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TOWARD A SMART ECOSYSTEM WITH AUTOMATED SERVICES

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Abstract. *New ICT architectures enable a better response to constant pressure on the industry and services to improve their business performance and productivity, especially in data processing. At the same time, due to the growing number of sensor modules, the amount of data that needs to be processed, in real time, is growing. Delays in communication with the cloud environment can lead to poor management decisions or user dissatisfaction. In automation and services, one of the new ICT architectures is Edge computing in the data processing. Edge computing is a networking architecture that brings computing close to the source of data in order to reduce latency and bandwidth use. Edge computing brings new power to data processing and the ability to process large amounts of data in real time. This is essential for predicting the behavior of machines, systems, or customers in order to detect errors or provide personalized service as in the case of smart vending machines. In that way, Edge computing enables taking steps toward establishing a smart ecosystem in automation and services.*

Key Words: *IoT/IIoT, Cloud Computing, Edge Computing, Ecosystem*

1. INTRODUCTION

Nowadays the edge between the physical and the digital worlds is starting to disappear. The reason for this is communication and artificial intelligence implemented in machines, and devices, not only in the industrial but also in the non-industrial environment. In that way society can gain added value in every aspect of everyday life, and also, availability to innovate in new ways, using smart ecosystems to create new digital revenue streams.

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One of the key technologies that enable the formation of a smart ecosystem is the Internet of Things (IoT). IoT is a network of devices, equipment, and machines capable of interacting with each other. The idea is to obtain information about the environment to understand, control and act according to this information. A specific part of IoT is Industrial IoT (IIoT). IIoT is implemented in the industrial environment thus providing more accurate and real-time visibility in the flow of materials, parts and products in a production line and warehouse management. Also, production systems are investing in the IIoT to redesign production workflows, improve tracking of materials, tools, and optimize production costs [1].

IoT uses different kinds of sensors and devices to collect data from the targeted environment about status/changes of interest. The changes in the surroundings are detected by the sensor and sent to a device. Sensors come in a variety of formats depending on the data of interest, so they can be in form of passive sensors, active sensors, or optical, thermal, mechanical, electrical ones, etc. These sensors forward their data to the devices. A device aggregates data and sends it to the cloud for processing. The device uses a gateway to transmit the data to the network within the cloud. This data is stored in the cloud which in turn makes services and functions accessible [2].

IoT system generates numerous data that needs processing, storage, caching, transmission and computation. Some applications, especially industrial ones, need responses in a shorter time (real-time). Processing a large quantity of data also brings a great burden to the network [3]. This is the main reason why edge computing, cloud computing and fog computing were introduced and are of essential importance in the development of the smart ecosystem.

Edge computing means computing at the edge of the network, where the edge refers to the resources and equipment along the path between data sources and cloud data centers, especially in the proximity of terminal devices. In edge computing, people utilize open platforms provided with capabilities of computation, storage, communication and application around data sources to supply different services, within the requirements of agile connection, real-time service, data optimization, application intelligence and security protection [4]. An essential part of Edge computing is the middle layer, placed between the end device layer and the central cloud layer named Edge gateway layer. This layer consists of the edge gateways that are in the vicinity of end devices and have relatively rich resources. In many cases, end devices may not be able to process continuously generated sensor data in real-time. Many works aim at offloading computation from end devices to edge gateways to achieve a lower processing latency [5].

Cloud computing is a model for enabling ubiquitous, convenient and on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [6].

Fog computing, on the other hand, represents the link between IoT nodes/devices and the cloud by empowering storage, data management, networking, and computing on the network nodes [7]. Fog computing reduces the burden of traditional cloud computing data centers and works based on decentralized computing concepts to improve the computational speed [8].

2. IoT ARCHITECTURE

For a better understanding of the steps involved in the design of different IoT architectures, we can keep in mind the following and most common ones among many existing definitions of IoT:

- The interconnection *via* the Internet of computing devices is embedded in everyday objects, enabling them to send and receive data [2],
- IoT is a recent communication paradigm that envisions a near future, in which the objects of everyday life will be equipped with microcontrollers, transceivers for digital communication, and suitable protocol stacks that will make them able to communicate with one another and with the users, becoming an integral part of the Internet [3],
- IoT is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment [4].

It is obvious that IoT is a complex system, and all the elements of the architecture must be synchronized together perfectly in a systematic structure. To organize this complex structure a variety of IoT architecture models were suggested.

The most widely used IoT architecture is the Five-Layered model [9]. This model consists of the following layers:

1. Perception layer - The Perception Layer is the tangible layer that uses devices and sensors for the collection of data from the environment. (sensors, RFID (Radio Frequency Identification) tags, cameras) [10],
2. Network layer - The Network Layer connects the devices to other smart devices by the transmission of the data to the cloud servers for processing (Wi-Fi, ZigBee, Signal, Bluetooth) [10],
3. Middleware layer - The Middleware Layer links the database and matches services with equivalent requesters as a software layer (data storage, cloud network) [11],
4. Application layer - The Application Layer delivers the operation essential services to the user that depicts large-scale IoT applications (Smart Cities, Smart Homes, Smart Health) [10], and,
5. Business layer - The Business Layer can manage the overall system and this layer builds assorted business models (Business Models, Monitoring) [11].

When analyzing the complexity of industrial and non-industrial processes, in most cases, there emerges a problem of processing and storing a large quantity of data. In these cases, efficient architecture that can be established is IoT-Edge-Fog-Cloud architecture (Fig. 1.) and the layers in this architecture are the following [12]:

1. IoT things layer - The IoT Things layer mostly manages information sensing and capturing. Things implanted with sensors and actuators form a part of this layer (sensors and smart devices) [13],
2. Edge layer - In the Edge layer, the processing is carried out along the network's edge. This is an intermediate layer between the end-user and the cloud and it provides storage and processing functionalities to an enormous number of IoT devices (routers, switches) [13],
3. Fog layer - In the Fog layer, computing is shifted below to the Local Area Network for information to be processed at IoT gateways or micro-data centers (fog nodes, satellites) [13],

4. Cloud Layer - The cloud layer focuses on big data analytics, industrial-level databases, and processing along with data warehousing. All these calculations are carried out centrally in far-away cloud centers (cloud storage, cloud servers) [13].

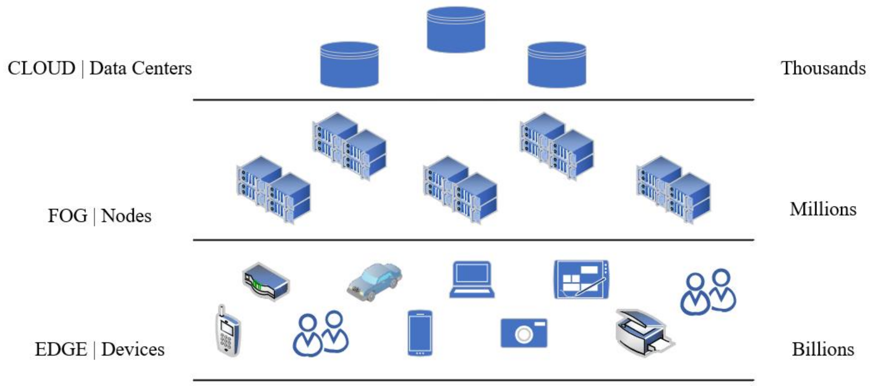

Fig. 1 IoT-Edge-Fog-Cloud architecture based on [12]

In some cases, where there is a need for trusted data and security, this architecture needs implementation of blockchain technology. Blockchain enables forming of distributed databases, multi-party cooperation, openness and transparency with disabling non-tampering and non-repudiation data access [14].

The services obtained by using self-service automated systems (like vending machines) are just one of the examples showing the complex structure of IoT. The growing demand for a fast and personalized service has led to an increase in the use of self-service automated systems in various fields. Self-service automated systems are becoming digitalized, enabling them not only to provide a service to customers, but also a marketing service for retailers. With the development and adoption of new ICT technologies today, self-service automated systems are becoming smart. They collect their data through IoT technologies for processing, in order to improve the service. Interconnected systems, which are service-oriented solutions in the cloud environment, enable retailers to provide customers with a better shopping experience. Understanding and predicting customer behavior is a very important feature of smart automated systems. The goal is to approach each customer with personalized service and to suggest products that are interesting to him/her based on his/hers habits. Real-time data collection and processing with the introduction of business intelligence is necessary to display personalized messages to customers. Due to the growing number of sensor modules, the amount of data that needs to be processed in real time is also growing. Delays in communication with the cloud environment can lead to wrong management decisions and/or user dissatisfaction. One possible solution to this problem is the application of Edge computing, which enables the processing of large amounts of data in real time. This is essential for predicting customer behavior, providing personalized service as well as troubleshooting smart service machines (e.g. vending machines).

2.1 IoT Self-Service Automated Systems

Self-service automated systems are present in almost every aspect of our lives. They provide their services or products to customers 24/7 without the need for employees to be present. This reduces labor costs [15]. One of the best examples of self-service automated systems is a vending machine. According to the European Sales Association, there are about 4 million vending machines in Europe that sell about 80 million items a day. The total turnover of vending machines for 2018 is 15 trillion euros [16]. Due to the increasing use of self-service automated systems, various services and products, a constant tendency to improve them also emerges. One way of achieving an improvement is to expand the functionality and implementation of new technologies. The cost-effectiveness of any self-service automated system depends on its productivity and the quality of services it provides [17]. However, it is not only the provision of services that is important to users but also the way in which the service is provided, which must be accessible, consistent and reliable. Otherwise, users will be dissatisfied and will not use a self-service automated system or will use the service of another manufacturer [18-19]. As more services appear, i.e. new self-service automated systems, the user experience will be the dominant factor for the successful usage of new systems and services [20]. Customer satisfaction is becoming one of the most important goals of all the manufacturers who want a long-term relationship with the customer. One of the main aspects that determine customer satisfaction is the perceived quality of service. Consumer perceived quality is the ratio between the user's expectations of the service itself and the perception of the service received [21-23]. The quality of service of the self-service automated system is deeply related to customer satisfaction and loyalty (Fig.2.) Customer loyalty is a consequence of the overall and cumulative experience that customers have with the service provided. Customer satisfaction can lead to customer loyalty because customers tend to use services with which they have already had positive experiences. Customer loyalty and satisfaction are the most researched areas of marketing today. However, measuring loyalty and satisfaction is not an easy task. What one user perceives as good, another user may consider average or even poor. One of the most commonly used models for measuring the quality of service is SERVQUAL, developed in 1988 and designed to analyze customer expectations and perceptions of service in five dimensions believed to represent service quality [24-25], namely:

- Reliability - consistency of service delivery,
- Tangibility - visual experience of customers and quality of equipment,
- Helpfulness - willingness to help customers and provide fast service,
- Security - knowledge and kindness of employees and their ability to inspire trust, and,
- Empathy - care and individual approach to customers.

With the concept of the IoT, data is collected, analyzed and made available for further use. IoT expands the connection between things with minimal need for human intervention. IoT means that standard and smart devices and even living beings (plants and animals) are assigned identification numbers and the ability to communicate and exchange data over the Internet completely independently. Information-communication technologies enable the connection "at any time" and "at any location", while the application of the IoT enables the connection of "anything". The concept of the IoT is not the result of one new technology, but a combination of several technologies which, when combined, enable a connection between the virtual and the physical world. Those technologies are the following:

- Sensors,
- Data processing,
- Actuation,
- Communication and cooperation,
- Addressability,
- Identification,
- Localization, and,
- User interface.

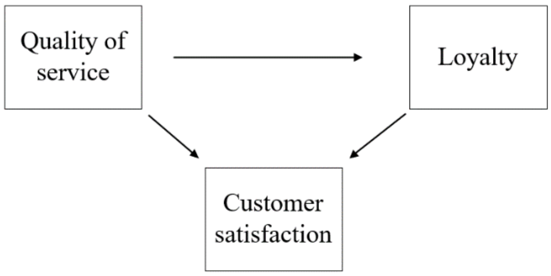

Fig. 2 The relations between service quality, customer satisfaction and loyalty to the manufacturer based on [22]

Data are collected and analyzed to increase the efficiency and productivity of a self-service automated system [26-29]. Smart systems that are more service-oriented cloud solutions enable retailers to provide customers with a better shopping experience [30-31].Understanding and predicting customer behavior is a very important feature of smart automated systems [32].The customer experience, as mentioned earlier, has the greatest impact on the customers' intentions toward innovative ways of buying, paying and providing services. The goal is a personalization of customers' service and suggests products that are of interest based on customers' habits. Self-service automated system data collection, with the implementation of business intelligence and knowledge management services can enable the displaying of personalized messages to customers to entice them to use a self-service automated system.

3. SMART ECOSYSTEMS

With a strong tendency to achieve sustainability, cities are turning to their smartness. Smart cities mean city/infrastructures' ability to adapt to everyday changes by using advanced technologies and resources in an integrated way in order to achieve socially and environmentally viable economic growth. City smartness relies on two pillars [33]:

1. A tangible one, including the physical infrastructures and channels that intertwine the entities who participate in the functioning of the city, and,
2. An intangible one, consisting of the tacit and immaterial factors that underpin the city's identity and subjectivity.

In order to establish smart ecosystem implementation, both natural and artificial components must be considered, which are strictly intertwined in the design and implementation of initiatives intended to foster the achievement of sustainability.

Concerning strategy, three different aspects of a smart ecosystem [34] can be identified, namely: business ecosystem, which centers on an industry and its environment (industry); platform ecosystem, which considers how stakeholders organize around a platform (software providers); and innovation ecosystem (industry, innovation centers, university), which focuses on a particular innovation or new value proposition and the constellation of the actors supporting it. Innovation ecosystems require multiple stakeholders to come together and collaborate for a new innovative value proposition to take effect.

In [35] authors define a smart ecosystem as a system that is much like a natural biological ecosystem: a distributed, adaptive, open socio-technical system with the properties of self-organization, scalability, and sustainability. Usually, in the smart ecosystem devices are connected to a network and allowed to communicate outside their domain (typically by the Internet) [36]. An example of devices in a smart ecosystem in [37] is presented HVAC (heating, ventilation, and air conditioning) system for controlling the energy supply to an electric motor that powers pumps, fans, compressors, and other equipment (Fig. 3). This smart ecosystem can be applied in different environments like water distribution systems [38].

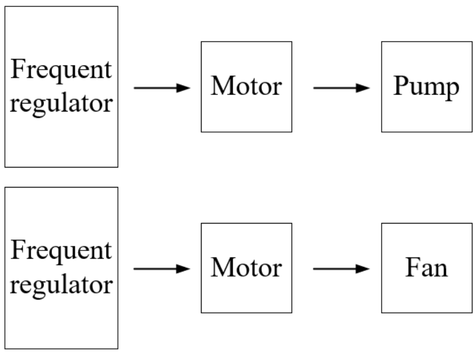

Fig. 3 Examples of devices in a smart ecosystem based on [37]

In [39] authors present a concept and the framework for designing a smart energy network ecosystem for integrated energy services in urban areas. Also, they present initial results for the test platform Smart Otaniemi which is an innovation ecosystem that connects experts, organizations, technologies, and pilots. The platform is based on the framework of the smart energy network ecosystem which is shown in Fig. 4.

Initially, the platform involved 11 companies and three research institutes and the first experiment with the platform began in 2018.

Using the idea from the framework of the smart energy network ecosystem shown in Fig. 4, the University of Novi Sad and the University of Niš, started to develop applications for a smart gas network eco-system in Serbia. In the next chapter some of the ideas of the smart gas network ecosystem in Serbia will be presented.

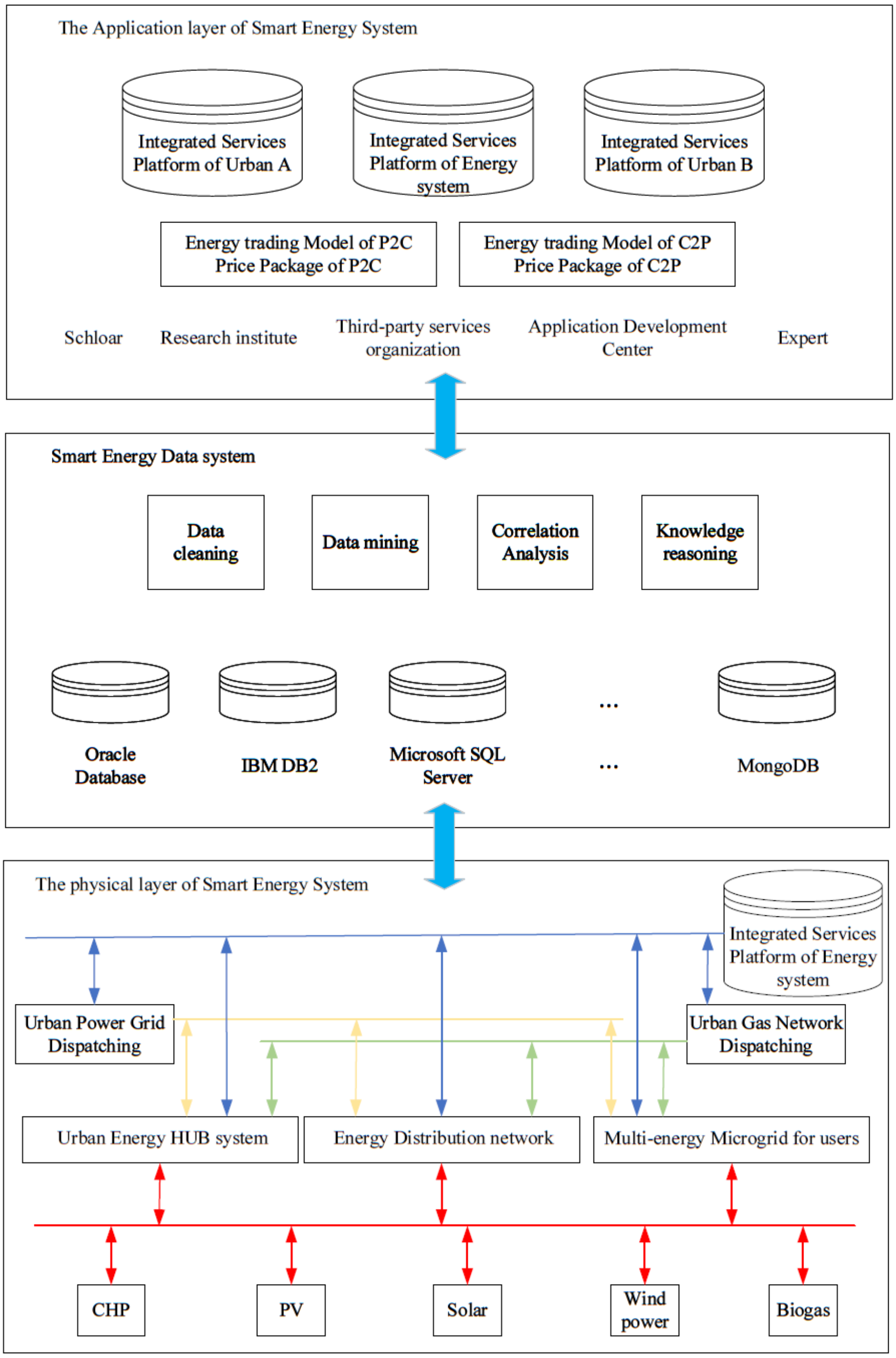

Fig. 4 The framework of the smart energy network ecosystem based on [39]

A typical self-service automated system consists of a LCD touch panel, payment devices (cashless payment device and bill and coin payment device), an embedded industrial PC, a control board, a thermal ticket printer and a communication module (Fig. 5.).These components enable a self-service automated system to be part of a smart ecosystem and are present in most automated systems today [40-44].

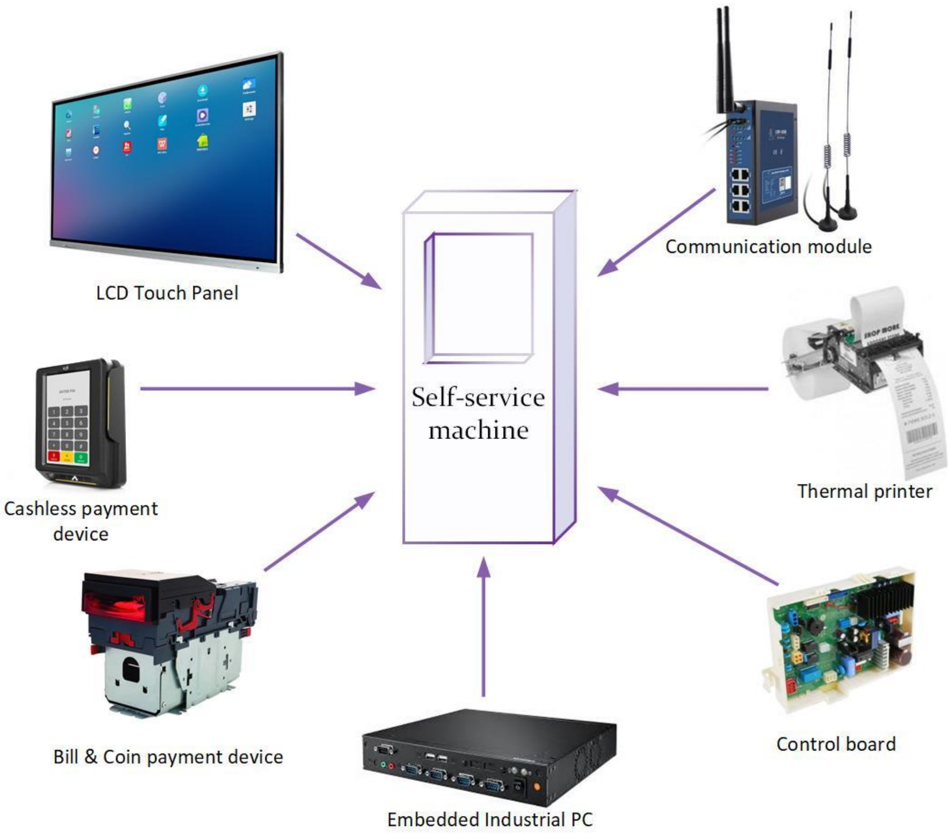

Fig. 5 Components of a typical self-service automated system

Self-service automated systems, in the case of vending machines, are also a typical representative of systems that have two types of users: Customer and Administrator. Their basic roles are shown in Fig. 6.

In order to develop a new generation of smart ecosystems with self-service automated systems, at the University of Novi Sad and the University of Nis, a model of augmented reality support with self-service automated systems has been developed. The next chapter presents how the model can be applied in a smart shop with a smart vending machine.

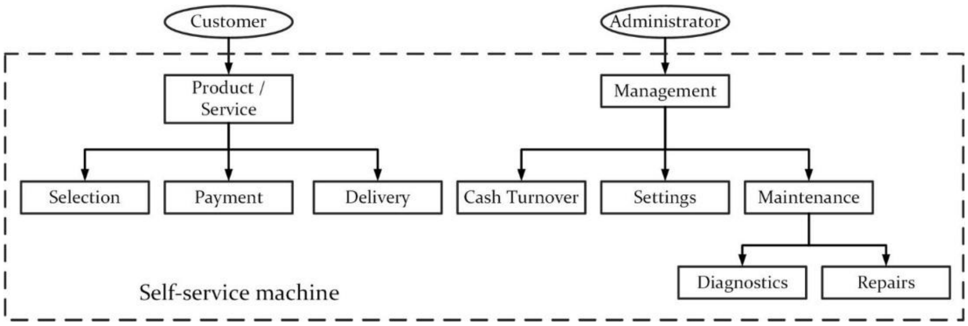

Fig. 6 Two types of users on the self-service automated system/vending machines

4. Smart Ecosystems: Case Studies

4.1 The Smart Gas Network Ecosystem

For every individual home, buildings, industries, and communities, one of the main challenges concerns the way energy is managed because energy is one of the biggest cost drivers for each of these entities. Especially, in the light of global rising energy costs and strict environmental regulations, this challenge is becoming more important. In many buildings and factories, a smart ecosystem to monitor, control, measure, and optimize energy consumption, can be found. Usually, these smart ecosystems use available smart energy management systems. In the case of individual homes, another approach can be offered, like using a smart gas network eco-system (to optimize gas consumption). In Fig. 7, the framework of the smart gas network ecosystem, based on the framework of the smart energy network ecosystem [39] is represented.

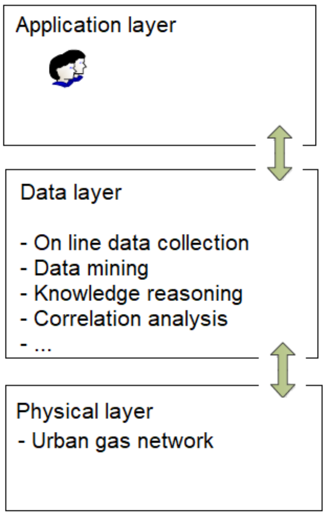

Fig. 7 The framework of the smart gas network ecosystem

At the application layer, any customer who has a gas meter can check the current status of the consumed gas on the mobile/web application. One of the images which appear in the application for mobile devices is shown in Figs. 8 and 9. The data displayed in the application is obtained by accessing the server located within the data layer. As part of the version I of this application, the customer can have an insight into the current state of his/her gas meter and check the consumption in a certain period.

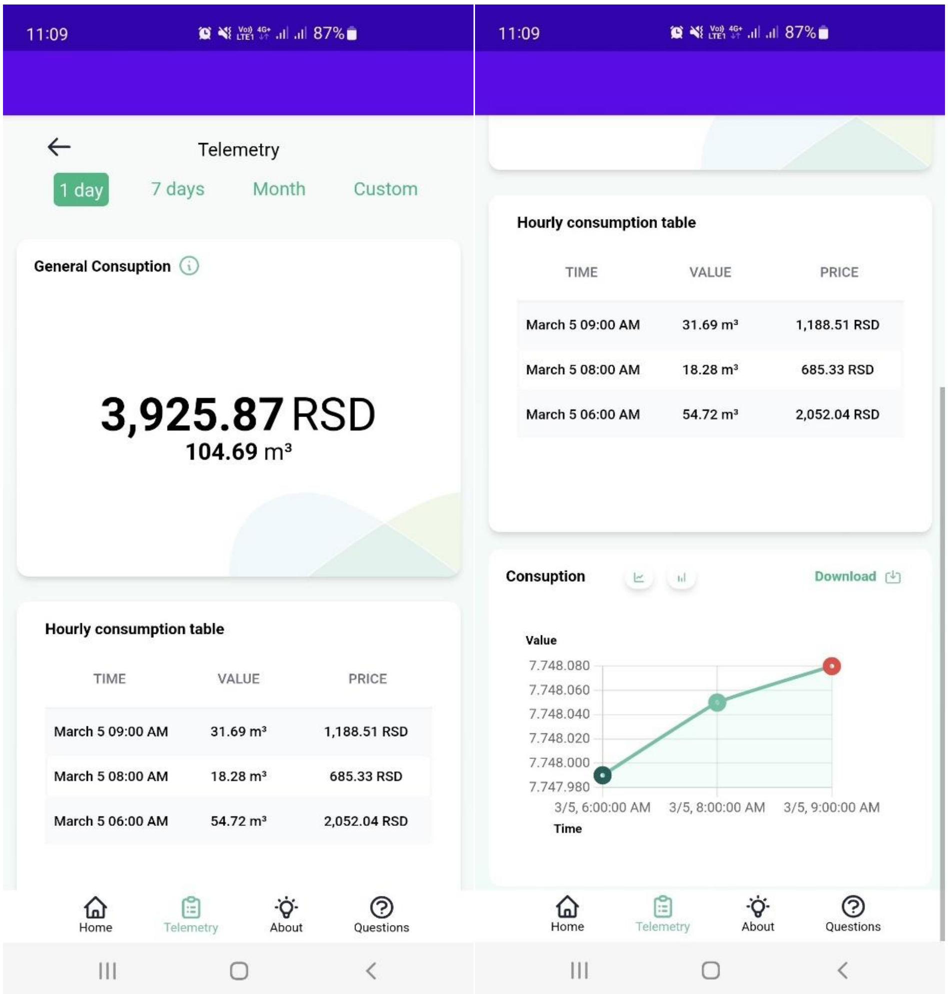

Fig. 8 Screenshots of the mobile application for displaying gas consumption for 1 day

In order to minimize communication requirements, data exchange between the application layer and the data layer is performed once per hour [45].

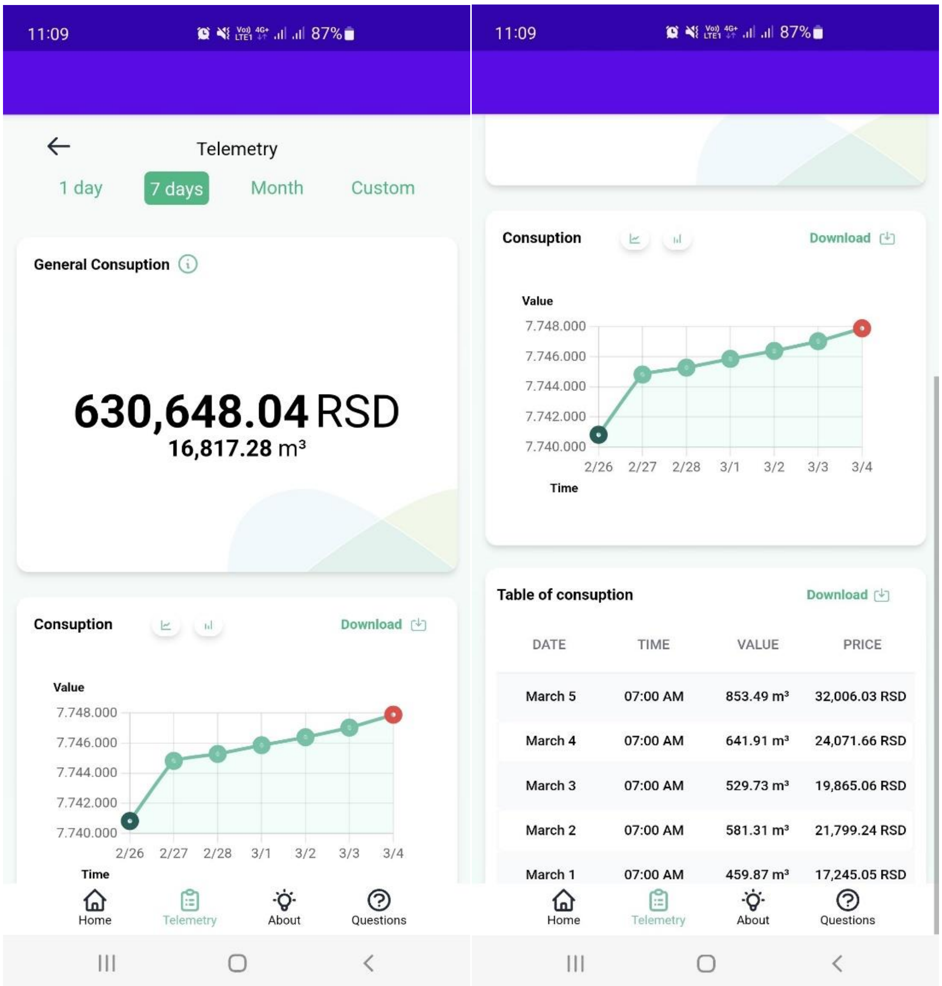

Fig. 9 Screenshots of the mobile application for displaying gas consumption for 7 days

The current read value from the gas meter represents the total gas consumption. In the case where is a problem in receiving data from the gas meter, the value temporarily entered is 0 for the particular hour of reading. The approximate value for the particular hour of reading when the data (M) of gas consumption has not been received, is determined based on the formula M = L + S * (C-L) / H where C represents the current value of gas consumption from the gas meter, L represents the last read value from the gas meter, H represents the difference in the number of hours between the readings of C and L, S represents the difference in the number of hours between the readings of M and L.

At the data layer, there are servers and databases. Servers allow data to be collected from the physical layer and forwarded to the application layer. Databases allow the storage of all collected data. In version II of the data layer, modules for data analysis will be added in order to make better decisions for the management of gas supply, distribution and consumption.

At the physical layer, there are smart gas meters, which enable the sending and receiving of data via the LoRa network. The data sent from the gas meter refers to the gas consumption, the gas pressure in the network, and the received data from the application can be used to open and close the gas control valve.

Version II of this application will have the incorporation of consumption prediction based on previous consumption and predicted weather conditions. Version III of this application will have the incorporation of artificial intelligence that will enable the user to set conditions that would allow the application to manage gas consumption. For example, the user sets the desired amount of money (gas consumption) for a certain period, and the application determines how much would be spent each hour during a given period.

4.2 The Smart-Shop Network Ecosystem

Self-service automated systems base their success on the successful realization of the link between service quality, customer satisfaction and customer loyalty (Fig. 2).One of the important steps in this realization is the recognition of customers' habits as well as typical customers' behavior. Besides the successful implementation of these relations, for the realization of a self-service automated system, the following characteristics should be taken into account (especially in the case of smart vending machines) [46].

- Cashless payment,
- Networked location data,
- Video and touch screen communication,
- Mobile and facial recognition,
- Remote experts,
- Point-of-purchase marketing opportunity, and,
- Targeted advertising impressions.

In addition to these parameters in the implementation of the smart shop, the following parameters were monitored and analyzed in order to determine the typical behavior of users:

- Customers age,
- Customers gender,
- Season of the year, and,
- Time of day and temperature.

A smart shop is a new type of kiosk that can be easily transformed from a standard vendor kiosk to a vendor-less kiosk [47].This vendor-less kiosk is developed based on the proposed architecture in Fig.10. An example of this smart shop is shown in Fig.11.

Smart-shop as the IoT extends the connectivity between things with minimal need for human intervention [48]. This characteristic is desirable for retailers who seek to ease the shopping experience for the consumers. One of the key preconditions, in order to ease the shopping experience, is to offer IoT payment to the customers. IoT payment is a process of money transfer based on the user device that is connected to his/her money account. The usage view sets up the technical solution by describing the customers' journey through all the steps of the use case being implemented. This view would include the key actors, which may be customers and/or machines, and the activities involved. The usage view also describes the use case from the point of view of customers' needs and system capabilities.

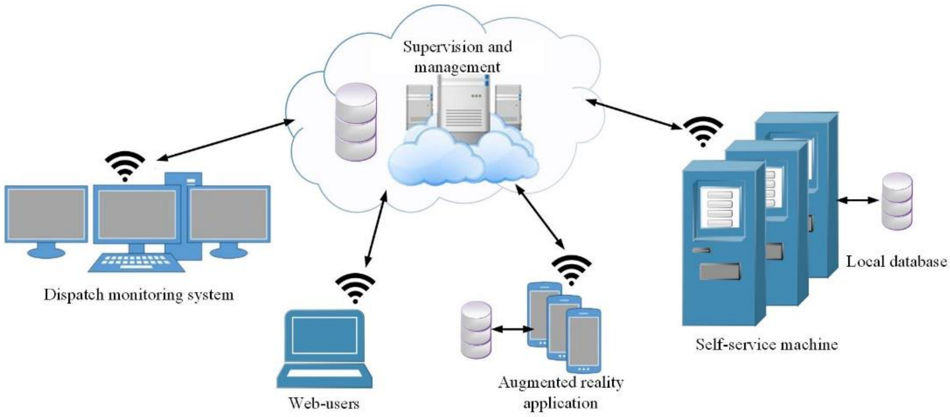

Fig. 10 Architecture of the smart-shop network system

Fig. 11 Smart-shop kiosk (image source: http://www.smart-shop.rs)

Fig. 12 illustrates Deloitte's reference architecture, a typical IoT use in a store [49]. Applying this scenario, every new user (customer) has much more chance to have good satisfaction using IoT payment. More users, and more experience (this means more data), enable the opportunity of using the data analytics process of IoT payment as a smart process.

The software that is installed in the vending machines at smart shops, based on the concept presented in Deloitte's reference architecture, makes IoT payment possible to follow the habits of each customer and, on that basis, to suggest products with a greater chance of being firstly selected by the customer. Each customer is personalized, which means that all menus on the vending machine are automatically configured according to the customer. In this way, the customer gets the impression that he/she is buying from a salesperson, who knows his/her typical habits.

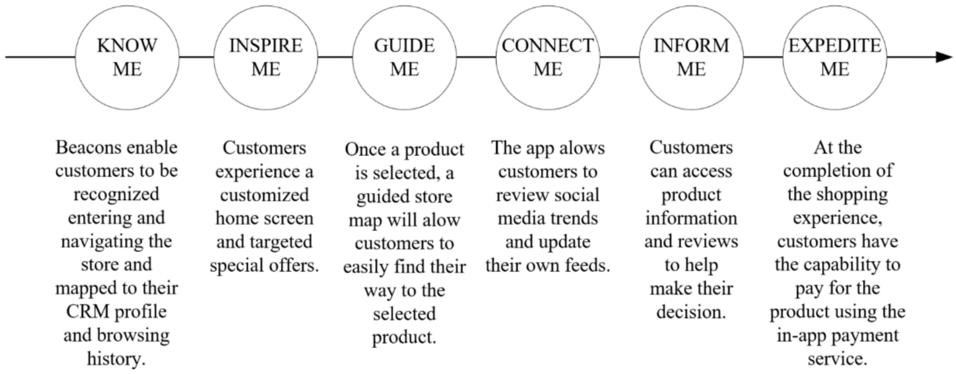

Fig. 12 The IoT usage view based on [49]

The authors of this paper are part of the team that developed this smart shop. For the first time, in Serbia, this smart shop will work in conjunction with a salesperson to allow the sale of products that would require specific vending machines.

4.3 Discussion

In the case studies described, the solutions are developed with the aim to develop smart ecosystems. The achieved results fully justify the approach to the development of such systems. In the study of a smart gas network ecosystem, the customer can monitor gas consumption and, in that way, if possible, correct or reduce gas consumption. Also, the customer can immediately estimate gas consumption in terms of the price of gas, bearing in mind that the price of gas consumed is affected by the pressure in the transport system as well as the gas temperature. The next step in the development of this application is that the application will have the incorporation of consumption prediction based on previous consumption and predicted weather conditions. This prediction is important not only for the customers but also for the gas distributor in order to provide for the estimated gas needs in time. The final version of this application will have the incorporation of artificial intelligence that will enable the customer to set conditions that would allow the application to manage gas consumption. Also, this function in the application is important not only for the customers but also for the gas distributor. For example, if the customer wants to set the desired amount of money (gas consumption) for a certain period, the gas distributor should allow control valves to be installed at the customer, to accomplish this task. The plan is to implement functions in the application that will determine how much would be spent each hour during a given period. These functions are typically found in SCADA systems, and, therefore, the gas application will need to be integrated with the existing SCADA system.

In the case of a smart-shop, the system is more demanding because a large number of customers can demand service in different locations at the same time, i.e. to use different smart-shop. A large number of products are present in every kiosk, which is of special importance when it comes to predicting their consumption not only in an individual kiosk but also in the kiosk network. In addition, each kiosk requires maintenance. One way of solving these problems (tasks) is to introduce an augmented reality support model with self-service automated systems, as shown in Fig. 13.

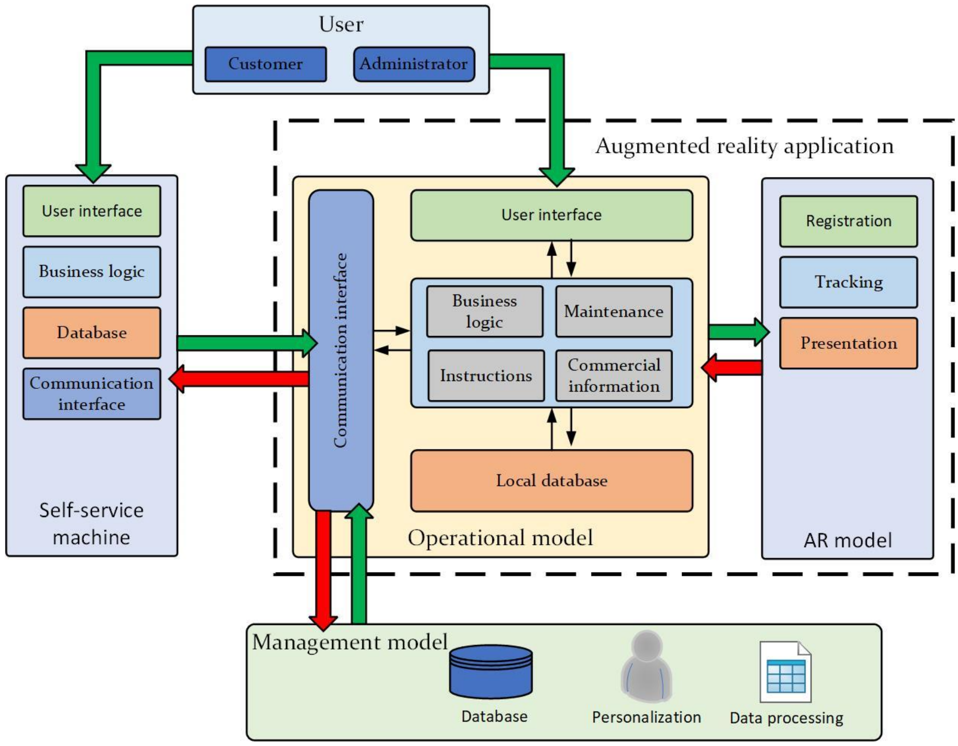

Fig. 13 Smart-shop kiosk architecture based on augmented reality

In the model of augmented reality support with self-service automated systems the following units can be defined:

- AR model - registration, tracking the position and orientation of the customer, as well as the presentation of interactive content,
- Operational model - execution of various functionalities of the self-service automated system,
- Management model - centralized database with monitoring, management and analysis of data from a remote location, and,
- Model of the self-service machine - customers' interaction and product/service provision.

In order to display virtual content in a real environment on a self-service automated system, it is necessary to register the position and orientation of the customer in relation to the reference coordinate system (self-service automated system) *via* a smartphone. The obtained position and orientation must be updated in real time in order to properly display the virtual content. Identical self-service automated systems are installed in different locations. Using the GPS position, it is possible to determine which specific machine the customer is at.

The implementation of augmented reality will enable smart-shop customers' new features. Customers will have new opportunities to get information about the product they want to buy while the kiosk administrator will be able to more easily manage and maintain the kiosk itself.

5. CONCLUSION

The new ICT architecture allows expanding the traditional ways of device management, allowing their users to correct management decisions, considering the economic aspects using of the device. With this approach, we get smart ecosystems.

This paper presents some ideas from the concept of the smart gas network ecosystem, which can be part of the energy smart network ecosystem and the smart-shop network ecosystem. The first results from these case studies show justification for the development of smart ecosystems.

The development of smart ecosystems is a challenge not only for their producers but also for all participants involved in each phase of the life cycle of a smart ecosystem. Certainly, computer technologies such as Artificial Intelligence, Edge Computing, and Cloud Computing will facilitate the development and application of ecosystems. The greatest benefit from the application and development of a smart ecosystem will certainly have the end user, who, in addition to the already known functionalities of a system, will also have an immediate insight into the economic effects of using such a system.

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