Analysis of IoT Concept Applications: Smart Home Perspective

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Abstract. The concept of the Internet of Things (IoT) is a widely applicable set of technologies and services. Therefore, it is essential to have a clear insight into the trends of development and application of this concept in different vertical and horizontal economic areas and follow future trends' predictions. In this way, it is possible to direct future research into several problems in those areas where the concept of IoT is most widespread. With this research, the analysis is focused on the smart home environment as one of the most common and fastest-growing applications of the IoT concept. The positive trends of current and future growth of this area in various categories and functionalities of IoT devices such as comfort and lighting, energy, security, monitoring, entertaining and home appliances have been confirmed. Growth is seen in the number of devices used, the number of homes using at least one IoT device, total revenue and market value. Therefore, it is concluded that it is necessary to intensify efforts in researching problems related to smart homes by optimizing access communication networks, the impact of generated traffic on core network parameters, cybersecurity, identification and classification of such devices in the network, development of innovative smart services home and several other research challenges.

Keywords: Smart energy · Smart home security · Smart home entertainment · Smart home appliances · Smart home control · Smart lighting

1 Introduction

The concept of the Internet of Things (IoT) is a direction of technological development that has found its application in almost all industries. This concept's benefits have resulted in its implementation in a number of vertical and horizontal economic areas, processes, and activities.

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Due to this concept's wide application, it is essential to have a clear insight into how it is represented in a particular area. This makes it possible to focus future research on various problems in the field of application where it is needed. An example of this is the strengthening of research efforts in the security problems of those IoT concept applications that are most widespread because thus the security challenges are more significant and their solution is crucial. To this end, it is important to analyze historical and current data on the application of the IoT concept and consider predictions of future trends.

This research is focused on the analysis of trends in the application of the IoT concept from the perspective of a smart home environment. Numerous indicators show that this type of application of the IoT concept is the most common. It can attract numerous investments, generate large profits, and introduce specific challenges such as cybersecurity challenges caused by various restrictions imposed through numerous requirements before applying this concept.

2 Previous Research

The IoT concept was first defined by Kevin Ashton, co-owner and CEO of Auto-ID Center in 1999. Auto-ID Center has researched and developed automatic identification technology. In doing so, they presented a concept in which all objects, regardless of whether they are physical or electronic, have an electronic identification mark assigned to them. Such a tag contains information about the object to which it is assigned. In doing so, each physical object with the assigned label becomes a node in the communication network, which enables remote, contactless access to information related to the observed object [1, 2]. With further development and increase in application, the concept of IoT has been defined by numerous professional standardization bodies, organizations and associations in the field of IC technologies, and numerous researchers. Therefore, the definition of the concept of IoT can be considered from the aspect of professional organizations in the field of IC technologies and the scientific-research aspect.

According to the European Internet Research Cluster, this concept is global and requires a generic definition. According to the IERC document, defining the IoT concept is a demanding task given the foundations of the concept and the technologies and technological processes used, from sensor devices, communication systems, data aggregation and preprocessing to the provision of services to the end-user [3]. Thus, IERC defines the concept of IoT as a dynamic global network infrastructure with the ability to configure independently and is based on standard and interoperable communication protocols where physical and virtual objects have identities, physical attributes and virtual personalities and use intelligent interfaces. They are integrated into the communication network.

Numerous professional bodies and organizations in the field of IC technologies recognize IoT as an important concept in the further development of IC technologies that can automate various processes, decision-making, provide new forms of services, and provide added value for the end-user. In addition to expert bodies, the concept of IoT has been the subject of research by several researchers who have provided different but overlapping definitions and explanations. The European Internet of Things Research Cluster is one of the most important associations in the field of IoT research [4].

The research [5] recognized the importance of the concept of IoT and was defined through three ways of mutual communication between man and object: man - man, man - object and object - object. According to the same research, objects can recognize and communicate, and built-in intelligence allows them to make decisions based on context and exchanged information. According to research [6], IoT addresses and potentially plays a key role in addressing the global societal challenges defined by the Horizon 2020 framework, relating to health, demographic change, sustainable agriculture, safe, clean and efficient energy, smart and integrated transport. and transport, climate change, environment and safe and innovative society.

Acceptance and prevalence of the IoT concept require an analysis of this concept's application and penetration in various industries that this research seeks to provide. In this way, the scientific community will have a clearer insight into the representation of this concept, which will enable better guidance of future research in various fields and fields of science. An example of this is seen in the potential of research and development of new services, encouraging the application of the IoT concept in less represented areas, discovering new areas of application to researching cyber threats in areas where this concept is most widespread, and intensify research on identification and classification of such devices in the network [7–11].

3 Vertical Areas of the IoT Concept Application

The concept of IoT can be observed by expanding the existing interaction between people and applications through a new dimension of integration and communication represented by objects. The IoT concept's potential enables its implementation and application in various areas covering society, environment and industry, the descriptions and indicative examples of which are shown in Table 1 [12].

Table 1. Areas of the IoT concept application [12]

Scope	Description	Indicative examples
Industry	Activities involving financial or commercial transactions between companies, organizations and other entities	Production, logistics, service sector banking, intermediation, etc.
Environment	Activities related to the protection, control or development of all natural resources	Agriculture and cultivation, recycling, environmental management services, energy management, etc.
Society	Activities/initiatives related to the development and involvement of societies, cities and people	Government services to citizens and other social structures, e-inclusion (seniors and people with disabilities), etc.

Depending on the area of application, objects can be perceived differently. For example, facilities in an industrial area can represent products, equipment, means of transportation, and anything involved in the product life cycle. In the environment, the object

can represent construction objects, devices for measuring environmental conditions, etc. Finally, in the field of society, the object can refer to devices in public spaces, household devices, etc. In applying the IoT concept, it is almost impossible to isolate one sub-scope of application, but a single service is often applied at a level that covers more than one area. For example, the hazardous waste monitoring service is not applying only to the industry as an application area but also to the environment and society.

Numerous authors and researchers have identified different applications of the IoT concept. As part of the IoT-I project implemented in 2010, a total of 65 concrete applications of the IoT concept were identified, grouped into 14 vertical areas (smart cities, smart environment, smart water supply, smart metering, security, sales, logistics, industrial control, smart agriculture, smart livestock, home automation and smart health).

In contrast, research [13] classifies the application of the IoT concept to seven vertical areas, also called smart environments, i.e., smart city, smart home, smart energy grid, smart buildings, smart traffic, smart healthcare and the smart industry shown in Fig. 1. Mutual communication of devices in the environment, automation of individual processes and decision-making without human intervention has resulted in the frequent use of the term "smart" in a particular application area. Thus, a set of services based on the IoT concept in the city environment results in a concept called the smart city, the application of environmental management results in the concept of smart environment and the like.

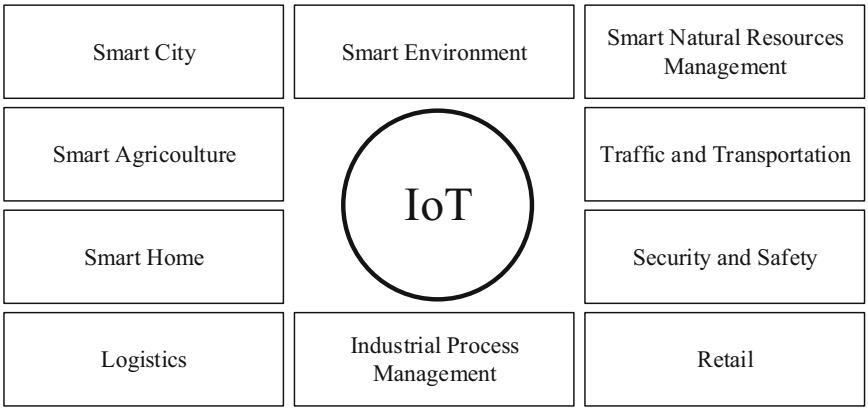


Fig. 1. Areas of the IoT concept application

Consequently, it is possible to conclude that a set of services based on the IoT concept, and applied in a specific environment, makes such an environment smart in the context of communication, data processing, decision making and activities.

Smart City is an environment where all city resources are virtually connected and remotely managed [14]. The IoT concept introduces new capabilities, such as the ability to remotely monitor and manage devices, analyze and take action based on information received from different real-time data streams. As a result, the IoT concept's application is changing cities by improving infrastructure, creating more efficient utilities, improving

transportation services by reducing road congestion, and improving citizens' safety. According to [15], the smart city context services are shown in Table 2.

Table 2. IoT-based services within the smart city concept [15]

Service name	Service description
Smart parking	Monitoring the occupancy of parking spaces in the city
Structural correctness	Monitoring of vibrations and condition of materials of buildings, bridges, traffic infrastructure, etc.
City noise maps	Real-time noise monitoring
Traffic congestion management	Vehicle and pedestrian tracking to optimize the driving route or walk routes
Smart lighting	Intelligent and time-efficient street lighting control
Waste management	Container filling detection to optimize the removal route
Intelligent transport systems	Smart roads and highways with the application of dynamic warning and diversion signs depending on weather conditions and unexpected events such as accidents or congestion

According to the above, smart cities must meet two key goals. The first is to provide an advanced infrastructure that enables collecting and processing data using and interacting with IC technologies and services based on them listed in Table 2. The second goal is users' ability to interact with the environment using applications to positively impact the environment and reduce pollution and quality of life in cities.

Given the continuous growth of electricity consumption in private households and the growing number of electricity users and increasing environmental and regulatory constraints, the need to improve electricity networks' overall efficiency is one of today's fundamental problems [16]. Smart grid environment services have their application in the generation, transmission, distribution and consumption of electricity. The integration of advanced services based on the IoT concept increases the traditional energy network's efficiency by providing a higher level of automation, reliable power network load prediction, and safer operation of electrical devices, resulting in increased quality of energy delivery service and greater customer satisfaction. Lower load fluctuations and subsequent reductions in network dynamics, greater stability, lower line losses and lower operating costs are also expected in terms of matching energy demand with supply [17].

Over the years, residential buildings and structures have become more complex and dynamic with multiple systems and devices supporting a number of activities and processes. Complexity often leads to inefficiencies in managing such environments. A smart building environment has existed for many years, and examples of this can be seen in motion-activated lighting and a programmable heating, cooling and ventilation control system (Heating, Ventilation, Air-Condition, HVAC). The IoT concept application in a smart building environment allows managers better visibility of building components, greater control, and management efficiency [18, 19]. Figure 2 shows the architecture of

a smart building environment using the IoT concept. The multiple application of various sensors to monitor numerous parameters (movement, air pressure, lighting, temperature, water flow) in different scenarios is visible to enable autonomous collection of relevant data, their transmission, analysis, and execution of activities based on the information obtained.

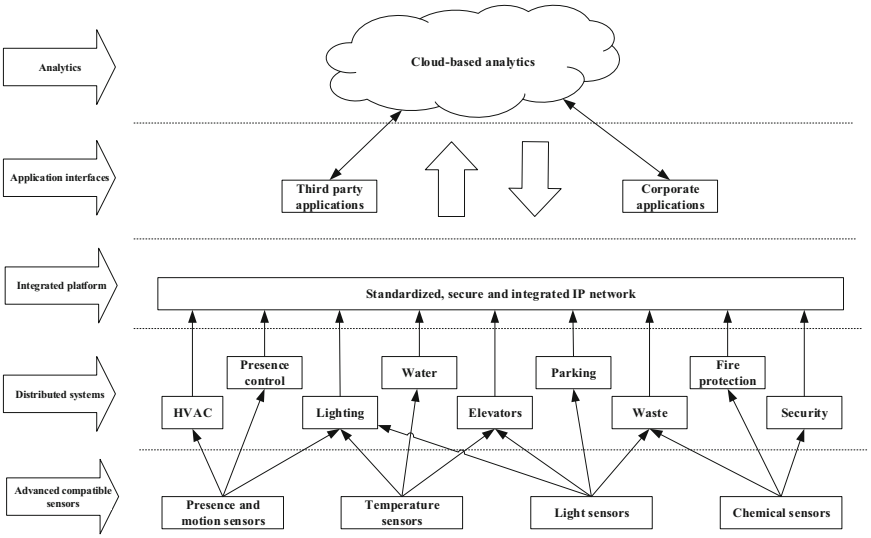


Fig. 2. The architecture of IoT concept application in smart building environment [20]

Building owners are enabled to manage costs and resources more clearly by addressing inefficiencies and improving space utilization. Building owners' problem is a holistic insight into all the processes that take place within a building. Smart building solutions enable stakeholders to identify problems faster, correct maintenance, improve processes, save resources and adapt to different stakeholder requirements [21].

4 Statistical Indicators of the IoT Concept Application

4.1 Trend Analysis for the Overall Application of the IoT Concept

The number of IoT devices has been steadily increasing over the last decade. The exact number of u-devices and growth rate varies depending on the research. According to [22], approximately 20.5 billion IoT devices are projected by the end of 2020, while research [23] predicts approximately 30.7 billion IoT devices by the end of the same year and 75 billion IoT devices by 2025, as shown in Fig. 3.

According to Ericsson's global statistics, which refer to the representation of a particular category of connected devices, IoT devices' dominance is observed in relation to the hitherto dominant mobile devices. Figure 4 shows the number of connected devices by categories for the period from 2015 to 2022. According to forecasts, IoT devices' annual growth rate (CAGR) is expected to be 23% from 2016 to 2022 [24].

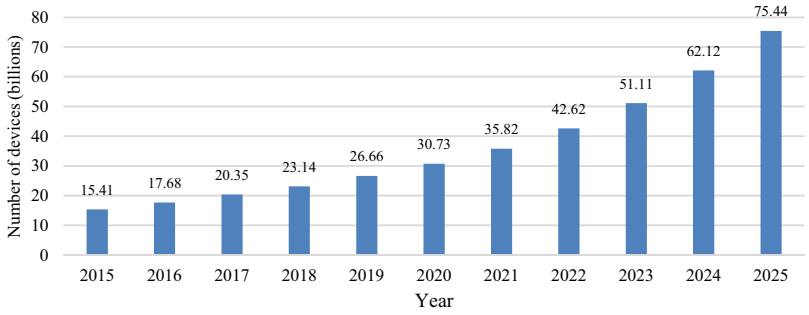


Fig. 3. Prediction of the total number of IoT devices by 2025 (globally) [23]

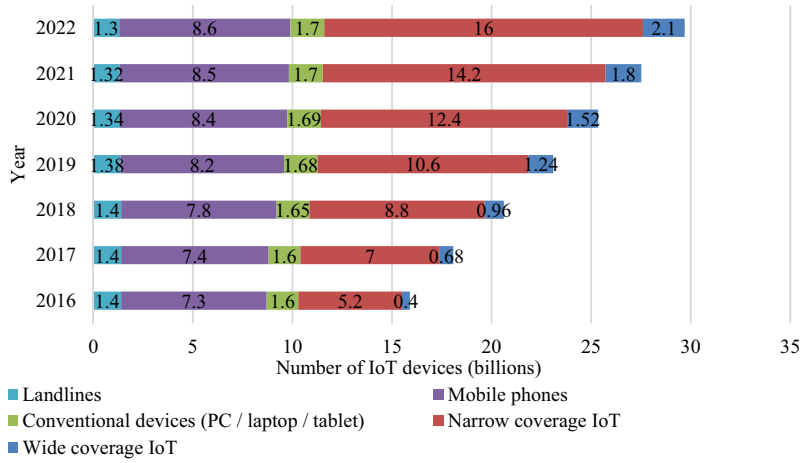


Fig. 4. Number of connected devices by categories from 2016 to 2022 [24]

The application of the IoT concept in different economic sectors is becoming a key factor for business improvement. According to [25], 92% of companies believe that the concept of IoT will be important for their business by 2020. Consequently, companies see security, privacy, cost, and regulatory issues as the biggest challenges in implementing and enforcing the IoT concept.

Research [26] conducted on 1430 companies (small, medium and large) indicates many advantages recognized by the vast majority (95%) of adopters of the IoT concept. At the same time, more than half (53%) of respondents confirm the significant advantages of implementing the IoT concept in business, while 79% of respondents believe that applying the IoT concept achieves positive results in various areas of work that would not otherwise be achieved. Some of the more prominent advantages are shown in Fig. 5.

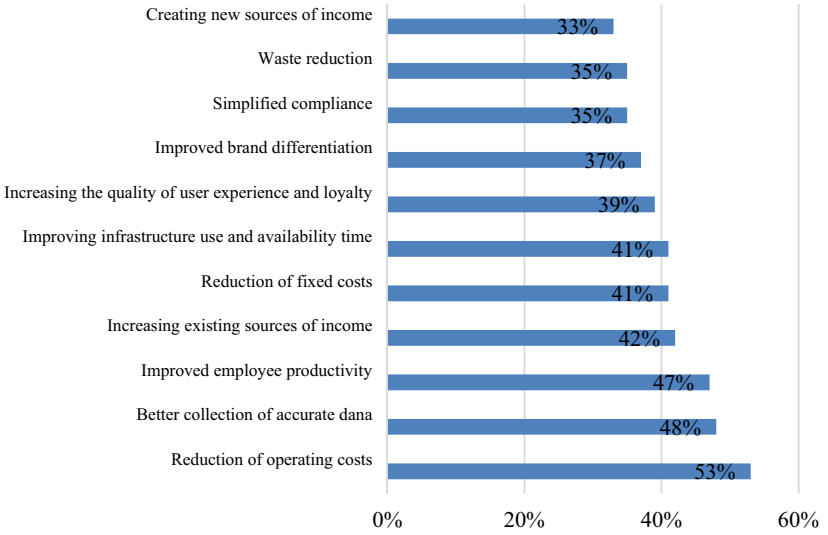


Fig. 5. Advantages of implementing the IoT concept in a business environment [26]

4.2 Analysis of Trends in the Application of the IoT Concept in the Household Environment

According to Gartner, the largest representation and application of the IoT concept in terms of the number of IoT devices used until 2017 was in the area of smart building environments. After 2017, the smart home concept is an environment that brings together the largest number of IoT devices [20]. The representation of IoT devices by application categories is shown in Fig. 6, where the dominance of IoT devices in the private sector, which includes the smart home environment, is observed in relation to the business sectors.

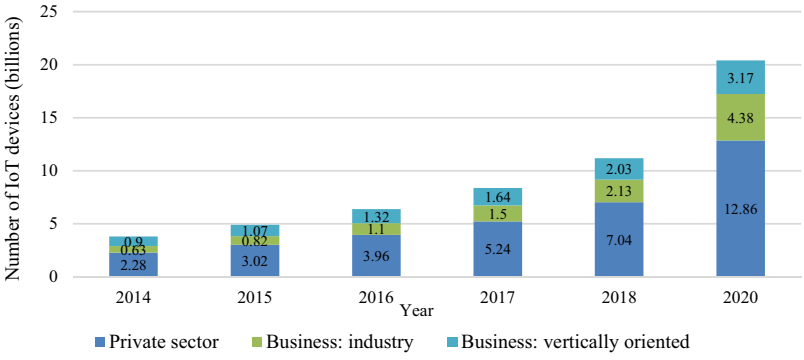


Fig. 6. Number of implemented devices by application category [22, 23]

More precise insight into the representation of IoT devices by individual areas of application is provided by the company IHS Markit's research [27]. Figure 7 shows that the smart home concept records the largest number of installed IoT devices (822.6 million) than other sub-areas of application. The annual growth rate (prediction by 2021) is 19.6%, which makes the concept of smart homes and the concept of industrial IoT (CAGR 23.4%), the fastest-growing area of IoT applications.

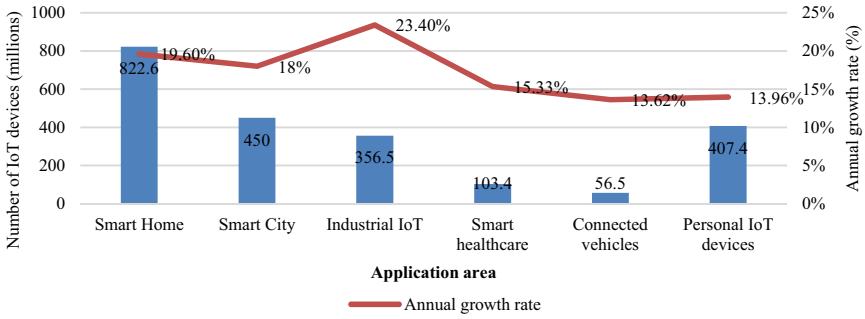


Fig. 7. Number of IoT devices and annual growth rate by area of application [27]

The number of smart homes that have implemented SHIoT devices from each group is shown in Fig. 8. The graph shows the prediction of continuous growth in devices' implementation from all these categories until 2023. According to [28], the largest increase is expected for homes with implemented SHIoT devices from the group "surveillance and connectivity," including devices such as smart sockets, switches and speakers. The statistical indicators presented in [29] indicate a continuous increase in revenues of this group of devices until 2023 by region. The prediction for the Asia area (refers to China) indicates an annual revenue growth rate of 35%, while for the US and Europe area it ranges from 17% to 25%.

The other fastest-growing smart homes implement SHIoT devices from the group "comfort and lighting", which includes devices such as lighting fixtures as the most common devices in this group and window and door sensors and control devices such as garage doors. Given the ease of implementation of devices in this category, which primarily refers to lighting fixtures, they often represent an entry point for users to implement the concept of a smart home. According to [30], this group's global market value in 2023 will be approximately $ 14.32 billion. China's expected annual revenue growth rate is 41%, and for Europe and the US, ranging from 19% to 27%.

The number of homes with implemented SHIoT devices from the category smart appliances is approximately equal to the number of homes with implemented devices from the previous group. This group includes appliances such as washing machines, refrigerators, coffee machines, etc. Figure 9 shows the market value for each group of appliances by years, expressed in billions of dollars. Comparing the values and trends of individual groups of devices in Graphs 8 and 9, the disproportion of market values concerning the number of smart homes that have or will have implemented this categories' device is noticeable. The observed disproportion results from the price of devices of this

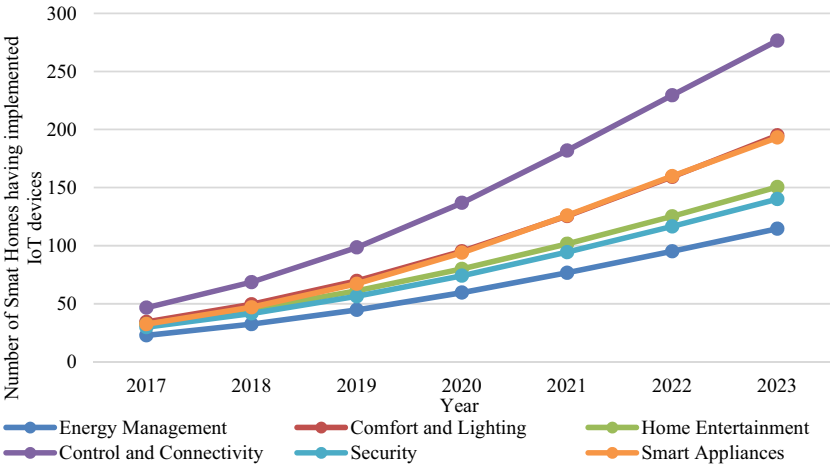


Fig. 8. Number of smart homes that have implemented SHIoT devices from one of the categories (2018–2023.) [28]

category, which is higher than the price of other categories' devices. Smart homes that implement SHIoT devices from the group "multimedia", "security", and "energy management" are represented to a lesser extent than the previous two groups. Nevertheless, continuous growth and significant market value are expected for these three categories as well.

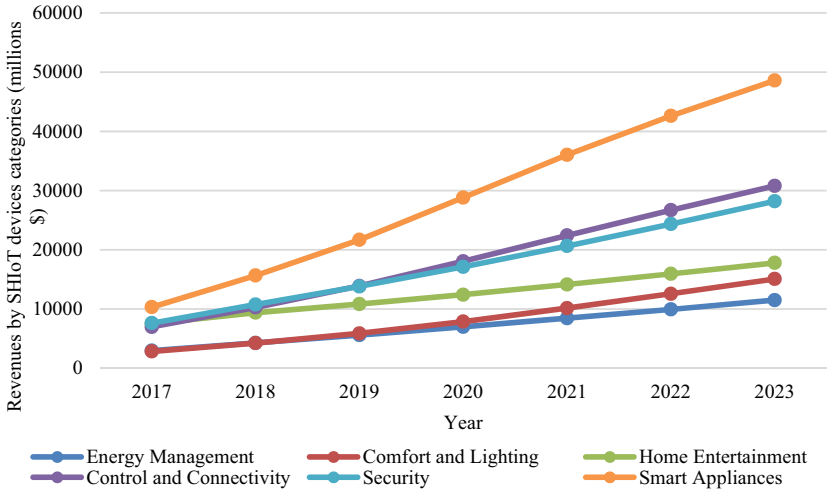


Fig. 9. Market value by individual SHIoT devices category (2018–2023.) [28]

An essential indicator of the smart home concept's growth and importance is the number of SHIoT devices per household. Predictions differ depending on the source, so Kaspersky states that currently, the average household has 6.3 connected devices,

including all types of devices (conventional and SHIoT) that connect to the Internet [31].

Figure 10 shows Statista and Forrester's aggregate data, comparing the number of smart homes and other connected devices, including SHIoT devices. According to the picture shown, it is predicted that by the end of 2020, there will be 19.9 million smart homes and 130 million implemented SHIoT devices, which makes an average of 6.53 SHIoT devices per smart home.

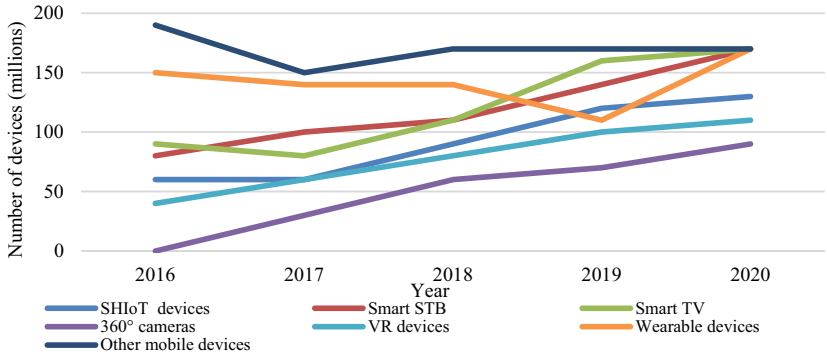
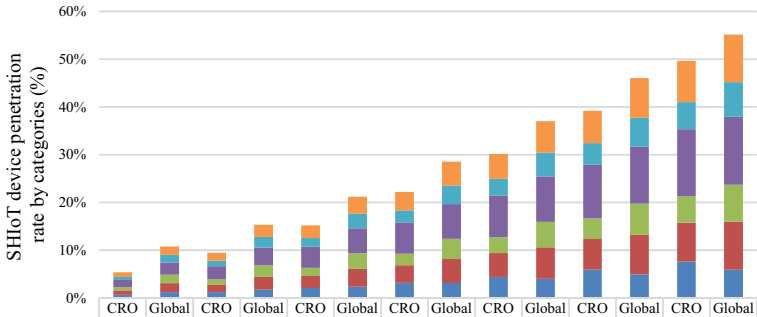


Fig. 10. The ratio of the prediction of the number of smart homes, SHIoT and other connected devices [32, 33]

A study by Telsyte in Australia indicates that the average household owns 13.7 connected devices and predicts that by the end of 2021, there will be 30.7, of which 14 will be SHIoT devices [34]. Given the limited number of statistical indicators that indicate the average number of SHIoT devices installed per smart home, impact indicators of such devices can be observed through the current number and prediction of the future trend in the number of connected devices (conventional + SHIoT) per user. Thus, Cisco research predicts that by the end of 2021, there will be four connected devices per user (globally), with the largest number of connected devices (13) being in North America, 6.5 in Europe (average value), while the lowest number of connected devices per user is foreseen for the Middle East and Africa (1) [35].

A comparison of the global market with that in the Republic of Croatia (RH) in terms of each category of SHIoT devices' penetration rate can be seen in Fig. 11. The penetration rate indicates the ratio of the number of smart homes and the total number of private homes. Despite the indicators that predict a lower penetration rate in the Republic of Croatia compared to the global market, continuous growth is predicted. According to [36], the total value of the smart home market in 2018 in the Republic of Croatia was $ 40 million, and by 2023, linear growth and a value of $ 151 million is projected. The current representation of smart homes in the Republic of Croatia is 0.14 million, with an average price of implemented SHIoT devices of $ 441.94 per smart home, and by 2023 0.36 million smart homes are projected with an average price of $ 419.27 per smart home.



	CRO 2017	Global 2017	CRO 2018	Global 2018	CRO 2019	Global 2019	CRO 2020	Global 2020	CRO 2021	Global 2021	CRO 2022	Global 2022	CRO 2023	Global 2023
Smart Appliances	0.96%	1.76%	1.66%	2.53%	2.64%	3.58%	3.83%	4.97%	5.21%	6.60%	6.79%	8.31%	8.64%	9.96%
Security	0.67%	1.62%	1.16%	2.24%	1.83%	3.01%	2.63%	3.92%	3.51%	4.95%	4.51%	6.06%	5.63%	7.22%
Control and Connectivity	1.49%	2.53%	2.71%	3.69%	4.43%	5.25%	6.47%	7.24%	8.72%	9.53%	11.22%	11.93%	14.05%	14.25%
Home Entertainment	0.66%	1.77%	1.10%	2.44%	1.69%	3.26%	2.43%	4.23%	3.31%	5.33%	4.33%	6.51%	5.52%	7.76%
Comfort and Lighting	0.93%	1.87%	1.60%	2.67%	2.54%	3.72%	3.68%	5.03%	4.97%	6.58%	6.44%	8.28%	8.14%	10.05%
Energy Management	0.67%	1.24%	1.24%	1.75%	2.08%	2.39%	3.16%	3.15%	4.43%	4.02%	5.91%	4.95%	7.64%	5.91%

Fig. 11. Comparison of the penetration rate of SHIoT devices in the Republic of Croatia and globally [28, 36]

5 Conclusion

The analysis of trends in applying the IoT concept presented in this paper indicates its strong growth in several economic and application areas. Globally, by 2025, the total number of IoT devices is projected to exceed 75 billion. This figure indicates the need to invest significant research efforts in many areas because the stated number of devices will have implications, i.e., resulting from or being a cause and driver of numerous needs. There is a need to increase cybersecurity, reorganize business and business processes, and need for new business models or improvement of existing ones, develop higher performance and capacity network equipment, optimize communication networks, and many others. The results of this research indicate a significant increase in the application of this concept in the private segment, which focuses primarily on environments such as smart homes, which shows one of the highest annual growth rates (with industrial IoT) and among the largest number of IoT devices in use.

An additional analysis of trends in applying the IoT concept in the smart home segment concludes the positive growth trend in smart homes that have installed IoT devices from different device categories, with those devices from the Control and Connectivity category standing out. Besides, all categories of IoT devices applicable in a smart home environment record significant revenue growth with the prediction of future growth, which indicates the business importance of this area of application of the IoT concept.

The positive trend of penetration of the IoT concept into households is also visible in the Republic of Croatia, which monitors global trends. The analyzed indicators precisely and unambiguously indicate that the concept of a smart home is currently the most common and fastest-growing area of application of the IoT concept.

According to the analyzed and presented indicators, the critical role in researching the application of the IoT concept in the smart home environment is exact. Numerous

research problems and issues arise, such as cybersecurity, communication network optimization and adaptation to the smart home environment's requirements in the access and core segment, development and implementation of innovative services and applications of IoT devices in the household. The authors will try to address these research domains in future research.

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