# Deliverable 2.1

# Initial product and service concept

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# Contents

# 1 Introduction

ENSAFE AAL Joint Programme project (Elderly-oriented, network-based Services Aimed at Independent Life), aims to support older people in prevention and self-care by providing them with smart services.

The main idea of the project is to use technology to strengthen the connection between the elderly person and his life environment (both in the sense of spaces and of human relationship) in order to promote a more independent lifestyle.

From a technology point of view, smart services are enabled by a perceptive layer, based on an heterogeneous set of sensing devices, including: smartphones, wearable sensors, home environmental sensors and clinical monitoring devices. Data coming from such devices will be gathered, fused together and analyzed to infer useful information about the user daily life and health status. Outcome of such data processing will in turn enable feedback strategies toward the user itself (supporting awareness and motivation in pursuing healthy behaviors) as well as toward caregivers and healthcare services (supporting continuous monitoring, prevention and early diagnosis strategies). The ENSAFE technology is summarized in the conceptual view given in Fig. 1 below.

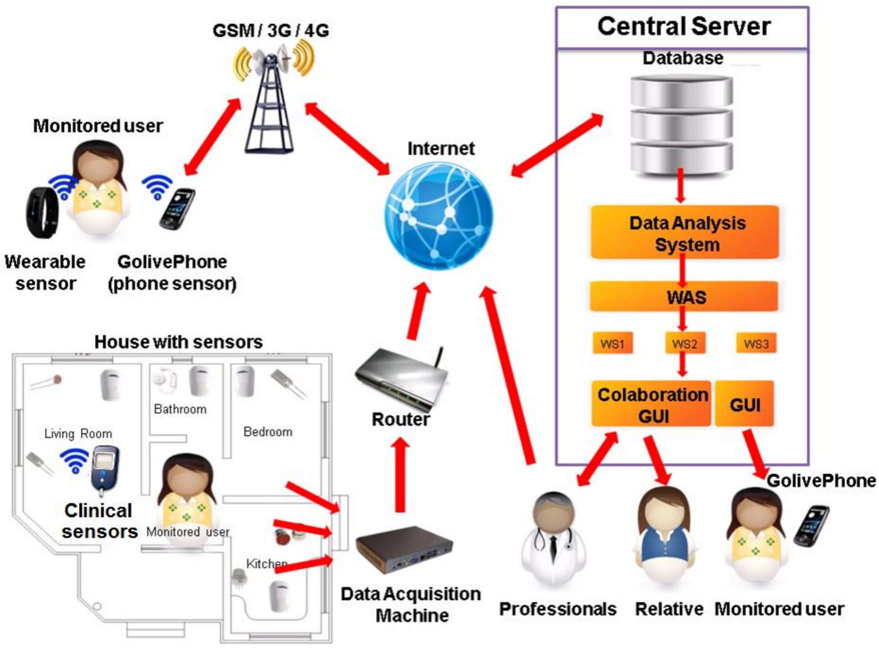


Figure 1 - ENSAFE Integrated System Architecture

ENSAFE technology research and development will thus focus mostly at:

- Development and characterization of sensing devices, with specific goals related to accessibility, intrusiveness, reliability.
- Design and implementation of cloud-based infrastructure, providing for flexibility, scalability, data safety and interoperability

- Identification of suitable data-processing techniques, suitable for effective data fusion and classification, aimed at inferring, from raw sensor data, expressive and meaningful health-related information.  In order to deal with the large variability of human behaviors, machine-learning capabilities should be implemented.
- Interaction techniques suitable for providing end-users (primary as well as secondary and tertiary) with effective perception of relevant information. This involves both User Experience design and data visualization techniques.

Within the overall project organization, Work Package 2 “Product and service development” is in charge of the development of the platform for the integration of various sub-systems, dealing with all tasks listed above.

The ENSAFE project strictly enforce a user-centric design approach, in which detailed design specification are built upon end-user involvement. WP1 is in charge of users need assessment, which is to be developed in the initial project phases. Therefore, detailed specification for actual service implementation will be available only at a later stage and WP2 has initially focused his work on the infrastructural side of the system, which is less dependent on the actual service specification details. This deliverable therefore deals with such an initial phase and describes solutions that have been devised for the infrastructure and the overall architecture of the system. In particular, activities in initial project months regarded the selection, characterization and management of “peripheral” devices and the design and implementation of a suitable cloud infrastructure. Data analysis and visualization, as well as user experience design depends more closely on the actual service definition, and will be described at a later stage of the project. Therefore, in the following, section 2 will review the variety of sensing devices accounted for by the ENSAFE project, and section 3 will discuss the devised cloud architecture. Some account of potential services is given in section 4, while preliminary conclusions are drawn in section 5.

# 2 Sensing devices

As mentioned above, the sensing layer encompasses a variety of devices, pertaining to different classes:

- **wearable sensors:** either embedded in a smartphone, or conceived as stand-alone devices, wirelessly connected to a communication hub (possibly the smartphone itself). Purpose of wearable sensors is to provide personal information such as spatial position of the bearer, its movements, etc.
- **home/environmental sensors**: monitoring different daily living activities in an indirect way, by checking interaction of the system end-user with home spaces and devices. Their primary aim is usually related to safety and/or comfort. In the ENSAFE vision, they also contribute at the assessment of behavioral profiles, suitable for being correlated to health features and thus to foster continuous monitoring.
- **clinical sensors:** allowing for acquiring, in a self-managed fashion, direct measurement of relevant physiological parameters.  They provide the best possible accuracy to health

assessment tasks, requiring however to the user to comply with checking routines, and thus resulting in some intrusiveness.

Candidate devices in all classes have been selected, and are described in following subsections.

## *2.1 Wearable devices*

A simple app (GoLivePhone App) turns a client's smartphone or wearable into an intelligent mobile Personal Emergency Response Solution (mPERS). Advanced software provides remote monitoring for caregivers and in the background Gociety keeps everyone connected and informed.

*Affordable connected care for everyone*

One of the biggest social transformations of our time is the aging of the population. It’s already had a tremendous impact in the growing demand for acute and long-term care services. At the same time, healthcare organizations are dealing with reimbursement cuts and increasing costs. The solution cannot be found in the growing numbers of informal caregivers alone. As the demands on all parties mount, professional organizations, and informal caregivers are looking for new ways to deal with their present and future challenges. With ENSAFE we believe technology creates new opportunities for integrated and higher quality older adult care at a surprisingly affordable monthly fee. With easy-to-use prevention-driven innovations, we support healthcare organizations to create new remote services that enhance client's feelings of safety, well-being and independence. Informal care integration connects family and friends, and enables them to support their loved ones when they can’t physically be there. Together we support the older population to get the care they need and live a high quality of life.


The GoLive Phone App

*Alert - Direct emergency access AND auto-detection*

In case of an emergency, a single button summons help. Caregivers get an automatic notification when the client falls, gets lost, is inactive for longer periods of time; and even when the battery of their phone or wearable is almost empty. But as an advanced mPERS, the Gociety solution does so much more. It continuously runs trend analyses, searching for abnormalities in the client's physical parameters and behavior.

*Connect - 24/7 connection with formal and informal caregivers*

Older adults are eager to stay connected with their family and friends. They want to enjoy life, feel free and be independent. They also want to get in touch with a healthcare professional or an emergency call center when needed. Gociety Solutions enables older adults to connect – with more ease to the world around them, through a superior easy-to-use smartphone interface. Seamlessly Gociety connects informal and formal care support as needed with a selected 24/7 emergency center – from wellness nurses to doctors on-call to 112/911 emergency calls. Empower clients and the people around them to take a more active role in the management of their personal care, safety and well-being.

*Monitor - Remote continuous care and advanced risk analyses*

Gociety Solutions delivers advanced monitoring functionality and informal caregiver integration. Provide family and friends with peace of mind, efficient remote informal care and the remote management of their loved ones via a Web application.

Gain real-time insights into health-related metrics and understand trends and abnormalities in routine day-to-day activities. Formal care providers can leverage their staff better with more attention on higher risk older adults and increase service levels with advanced risk analyses.

*Learn - A better solution everyday*

The Gociety solution keeps getting smarter and smarter with its self-learning algorithms. After 15 days of logging data for an individual client, the sophisticated algorithms can predict and help prevent high-cost, painful and emotionally draining acute episodes. It's completely automatic and non-obstructive. Early indicators generate alerts for early preventative intervention opportunities.

*Data - Committed to the highest security standards*

All data is securely collected, centrally managed and analyzed in a state of the art database architecture; guaranteeing secure synchronization and back up procedures.

The GoCiety wearable sensor

## 2.2 Home devices

UNIPR will deal with home devices, exploiting and extending the “CARDEA domus” technology previously developed in the framework of several projects and currently being marketed by I-Cubo Srl, participating in the ENSAFE project as a linked third party. The home subsystem is composed by:

- A set of wireless sensors
- Wireless networking gear
- A “gateway” node, gathering sensor information and dealing with cloud communication.

The wireless sensors network is composed of devices that communicate by the means of a ZigBee connection.

The set of sensors provided by UNIPR for the ENSAFE project, can produce information about the behavior of users, monitoring their activities of daily live. Below, the description of such sensors.

**Bed and Chair Occupancy Sensor**

Is used to monitor the presence of a person on the bed or on the chair/armchair.

It consists of a sensitive pad connected to a wireless ZigBee Transmitter Module, which provides the network connection to the sensor.

The pad used for the chair monitoring can be placed under a pillow; the pad used for the bed monitoring has to be placed on top of the mattress (under the bed sheet).

Each time the user occupies or frees up the bed (or the chair), a message is sent over the network using the ZigBee wireless connection.

It is useful for monitoring and analyze users' nightly behavior and habits, such as: the time spent sleeping, the number of times that users get up at night, and the sleep/wake up time.

Furthermore, it can possibly be used for the generation of immediate warnings (for example, in case of numerous anomalous get up are detected).

Chair Pad sensor (38 x 25 cm)

Bed Pad Sensor (66 x 51 cm)


ZigBee Transmitter Module

**Door Open/Close Sensor**

Is used to detect if a door (or a window, a drawer, a furniture door, etc.) is open.

If installed on the perimeters doors (or windows) of the users' home, it can be mainly useful for security issues.

If installed on a particular drawer (for example, the medicine cabinet), it can be used to monitor specific behaviours.

Magnetic Contact Sensor

**Fridge Open/Close Sensor**

Is placed on one of the shelf of the fridge, in order to detect if the door is open.

When the door is opened or closed, a message is sent over the wireless network.

Periodically, others local parameters (as the temperature and the humidity) are monitored and communicated.

In addition to the analysis of the eating habits, it can be used to give specific alerts (for example in the case users have forgotten open the fridge door or the temperature is abnormally increased).


Fridge Sensor

**PIR (Presence Infra-Red) Motion Sensor**

A wall-mounted device that detects the motion of a person in the room. Typically used in security systems (or to turn on the lights automatically), it can be used to monitor the amount of movement of users inside their home.

When the average amount of movement of an elderly person tends to decrease this may indicate a state of malaise.

Motion Sensor

**Power Outlet Monitoring Sensor**

A ZigBee smart plug that enables to measure the instant electrical consumption. Can be used to detect if a particular appliance (for example the Television) is On or Off. It can be particularly effective to define specific behaviors of a user.

For example, mixing data provided by the chair occupancy sensor and by the smart plug connected to the TV, the amount of time spent watching the TV can be estimated.

Power Outlet Monitoring Sensor

**Toilet Occupancy Sensor**

It allows to know if someone is using the WC. Despite being composed of two boxes, the WC sensor is a “single sensor”.

The monitoring of the frequency with which the toilet is used, especially at night, is a very important parameter in order to assess the state of being of a

person.

**ZigBee Network Coordinator & Router**

Though it is not properly a sensor, the Coordinator plays a key role in the handling of the wireless sensors network, enabling the communication between the sensors and the central Control Unit (a mini-server PC).

It consists of a USB-key that must be plugged into a USB port of the CU.

A similar device, is the ZigBee Router that extends the wireless network covering. Powered via standard USB Power Adapter, the Router is used only in case a device is too far from the UC, or an obstacle (as walls or furniture) reduces the intensity of the radio signal.

**Toilet Occupancy Sensor**

**ZigBee Network Coordinator**

All wireless sensors communicate, by means of a ZigBee communication infrastructure, with a central Control Unit, typically a mini-server PC, equipped with the ZigBee Network Coordinator.

The UC, provided with a Linux OS, hosts a software that has the tasks of:

- create and set up the network during the installing operations
- coordinate the ZigBee network
- check that sensors are regularly connected and operating
- collect data from the sensors
- communicate data provided by sensors to the ENSAFE cloud-based infrastructure

The data gathered by the home sensor network must then be forwarded to the cloud-based (Microsoft Azure IoT Hub) ENSAFE infrastructure. This is taken care of by a dedicated gateway, namely, a program running on the Linux-based CU. The gateway subscribes to notifications about sensor state change as detected by the CU, and act as a bridge towards the cloud for such notifications.
The gateway is implemented in C/C++ language, making use of a dedicated IoT Hub API (Application Programming Interface). Secure connection is established with the cloud environment, and messages are dispatched reliably, raising errors if delivery did not complete successfully. The API also allows to receive message from the cloud to the gateway device, sketching a bi-directional communication flow.

## *2.3 Clinical devices*

METEDA provides the clinical devices for the control of the most important clinical parameters. All the devices use the Bluetooth technology for the data exchange. Simple and easy to use even by elderly people and without the assistance of a caregiver (formal or informal).

**Precision Scale**

The Precision Scale with Bluetooth communication system provides highly accurate and precise measurements to 0.2 lb (0.1 kg). This scale has a “motion tolerance mode” to provide an accurate reading for those patients who are unsteady on the scale, a feature especially beneficial for elderly or fatigued patients. This scale has a high weight capacity of 450 lb (200 kg).

Precision scale

**Blood pressure monitor**

Fully automatic Blood Pressure monitor validated to highest grade, 100 measurement memory, Irregular Heartbeat Indicator, Clock display updates when data is transmitted. Is equipped with Bluetooth® wireless communication technology, giving it extended and advanced capabilities. Ideal for the home and professional health provider. Professional accuracy via oscillometric method. One button operation, this device allows to measure the:
- Systolic pressure (mmHg)
- Diastolic pressure (mmHg)
- Pulse rate (bpm)


Blood pressure monitor

**Blood glucose monitor**

ForaCare is designed to let the maximum ease of use. No coding is required. Only takes 0.5uL blood sample and you get a result within 5 sec. It has an alarm function to remind a user to take 4 measurements a day. Memory for up to 1000 testing results with before/after meal/quality control indicator and date/time. Additionally, the strip ejector helps prevent contagion from blood. The blood glucose monitor can check the glucose level in only one unit of measurement: mg/dL or mmol/L.


Blood glucose monitor

**Pulse oxymeter**

Finger Pulse Oximeter is an affordable and accurate way to check pulse rates and blood oxygen saturation levels. Self-adjusting finger clamp plus simple one-button design allows for easy operation. Small portable size makes it easy to handle and carry. Helpful for athletes and pilots to obtain quick and


Pulse oxymeter

accurate oxygen saturation readings.

Features include an easy to read bright digital LED display, 30+ hours of continuous monitoring on one set of batteries. Integrated SpO2 probe and processing display module plus SpO2 and Pulse Rate and bar. Low battery level indicator. Auto power off. Low power consumption on 2 AAA batteries. Comes with a hanging neck/wrist strap and case for use on the move. Intended use for spot check of pulse rates and blood oxygen saturation level at home.

**CLINICAL DEVICE FEATURES**

- Measurement frequency:
    - Devices could be used multiple times during the day (max ~4 times a day)
- Measurement payload:
    - Small JSON objects containing monitored variables, timestamp, unique user id
- Transmission protocol
    - Bluetooth SPP
- Basic programmability features:
    - set device timer, memory configuration, unit of measures.

# 3 ENSAFE Cloud Architecture

The goal in ENSAFE is to design and develop a platform and services that should be possible to implement in all our countries and as well be able to commercialize in a broader market with business models that make it possible for partners and suppliers to make business. The design approaches take in account a planned future solution with possibility to over time implement new services and products as well as new consumers and user profiles. Some of the requirements for ENSAFE are more important than others.

- To open up and make it possible for different actors/suppliers to be a part of the solution over time in all of the three parts of the solution
    - Data collection (sensors, mobile devices and other data sources)
    - Storing of individual data incl. security and access
    - Usage, services, applications etc.
- Be able to get at flexible and easy way of scaling
    - Cloud based solutions
    - Base system critical function on commercial available software
- The individual freedom of choice and decisions
    - For storing your individual data
    - Who will get access to your data
    - Witch applications, services to use

The solution is designed for possible implementation in an international environment. Different countries have different laws, requirements and conditions for implementation of IT-solutions handling personal data. The technical solution is designed for an open approach to make it possible to implement different configurations, with different devices and data collectors from different suppliers, different hosting and storage solutions as well as open up for third parties to connect applications and services to the platform.

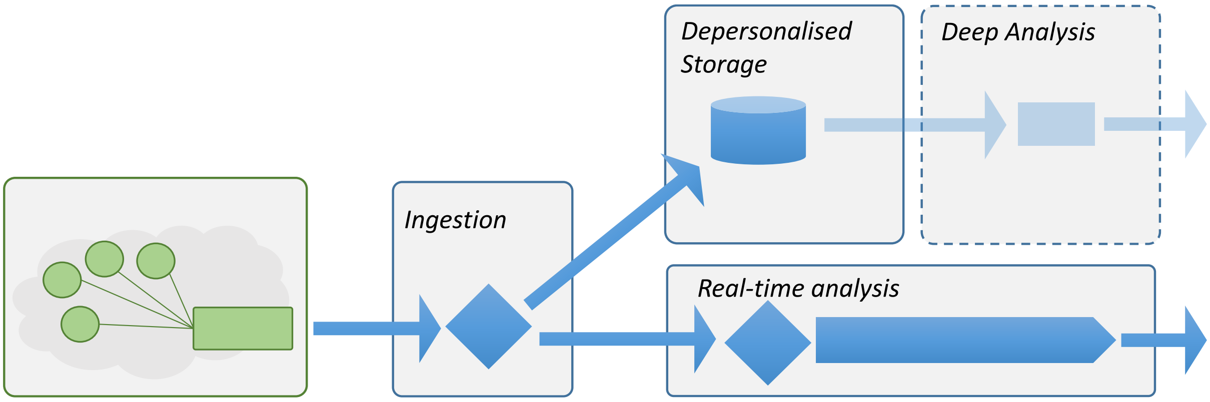


Figure 1 Ensafe Cloud Architecture (in blue) containing functionality for Ingestion, Storage and Real-time analysis

## 3.1 Ingestion - Event & data collection

The back-end system and databases are designed for open integration points to be able to use different data collectors like sensors and mobile devices in different implementations and to make integration of new devices easy over time. This will also open up for flexible and attractive business models for suppliers to integrate their products and services to the platform. The possibility to handle different types of input data is critical, all from real time oriented sensor data to more document centric input and non-time critical data.

The ingestion functionality is implemented using the Azure IoT Hub platform service.

## 3.2 Real-time analysis and detection of anomalies

In order to support the monitored individual in everyday life it is important for the solution to be quick and give suggestions, reminders and alerts in a near real time fashion. To enable this type of functionality a real-time analysis capability has been built into the foundation of the solution.

The Real-time analysis functionality is implemented using a combination of the Azure Stream Analytics and Azure Event Hub platform services.

## 3.3 Storage of collected and depersonalised data as a base for further analysis

All collected data (events and telemetry) needs to be stored before it is used for further deeper analysis. All data is depersonalised ahead of being stored and can only be traced back to the individual user using a key, being secret to the user and whomever the user has shared it with.

Different analysis technologies and different analysis providers might have different preferences when it comes to storage technology. The collected data is therefore stored in three different ways:

- Azure Event Hub, temporarily stored in queue like manner for up to 7 days for further processing
- Azure SQL DB, a relational database accessible and queryable using SQL

- Azure BLOB Storage, a raw format dump of data messages to disk. Accessible using for instance via FTP

## 3.4 *Test Harness*

As a test harness, a web application called ENSAFE Monitor, has been built on top of the ENSAFE IoT Hub. Via the ENSAFE Monitor, it is possible for the involved partners to hook up new devices to the ENSAFE platform and monitor the data collection from each device.

The ENSAFE Monitor may be evolved to a real time monitor for the ENSAFE solution in the future.

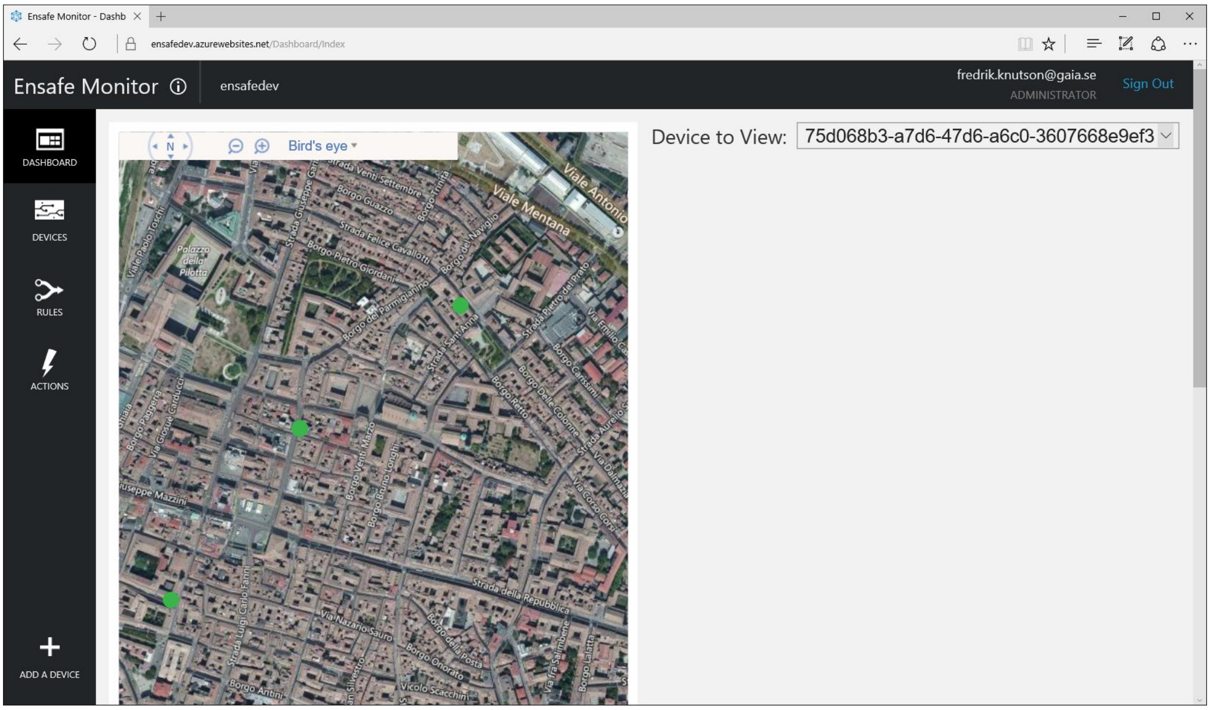


Figure 2 Test Harness for the ENSAFE Cloud platform

# 4 ENSAFE service perspective

The ultimate goal of the whole data gathering and storage process is to enable the subsequent data analysis phase, during which the ENSAFE engine should be able to extract meaningful information about user's daily life habits and provide useful feedback to encourage healthy behaviours. In order to perform such a task, heterogeneous data fusion is necessary: merging the information provided by the smart home, the mobile phone and the clinical sensors together creates a richer description of what the routines of the user may look like. Also, combining information from multiple users may lead to much accurate and useful system feedback

In order to do so, a two-step procedure is devised. At first, each "data provider" (smart-home, mobile, clinical sensors) is analyzed separately to look for recurrent patterns and/or deviation from them. Depending on the target-data of such analysis, the specific implementation changes. For example, for smart home sensors, it is possible to detect trend and anomalies in sensor activation patterns: the probability of a presence in specific rooms distributes with the time of the day, as so do bed/chair occupancies. At the same time, activity patterns picked up by the mobile phone may present regularities (minutes active, steps, visited places). Being able to recognize patterns, performing trend analysis and anomaly detection is the core of this step.

These findings can then be correlated or, more in general, used to build higher-level models. For example, anomalies found in sensor activation patterns could reflect in different behaviors sensed by the mobile phone, therefore validating the discovery. At this stage, information from clinical sensors can be used to provide some form of labeling on the user's health status.

More importantly, at this level, information from multiple users could be exploited to look for similarities between them, possibly discovering interesting information and enabling more meaningful feedback.

The analyses so far provided, along with the feedback stemming from them, constitutes the service prototype. The system is responsible of identifying potentially interesting information but, in the end, users need to interpret such findings. Effective data visualization and presentation is, therefore, capital for the ENSAFE project. It is finally worth remarking that feedback and data presentation may change, depending on the actual target of such information: the end-user (which may be more interested in the feedback or the general trends) or the caregivers (which may want to access the whole data-set in order to gain deeper insights and formulate appropriate interpretation).

# 5 Conclusions

In this document, a description of the products that ENSAFE project intends produce, has been provided.

The products of the ENSAFE system can be seen as two different components:

1. A shared communication infrastructure and a sets of heterogeneous systems to gather and store data related to users' behaviours and habits (both in their home environment and outside).
2. A set of smart services to return useful information to the users and their formal and informal caregivers.

The first component was presented in this document, consisting of a shared communication network and the cloud-enabled sensing technologies. All the sensing elements (wearable/mobile, home and clinical, described in section 2) within the ENSAFE project shall be able to connect to and exchange data with the shared cloud infrastructure (described in section 3). In turn, the cloud infrastructure handles data storage and paves the way for data analytics and service implementation.

The second component is still in a state of preliminary definition. The services that will be implemented are tightly coupled with the outcome of task2 in WP1, which is expected to define use cases and target services.

A key point to highlight is the features of openness, flexibility and scalability of the ENSAFE architecture. From a hardware point of view, the system has been devised to work with any kind of sub-system. The only requirement is that the sub-system must write its data on the shared ENSAFE communication infrastructure. Currently, the behaviour of users is monitored by using a smartphone, home environment sensors and clinical sensors. But, in the future, other monitoring technologies can be added. For example, assuming that in the market there is a new technology specific for the monitoring of eating habits, this feature can be added to the ENSAFE system, simply allowing that system to write its results in the shared ENSAFE infrastructure.

Likewise, from the point of view of smart services, other partners could apply their particular analysis methods to produce other service products. An example could be a pharmaceutical industry that wants to monitor the behaviour of users who are being treated with a certain drug. In this way, a relationship between taking the drug and some changes in behaviours, could be detected.

In addition, the adoption of a standard commercial cloud-based technologies such as infrastructure of the ENSAFE system, allows to maintain, without substantial changes, the same architecture regardless of the number of users and their geographical location.