**TELKOMNIKA Telecommunication Computing Electronics and Control**
Vol. 20, No. 4, August 2022, pp. 788~796
ISSN: 1693-6930, DOI: 10.12928/TELKOMNIKA.v20i4.23762 

# Resource placement strategy optimization for IoT oriented monitoring application

**Saad-Eddine Chafi[1], Younes Balboul[1], Mohammed Fattah[2], Said Mazer[1], Moulhime El Bekkali[1], Benaissa Bernoussi[1]**
[1]Artificial Intelligence, Data Sciences and Emerging Systems Laboratory, Sidi Mohamed Ben Abdellah University, Fez, Morocco
[2]Superior School of Technology, Moulay Ismail University, Meknes, Morocco

**Article Info**

***Article history:***

Received Jun 15, 2021
Revised May 20, 2022
Accepted Jun 01, 2022

***Keywords:***

IFogSim
IoT
Monitoring application
Placement strategy
Quality of service

**ABSTRACT**

Cloud computing and the low power wide area network (LPWAN) network represent the key infrastructures for developing intelligent solutions based on the internet of things (IoT). However, the diversity of use cases and deployment scenarios of IoT in the different domains makes optimizing IoT-based cloud solutions a major challenge. The cloud solution’s cost increases with the increase in central processing unit (CPU) resources and energy consumption. The optimal use of edge material resources in industrial solutions will reduce the consumption of resources and thus optimize cloud infrastructure costs in terms of resources and energy consumption. The article presents the network and application architecture of an IoT monitoring solution based on cloud services. Then, we study the integration of IoT services based on application placement strategies on the fog cloud compared to the traditional centralized cloud strategy. Simulations evaluate the scenarios with the iFogSim simulator and the analyzed results compare the traditional strategy with the cloud-fog. The results show that cost and energy consumption in the cloud can be significantly reduced by processing the application at the end devices level with respect to the possible limit of CPU processing power for each IoT end device. Latency and network usage respect quality of service constraints in cloud-fog placement for this type of monitoring-oriented IoT application.



***Corresponding Author:***

Saad-Eddine Chafi
Artificial Intelligence, Data Sciences and Emerging Systems Laboratory
Sidi Mohamed Ben Abdellah University, Fez, 30050, Morocco
Email: saad.chafi@usmba.ac.ma

## 1. INTRODUCTION

The intelligent decision-making systems based on the internet of things (IoT) have become the most effective way to solve the problems and technical complexities of resource management in industry. The data-driven decision-making has become a very important means of taking corrective action and ensuring that systems work. These solutions cannot be achieved without the existence of intelligent connected objects capable of taking the necessary measurements and also applications capable of processing its data intelligently and quickly and storing it in the cloud [1], [2].

Gilchrist [3] explains that the need to implement IoT applications as industrial systems is already very complicated, so that the capabilities of human operators to understand, manage, and optimize their overall performance have reached their limits. Collecting appropriate data and extracting relevant data observed with the aid of their analysis permits gaining insight and new knowledge to realize optimization of production performance, which is a lot more difficult to match for traditional methods [4]. IoT applications have precise necessities such as long-range, low data rate, low energy consumption, and cost [5]. Currently, with the explosive boom of IoT technologies, a growing range of practical applications can be located in many fields, which includes smart cities [6], [7], which is used to monitor the state of urban infrastructure [8]-[10] (roads, bridges, tunnels, subways, airports, power and water transmission lines) and efforts are made to optimize the use of resources [11]. In the field of the intelligent industry, it can be utilized to monitor product availability in real-time and monitor product stock in the warehouse [12]-[14]. In healthcare, it can allow people to monitor their daily activities (e.g., calorie intake, and heart rate). On this basis, suggestions can be made to improve their lifestyle to prevent the appearance of health problems [12], [15], [16].

This paper aims to give a clear understanding of the difference between placement strategies based on centralized cloud and placement strategies based on the cloud fog [17] and give the savings in deployment costs and energy consumption in the cloud provided by the proper use of all edge resources. The rest of this paper is organized as follows. Section 2 summarizes the related works with state of the art for IoT monitoring applications. In section 3, we explain our proposed IoT monitoring solution Infrastructure in detail. Section 4 discuss deployment strategy and simulation scenarios with iFogSim. In section 5, we discuss the problem with the solution. In section 6, we analyze the results of the two placement strategies applied in simulation. The conclusion of this work provides in section 7.

## 2. RELATED WORKS FOR IoT MONITORING APPLICATION

Explaining an extensive number of projects have been described in the literature that utilizes IoT real-time monitoring. For example, several works present intelligent IoT solutions capable of tracking the health status of sensitive people or the elderly. In [18] several IoT technical architectures for providing health care services are presented. In another study, Schürholz *et al*. [19] presents a technique to supervise and monitor air quality named "my air quality index", the solution relies on a smart notification application integrate with an IoT system to recommend solutions to users to improve air quality in their living environments. Vega *et al*. [20] presented a system to assist caregivers in real-time monitoring of patients' health status and also to enable close communication between caregivers and patients' families. Vishwakarma *et al*. [21] proposed a secure system capable of handling all domestic equipment via the internet. This system allows better visibility and optimization of energy consumption in connected homes. Salhaoui *et al*. [22] proposed a surveillance solution based on connected drones capable of extracting and processing information in real time based on the services offered by fog fomputing.

The intelligence of this surveillance system lies in the fact that the sets of images captured by the drones are sent and processed quickly at the fog computing nodes and then the relevant images are sent and stored in the cloud. This enables optimized processing and consumption of resources in the cloud. Thamaraimanalan *et al*. [23] proposed a system for monitoring and automating the biological and physical parameters of gardens in order to improve the quality of plants. In another study by Moparthi *et al.* [24], invented a system for monitoring water quality in lakes which is based on the variation of the potential of hydrogen (pH) to measure the quantity of pollutants in the water and send warning messages to the authorities concerned.

To meet the future needs of internet of things applications, it is necessary to take into consideration several basic parameters which can be summarized as: the type and range of the link, speed, latency, energy consumption , the type of connection between the objects and the cloud (edge, fog, classic) and finally the cost of the solution. Regarding the type and scope of the solution, it should be realized that solutions based on radio personal area network (PAN) networks wireless fidelity (WiFi), zonal intercommunication global-standard (ZigBee), Bluetooth) will not satisfy a long-range radio communication solution and that also traditional radio mobile solutions based on third generation partnership project (3GPP) standards (2G, 3G, 4G) can provide long range connection, but with high power consumption. This allows us to say that the classic solutions that already exist will not meet the real needs of future applications where all the objects will be connected [25].

The requirements of IoT applications have led to the creation of low power wide area network (LPWAN) radio access technologies such as (long range radio (LoRa), narrowband IoT (NB-IoT), Sigfox, and others) and these technologies meet energy needs and can reach 5 km ranges in urban areas and up to 15 km in rural areas [26], [27]. In addition, the cost of the radio chipset is less than 2 euros and the operating cost is of 1euros per device per year [28]. Regarding the type of connection between IoT and the cloud many service placements were proposed in the literature as a solution to map IoT services among fog and cloud resources, Hassan *et al.* [29] proposed an efficient policy, called MinRE, for service placement problem (SPP) in fog-cloud systems.

To supply each quality of services (QoS) for IoT services and energy efficiency for fog service providers to minimize response time and energy consumption of fog environment, Azizi and Khosroabadi [30] introduced an algorithm that takes into account the deadline requirement of every IoT application so that the most delay-sensitive applications are positioned on the devices as nearer as possible to the service consumer.

Furthermore, in order to reduce the network bandwidth and the cost of execution in the cloud. Skarlat *et al.* [31] proposed a genetic algorithm as a problem resolution heuristic and show, via experiments, that the service execution can obtain a reduction of network communication delays when the exact genetic algorithm optimization approach is utilized.

## 3. IoT MONITORING SOLUTION STRUCTURE

### 3.1. System concept

IoT platforms are the middleware solutions that connect the IoT devices to the cloud and help seamlessly exchange data over the network. It acts as a mediator between the application layer and the hardware. Most IoT platforms for monitoring adopt the architecture in Figure 1. This architecture presents several objects connected via special gateways LPWAN that are connected to the core network operator to link objects to remote clouds.

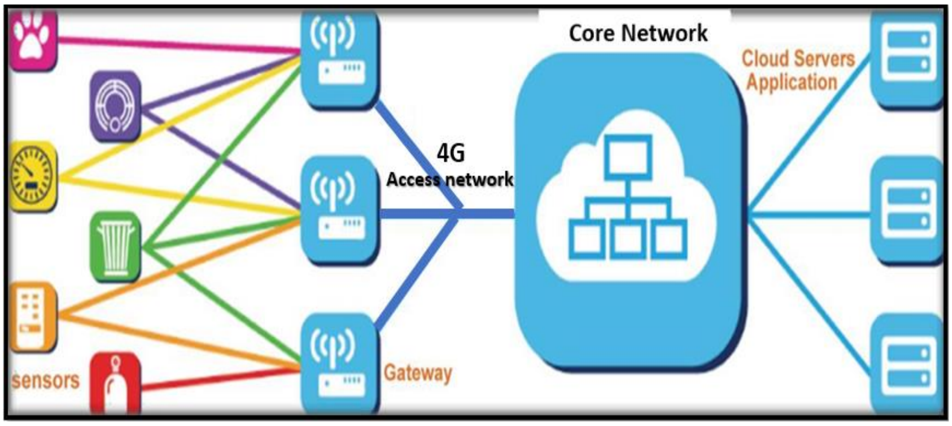


Figure 1. Typical network architecture for an IoT platform

The measurement, for example, of temperature, pressure, carbon dioxide ($CO_2$), and geolocation, taken by the sensor is then sent to the bridge using an initial communication protocol. The gateway has a very important role in IoT applications, it allows the translation of communication protocols between objects connected via low power area networks and the operator access network to reach the cloud. It should be noted that the gateway can play the role of a local cloud in order to reduce application latencies. For low-power personal area network (LPPAN) protocols (Z-Wave and ZigBee), the gateway is local and connected to the internet service provider (ISP)'s box. For LPWAN protocols (Sigfox, LoRa, and NB-IoT) [32]-[34], the gateway is on the telecom operator's network. After the collection of data in the cloud comes the role of the IoT platform which is linked directly to the end user and allows him to benefit from the applications services (alert messages, and recommendations) [35].

### 3.2. The application used for our simulation scenario

We have three different important modules on our simulated IoT monitoring application; the caption module in our case is the client module who get all the data collected by the sensor, the main module who get the necessary data needed by our application and organize data in the appropriate table format and the storage module which saved the data in the cloud. The application model is delineated in Figure 2. We expect that client module is located in end fog end devices, and storage module is located in the cloud. The main module requires a certain measure of computational resources to be started. To serve the interest of various end devices inside their cut-off time, extra resources can be asked by end devices to connected gateway fog devices.

We This type of application represents the typical operation of IoT applications for intelligent monitoring and supervision. These applications have no latency constraints generally, and the amount of data sent are very low for each sensor but be careful that the number of sensors deployed is huge to ensure the monitoring (so the data sent in total are big data). The typical frequency of sending data for IoT monitoring applications is from 1 s to several seconds. For example, monitoring in the intelligent industry like industrial equipment (electric motors or others) regularly sends data for energy consumption at continuous frequencies to control the power and prevent future failures (preventive maintenance).

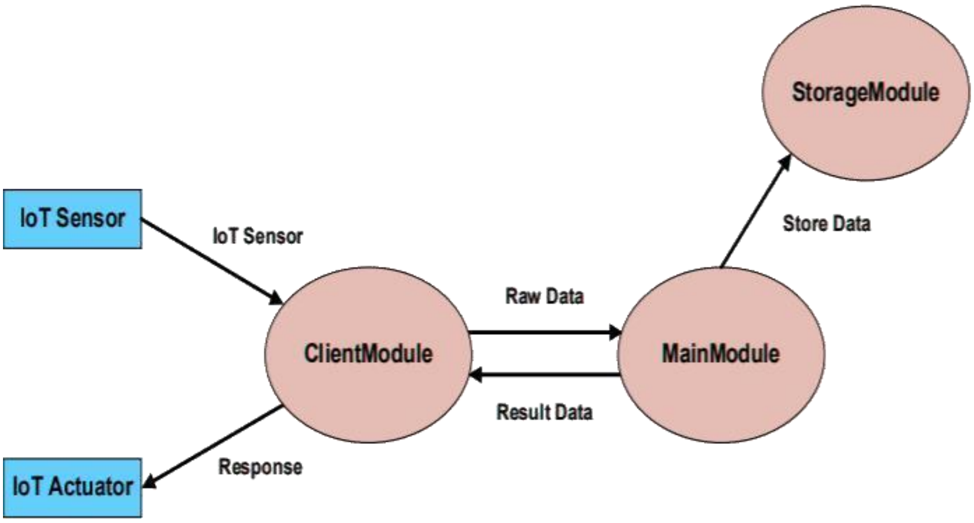


Figure 2. Application model for IoT monitoring application

### 3.3. The architecture and parameters used in our scenario with the iFogSim simulator

To model and simulate our architecture and application solution in the iFogSim simulator [36] we need the following steps. First, we create and give the specific configuration for the network physical elements. The configuration parameters consist of ram, processing capability in a million instructions per second (MI/S), cost per million instruction processing (MIPS), uplink and downlink bandwidth, busy and idle power, along their hierarchical level. The associate IoT devices (sensors and actuators) need to be created. Next, the logical element for modeling the monitoring application such as AppModule, AppEdge, and AppLoop must be created. While creating the AppModules, their configurations are furnished, and the AppEdge objects encompass information related to tuples type, their direction, central processing unit (CPU), and networking length alongside the reference of source and destination module.

Finally, the mapping modules procedure allow to create and manage the strategies of placement of the application modules (AppModule), the application investment policies can take into consideration several criteria like the cost of operations (CPU, random-access memory (RAM), storage), energy consumption, throughput, latency and also the heterogeneity of the connected objects. Then there is the mapping of the fog objects and the validation of the “AppEdges” and tuples simulation parameters. Finally, all the system configurations and the topology are sent to the controller object, then the controller transfers the entire system to the cloudsim to run the simulations. Figure 3 presents the hierarchical topology used in the iFogSim simulator to present our model for IoT monitoring applications [37].

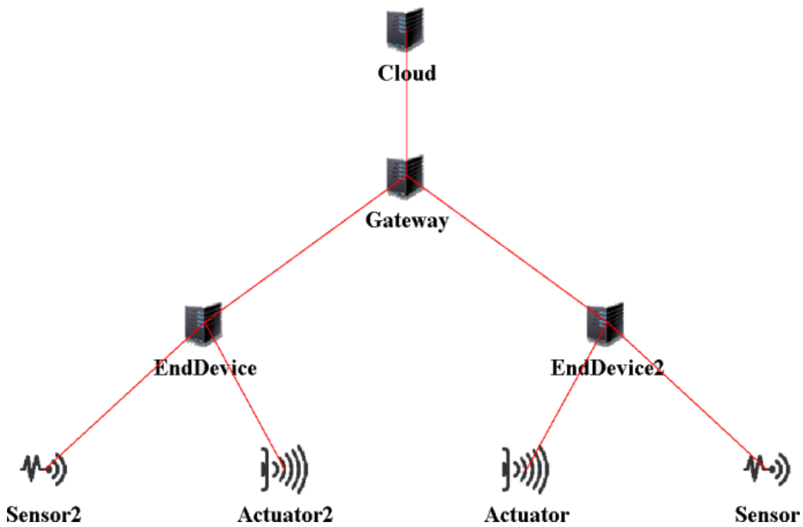


Figure 3. Simulated IoT monitoring architecture on iFogSim

In our simulations, the fog devices are divided into 3 hierarchical levels: the first level is the “end-devices” which are connected to the sensors and actuators. In level 2 we find the gateway which links the “end-devices” via the 4G operator access network to the level 3 which represents the cloud data center. In the simulations the sensing frequency is the same for all sensors and the fog devices of the same hierarchical levels are considered homogeneous. Also, we have to configure the links between each network (access, end device gateway, collection network, and operator core): the parameters: uplink/downlink throughput, latency and for equipment, it is computing power). Our configuration is based on the 4G access network performance, and we used a standard sensor in the market with a CPU of 1200 MIPS.

Moreover, we can use more sensing capacity. The interest is to create a next-generation application that will reduce latency and power consumption. Our application favors the processing at the end devices that the need for the new generation applications requires the processing in the end devices to improve the latency, of course, the response time. The configuration is presented in Table 1.

Table 1. IFogSim simulation parameters

| Parameter | Cloud | Gateway | End device |
|---|---|---|---|
| MIPS | 44800 | 3800 | 1200 |
| RAM | 40000 | 4000 | 1000 |
| Uplink bandwidth (KB/s) | 100 | 10000 | 10000 |
| Downlink bandwidth (KB/s) | 10000 | 10000 | 270 |
| Level hierarchy | 0 | 1 | 2 |
| Rate per MIPS | 0.01 | 0.0 | 0.0 |
| Uplink latency (ms) | None | 50 | 20 |

## 4. PROBLEM WITH SOLUTION

Our job is to investigate a data placement method for IoT in fog infrastructure to minimize the cloud system energy consumption and operational cost taking into account the network bandwidth and latency constraints of our monitoring application. So how the resource requirement changes depending on the deployment strategy of the IoT monitoring application in the system. Our solution is to create a different placement strategy to know the impact of each strategy based on the constraints of the operator network. Before we introduce the strategy implemented, we need to know the strategy policy; it determines how the application modules are placed in the fog devices on the strategy process can be guided by such objectives as reduction of end-to-end latency, network usage, operational cost or energy consumption. The Module placement class is the abstract strategy policy that must be extended to incorporate new policies. Using the first placement policy, we target to place the main module and the client module to be executed in the end device based on their resource availability in the host devices. The storage module is implemented in the cloud on our architecture. However, for the second placement policy, we integrate all the application entities to be run on the cloud. For easier understanding, the flowchart of the application placement policy is represented in Figure 4.

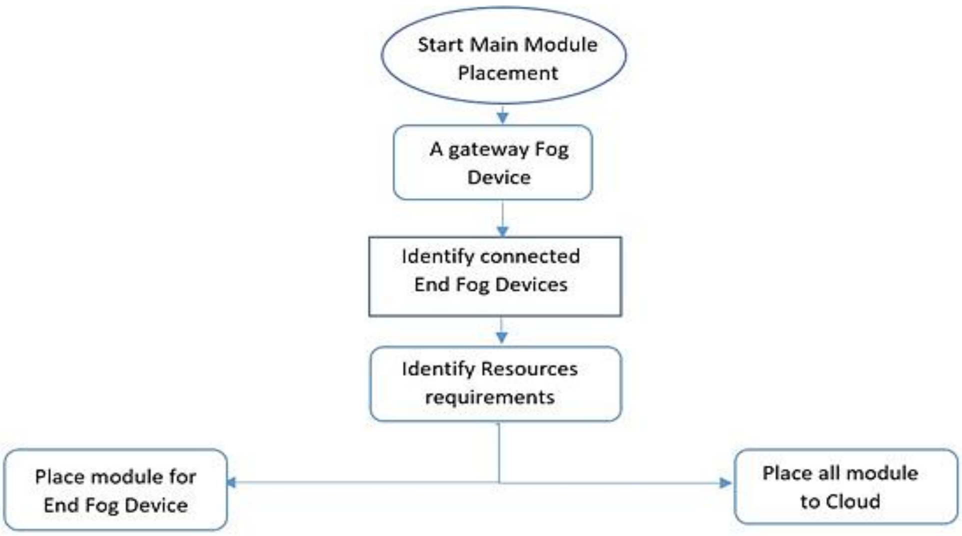


Figure 4. Flow-chart of the application placement policy

## 5. PERFORMANCE ANALYSIS

Provide Figure 5 and Figure 6 show that the cost in the cloud and the system energy consumption can be significantly reduced by carrying out the application processing at the end devices level and setting the limit of the CPU usage processing power (in MIPS) for each end device. In our simulation, two parameters are involved: (the end device limit CPU and the number of objects in parallel processing) for a CPU processing limit of 1200 MIP for end devices which is typical of low power IoT applications and a limit of 10 end devices. Running the application in end devices optimizes energy consumption in the cloud by 21% for 4 end devices and up to 51% for 10 end devices compared to energy consumption in the case of processing the application only in the cloud. Regarding the cost of execution in (MIPS) of the system, the end device placement strategy provides a resource-saving of 79.5% for a system with 4 end devices and 47.33% for a system with 10 end devices.

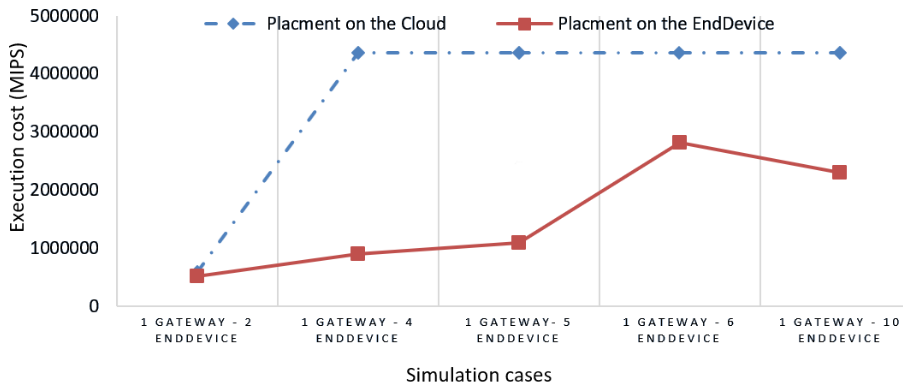


Figure 5. Execution cost in the cloud

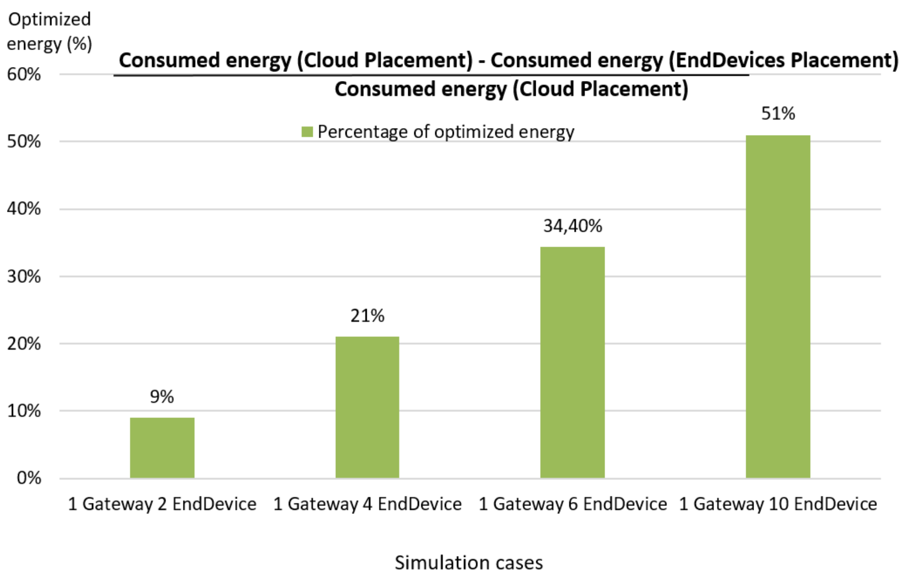


Figure 6. The percentage of optimized energy with end devices placement compare to cloud placement

Regarding the execution of the application on the end devices, the latency slightly exceeds that of the execution in the cloud by approximately 10%, so an additional delay of 8 ms between the two processing scenarios is very permissible. In IoT monitoring applications, the latency can reach between 2 to several seconds. Figure 7 gives the loop delay for the end devices placement strategy and the cloud placement strategy.

For the network flow. The application processing in the end device represents a network use double share compared to that where the application processing is located on the cloud. but in this type of application, the amount of data does not exceed the Mb. for example for 10 parallel end devices the network usage does not exceed 96 Mb as we can see in Figure 8.

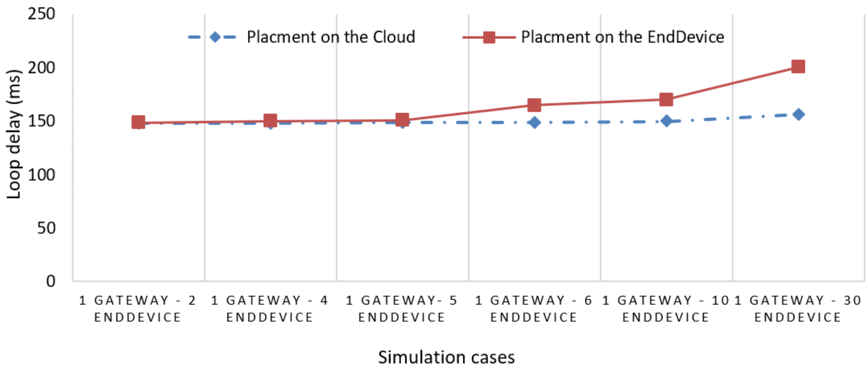


Figure 7. The loop delay for end devices placement strategy and the cloud placement strategy

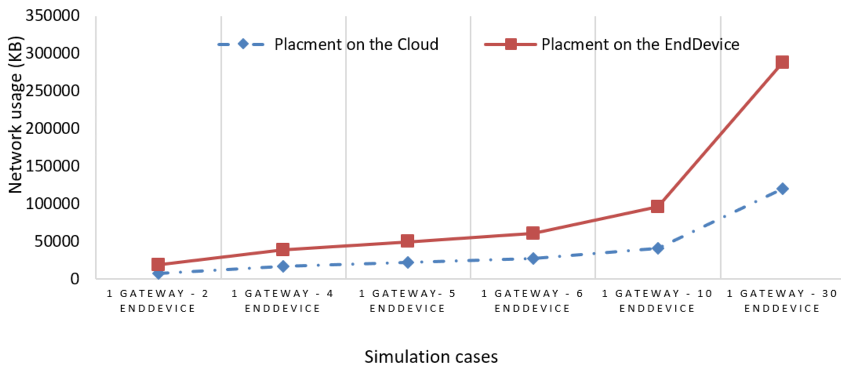


Figure 8. Network usage for end devices placement strategy and the cloud placement strategy

## 6. CONCLUSION

In this paper, we propose a two-placement algorithm using an architecture of an IoT monitoring solution based on cloud services, and we study the integration of IoT services based on application placement strategies on the fog cloud compared to the traditional centralized cloud strategy. We compared the performance of the proposed two algorithms based on the iFogSim simulator, and we analyzed the results concerning the optimization of the system cost and the energy consumption in the cloud. The results show that energy consumption in the cloud can be considerably decreased by processing the application at the end devices level with respect to the possible limit of CPU processing power for each IoT end device. Latency and network usage respect quality of service constraints in the case of cloud-fog placement for this type of monitoring-oriented IoT application. In the future, we plan to include a new hybrid algorithm between the application placement in the end devices and the application placement in the cloud according to constraints of CPU limit on end devices, and the number of objects processed in parallel to optimize the energy consumption function.

## REFERENCES

[1] R. G. F. Braz, L. F. Scavarda, and R. A. Martins, "Reviewing and improving performance measurement systems: An action research," *International Journal of Production Economics*, vol. 133, no 2, pp. 751-760, Oct. 2011, doi: 10.1016/j.ijpe.2011.06.003.
[2] M. Syafrudin, G. Alfian, N. L. Fitriyani, and J. Rhee, "Performance analysis of IoT-based sensor, big data processing, and machine learning model for real-time monitoring system in automotive manufacturing," *Sensors*, vol. 18, no 9, 2018, doi: 10.3390/s18092946.
[3] A. Gilchrist, *Industry 4.0: The industrial internet of things*, Bangken, Nonthaburi, Thailand: APRESS, 2016. [Online]. Available: https://www.academia.edu/38736167/The_Industrial_Internet_of_Things_Industry_4_0
[4] H. G. Miller and P. Mork, "From data to decisions: a value chain for big data," *IT Professional*, vol. 15, no 1, pp. 57-59, 2013, doi: 10.1109/mitp.2013.11.
[5] R. Ratasuk, N. Mangalvedhe, and A. Ghosh, "Overview of LTE enhancements for cellular IoT," *2015 IEEE 26th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, 2015, pp. 2293-2297, doi: 10.1109/PIMRC.2015.7343680.
[6] T. S. Gunawan *et al.*, "Prototype design of smart home system using internet of things," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 7, no 1, pp. 107-115, 2017, doi: 10.11591/ijeecs.v7.i1.pp107-115.
[7] R. Ramly, A. A. B. Sajak, and M. Rahid, "IoT recycle management system to support green city initiatives," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 15, no 2, pp. 1037-1045, 2019, doi: 10.11591/ijeecs.v15.i2.pp1037-1045.

[8] V. A. Memos, K. E. Psannis, Y. Ishibashi, B. -G. Kim, and B. B. Gupta, "An efficient algorithm for media-based surveillance system (EAMSuS) in IoT smart city framework," *Future Generation Computer Systems*, vol. 83, pp. 619-628, 2018, doi: 10.1016/j.future.2017.04.039.

[9] B. Hammi, R. Khatoun, S. Zeadally, A. Fayad, and L. Khoukhi, "IoT technologies for smart cities," *IET Networks*, vol. 7, no. 1, pp. 1-13, 2018, doi: 10.1049/iet-net.2017.0163.

[10] C. R. Srinivasan, G. Charan, and P. C. S. Babu, "An IoT based SMART patient health monitoring system," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 18, no 3, pp. 1657-1664, 2020, doi: 10.11591/ijeecs.v18.i3.pp1657-1664.

[11] O. Vermesan and P. Friess, *Internet of things-from research and innovation to market deployment*, Aalborg, Denmark: River Publishers, 2014. [Online]. Avalaible: https://www.riverpublishers.com/pdf/ebook/RP_E9788793102958.pdf

[12] D. Miorandi, S. Sicari, F. D. Pellegrini, and I. Chlamtac, "Internet of things: Vision, applications and research challenges," *Ad Hoc Networks*, vol. 10, no 7, pp. 1497-1516, Sep. 2012, doi: 10.1016/j.adhoc.2012.02.016.

[13] A. Čolaković, S. Čaušević, A. Kosovac, and E. Muharemović, "A Review of Enabling Technologies and Solutions for IoT Based Smart Warehouse Monitoring System," in *International Conference New Technologies, Development and Applications*, 2020, vol. 128, pp. 630-637, doi: 10.1007/978-3-030-46817-0_73.

[14] M. Rath and B. Pattanayak, "Technological improvement in modern health care applications using Internet of Things (IoT) and proposal of novel health care approach," *International Journal of Human Rights in Healthcare*, vol. 12, no. 2, 2019, doi: 10.1108/ijhrh-01-2018-0007.

[15] P. Verma and S. K. Sood, "Fog assisted-IoT enabled patient health monitoring in smart homes," *IEEE Internet of Things Journal*, vol. 5, no. 3, pp.1789-1796, 2018, doi: 10.1109/jiot.2018.2803201.

[16] S. M. R. Islam, D. Kwak, M. H. Kabir, M. Hossain and K. -S. Kwak, "The Internet of Things for Health Care: A Comprehensive Survey," in *IEEE Access*, vol. 3, pp. 678-708, 2015, doi: 10.1109/ACCESS.2015.2437951.

[17] S. -E Chafi, Y. Balboul, S. Mazer, M. Fattah, M. El Bekkali, and B. Bernoussi, "Cloud computing services, models and simulation tools," *International Journal of Cloud Computing*, vol. 10, no. 5-6, pp. 533–547, 2022, doi: 10.1504/ijcc.2021.120392.

[18] A. H. Ali, R. F. Chisab, and M. J, Mnati, "A smart monitoring and controlling for agricultural pumps using LoRa IOT technology," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 13, no. 1, pp. 286-292, 2019, doi: 10.11591/ijeecs.v13.i1.pp286-292.

[19] D. Schürholz *et al*., "MyAQI: Context-aware Outdoor Air Pollution Monitoring System," in *Proc. of the 9th International Conference on the Internet of Things*, pp. 1-8, 2019, doi: 10.1145/3365871.3365884.

[20] L. A. D. -Vega *et al*., "An IoT system for remote health monitoring in elderly adults through a wearable device and mobile application," *Geriatrics*, vol. 4, no 2, 2019, doi: 10.3390/geriatrics4020034.

[21] S. K. Vishwakarma, P. Upadhyaya, B. Kumari, and A. K. Mishra, "Smart energy efficient home automation system using IoT," in *2019 4th international conference on Internet of things: Smart innovation and usages (IoT-SIU)*, 2019, pp. 1-4, doi: 10.1109/iot-siu.2019.8777607.

[22] M. Salhaoui, A. G. -González, M. Arioua, F. J. Ortiz, A. El Oualkadi, and C. L. Torregrosa, "Smart industrial IoT monitoring and control system based on UAV and cloud computing applied to a concrete plant," *Sensors*, vol. 19, no 15, 2019, doi: 10.3390/s19153316.

[23] T. Thamaraimanalan, S. P. Vivekk, G. Satheeshkumar, and P. Saravanan, "Smart garden monitoring system using IoT," *Asian Journal of Applied Science and Technology (AJAST)*, vol. 2, no 2, pp. 186-192, 2018. [Online]. Available: http://ajast.net/data/uploads/4026.pdf

[24] N. R. Moparthi, C. Mukesh, and P. V. Sagar, "Water quality monitoring system using IoT," *2018 Fourth International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB)*, 2018, pp. 1-5, doi: 10.1109/aeeicb.2018.8480963.

[25] M. Moutaib, M. Fattah, and Y. Farhaoui, "Internet of things: Energy consumption and data storage," *Procedia Computer Science*, vol. 175, pp. 609-614, 2020, doi: 10.1016/j.procs.2020.07.088.

[26] M. Centenaro, L. Vangelista, A. Zanella, and M. Zorzi, "Long-range communications in unlicensed bands: the rising stars in the IoT and smart city scenarios," *IEEE Wireless Communications*, vol. 23, no 5, pp. 60-67, 2016, doi: 10.1109/mwc.2016.7721743.

[27] D. Patel, and M. Won, "Experimental study on low power wide area networks (LPWAN) for mobile Internet of Things," in *2017 IEEE 85th Vehicular Technology Conference (VTC Spring)*, 2017, pp. 1-5, doi: 10.1109/vtcspring.2017.8108501.

[28] U. Raza, P. Kulkarni, and M. Sooriyabandara, "Low power wide area networks: An overview," *IEEE Communications Surveys and Tutorials*, vol. 19, no 2, pp. 855-873, 2017, doi: 10.1109/COMST.2017.2652320.

[29] H. O. Hassan, S. Azizi, and M. Shojafar, "Priority, network and energy-aware placement of IoT-based application services in fog-cloud environments," *IET Communications*, vol. 14, no 13, pp. 2117-2129, 2020, doi: 10.1049/iet-com.2020.0007.

[30] S. Azizi and F. Khosroabadi, "A QoS-aware Service Placement Algorithm for Fog-Cloud Computing Environments," in *4th International Conference on Natural Sciences (ICNS2019) - Mathematics and Computer*, 2019, pp. 1-9. [Online]. Available: https://www.researchgate.net/publication/334507526_A_QoS-aware_Service_Placement_Algorithm_for_Fog-Cloud_Computing_Environments

[31] O. Skarlat, M. Nardelli, S. Schulte, M. Borkowski, and P. Leitner, "Optimized IoT service placement in the fog," *Service Oriented Computing and Applications*, vol. 11, pp. 427-443, 2017, doi: 10.1007/s11761-017-0219-8.

[32] K. Mekki, E. Bajic, F. Chaxel, and F, Meyer, "A comparative study of LPWAN technologies for large-scale IoT deployment," *ICT express*, vol. 5, no 1, pp. 1-7, 2019, doi: 10.1016/j.icte.2017.12.005.

[33] B. Younes, F. Mohammed, M. Said, and M. El Bekkali, "5G uplink interference simulations, analysis and solutions: The case of pico cells dense deployment," International *Journal of Electrical and Computer Engineering (IJECE)*, vol. 11, no. 3, pp. 2245-2255, 2021. doi: 10.11591/ijece.v11i3.pp2245-2255.

[34] A. Es-saqy *et al*., "28 GHz balanced pHEMT VCO with low phase noise and high output power performance for 5G mm-wave systems," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 10, no. 5, pp. 4623-4630, 2020, doi: 10.11591/ijece.v10i5.pp4623-4630.

[35] M. Sruthi and B. R. Kavitha, "A Survey on IoT Platform," *International Journal of Scientific Research and Modern Education (IJSRME)*, vol. 1, no.1, pp. 468-473, 2016. [Online]. Available: http://ijsrme.rdmodernresearch.com/wp-content/uploads/2016/06/58.pdf

[36] R. Mahmud, F. L. Koch, and R. Buyya, "Cloud-fog interoperability in IoT-enabled healthcare solutions," in *Proc. of the 19th International Conference on Distributed Computing and Networking*, 2018, pp. 1-10, doi: 10.1145/3154273.3154347.

[37] H. Gupta, A. V. Dastjerdi, S. K. Ghosh, and R. Buyya, "iFogSim: A toolkit for modeling and simulation of resource management techniques in the Internet of Things, Edge and Fog computing environments," *Software: Practice and Experience*, vol. 47, no 9, pp. 1275-1296, 2017, doi: 10.1002/spe.2509.

**BIOGRAPHIES OF AUTHORS**

**Saad-Eddine Chafi** is currently a PhD candidate at the National School of Applied Sciences. He is member of the team research Information Processing and Transmission– Sidi Mohamed Ben Abdellah University. His research interests include cloud-computing, quality of service of cloud and Internet of things. He can be contacted at email: saad.chafi@usmba.ac.ma.

**Younes Balboul** received his Ph.D. in Telecommunications at the University of Sidi Mohamed Ben Abdellah (USMBA) Fez, Morocco, 2016. Currently professor at the National School of Applied Sciences of Fez, Morocco and member of Artificial Intelligence, Data Sciences and Emerging Systems Laboratory at the University of Sidi Mohamed Ben Abdellah Fez. He can be contacted at email: younes.balboul@usmba.ac.ma.

**Mohammed Fattah** received his Ph.D. in Telecommunications and CEM at the University of Sidi Mohamed Ben Abdellah (USMBA) Fez, Morocco, 2011. He is a professor in the Electrical Engineering Department of the High school of technology at the Moulay Ismail University (UMI), Meknes, Morocco and he is member of the team research Information Processing and Transmission, LIA laboratory, UMI. He can be contacted at email: m.mohammedfattah@umi.ac.ma.

**Said Mazer** received born in 1978. He received the Ph.D. degree in electronics and signal processing from the University of Marne-La-Vallée, Champs-sur Marne, France. He is currently a full Professor with the National School of Applied Sciences of Fez, Morocco. He is member of IASSE Laboratory, University of Sidi Mohamed Ben Abdellah Fez. His research interests include the development of microwave-photonics devices for radio-over fibre and wireless applications and he is involved in network security. He can be contacted at email: said.mazer@usmba.ac.ma.

**Moulhime El Bekkali** holder of a doctorate in 1991 from the USTL University - Lille 1- France, he was a professor at the Graduate School of Technology, Fez (ESTF) and he was a member of the Transmission and Data Processing Laboratory. In 1999, he received a second doctorate in electromagnetic compatibility from Sidi Mohamed Ben Abdellah University. Since 2009, he has been Vice-President of Research and Cooperation at the Sidi Mohamed Ben Abdellah University in Fez-Morocco until 2018. Currently, he is a professor at the National School of Applied Sciences and member of the LIASSE laboratory at USMBA University. He can be contacted at email: moulhime.elbekkali@usmba.ac.ma.

**Benaissa Bernoussi** born in 1959. He received the Ph.D. degree in appleid mathematics form the University of Perpignan, France. He is currently a Professor with the National School of Applied Sciences of Fez, Morocco. He is membre of IASSE Laboratory, University of Sidi Mohamed Ben Abdellah Fez. He is involved in numerical analysis, cryptography and cloud computing. He can be contacted at email: bbernou@gmail.com.