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Research Highlights

- Presentation of BD, CC, IoT, Monitoring technologies with focus on common operations
- Investigate of a new system for collecting & managing sensors' data in a SB.
- CC used as a bases technology for IoT, BD & Monitoring technologies.
- Proposed solutions could lead in an energy efficient SB (Green Smart Building).

Abstract - Internet of Things (IoT) provides to everyone new types of services in order to improve everyday life. Through this new technology, other recently developed technologies such as Big Data, Cloud Computing, and Monitoring could take part. In this work, we survey the four aforementioned technologies in order to find out their common operations, and combine their functionality, in order to have beneficial scenarios of their use. Despite the boarder concept of a smart city, we will try to investigate new systems for collecting and managing sensors' data in a smart building which operates in IoT environment. As a bases technology for the proposed sensor management system, a cloud server would be used, collecting the data that produced from each sensor in the smart building. These data are easy to be managed and controlled from distance, by a remote (mobile) device operating on a network set up in IoT technology. As a result, the proposed solutions for collecting and managing sensors' data in a smart building could lead us in an energy efficient smart building, and thus in a Green Smart Building.

***Keywords* - Internet of Things, Cloud Computing, Big Data, Smart Building, Sensor Management, Energy Efficiency, Data Collection, Sensor Management, Contiki OS.**

I. INTRODUCTION

In recent years, with the significant advances in computer and communication technologies, which are new big leaps in the digital world, a term called "Internet of Things" (IoT) made its' appearance. IoT is a sector that is rising really fast. After all, many consider a technological review, because by interpreting IoT, it changes the everyday life of people. It changes the way of moving, working, transforming even entire cities. Everything becomes smarter since the devices communicate with each other, carry out work independently, and display measurements and results [1-3]. It is something worthwhile that IoT is the key for the control and the surveillance of "Intelligent Buildings" (IBs).

Another term used to describe the large amounts of data produced by all these inter-connected devices is called "Big Data" (BD). The most common type of BD is the IoT-Big Data. It can also be said that IoT and BD are interdependent technologies and should be developed jointly [4-6]. In this paper we try to collect, transmit, and analyze these enormous amounts of data transmitted through the Internet and to the cloud environment.

In the cloud environment, the management and analysis of data transmitted takes place. This new technology called "Cloud Computing" (CC) or just "Cloud" provides better storage capacity, low-cost, scalability, flexibility, efficiency, durability, and reliability [7] [8].

However, in this research we address a subset of IoT, namely "Wireless Sensor Networks" (WSNs). They usually consist of small sensing devices, with few resources, which are wirelessly connected to each other. These devices are also referred to as Wireless Network Nodes (or Motes in the Contiki Operating System) and can communicate with each other and with the Internet. They are sensory because they can collect information from their environment through their specific sensors, which they then process and transmit to the Internet. It is worth noting that the WSN nodes can move by taking measurements from different points continuously. They are also smart enough to deal with faults on the network. Together with their other advantages, they are easy to install and use. Conversely, one of the major drawbacks is the limitation of power consumption by the nodes which are usually battery operated. This issue is an objective for community development to resolve, and significant steps have already been taken with the use of alternative energy sources (Smart Grid), such as solar, water, and wind [9-13].

All these technologies described above can be converged in entire systems to support and implement efficient solutions for Smart Cities. Some of these solutions are the reduced cost and the more comfortable, safer, and friendlier environment. A Smart City consists of many components such as Smart Grid, Smart Buildings, Smart Citizens, Smart Security, Smart Infrastructure, Smart Technology, and many others. In this paper, we will focus on Intelligent Buildings and some related work is discussed in [14-19].

Actually, in section 2 we present our study, in which are used similar technologies and systems proposed by other researchers in this field. Moreover, in section 3 we proposed efficient smart building network architecture, which consist of sensor devices. These devices are smart enough to transmit the produced IoT-large-scale data (IoT-Big Data) through the routers to the Internet. Furthermore, in section 4 we compared our proposed scheme with other related approaches. Then, in section 5 we use an operating system named Contiki and an emulator called Cooja to simulate our proposed network design in real time and take measurements for various factors. Also, Wireshark was used to analyze every packet transmitted in and out of our network. In section 6, we present the experimental results. Finally, in section 7 we conclude our research paper and provide future directions for more efficient IBs.

II. RELATED WORK

For the purpose of this paper we study and analyze previous literature which has been published in the field of Sensor Data Collection & Management in Smart Buildings. The following paragraphs present the papers which contributed significantly in our study.

In [20] is proposed a framework for IoT environments that is based on localized data processing and decision making. Efficient management is provided by this framework for the local sensor network. The proposed master unit makes a collection of data from the network of the installed sensors which were located in various places within and around the house and intelligently identifies the dependencies among them. Furthermore, with the aim to extract knowledge locally, the sensors are turned in real time in order to minimize the redundancy in usage and power consumption.

In [21] there is an assessment of the opportunities along with the criticism for a fully IoT enabled and controllable intelligent building against the well-established and legacy automation systems in a fair and transparent approach. Continuously, in [21] there is a proposal of an interoperable intelligent building design for the creation of advanced building management schemes, by integrating the assets of current automation tools and the emerging innovations.

The authors in [22] propose an IoT-based security framework on smart building scenarios. By this, they are integrating coherent data as fundamental components. The aim of the integration is to drive the building management and security behavior of indoor services accordingly. A holistic platform named City Explorer, which provides security and discovery, is the component in which the proposed framework is manifested.

The authors in [23] with the purpose of creating an easy-to-use simulator for designing ubiquitous environments, they made a proposal of a simulator and autonomous agent generator that monitors human activity in smart homes. The proposed simulator provides a three-dimensional (3D) graphical user interface (GUI). This 3D-GUI activates spatial configuration and virtual sensors that act as actual sensors. Additionally, an artificially efficient agent is provided by the simulator for the interaction with smart homes. For this, a behavior planning method is used.

In [24] is presented an energy saving solution in buildings with the aim to generate predictive models of energy consumption in buildings. Moreover, the authors in [24] use a reference building, for which they have one year’s coherent data, in order to verify the proposed solution. At the end, the authors propose strategies and control actions for energy saving in the building.

In order to take measurements about the temperature, the humidity, and the light in a building, the authors in [25] present an IoT-based sensing and monitoring platform which is wirelessly connected. Also, in [25] there is a development of an Android application through which data is transferred from Laboratory Virtual Instrument Engineering Workbench (LabVIEW), which is a platform and a development environment, to a smart mobile device through which data are monitored remotely.

In [26] researchers propose a localization system for inside an intelligent building. In this building various services are provided to the population of the building, such as solutions for energy consumption issues. Also, the authors in [26] propose a mechanism to give solutions to localization requirements, with the use of radio frequency identification and infrared data. Finally, the results that have been acquired from the estimation performed are very accurate about the user location data. Thus, they provide a solution for ambient adaption based on human presence, and also in very low-costs.

The aim of [27] is to provide a comprehensive review about smart cities. In addition, [27] describes the IoT-based technologies used in smart cities. At the end, in [27] are explained practical experiences over the world and the main challenges such as those related with privacy issues of the citizens.

In [28] a framework is proposed so that the power in a smart campus can be managed. Furthermore, the authors in [28] discuss about the optimum scheduling of power consumption by the Energy Management System. They also discuss about the data exchange through a telecommunications design and about algorithms used for the energy management. Also, the authors provide various metrics about the quality for the performance appraisal of the framework.

In [29] the authors present a novel approach for a research design which is based on the relationship between the components of a smart city. These components are namely, the intelligent buildings and the intelligent users. The authors also use low-cost equipment such as the Raspberry Pi, the Edison, the Arduino, and various sensors. The citizens' data and the buildings' data collected from smart mobile devices and sensors respectively, can be managed and analyzed so that they can make out more efficient cities.

The authors in [30] propose a localization method for pedestrians, namely Localization Method (LNM). This method builds a fingerprint database with the use of the received signal strength from the neighbor. It also espouses a Markov's model for predicting the position of the pedestrians. Moreover, further analysis of the un-predicted signal variance is done using the history. The results are magnificent since after experimentation the proposed scheme seems to be better than others compared with, even if heterogeneity problems and Wi-Fi signal variances exist.

A novel intrusion detection algorithm is proposed in [31]. This algorithm is based on sampling with Least Square Support Vector Machine (LS-SVM). Also, the authors in [31] in order to prove how effective is the algorithm proposed, they carried out experiments on a standard database, namely KDD 99 which is a "de facto" benchmark for the evaluation.

In [32] the authors addressed the problem of imperfection in smart city data. Also, the authors focus on the management of these not perfect data and additionally create an evidential database by using the evidence theory in order to improve the efficiency of the smart city. A special case of modeling imperfect data in the healthcare sector is also presented in this article. Finally, a database which includes both imperfect and perfect data was built up and the various imperfect aspects, in this database are expressed by the theory of beliefs and presented in this paper.

III. Comparative Analysis

From previous works, various topologies, and architectures for Intelligent Buildings are studied. In this section we will make a comparative analysis study of the some previous works which we have distinguished. Initially, we analyze what each of them deals with.

The authors in [33] have designed and validated an indoor location-aware architecture which is able to enhance the user experience in a museum. Specifically, the proposed system of [33] relies on a wearable device that combines image recognition and localization capabilities to automatically provide the users with cultural contents related to the observed artworks. This proposed system interacts with the Cloud with the aim to store multimedia contents that produced by the user and to share environment-generated events on user's social network.

The [34], addresses the convergent domain of Cloud Computing and Internet of Things, for any smart city application deployment. Additionally, in [34] is proposed by the authors an IoT-based healthcare framework.

The authors of [35] in order to address the issues of Smart Building construction build an efficient rule engine. More specific, in [35] there is a design of an atomic event extraction module for extracting atomic event from messages, and then build a β-network with the aim to acquire the atomic conditions for parsing the atomic trigger events. Additionally, the authors construct the minimal perfect hash table which can filter the majority of the unused atomic event with O(1) item overhead, by taking the atomic trigger events as the key set of MPHF. Furthermore, there is also proposed a rule engine adaption scheme with the aim to minimize the rule matching overhead. As a result, they implemented the proposed rule engine in a practical smart building system.

The [36] describes the approaching challenges of this architectural singularity, by exploring self-organizing behavior in biological development. Moreover, the authors of [36] introduces a science fiction prototyping (SFP) scenario that proposes a morphogenetic design process for intelligent buildings based on Drosophila melanogaster development and grounded in the contemporary technologies of Building Information Modelling (BIM), digital fabrication and parametric design. Concluding, a morphogenetic architecture framework for IB is proposed count on a discussion of the implications for the design team.

The authors of [37] present the design and implementation details of an Artificial Intelligent based smart building automation controller (AIBSBAC). This design has the capability to perform intelligently adaptive to user-preferences, which are focused on improved user comfort, safety and enhanced energy performance. Moreover, the design architecture of AIBSBAC facilitates quick install flexible plug and play concept for most of the residential and buildings automation applications without a barrier to infrastructure modifications in installation.

Table 1. Related Work Comparison.

Architectures	Surveillance Environment	Communication Protocol	Efficiency	Security	Transmission Speed	QoS
[33]	Indoor	BTLE			X	X
[34]	Indoor / Outdoor	PaaS & IaaS	X			X
[35]	Indoor / Outdoor	ZigBee	X	X		X
[36]	Indoor	SFP	X			
[37]	Indoor / Outdoor	AIBSBAC			X	X

Based on Table 1 we can observe that most of the relative work papers are involving and trying to improve issues related to Quality of Services (QoS). In addition to this, most of the previous works deal with the Efficiency and propose both Indoor and Outdoor Surveillance Environment. Moreover, from the other hand, only one paper deals with the Security issue, and two of them deal with the Transmission Speed issue. Additionally, through Table 1 we can realize that the previous works studied in this paper used different type of Communication Protocols. This leads us to the conclusion that the Communication Protocol is not a standard issue, but differs in each type of network proposal. To sum up, we would try to propose an new topology scenario of a Smart Building Architecture which will try to deal and improve issues such as Security and Transmission Speed.

3.1. Proposed System

Concerning the related work and the comparative analysis, we designed and simulated a topology-architecture system for a smart building, in order to offer energy efficient solution by using the collected and managed sensors' data.

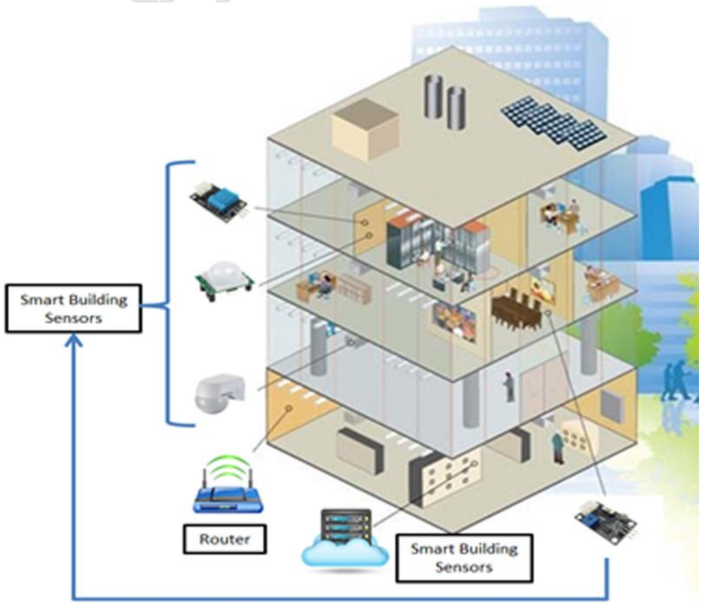

Figure 1: Smart building components.

Based on figure 1, we implemented a system that includes sensors that took measures for temperature, movement, light and moisture with the aim to achieve a better management of the building and also to make the building "smart" and efficient. As we can observe by figure 1, in the low level of the building, there will be a Cloud server that would help to building's management and store the valid information from sensors.

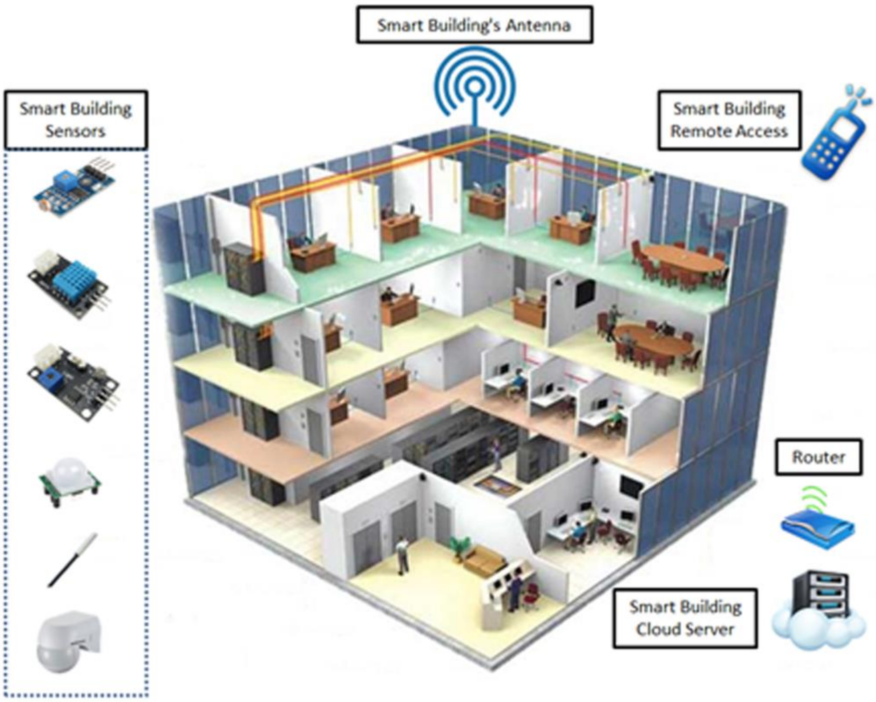

Figure 2: Smart building connection.

More specifically, in figure 2 we can see the communication between the various sensors that can be installed in the building and the Cloud Server with the users. The users would have remote access to sensors' data, and also they could manage the information of the data in order to be able to make some actions. For example, through the remote access a user could receive a signal that there is a high temperature with the aim to activate the air conditioning before going home. Additionally, using the analyzed, from the cloud server, measurements which were recorded by the motion sensor, the user will be able to understand if there is someone in the house, which can offer "security" sense.

Figure 3: Proposed Architecture.

Figure 3, demonstrates the architecture of the proposed system, and the logic of communication between the user, the sensors, and the whole smart building. The topology of the network would be hybrid, relaying on star and mesh topologies. This could offer a reliable network, easy to be managed in error detecting and troubleshooting. The mesh topology which already is and will be more popular in the future provides many benefits. One of these benefits is the tolerance that it has in errors. The star topology, which is widely used in home networks, provides also fault tolerance but since the middle connection point is working properly.

Also, the installed Cloud Server would operate autonomously by using a voltage stabilizer (UPS) to avoid any problem. All the users could easily connect to the network through the Wi-Fi connection of the building and remotely through their mobile providers. The installed network will support the communication protocol IPv6 and a Network Adaptive Multisensory Real-time Transmission Protocol (NAMRTP) proposed in previous work. This protocol can transmit from the remote environment to the database real-time multisensory data in a reliable way.

IV. Simulation Using Contiki OS

In this section, it is described an operating system investigated by A. Dunkel and which is called Contiki (Instant Contiki 2.7) [38]. In Figure 4 is presented the proposed simulation using the Contiki Operating System (OS) and its applications to simulate the network and extract from the network nodes measurements for the data collected and transmitted. Also, these data can be stored in specific files for analysis at future time. The Contiki OS is open-source and was designed for small and smart devices which are not expensive and provide low power consumption. Also, it is used for the collection of the large amount of data. Furthermore, we used Contiki Simulator instead of the lack of hardware resources. For the simulation of our network in real-time we use the Cooja emulator.

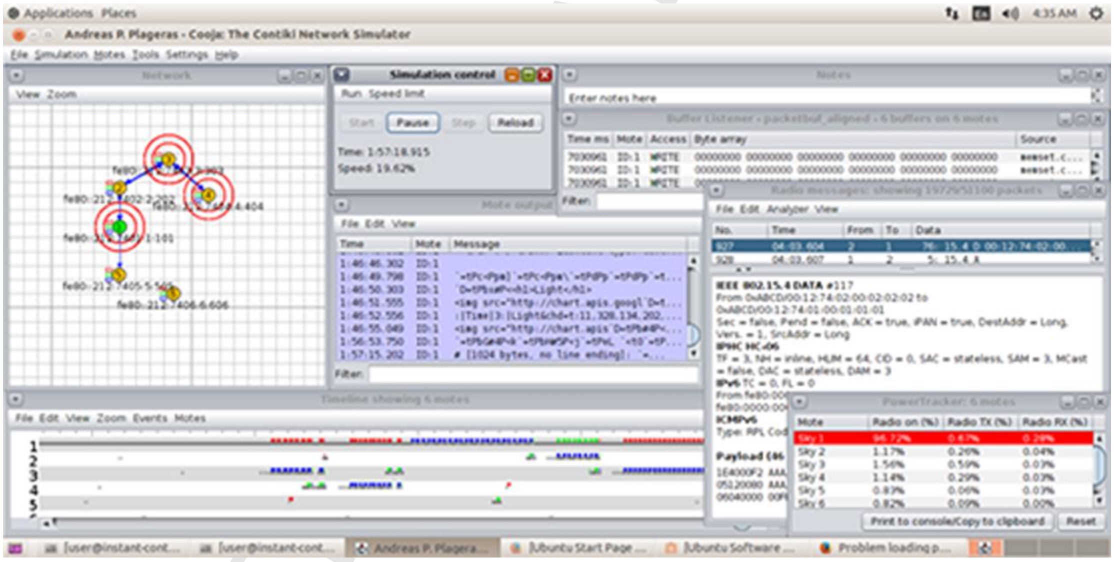

Figure 4: Simulating with Cooja emulator of the Contiki OS.

The new simulation is shown in Figure 4 above, where there are several windows. The one on the left-up corner is the “Network” window where we can see our network topology. From this window we can also access every node in our network so that we can configure it or take measurement for it. The second window is the “Simulation Control” window from where we can “start”, “pause”, make a “step” forward, and “reload” the simulation. The window on the top-right corner is where we can take notes, and that is why named “Notes” window. The window in the middle called “Mote output” is where are printed for each node all outputs of serial ports. The last window observed when we create a New Simulation, is the “Timeline” window. There, are shown the packets of data delivered over time. Since we have built our IPv6 over Low-power Personal Area Network (6LoWPAN) shown in Figure 4 above, we can use more tools such as the Radio Messages tool from the menu Tools. In the “Radio messages” window, we choose the “6LoWPAN Analyzer with PCAP” from the menu Analyzer. With that choice we made and after we start the simulation, the network traffic (data packets) is saved in a PCAP file for future analysis. Another useful tool is the Power Tracker which can be found in the menu Tools with the name “Mote radio duty cycle” [34]. With this tool we can calculate the percentage of power used by every node in the network separately, and the average power used by all nodes. These measurements can be observed in Table 2 below.

Table 2. The power of each node in different states.

Motes	Radio on (%)	Radio TX (%)	Radio RX (%)
Sky Mote 1 (Border Router)	96.72%	0.67%	0.28%
Sky Mote 2	1.17%	0.26%	0.04%
Sky Mote 3	1.56%	0.59%	0.03%
Sky Mote 4	1.14%	0.29%	0.03%
Sky Mote 5	0.83%	0.06%	0.03%
Sky Mote 6	0.82%	0.09%	0.00%
AVERAGE	17.20%	0.35%	0.03%

Specifically, we take information about the power used by each node and the average power of all nodes and the power used during the processes of transmission (TX) and receiving (RX) of data packets for each node and for the average of all nodes.

Then we have to build our network by inserting nodes in the Network window. We just need to go to the menu Motes and select the appropriate type. In our case, we use the Sky mote type, which provides 8MHz MSP430 low power microcontroller, 10 KB RAM and 48 KB flash memory. This type of nodes also provide 250 Kbps, 2.4GHz, IEEE 802.15.4, Chipcon Wireless Transceiver and sensors that take measurements about the humidity, the temperature and the light, 16-pin expansion support and optional SMA antenna connector. We also use Sky mote type, because they are supporting 6LoWPAN. But, why do we choose 6LoWPAN? This type of network is chosen because it is basically an IPv6 duplicated version, so that the IPv6 can work with low-power radio frequency at the physical layer. And why it is required the IPv6? It is required because by that way, IoT devices communicate over the Internet separately one at a time. Firstly, a border router is added. Moreover, we have to add some more sensor nodes of the type “Sky Mote” in the network. We have also chosen to add the program sky-websense.c. This application is used to produce sensor data and to give access to the most recent data. This happens through a web server who is converged in the application. So, it is needed to add some sensor nodes in the network, in order to collect the data produced by them. After starting the simulation the blank windows are filled with information as demonstrated in Figure 4. Specifically, in the Radio messages window, if we click on a message we can obtain precious information, for example, we can find out if IPv6 is used. In addition, a program named tunslip6 is used in order to connect the router with Cooja.

In the next section, the experimental results from the simulation, which we have run on Cooja, are demonstrated.

V. EXPERIMENTAL RESULTS

Now our simulation is ready to start, and a ping can be executed in a new terminal for any address which belongs to a node in the network. The results are presented in Figure 5, where from the “*ttl*” and the “*time (ms)*” the hops of each node from the router are noticeable. More accurately, the border router has ttl=64, the node which is one hop away has ttl=63, the node which is two hops away has ttl=62, and so on. That can be observed in the next Figure 5. The same is observed with the transmission time which is lower at the nearest to the router hops.

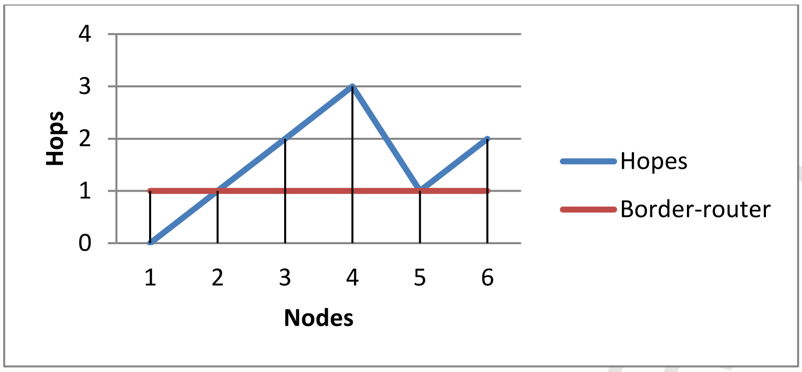

Figure 5 Hops per node from the Border Router.

With the ping that was executed are also provided information about the duration of transmission and the packet loss which is described by the following Equation (1):

$$TDS = TDR + PL \qquad (1)$$

Where TDS, TDR, and PL represent the total data sent, the total data received, and the packet loss respectively.

As we already said, information are provided about the protocols used for the communication between the nodes, for example, the IEEE 802.15.4, the IPv6, the 6LoWPAN, the Constrained Application Protocol (CoAP), and so on. Moreover, by opening a browser (e.g. Firefox) and typing the IPv6 address of the border router, it prints as output the neighbors and the routes. By typing the IPv6 address of any other node, there are printed the temperature and the light. The temperature shown in Figure 6 is same and stable for all nodes. This could be described by the following Equation (2):

$$TT = T1 = T2 = T3 = T4 = T5 = T6 \qquad (2)$$

where TT is the Total Temperature and T1 to T6 are the temperatures of nodes 1 to 6.

The data collected by these light-sensors are represented for each node in Figures 7, 8, 9, 10, and 11 respectively.

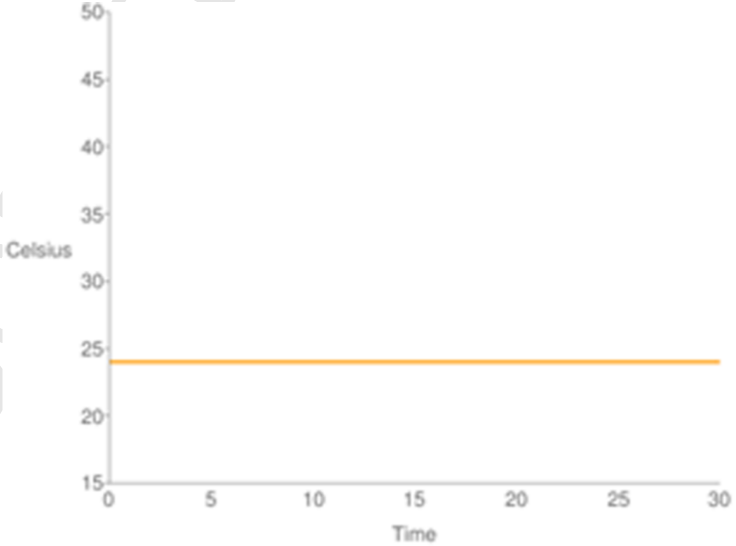

Figure 6: Temperature in all nodes.

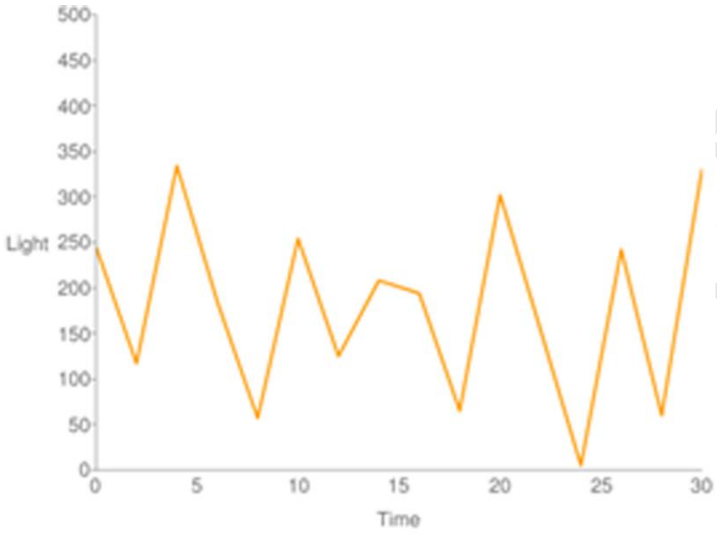

Figure 7: Light in Node 2.

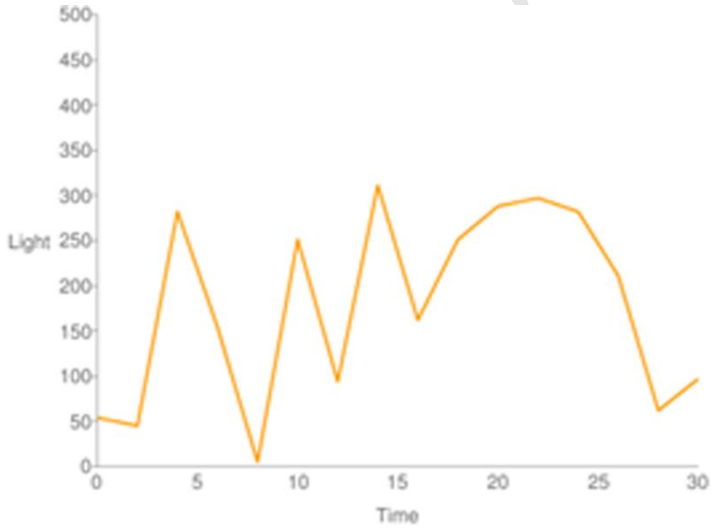

Figure 8: Light in Node 3.

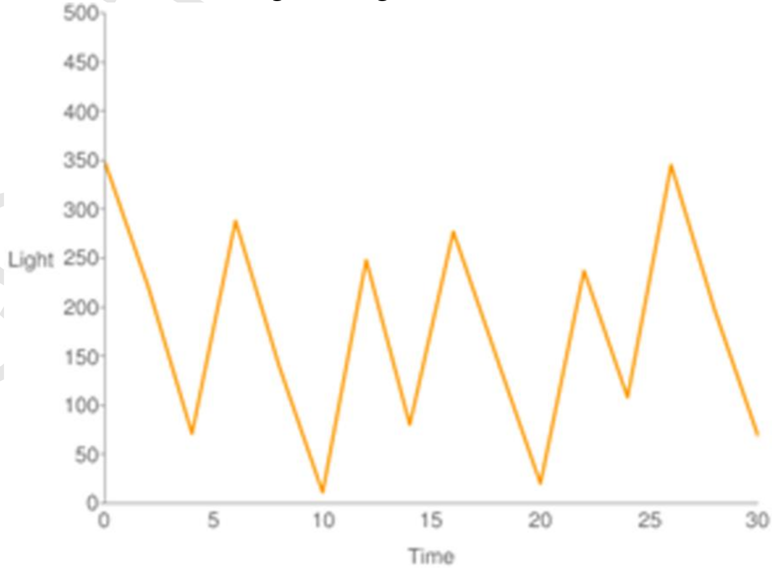

Figure 9: Light in Node 4.

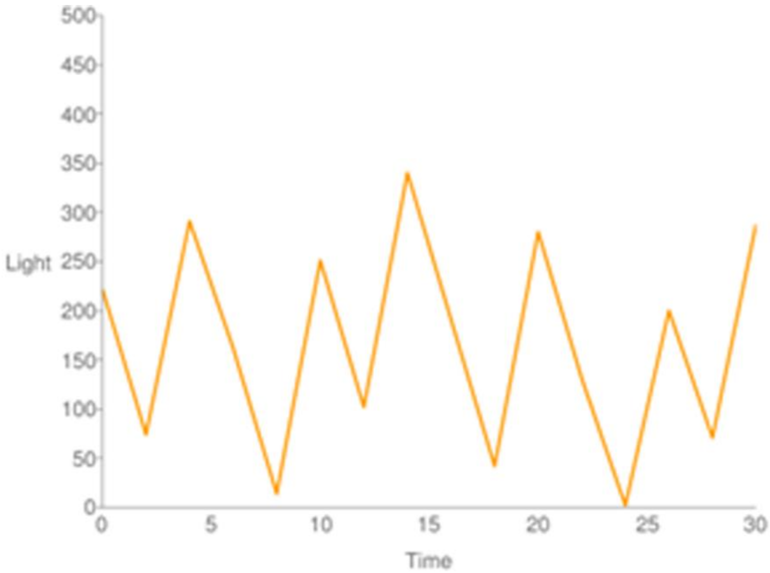

Figure 10: Light in Node 5.

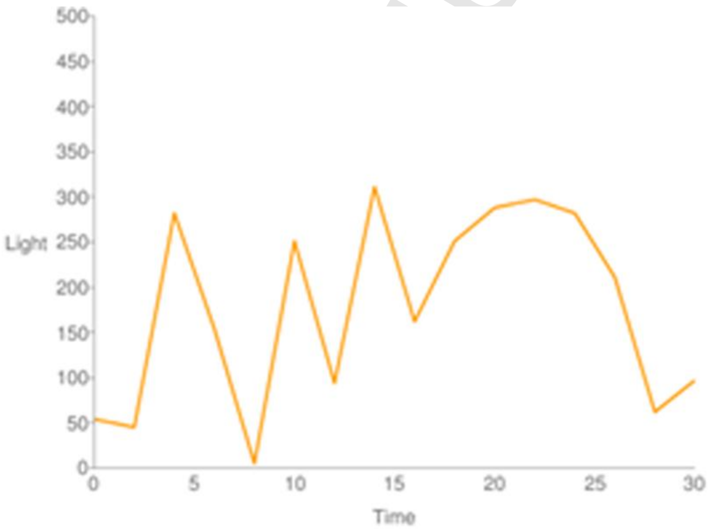

Figure 11: Light in Node 6.

After we stop the simulation, we can open Wireshark and then, open the "*.pcap"* file created. As we already said, this file contains all packets transmitted. So, using Wireshark, we can observe, various information about the communications. In the following Figure 12 presented the situation described above.

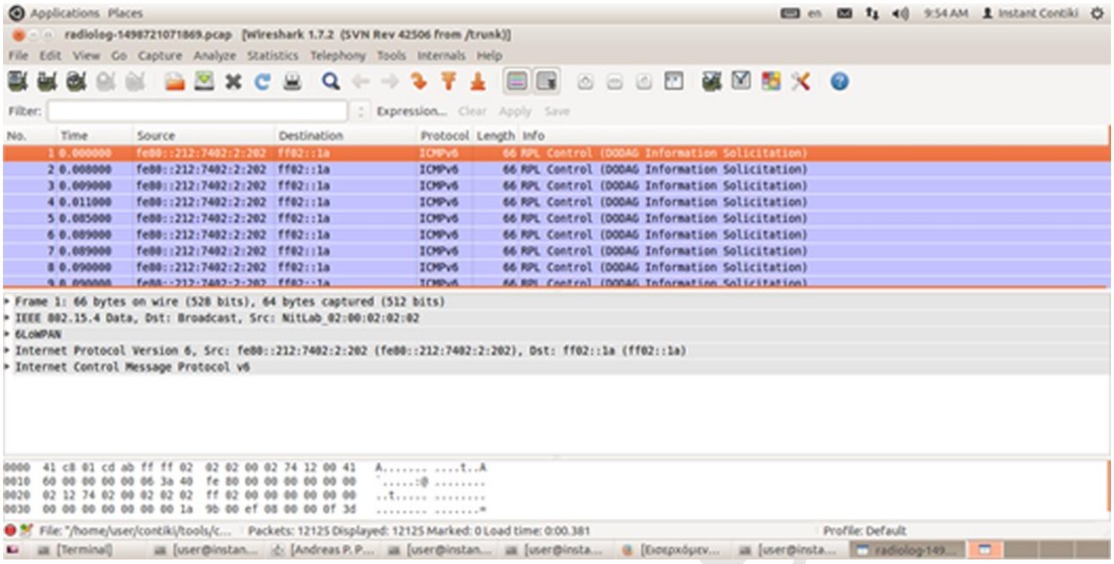

Figure 12: Using pcap files in Wireshark.

With our proposed system we can achieve energy efficiency with the use of the collected and managed sensors' data. In contrast with the previous works, we implemented a system that includes sensors that took measures for temperature, movement, light and moisture with the aim to achieve a better management of the building and also to make the building "smart" and efficient. In our proposed system the users would have remote access to sensors' data, and also they could manage the information of the data in order to be able to make some actions. Furthermore, with the use of the analyzed data, measurements which were recorded by the motion sensor, the user will be able to understand if there is someone in the house, which can offer "security" sense.

VI. Conclusion

New and better solutions for making Smart Cities more efficient implanted and presented by the technologies surveyed in this work. Cost reduction, safer environment, comfortable and friendly applications could be achieved through a system which can exploit all the abilities of the technologies we studied. With multiple sensors installed in a Smart Building we can achieve a better monitoring system of the whole building. The proposed systems implemented in a simulation environment of Cooja Contiki.

This paper surveyed Internet of Things, Cloud Computing, Big Data and Sensors technologies with the aim to find their common operations and combine them. Moreover, regarding smart city concept, we tried to propose new methods in order to collect and manage sensors' data in a smart building, which operates in IoT environment. Finally, the proposed solutions for collecting and managing sensors' data in a smart building could lead us in energy efficient smart building, and thus in a Green Smart Building.

In future research, we recommend that the use of the Internet of Things is blended with the technology of Monitoring, despite the use of sensors, with the aim to achieve optimum results in its use, under a Cloud environment. Additionally, we would further examine the methods and the solutions for collecting and managing sensors' data in a smart building with the aim to make a beneficial use of the network of the building. Moreover, we have already started to implement the proposed system with the use of an Arduino Board and compatible sensors in our university campus. Also, this could lead us in reducing the energy, and thus the cost of the energy that used in the building. This can be the field of future research.

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REFERENCES

[1] Y. Kryftis, G. Mastorakis, C. Mavromoustakis, J. Mongay Batalla, E. Pallis, G. Kormentzas, "Efficient Entertainment Services Provision over a Novel Network Architecture", IEEE Wireless Communications Magazine, vol. 23, issue 1, pp. 14-21, March 2016.

[2] C. Stergiou, K. E. Psannis, "Recent advances delivered by Mobile Cloud Computing and Internet of Things for Big Data applications: a survey", Wiley, International Journal of Network Management, pp. 1-12, May 2016.

[3] C. Stergiou, K. E. Psannis, B.-G. Kim, B. Gupta, "Secure integration of IoT and Cloud Computing", Elsevier, Future Generation Computer Systems, December 2016.

[4] S. Sahu, Y.a Dhote, "A Study on Big Data: Issues, Challenges and Applications", International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE), vol. 4, issue 6, pp. 10611-10616, June 2016.

[5] M. Chen, S. Mao, Y. Liu, "Big Data: A Survey", Springer, Mobile Network Applications, vol. 19, issue 2, pp. 171-209, January 2014.

[6] R.Toshniwal, K. G. Dastidar, A. Nath, "Big Data Security Issues and Challenges", International Journal of Innovative Research in Advanced Engineering (IJIRAE), Vol. 2, Issue: 2, February 2015.

[7] R. Kaur, S. Kinger, "Analysis of Security Algorithms in Cloud Computing," International Journal of Application or Innovation in Engineering & Management (IJAIEM), vol. 3, no. 3, pp. 171-176, March 2014.

[8] C. Stergiou, K. E. Psannis, "Efficient and Secure Big Data delivery in Cloud Computing", Springer, Multimedia Tools and Applications, pp. 1-20, April 2017.

[9] G. Kokkonis, K. E. Psannis, M. Roumeliotis, D. Schonfeld, "Real-time wireless multisensory smart surveillance with 3D-HEVC streams for internet-of-things (IoT)", Journal of Supercompuitng, vol. 73, issue 3, pp. 1044-1062, June 2016.

[10] D. Tomtsis, S. Kontogiannis, G. Kokkonis, I. Kazanidis, S. Valsamidis, "Proposed cloud infrastructure of wearable and ubiquitous medical services", 5th Int. Conf. on Digital Information Processing and Communications (ICDIPC 2015), pp. 213-218, Switzerland, October 2015.

[11] C. Stergiou, K. E. Psannis, A. P. Plageras, G. Kokkonis, Y. Ishibashi, "Architecture for Security in IoT Environments", in Proceedings of 26th IEEE International Symposium on Industrial Electronics, 19-21 June 2017, Edinburgh, Scotland, UK.

[12] A. P. Plageras, C. Stergiou, K. E. Psannis, G. Kokkonis, Y. Ishibashi, Byung-Gyu Kim, Brij Gupta, "Efficient Large-Scale Medical Data (eHealth Big Data) Analytics in Internet of Things", in Proceedings of 19th IEEE International Conference on Business Informatics (CBI'17), International Workshop on the Internet of Things and Smart Services (ITSS2017), 24-26 July 2017, Thessaloniki, Greece.

[13] C. Stergiou, K. E. Psannis, "Algorithms for Big Data in Advanced Communication Systems and Cloud Computing", in Proceedings of 19th IEEE Conference on Business Informatics 2017 (CBI2017), 24-26 July 2017, Thessaloniki, Greece.

[14] F. Pfarr, T. Buckel, A. Winkelmann, "Cloud Computing Data Protection – A Literature Review and Analysis", in Proceedings of 47th Hawaii International Conference on System Science, Waikoloa, HI, USA, pp. 5018-5027, 6-9 January 2014.

[15] G. Suciu A. Vulpe, S. Halunga, O. Fratu, G. Todoran, V. Suciu, "Smart Cities Built on Resilient Cloud Computing and Secure Internet of Things", in Proceedings of 19th International Conference on Control Systems and Computer Science, Bucharest, Romania, 29-31 May 2013.

[16] A. P. Plageras, K. E. Psannis, Y. Ishibashi, B.-G. Kim, "IoT-based Surveillance System for Ubiquitous Healthcare", in Proceedings of 42nd Annual Conference of IEEE Industrial Electronics Society, Florence, Italy, 2016.

[17] [A. P. Plageras, C. Stergiou, K. E. Psannis, Byung-Gyu Kim, Brij Gupta, Y. Ishibashi, "Solutions for Inter-connectivity and Security in a Smart Hospital Building", in Proceedings of 15th IEEE International Conference on Industrial Informatics (INDIN 2017), 24-26 July 2017, Emden, Germany.

[18] Terence K.L. Hui, R. Simon Sherratt, Daniel Díaz Sánchez, Major requirements for building Smart Homes in Smart Cities based on Internet of Things technologies, Future Generation Computer Systems, Volume 76, 2017, Pages 358-369, ISSN 0167-739X.

[19] Tai-hoon Kim, Carlos Ramos, Sabah Mohammed, Smart City and IoT, Future Generation Computer Systems, Volume 76, 2017, Pages 159-162, ISSN 0167-739X.

[20] P. K. Choubev, S. Pateria, A. Saxena, V. P. Chirayil SB, K. K. Jha, S. Basaiah PM, "Power Efficient, Bandwidth Optimized and Fault Tolerant Sensor Management for IOT in Smart Home", Advance Computing Conference (IACC), 2015 IEEE International, 12-13 June 2015, Banglore, India.

[21] G. Lilis, G. Conus, N. Asadi, M. Kayal, “Towards the next generation of intelligent building: An assessment study of current automation and future IoT based systems with a proposal for transitional design”, Sustainable Cities and Society, vol 28, pp. 473-481, January 2017.

[22] J. L. Hernandez-Ramos, M. V. Moreno, J. B. Bernabe, D. G. Carrillo, A. F. Skarmeta, “SAFIR: Secure access framework for IoT-enabled services on smart buildings”, Journal of Computer and System Sciences, vol. 81, issue: 8, pp. 1452-1463, December 2015.

[23] W. Lee, S. Cho, P. Chu, H. Vu, S. Helal, W. Song, Y.-S. Jeong, K. Cho, “Automatic agent generation for IoT-based smart house simulator”, Neurocomputing, vol. 209, pp. 14-24, October 2016.

[24] M. V. Moreno, L. Dufour, A. F. Skarmeta, A. J. Jara, D. Genoud, B. Ladevie, J.-J. Bezian, “Big data: the key to energy efficiency in smart buildings”, Soft Computing, vol. 20, issue: 5, pp. 1749-1762, May 2016.

[25] J. Shah, B. Mishra, “Customized IoT Enabled Wireless Sensing and Monitoring Platform for Smart Buildings”, Procedia Technology, vol. 23, pp. 256-263, February 2016.

[26] V. Moreno, M. A. Zamora, A. F. Skarmeta, “A Low-Cost Indoor Localization System for Energy Sustainability in Smart Buildings”, IEEE Sensors Journal, vol. 16, issue: 9, pp. 3246-3262, February 2016.

[27] H. Arasteh, V. Hosseinnezhad, V. Loia, A. Tommasetti, O. Troisi, M. Shafie-khah, P. Siano, “Iot-based Smart Cities: a Survey”, in Proceedings of IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), 7-10 June 2016, Florence, Italy.

[28] A. Barbato, C. Bolchini, M. Delfanti, A. Geronazzo, E. Quintarelli, V. Olivieri, C. Rottondi, G. Verticale, G.Accetta, A. Ded`e, G. Massa, M. Trioni, “An Energy Management Framework for Optimal Demand Response in a Smart Campus”, , in Proceedings of 4th International Conference on Green IT Solutions REEN, June 2015.

[29] L. Berntzen, M. R. Johannessen, A. Florea, “Sensors and the Smart City: Creating a Research Design for Sensor-based Smart City Projects”, in Proceedings of 5th International Conference on Smart Cities, Systems, Devices and Technologies (SMART 2016), Valencia, Spain, May 2016.

[30] K. Lin, M. Chen, J. Deng, M. M. Hassan, G. Fortino, “Enhanced Fingerprinting and Trajectory Prediction for IoT Localization in Smart Buildings”, IEEE Transactions on Automation Science and Engineering, vol. 13, issue: 3, pp. 1294-1307, April 2016.

[31] Enamul Kabir, Jiankun Hu, Hua Wang, Guangping Zhuo, A novel statistical technique for intrusion detection systems, Future Generation Computer Systems, 2017, ISSN 0167-739X.

[32] Hatem Ben Sta, Quality and the efficiency of data in “Smart-Cities”, Future Generation Computer Systems, Volume 74, 2017, Pages 409-416, ISSN 0167-739X.

[33] S. Alletto, R. Cucchiara, G. Del Fiore, L. Mainetti, V. Mighali, L. Patrono, G. Serra, “An Indoor Location-aware System for an IoT-based Smart Museum”, IEEE Internet of Things Journal, vol. 3, issue: 2, pp. 244-253, December 2015.

[34] M. J. Kaur, P. Matheshwari, “Building Smart Cities Applications using IoT and Cloud-based Architectures”, in Proceedings of 2016 International Conference on Industrial Informatics and Computer Systems (CIICS), 13-15 March 2016, Sharjah, United Arab Emirates.

[35] Y. Sun, T.-Y. Wu, G. Zhao, M. Guizani, “Efficient Rule Engine for Smart Building Systems”, IEEE Transactions on Computers, vol. 64, issue: 6, pp. 1658-1669, August 2014.

[36] T. McGinley, “A morphogenetic architecture for intelligent buildings”, Journal of Intelligent Buildings International, vol. 7, issue: 1, pp. 4-15, November 2014.

[37] J. Basnayake, R. Amarasinhe, R. Attalage, T. Udayanga, B. Jayasekara, “Artificial Intelligence Based Smart Building Automation Controller for Energy Efficiency Improvements in Existing Buildings”, International Journal of Advanced Information Science and Technology (IJAIST), vol. 40, No. 40, August 2015.

[38] I. Romdahani I. Romdhani, A. Y. Al-Dubai, M. Qasem, B. Ghaleb, I. Wadhaj, “Cooja Simulator Manual”, Technical Report, Edinburgh Napier University, July 2016.

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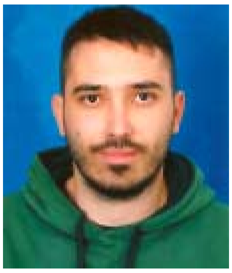

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