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An open and private-by-design Active and Healthy Ageing smart home platform

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Abstract

The increasing trend in the percentage of older people among the European population, and in the number of older people living alone, poses a number of challenges, some of which can be addressed from digital solutions monitoring and supporting comfort, physical activity and health. Nowadays, research efforts seek to ensure, through technology-based solutions, the quality of life as people age and the needs that arise during the process. The home environment can host modern home-automation solutions supporting information gathering, monitoring and early intervention to prevent risks to lead to major consequences. Smart homes can thus make a positive contribution to the Active and Healthy Ageing paradigm. However, one of the biggest limitations preventing smart homes from being a reality is the lack of interoperability among different-vendor devices or the fact that most of the commertial solutions rely on cloud-based solutions. This work faces these limitations and proposes an architecture that, based on the use of commercial sensors, ensures that information is gathered and processed locally, independently of the commercial solution provided by the manufacturer of the device. The architecture has been experimentally validated by implementing a monitoring system based on environmental and security sensors interconnected by means of the ZigBee wireless communication protocol. The proposed system also supports caregivers caring for their older people who will be granted access to collected data. Thus, the system offers a remote monitoring system based on an information storage and visualisation solution. This system is intended to provide a solution that improves the quality of life and extends the time of independent living at home for older people.

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Keywords: Internet of Things; Smart Home; Active Aging; Ambient Assited Living; ZigBee

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1. Introduction

The ageing of people is due to the set of physical, social and psychological changes [12], considering an older person from the age of 65 years or older according to the Institute for the Elderly and Social Services (IMSERSO) [16]. According to Eurostat statistics in 2019 the percentage of older people in the EU was 20.3% increasing by 0.3% from 2018 and 2.9% compared to a decade earlier [9]. Based on the latest report from 2020 around 91,967,866 are older people aged 65 and over within the EU-27, for their part Germany and France are countries with the most aged people [10].

According to European Commission projections, between 2016 and 2050 the number of older people in need of long-term care will increase from 19.5 million in 2016 to 23.6 million in 2030 and by 2050 to approximately 30.5 million [8]. If the gradual growth of care for older people living alone or with a degree of assistance is maintained, the health care system as well as specialised care facilities will face a possible collapse because this group faces multiple difficulties ranging from mobility, interaction with the environment and social isolation [11].

The ageing of the population has led to the increasing use of nursing homes for older people [30]. However, there are many studies that show that this situation can lead to symptoms of stress, depression, or changes in behaviour, negatively impacting the quality of life of the older person [29].

The EU demonstrates a strong globalised interest in improving the quality of life, safety and monitoring of physical activities for active ageing [33] by promoting support for programmes such as EaSI [6], EIP on AHA [7] and AAL [1], which encourage the practical use and development of innovative information and communication technologies (ICT) to maintain the quality of independent living as long as possible. Solutions such as "smart homes", "telehealth/telecare" or "telemedicine" for people with chronic diseases or serious conditions are being explored. long as possible.

For this reason, technological solutions providing assistance to relatives or caregivers, mainly deployed in the home environment, are gaining attention. Such solutions provide a modern, social and economic alternative to nursing homes [23], contributing to the sustainability of the health and care system.

Smart homes are becoming a reality from a technological point of view. In these environments, technology can be used to improve the wellbeing and quality of life of older people [13]. Factors such as indoor wellbeing can be of vital importance for older people. Thermal wellbeing goes beyond being comfortable for older people to become an issue of vital importance. Older people are less sensitive to detect changes in environmental temperature, because reduced muscle strength causes their metabolic rate to be lower than that of a younger person. Thus, older people may suffer from cardiovascular problems in cold weather suffering from hypothermia, whereas on the other hand they may suffer from dehydration or heart failure due to high temperatures [33][26].

In this sense, a smart home is a set of devices connected to a network of networks known as the Internet of Things (IoT) [35]. In this network, non-invasive sensors can be implemented and installed to monitor different factors, such as air quality, humidity and temperature [28]. These sensors can also monitor the activities carried out by older people without invading their privacy [21]. The main advantage of these sensors that record environmental parameters compared to others that involve video or voice capture, also used in the monitoring of older people, is that environmental sensors have fewer ethical implications because they have less impact on people's privacy [25].

However, smart home solutions suffer from two major limitations when it comes to exploiting its potential from the Active and Healthy Ageing paradigm. The first one is the lack of interoperability among different vendors. Every manufacturer provides its own software solution for remote control and monitoring. A possible solution to handle devices from more than one manufacturer could be to resort to a home assistant device like Alexa o Google Home, just to name a few. This might be a solution for the device interaction problem, nonetheless, when it comes to information gathering and monitoring, only cloud-based solutions are considered. This poses important challenges in terms of privacy and ethical issues. This work therefore addresses two major challenges of home automation for the Active and Healthy Ageing paradigm: 1) Interoperability support for smart home devices provided by different vendors; 2) Information is locally stored and processed, avoiding the dependance to manufacturer clouds. To this end, this paper proposes an architecture for home automation intended to improve the quality of life of older adults, as well as to ease the monitoring work carried out by caregivers. The architecture is experimentally validated by the implementation of a network of sensors communicating via ZigBee, the use of an MQTT broker, the storage of the data emitted by the sensors in InfluxDB and their visualisation using Grafana is proposed. This work aims to provide relevant information to family members or caregivers involved in the care of older people.

This paper is organized as follows. First, previous works are analysed in Section 2. This section focuses on the different wireless communication systems used for physical and thermal condition monitoring contributing to Active and Healthy Ageing. Section 3 describe the proposed architecture. Section 4 describes the details of the proposed prototype. Section 5 presents an scenario in which the proposed architecture and prototype have been experimentally validated. Section 6 presents the obtained results and, finally, section 7 summarizes the main conclusion and future works.

2. Related Work

The monitoring of health and physical condition by means of non-invasive sensors is becoming increasingly important in the domain of intelligent systems for older people care and attention [13][20]. Previous work on Ambient Assisted Living (AAL) [2] presents a general analysis of techniques for the prevention, detention and intervention from an environmental and technological point of view. Furthermore, the work in [22] even refers to the physical and health danger for the individual. On the other hand, we can conceptualise the AAL technology, as described by [3], in three stages as follows:

- The home state.
- The environmental comfort.
- The individual health condition.

Studies in which technology is used in the home domain to improve the quality of life of an older person are based on the use of wireless sensor networks for monitoring purposes. Such is the case of a smart home in Austria [19] where camera, infrared, motion and voice sensors connected to the Internet via WiFi communication were used for healthcare purposes. The result was an improvement in the physical activities and home environment of the older people. This solution was accepted because of its moderate cost, the disadvantage was privacy due to the use of cameras.

Furthermore, advances in Wi-Fi communication thanks to devices such as the ESP8266, which uses the TCP/IP protocol, have enabled projects such as [15], which monitors energy consumption in the home with the aim of preventing danger to older people in the event of electrical faults. Similarly, [18] implements the same Wi-Fi communication but also includes the use of a messaging protocol such as MQTT with an SSL/TLS transport, from which all the thermal comfort data was obtained both inside and outside a home, the disadvantage was that deployment both inside and outside the home required WiFi repeaters increasing the cost of devices and a delay in data.

The system proposed in [17] offers two advantages: the monitoring of personal safety and the health status of a person living at home. The system, which also supports SMS alerts, uses motion sensors, lighting and magnetic sensors all interconnected via Wifi-enabled IoT technology, one of the problems was that the user had to contract a phone plan to receive the text messages.

The work in [14] presents the implementation of a home automation system based on ZigBee wireless communication technology and an application designed for ARM processors and embedded Linux. The system collects and processes data about temperature, humidity, noise, smoke and positioning of the door or window in real time. It was determined that the energy consumption when implementing the system was more effective than Wi-Fi connectivity while being useful for the needs of a home environment.

An AAL-based system has even been prototyped in [4], where the network consisted of nodes with ZigBee communication, each node incorporating a temperature, light, pressure and motion sensor, so they were placed in each room of the house in order to monitor an older person through a web site. The system issued an alarm to the caregivers when any deviation from the activity patterns was identified, whether due to a fall or something ordinary.

A WSN system was implemented in [27] with six electrical sensors, four force sensors, two contact sensors, a temperature/humidity sensor and an alarm button, all interconnected by a ZigBee network mesh to collect data and visualise it using Microsoft Visual Studio. The system provided data on the behavioural activities of the adults, the determination of the use of household appliances and their health status during sleep, making the WSN a low-cost, robust and flexible system for the well-being of the older.

From the review and analysing its advantages and disadvantages, it is proposed to develop a multi-system that is integrated by: sensing, storage and visualization systems. Non-invasive sensors will be incorporated to obtain data according to the three stages of AAL technology. The same data will be stored in InfluxDB in a constant way and in real time the data will be visualised in Grafana. The multi-system will consist of the interaction of two protocols ZigBee and MQTT which are used in different IoT projects. The advantages in terms of reliability, security, cost and low power consumption are friendly compared to other technologies. The multi-system can be easily implemented in the home and nursing homes, being a more advanced aid for the caregiver and relatives.

3. Methodology and proposed architecture

The analysis of the state of the art reveals that it is very common to find a scenario in which older people have needs in terms of comfort, safety or health. To address this situation, technologies that facilitate active and healthy aging and the maintenance of a high level of quality of life for the older person are used. These solutions related to active and healthy aging mainly use IoT and Big Data platforms. Likewise, it is also important to know the behavior of the older person within his or her home so that family members or caregivers are aware of the older person situation, in many cases preventing an accident from taking place. Thus, the proposed solution consists of the development of a monitoring system to control the environment and the behavior of the older person. The use of this technology allows the older person to live independently for a longer period of time.

A typical monitoring scenario where older people live alone involves the use of sensors such as motion, door and window opening, temperature and humidity sensors. The motion sensor uses infrared detection to recognise the movements of people in the home. The door and window sensor monitors the security of the home by detecting if a door or window is opened in an unusual way (broken or knocked). Finally, the temperature and humidity sensor monitors the thermal comfort of the home in real time. This set of sensors has been chosen because they provide useful information for the safety and comfort of older people. These sensors also allow detecting possible problems related to intrusions in the home. The monitoring system proposed here relies on the collection of information provided by the sensors in real time so that, afterwards, the older person, his/her relatives or caregivers can visualise the data in a fairly simple and intuitive way for a general understanding of the person well-being.

The proposed architecture has been implemented using Zigbee wireless communication and the MQTT messaging protocol for the transport of data collected and published by the sensors. Xiaomi's Aqara and MiJia sensors have been used as they support the Zigbee wireless protocol. These are not the only option, as this architecture can support any of the various alternatives compatible with ZigBee2MQTT [34]. The main objective of this architecture is to monitor the home environment and behaviour of an older person. With this objective in mind, several factors have been taken into account when proposing this architecture. As shown in Figure 1, the design of the proposed architecture has followed a methodology based on 4 stages: a preliminary technology specification, human factors study, smart sensors technology and customer implementation. The first stage consisted in the specification of the technologies that would enable the achievement of the proposed objective, which is the environmental monitoring. For this purpose, the Zigbee and MQTT protocols were selected, as they were considered to be the most effective protocols for this scenario. In the second stage, the different spheres of an older person's life in their home and environment were analysed. Thus, three aspects were identified as having the greatest impact on promoting active and healthy ageing, namely safety, comfort and health. The use of smart sensors inside the home offers a less intrusive and more privacy-preserving solution in comparison to other solutions based on remote video and/or audio monitoring. Finally, in the fourth step, a prototype was implemented to validate the proposed architecture.

In the management of this proposed architecture, different roles are identified: the administrator, the home user and the family or caregiver user. The system administrator is in charge of providing the correct functioning of the monitoring of the older person's home. The home user is the one for whom the monitoring is intended, in this case the older person. Finally, the family or caregiver user is the user who has a relationship, as the name implies because he/she is a family member or caregiver, with the home user. The administrator role has permissions to manage the services but does not have access to the data in the database. He/she will only have access to this data if the home user gives his/her consent.

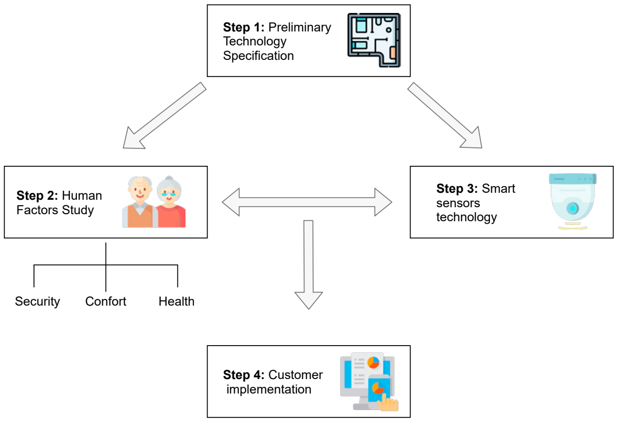


Fig. 1: Proposed Infrastructure

4. Implementation

The implementation carried out for the validation of this proposal involved sensors transmitting the data that were collected through a gateway implemented on a Raspberry Pi 4. This gateway provides a ZigBee wireless interface thanks to the zzh![5] adapter. All services are running on this gateway. Then, the MQTT broker, Mosquitto Eclipse, receives the data that would later be used by an agent to subscribe to the desired topic. The tools used for data storage and visualisation are Telegraf, InfluxDB and Grafana.

It has been also necessary to implement a MQTT client in Python for the motion and window/door sensor. These types of sensors publish Boolean data (true or false) whereas InfluxDB can only store numerical data. Given that the occupancy and contact attributes of these motion, door and window sensors respectively, were publishing true or false values, it was necessary to perform a data transformation so that these could be stored correctly in the database. The MQTT client collects the sensor data published in Mosquitto, changes the true or false value to a digital value and publishes the result of the transformation back to the Mosquitto broker. This data transformation allows this originally Boolean data to be stored correctly in the database.

The fields of the event structure provided by MQTT are entities and attributes. The entities are the sensors that are used in the monitoring and the attributes are the data emitted by these sensors. The key of each attribute is the topic to which the sensors are subscribed to broadcast the data they collect from the environment and the Telegraf agent to collect that data and store it in InfluxDB. The attributes of the sensors vary depending on the sensor type, although they commonly share the attributes of time, battery, host, linkquality, pressure, topic and voltage. In addition to these attributes, each sensor has a specific attribute that shows the behavior of the sensor. The door and window sensor has the attribute contact, the motion sensor has the attribute occupancy and the temperature and humidity sensor has the attributes temperature and humidity. Once they have been published to the MQTT broker, Telegraf stores them in InfluxDB, so the database structure will be made up of these attributes (see Figure 6). On the other side, currently the MQTT channel is configured in such a way that all events are communicated on the same channel, but in the future work will be done so that the event channel will have a channel configured for each room in the home or a channel for each type of sensor.

On the other hand, Telegraf has been used to subscribe an agent to each sensor's topic. Once this change was made for the sensors that needed it, an agent was subscribed to the topic, this agent used Telegraf. The objective of Telegraf is to collect, process and send the metrics of the data from the different topics to be stored in InfluxDB. The role of the database is to store the metrics that have been sent by the Telegraf agent, which is also designed to support high-load writes and reads. Finally, the monitoring process was carried out by the Grafana platform for data analysis. Figure 2 shows a diagram with the devices and technologies that comprise the monitoring environment.

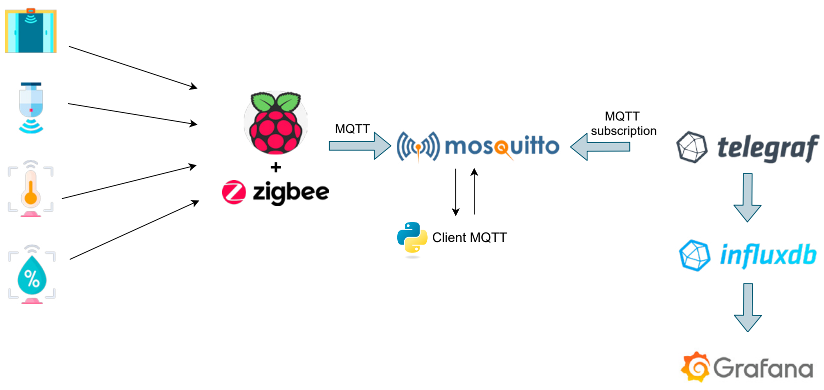


Fig. 2: The devices and the technologies used for the implementation

5. Validation

The proposed architecture has been validated using a real setup (see Figure 3), in which the following sensors have been employed:

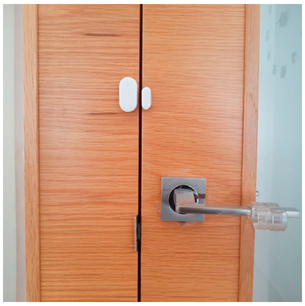
- A MiJia door and window sensor [31]
- A MiJia motion sensor [31]
- An Aqara temperature and humidity sensor [32]
- A Raspberry Pi 4 [24]
- A zig-a-zig-ah! (zzh!) [5]

The technical validation was performed in a private and real home (see Figure 4). For this purpose, the various sensors were placed in different rooms of the house. The temperature and humidity sensor was placed in the kitchen, the motion sensor was placed in the bedroom and the door and window sensor was placed on the living room door. Finally, the Raspberry Pi 4 along with the ZigBee protocol coordinator, the zig-a-zig-ah! was placed in the living room of the home. Once you have the necessary hardware, first run the services that make up the monitoring: ZigBee2MQTT, Mosquitto, Telegraf, InfluxDB and Grafana. Then, the sensors are synchronized to start emitting the data they collect from the environment. To do this, all you have to do is hold for a few seconds the reset button of the sensors you want to add to the monitoring. With these steps the sensors will be subscribed to the event channel. For validation, the prototype was running for a week to see the behavior of the environment and the person. In addition, by looking at the graphics you can get to observe the routine that the user has in his daily life.

6. Results

The proposed architecture is validated through the construction of a prototype based on ZigBee wireless communication and the use of the MQTT messaging protocol. This system monitors the home environment of an older person, collecting information about temperature, humidity, the presence of a person in a physical space and the contact status of doors and windows in the home. Figure 5 presents a capture of the information published in the messaging system (Mosquitto) providing information such as the channel on which the different values are published, the measured values or the timestamp. These observations correspond to data issued by the motion sensor, the door and window sensor and the temperature and humidity sensor. Telegraf will be the recipient of this information for further processing.

Once the Telegraf agent receives this information, it will store it in the InfluxDB database. This database is specifically designed for the storage of time series. Figure 6 shows a snapshot of how data is stored in the InfluxDB database.



(a) Door and Window Sensor

(b) Motion Sensor

(c) Temperature and Humidity Sensor

(d) Raspberry Pi 4 with a zzh!

Fig. 3: Real setup

Fig. 4: Plan of the real environment

Finally, Figure 7 shows an example of a visualisation of the status of the sensors in a given time frame. It has to be highlighted that this dashboard can be accessed remotely by those people authorised to access such informaction (i.e.: relative or caregivers). As it can be observed, the data collected by the sensors is displayed in an intuitive and simple way, supporting different visualization configurations (like the time frame). The image in Figure 7 just present an example of how the environmental monitoring can be carried out. Temperature is measured in degrees Celsius (°C), humidity is shown in percent (%) and movement and contact are shown with digital values (0/1).

In summary, the main result obtained was a technically validated functional prototype for future evaluation in end users, who are the older.

```
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:52:44: MQTT publish: topic 'zigbee2mqtt/smart_motion/SENSOR', payload '{"b
attery":100,"linkquality":105,"occupancy":true,"voltage":3025}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:53:27: MQTT publish: topic 'zigbee2mqtt/smart_temperature_humidity/SENSOR'
, payload '{"battery":100,"humidity":46.18,"linkquality":168,"pressure":946,"temperature":25.22,"voltage":3035}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:53:27: MQTT publish: topic 'zigbee2mqtt/smart_temperature_humidity/SENSOR'
, payload '{"battery":100,"humidity":40.9,"linkquality":168,"pressure":946,"temperature":25.22,"voltage":3035}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:53:27: MQTT publish: topic 'zigbee2mqtt/smart_temperature_humidity/SENSOR'
, payload '{"battery":100,"humidity":40.9,"linkquality":168,"pressure":946,"temperature":25.22,"voltage":3035}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:53:50: MQTT publish: topic 'zigbee2mqtt/smart_door_window_xiaomi/SENSOR',
payload '{"battery":100,"contact":true,"linkquality":138,"voltage":3005}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:53:53: MQTT publish: topic 'zigbee2mqtt/smart_door_window_xiaomi/SENSOR',
payload '{"battery":100,"contact":false,"linkquality":123,"voltage":3005}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:54:07: MQTT publish: topic 'zigbee2mqtt/smart_motion/SENSOR', payload '{"b
attery":100,"linkquality":117,"occupancy":true,"voltage":3025}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:54:52: MQTT publish: topic 'zigbee2mqtt/smart_temperature_humidity/SENSOR'
, payload '{"battery":100,"humidity":40.9,"linkquality":168,"pressure":946,"temperature":24.87,"voltage":3035}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:54:52: MQTT publish: topic 'zigbee2mqtt/smart_temperature_humidity/SENSOR'
, payload '{"battery":100,"humidity":40.95,"linkquality":171,"pressure":946,"temperature":24.87,"voltage":3035}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:54:52: MQTT publish: topic 'zigbee2mqtt/smart_temperature_humidity/SENSOR'
, payload '{"battery":100,"humidity":40.95,"linkquality":171,"pressure":946,"temperature":24.87,"voltage":3035}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:55:37: MQTT publish: topic 'zigbee2mqtt/smart_motion/SENSOR', payload '{"b
attery":100,"linkquality":117,"occupancy":false,"voltage":3025}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:57:36: MQTT publish: topic 'zigbee2mqtt/smart_motion/SENSOR', payload '{"b
attery":100,"linkquality":126,"occupancy":true,"voltage":3025}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:58:00: MQTT publish: topic 'zigbee2mqtt/smart_temperature_humidity/SENSOR'
, payload '{"battery":100,"humidity":40.95,"linkquality":165,"pressure":946,"temperature":24.34,"voltage":3035}'
zigbee2mqtt    | Zigbee2MQTT:info  2021-04-08 17:58:00: MQTT publish: topic 'zigbee2mqtt/smart_temperature_humidity/SENSOR'
, payload '{"battery":100,"humidity":41.56,"linkquality":168,"pressure":946,"temperature":24.34,"voltage":3035}'
```

Fig. 5: Capture of the output provided by the Mosquitto Messaging System

name: mqtt_consumer

time	battery	contact	host	humidity	linkquality	occupancy	pressure	temperature	topic	voltage
1617897125282139267	100		raspberrypi	52.59	159		946	25.76	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035
1617897125294889417	100		raspberrypi	46.18	159		946	25.76	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035
1617897125295816466	100		raspberrypi	46.18	159		946	25.76	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035
1617897157348805961	100		raspberrypi		138				zigbee2mqtt/smart_door_window_xiaomi/SENSOR	3005
1617897157353123857	100	1	raspberrypi		138				zigbee2mqtt/smart_door_window_xiaomi/SENSOR	3005
1617897159677847064	100		raspberrypi		120				zigbee2mqtt/smart_door_window_xiaomi/SENSOR	3005
1617897159680486453	100	0	raspberrypi		120				zigbee2mqtt/smart_door_window_xiaomi/SENSOR	3005
1617897164198215025	100		raspberrypi		105				zigbee2mqtt/smart_motion/SENSOR	3025
1617897164202279959	100		raspberrypi		105	1			zigbee2mqtt/smart_motion/SENSOR	3025
1617897207759194869	100		raspberrypi	46.18	168		946	25.22	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035
1617897207773159882	100		raspberrypi	40.9	168		946	25.22	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035
1617897207773787303	100		raspberrypi	40.9	168		946	25.22	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035
1617897230930757721	100		raspberrypi		138				zigbee2mqtt/smart_door_window_xiaomi/SENSOR	3005
1617897230930898627	100	1	raspberrypi		138				zigbee2mqtt/smart_door_window_xiaomi/SENSOR	3005
1617897233333353380	100		raspberrypi		123				zigbee2mqtt/smart_door_window_xiaomi/SENSOR	3005
1617897233336894855	100	0	raspberrypi		123				zigbee2mqtt/smart_door_window_xiaomi/SENSOR	3005
1617897247429765912	100		raspberrypi		117				zigbee2mqtt/smart_motion/SENSOR	3025
1617897247435828369	100		raspberrypi		117	1			zigbee2mqtt/smart_motion/SENSOR	3025
1617897292550940084	100		raspberrypi	40.9	168		946	24.87	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035
1617897292568235926	100		raspberrypi	40.95	171		946	24.87	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035
1617897292568781089	100		raspberrypi	40.95	171		946	24.87	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035
1617897337432417857	100		raspberrypi		117				zigbee2mqtt/smart_motion/SENSOR	3025
1617897337437168398	100		raspberrypi		117	0			zigbee2mqtt/smart_motion/SENSOR	3025
1617897456384990688	100		raspberrypi		126				zigbee2mqtt/smart_motion/SENSOR	3025
1617897456388969771	100		raspberrypi		126	1			zigbee2mqtt/smart_motion/SENSOR	3025
1617897480032613097	100		raspberrypi	40.95	165		946	24.34	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035
1617897480051580799	100		raspberrypi	41.56	168		946	24.34	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035
1617897480051706354	100		raspberrypi	41.56	168		946	24.34	zigbee2mqtt/smart_temperature_humidity/SENSOR	3035

Fig. 6: List of data in InfluxDB

7. Conclusions and future work

This paper presents an architecture intended to address two of the major challenges faced by home automation solutions for Active and Healthy Aging domains, as known, the need for interoperability support among different vendors devices and the need to avoid the vendors cloud solutions for privacy and ethical issues. The proposed architecture has been experimentally validated in the context of solution intended to monitor the older person behaviour and home environment using ZigBee wireless communication. The purpose of this monitoring system is to positively contribute to active and healthy ageing by enabling family members and caregivers to remotely monitor the older person's home and behaviour.

Commercial solutions offered by manufacturers are usually linked to the use of their own monitoring tool. This tool, furthermore, is usually based on cloud solutions, which means that the data is beyond the user control. Therefore, it is necessary to propose an alternative solution to the one proposed by the manufacturers whenever sensors from more than one manufacturer are to be deployed and whenever the aim is to guarantee that data is not transferred to the manufacturer's cloud. This work aims to address these issues by proposing an architecture based on Zigbee wireless communication, which enables the interconnection of sensors from different manufacturers, using a *gateway*. This solution is able to support a wide variety of sensors, not being necessary to limit to the set of sensors offered by a

Fig. 7: Data visualization in Grafana

certain manufacturer. ZigBee also has numerous advantages such as low cost, low power consumption and reduced resource consumption compared to Wifi. The gateway can be used to host a Fog Computing solution, where the storage and visualisation system can run. This gateway can offer a public interface for remote access. But this is not the only configuration as storage and visualisation can also be done in the cloud. In this case it would be a private cloud that would have nothing to do with the cloud offered by the different sensor manufacturers.

As future work, the prototype built will have to be validated in the real environment of end users where usability, robustness, scalability and security will have to be evaluated more thoroughly.

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References

[1] AAL, . Programme "active assisted living". URL: https://www.aal-europe.eu/.
[2] Belbachir, A.N., Drobics, M., Marschitz, W., 2010. Ambient assisted living for ageing well an overview. Elektrotechnik Und Informationstechnik 127, 200–205. URL: <GotoISI>://WOS:000218272900049, doi:10.1007/s00502-010-0747-9.
[3] Cahill, J., Portales, R., McLoughin, S., Nagan, N., Henrichs, B., Wetherall, S., 2019. Iot/sensor-based infrastructures promoting a sense of home, independent living, comfort and wellness. Sensors 19, 39. URL: <GotoISI>://WOS:000459941200048, doi:10.3390/s19030485.
[4] Dasios, A., Gavalas, D., Pantziou, G., Konstantopoulos, C., 2015. Hands-on experiences in deploying cost-effective ambient-assisted living systems. Sensors (Switzerland) 15, 14487–14512. URL: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84934888482&doi=10.3390%2fs150614487&partnerID=40&md5=da011d709c2d69ab8b163a3ef83ee40d, doi:10.3390/s150614487. cited By 27.
[5] Electrolama, . zig-a-zig-ah! URL: https://electrolama.com/projects/zig-a-zig-ah/.
[6] European Commission, a. Eu programme for employment and social innovation (easi). URL: https://ec.europa.eu/social/main.jsp?catId=1081.
[7] European Commission, b. European innovation partnershipon active and healthy ageing. URL: https://ec.europa.eu/eip/ageing/home_en.html.

[8] European Commission, c. Green paper on ageing: Fostering solidarity and responsibility between generations. URL: https://ec.europa.eu/info/files/green-paper-ageing-fostering-solidarity-and-responsibility-between-generations_en.

[9] Eurostat, a. Elderly population across eu regions. URL: https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/ddn-20200402-1.

[10] Eurostat, b. Population on 1 january by broad age group and sex. URL: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_pjanbroad&lang=en.

[11] Fernández Vilorio, L., et al., 2020. La soledad en las personas mayores URL: http://uvadoc.uva.es/handle/10324/42641.

[12] García, A.A., Maya, S., 2014. Aging concept analysis — análisis del concepto de envejecimiento. Gerokomos 25, 57–62. doi:10.4321/s1134-928x2014000200002.

[13] Ghorayeb, A., Comber, R., Gooberman-Hill, R., 2021. Older adults' perspectives of smart home technology: Are we developing the technology that older people want? International Journal of Human-Computer Studies 147, 13. doi:10.1016/j.ijhcs.2020.102571.

[14] He, J.H., 2016. The design of smart home for the elderly based on zigbee, in: 8th International Conference on Computer and Automation Engineering (ICCAE), E D P Sciences, CEDEX A. URL: <GotoISI>://WOS:000386717000049, doi:10.1051/matecconf/20165605016.

[15] Hlaing, W., Thepphaeng, S., Nontaboot, V., Tangsunantham, N., Sangsuwan, T., Pira, C., Ieee, 2017. Implementation of wifi-based single phase smart meter for internet of things (iot). 2017 International Electrical Engineering Congress (Ieecon) , 4URL: <GotoISI>://WOS:000425856700074.

[16] Instituto de Mayores y Servicios Sociales, . Falls. URL: https://www.imserso.es/InterPresent1/groups/imserso/documents/binario/informome_pmvol1_2000.pdf.

[17] Kodali, R.K., Jain, V., Bose, S., Boppana, L., 2016. Iot based smart security and home automation system. 2016 Ieee International Conference on Computing, Communication and Automation (Iccca) , 1286–1289URL: <GotoISI>://WOS:000393168500235.

[18] Kodali, R.K., Mahesh, K.S., 2016. A low cost implementation of mqtt using esp8266. Proceedings of the 2016 2nd International Conference on Contemporary Computing and Informatics (Ic3i) , 404–408URL: <GotoISI>://WOS:000406611800073.

[19] Mageroski, A., Alsadoon, A., Prasad, P.W.C., Pham, L., Elchouemi, A., Ieee, 2016. Impact of wireless communications technologies on elder people healthcare: Smart home in australia, in: 13th International Joint Conference on Computer Science and Software Engineering (JCSSE), Ieee, NEW YORK. pp. 145–150. URL: <GotoISI>://WOS:000389036200026.

[20] Marques, G., Pitarma, R., Garcia, N.M., Pombo, N., 2019. Internet of things architectures, technologies, applications, challenges, and future directions for enhanced living environments and healthcare systems: A review. Electronics 8, 27. doi:10.3390/electronics8101081.

[21] Maskeliunas, R., Damasevicius, R., Segal, S., 2019. A review of internet of things technologies for ambient assisted living environments. Future Internet 11, 23. URL: <GotoISI>://WOS:000505727300005, doi:10.3390/fi11120259.

[22] Miralles, F., Vargiu, E., 2015. Providing physical and social autonomy to disabled people through bci, telemonitoring and home support. Intelligenza Artificiale 9, 73–87. URL: <GotoISI>://WOS:000358145300007, doi:10.3233/ia-150078.

[23] Ni, Q., Hernando, A.B.G., de la Cruz, I.P., 2015. The elderly's independent living in smart homes: A characterization of activities and sensing infrastructure survey to facilitate services development. Sensors 15, 11312–11362. URL: <GotoISI>://WOS:000357183100089, doi:10.3390/s150511312.

[24] RaspberryPi, . Raspberry pi 4. URL: https://www.raspberrypi.org/products/raspberry-pi-4-model-b/.

[25] Schopp, A., Leino-Kilpi, H., Valimaki, M., Dassen, T., Gasull, M., Lemonidou, C., Scott, P.A., Arndt, M., Kaljonen, A., 2003. Perceptions of privacy in the care of elderly people in five european countries. Nursing Ethics 10, 39–47. URL: <GotoISI>://WOS:000180526200006, doi:10.1191/0969733003ne573oa.

[26] Soebarto, V., Zhang, H., Schiavon, S., 2019. A thermal comfort environmental chamber study of older and younger people. Building and Environment 155, 1–14. URL: https://www.sciencedirect.com/science/article/pii/S0360132319301945, doi:https://doi.org/10.1016/j.buildenv.2019.03.032.

[27] Suryadevara, N., Mukhopadhyay, S., 2012. Wireless sensor network based home monitoring system for wellness determination of elderly. IEEE Sensors Journal 12, 1965–1972. URL: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84860538536&doi=10.1109%2fJSEN.2011.2182341&partnerID=40&md5=d024ac55c7d86ceb927fa31ad96c67df, doi:10.1109/JSEN.2011.2182341. cited By 240.

[28] Taramasco, C., Riquelme, F., 2019. Design of a system of systems (sos) for the interoperability of non-invasive sensors for the care of older people. Medinfo 2019: Health and Wellbeing E-Networks for All 264, 1572–1573. URL: <GotoISI>://WOS:000569653400363, doi:10.3233/shti190540.

[29] Unroe, K.T., Sachs, G.A., Dennis, M.E., Hickman, S.E., Stump, T.E., Tu, W.Z., Callahan, C.M., 2015. Hospice use among nursing home and non-nursing home patients. Journal of General Internal Medicine 30, 193–198. URL: <GotoISI>://WOS:000349234300011, doi:10.1007/s11606-014-3080-x.

[30] Weathers, E., O'Caoimh, R., Cornally, N., Fitzgerald, C., Kearns, T., Coffey, A., Daly, E., O'Sullivan, R., McGlade, C., Molloy, D.W., 2016. Advance care planning: A systematic review of randomised controlled trials conducted with older adults. Maturitas 91, 101–109. URL: <GotoISI>://WOS:000381325800014, doi:10.1016/j.maturitas.2016.06.016.

[31] Xiaomi, a. Manual de usuario de mi smart sensor set , 16–17URL: https://i01.appmifile.com/webfile/globalimg/Global_UG/Mi_Ecosystem/Mi_Smart_Sensor_Set/es-ES_V1.pdf.

[32] Xiaomi, b. Temperature and humidity sensor manual , 5URL: https://files.miot-global.com/files/manuals%20updated/Temperature%20and%20Humidity%20Sensor%20Quick%20Start%20Guide.pdf.

[33] Zhang, D., Kong, W., Kasai, R., Gu, Z., Shiguematsu, Y., Cosentino, S., Sessa, S., Takanishi, A., 2018. Development of a low-cost smart home system using wireless environmental monitoring sensors for functionally independent elderly people, pp. 153–158. URL: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85048344764&doi=10.1109%2fROBIO.2017.8324410&partnerID=40&md5=c68982fb5f51c4786b585c097b52a2a6, doi:10.1109/ROBIO.2017.8324410. cited By 3.

[34] Zigbee, . Supported devices of zigbee. URL: https://www.zigbee2mqtt.io/information/supported_devices.html.

[35] Zouai, M., Kazar, O., Haba, B., Saouli, H., Ieee, 2017. Smart house simulation based multi-agent system and internet of things. Proceedings of the 2017 International Conference on Mathematics and Information Technology (Icmit) , 201–203URL: <GotoISI>://WOS:000425538100027.