS). The platform will be based on a cloud service client called Nextcloud. All the data stored in the server will be encrypted. The software used for the encryption and decryption procedure will be GnuPG. No partner will access to other partner's datasets without the corresponding secondary decryption key.

# 4 Reference List

J. Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., & Van de Weijer. (2011.). Eye Tracking: A Comprehensive Guide to Methods and Measures. . *Oxford University Press* .