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Proposed Design of a Wireless Communication Network For Water Management Applications in Mosul City

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Abstract
Water scarcity, drought, and population growth accompanying climate change are dangerous factors with serious consequences related to potable water file unless appropriate action is taken urgently to deal with these issues, especially with large populations in the major cities as well as the suburban areas. This work presents an enhanced wide area network for efficient management of the freshwater in the major cities. Hence, it adopts Mosul city as a typical case that contains about 100 residential districts that require 100 sites of water monitoring in the different locations in the city where each site owns three different types of water sensors (water flow, water level, and pressure) in addition to the video surveillance application. The water station sites send the data to the control and monitoring center of the water. The collected data is processed and analyzed by public cloud or private cloud for control and monitoring purposes. The suggested communication network addresses the requirements of the water section applications in terms of monitoring in real-time. This work addresses the WiMAX system as a communication network infrastructure to handle the advantages of resilience, low-cost maintenance, and expansion The suggested network offered excellent behavior in terms of latency (maximum latency is less than 57 msec) and data traffic of the adopted applications.

Keywords
Cloud, Real-Time Monitoring, Sensor, Water Section, Wireless Network.

I. INTRODUCTION

Due to the climate change crisis, the water sector is receiving significant global attention. [1], which has led to water scarcity and drought, in addition to significant population growth, particularly in developing countries [2]. On the other hand, political conflicts play a negative role in this area [3]. Historically, Iraq is one of the countries with good freshwater imports related to two major rivers, the Tigris and Euphrates. But in recent decades, Iraq has been experiencing water shortages and drought due to several reasons such as cutting a large proportion of small tributaries and rivers by upstream countries that were pouring into Iraq, low rainfall accompanied by significant population growth, and political with security unrest. Thus, the water sector suffers from a decaying infrastructure [4] [5] [5] [6]. However, Mosul City witnessed many problems affected deeply by some points: decaying and damaged water infrastructure by the war, significant water supply shortage [7], low water quality [8], and there is no smart management of this valuable resource. Mosul's water directorate prepared its cadres for the reconstruction of water infrastructure. The directorate of water carried out major maintenance work but the nominal infrastructure needs to the smart development [9]. However, one of the main parts of the water section infrastructure is the transportation water section (water pipelines) that convey fresh water for irrigation or consumption over long distances. Unfortunately, the major reason for water resources loss is the leak in the pipes of transportation. Therefore, it is necessary to monitor the pipelines of water in real-time to address any leak or assault on public property (the pipelines of the water). Further, the pipelines of water transportation are subjected to multiple hostile environmental factors that may lead to damages like material age, extreme

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soil conditions, and bedding forces [10]. As a consequence, the section of freshwater in Mosul City suffers from smart management absence. Hence, the main factor to address the smart management of freshwater is a robust communication network. The main contribution of this work is suggesting a suitable communication network for this purpose. Where, this work proposes a wide area communication network to serve the process of water control and monitoring based on the WiMAX system to address some privileges such as wide area coverage based on a centralized system (federated and authorized administration), resilience, low-cost maintenance, and real-time monitoring. This infrastructure is enhanced by cloud computing.

II. LITERATURE REVIEW

Most of the previous works have focused on sensing devices and pipeline monitoring hardware architecture. Hence, designing of a wide area communication network for the water section forms a research gap. A. J. R. Alves et al. in [11] offered real-time water consumption monitoring and control-based wireless sensor network. The proposed system sends the data to the cloud for storage and analysis. Then, the feedback is achieved from the cloud to the client based on the Internet of Things (IoT) platform. The target of work was representing a low-cost system. In the same context, M. Carminati et al. [12] submitted three sensing nodes with self-powered embedding of a miniaturized slime placed in the pipe of water to evaluate the micrometric thickness and type of slime to study the biological and chemical stability of the targeted water. The sensing node sends the data to the control center via the LoRaWAN technique to analyze the data. The works in [13–18] employed IoT and wireless sensors for the applications of control and monitoring the water and received feedback from the cloud to the received terminal at the client site. On the other hand, Juan P. G. et al. in [19] exploited IEEE 802.15.4g and Narrowband IoT (NB-IoT) standards to design smart water management low power consumption. Whilst, V. Muthukumar et al. in [20] concentrated on employing the services of cloud for water management applications. Table I illustrates a comparison among them. However, most of the related works regarding water management dealt with a prototype module without explaining how the nominal works could transfer the data to control center of this section. Moreover, such systems should deal with a wide area network and it requires the capability of expansion to accommodate the horizontal extension of urbanization particularly in the developing nations. To the best of our knowledge, no previous work was handled on the design of a communication network for the section of water in Mosul City to monitor the fresh water in the city to prepare for smart management.

TABLE I.
A COMPARISON AMONG PREVIOUS RELATED WORKS

Ref.	Scope	Tool	Shortcoming
[11]	Real-time water consumption monitoring	Prototype	Simple model without infrastructure
[12]	Self-powered water management	Prototype	Low data rate infrastructure
[13]	Wireless sensor networks (WSNs) for monitoring of water quality of the pond Tilapia	Node MCU (Micro-programmed Control Unit) module WiFi	Limited area and without sustainability
[14]	Developing an IoT system for industrial and municipal water monitoring.	Arduino Kit tool	Mini system without addressing the sustainability
[15]	Design a set of water tank monitoring systems based on the Internet of Things	Prototype-based on Zigbee	Short range without sustainability
[16]	Water Quality with Notifications System	Raspberry Pi	Without infrastructure and sustainability
[17]	Monitor the water quality	MCU (Micro-programmed Control Unit) and Bluetooth technology	Mini system
[18]	Smart water quality monitoring (SWQM) system	Prototype	Mini system without infrastructure
[19]	Smart water management based on low power consumption	Network Simulator 3	Low data rate, it focuses on the end devices
[20]	Employing cloud services for smart water management	IoT- based Prototype	Simple model and public network

III. CLOUD COMPUTING

In general, the concept of cloud computing is an attractive solution to assimilation the severe data processing of the control center of the smart grid from the data processing point of view. Cloud computing is a pattern of computing that provides resources (such as storage, processing, software systems, and applications, etc.) dynamically and scalable on demand over the internet, regardless of knowing how to implement the nominal services. There are three major models of services that are offered by the cloud: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) [21, 22]. The deployment of the cloud can be implemented in three types: public cloud, private cloud, or mixing between them. In public cloud computing, the services of such cloud are accessible to everyone and offer many strengths like scalability, low cost, and the independency of hardware devices but it has some issues such as adding extra delay on the data, suffering from the packets lost, and less secure [23]. On the other hand, the private cloud presents its services to specific utilizes or organizations where it fixes the problems of the public cloud. However, private cloud computing has shortcomings like less scalability, leased services, and restriction [24].

IV. IEEE 802.16 STANDARDS AND WIMAX

WiMAX is a wireless metropolitan area network (WMAN) mixing between wireless and broadband [25, 26]. It depends on the IEEE 802.16 standard and it supports fixed and mobile stations as well as it provides authenticated and encrypted communication [27]. In the WiMAX system, the centralized role of arranging the communication among clients depends on the base station (BS). Any communication between the clients is implemented via BS. In general, after the phase of connection establishment, BS polls the connected clients for any request. If a client has data to send, then the corresponding client requests from BS. BS makes the decision on the grant based on the available capacity of the system. However, the system of WiMAX is still successful if the available capacity is less than or equal to the requested capacity. However, the system of WiMAX collapses in the case of requested capacity by clients becomes larger than the available capacity. The capacity of WiMAX BS depends on many factors like bandwidth (BW), modulation type, and coding rate, etc. In the terminology of WiMAX based on the IEEE 802.16 standard, the basic unit of capacity is a symbol and it is defined as the part of the time [28]. The number of symbols can be calculated by dividing the length of the frame by the length of the symbols [29]. These symbols are granted by BS to the clients according to their nominal request of them.

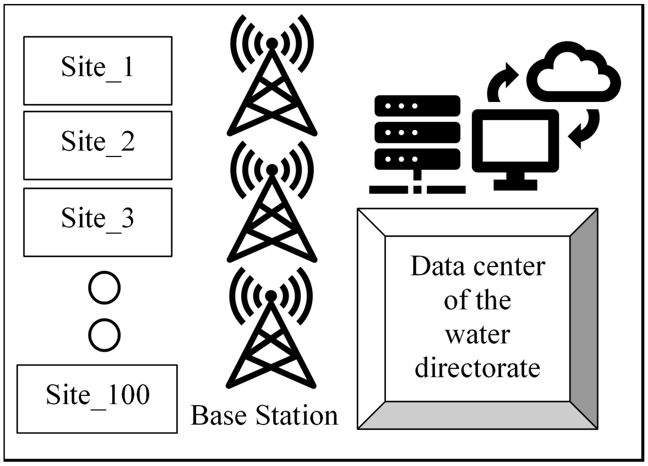

Fig. 1. Infrastructure of the communication network of the water structure.

V. SUGGESTED MODEL AND METHODOLOGY

The water station is the site that contains multi sensors to control and monitor the status of water at the local station. It is assumed that each workstation site contains three types of sensors based on IEEE 802.16 standards: water level sensor, pressure sensor, and flow water sensor to monitor and manage the flow of water in the pipelines [30]. In addition, the video application is employed at each station for video surveillance [31]. The sensors of the water can work according to three types of data rate: 9600 bps, 116K bps, and 250K bps [32, 33]. The inter arrival time of packets per sensor is 900 sec. All transmitted data is sent to the data center of the water directorate at the center of Mosul city. Fig. 1 explains the infrastructure of communication for the water directorate of Mosul city while Fig. 2 shows the components of the local water station site.

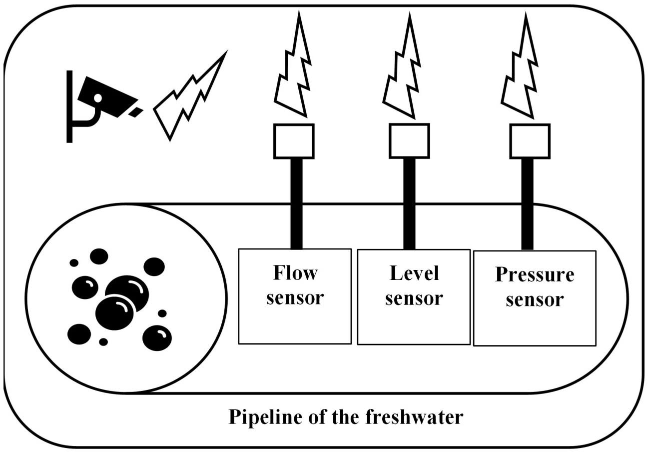

Fig. 2. Components of the local water station site.

TABLE II.
ADOPTED PARAMETERS

Parameter	Characterization
Area	200km2
Bandwidth of the system	20 MHz
Frequency range	2GHz to 11GHz
Type of sight	Line of sight
Height of BS tower	30 m
Duplexing technique	Time division
Transmitted power of BS	3 watts
Transmitted power of sensor node-based 802.16	0.5 watt
The gain of BS antenna	15dBi
The gain of the sensor node antenna	14dBi
The free BW of one BS sector	11.4 M symbol per sec (sps)
Number of sectors per one BS	3
Transmitted data from the sensors	9.6, 116, or 250 Kbps
The interarrival time	900 sec
Types of sensors	Pressure, water level, water flow, and video streaming
Video surveillance	1024 byte * 200 frame/sec

On one hand, the sensors and the base stations work are based on the IEEE 802.16 standard. The stack modeling of each sensor comprises of five layers according to TCP/IP stack: application layer, transport layer, network layer, data link layer, and physical layer. The data link layer and physical layer are set according to IEEE 802.16 standards. Table II demonstrates the adopted parameters of the suggested model. On the other hand, the data center of the water directorate processes the data based on Cloud computing. The results are collected using the modeler of OPNET where the simulation time is set to 3600sec.

The suggested network of the proposed model contains 100 clients, each client represents a water station site. In addition, each site deals with four different applications (four different types of data based on the sensors of the water station and video surveillance application. In such a model, it is necessary to locate how many clients could connect to one sector of BS (BS includes three sectors) with the condition of keeping on the requested capacity less than or equal to the available capacity. Therefore, Fig. 3 explains the flow chart of the suggested methodology to handle a successful system that could meet the requirements of water station applications. It is noted from Fig. 3 that, the methodology is firstly identifying the variables of the system in addition to the related applications. Then, it computes the available capacity of the BS sector and the requested capacity of each client. Hence, the requested capacity of each client depends on the devoted applications to the water station. Later, it compares the available capacity and requested capacity. Finally, it checks the nominated metrics (latency, sent traffic, and received traffic) to meet the requirements of the applications in addition to demonstrating the appropriate number of clients (water stations) that connect to one BS sector successfully.

TABLE III.
DEMAND BW AND THE NUMBER OF WATER STATIONS SITES AT ONE SECTOR

No. of Sites	Demand of DL (Ksps)	Demand of UL (Ksps)	DL Stand BW (Ksps)	UL Stand BW (Ksps)
1	771.2	777.6	5564.8	4540.8
2	1542.4	1555.2	4793.6	3763.2
3	2313.6	2332.8	4022.4	2985.6
4	3084.8	3110.4	3251.2	2208
5	3856	3888	2480	1430.4
6	4627.2	4665.6	1708.8	652.8
7	5398.4	5248.8	937.6	69.6
8	6169.6	5248.8	166.4	69.6

VI. RESULTS AND ANALYSIS

Firstly, it is necessary to determine how many local site water stations (clients) can connect to one BS sector without system collapse to serve four various types of applications per site. It is assumed that each sensor represents an independent application and it sends the real-time data to the control center of water in the middle of the city. It is noted from Table III that, the sites of water stations polled BW from BS to send the data of its applications where the polled BW is increased with the increment of water station sites. It is worth to mention that, the unit of BW is the number of symbols that are granted by BS to the clients in one second. In the case of seven water station sites, the UL stand BW reaches near to consumed completely therefore when the number of sites is increased up to 8 sites then the system of communication fails to meet the demands. Based on this table, the maximum number of water station sites that are served by one base station is six without congestion.

Fig. 4 shows the global traffic of the WiMAX system in terms of load data (the global traffic from data link layer of WiMAX to the channel via the physical layer at the senders) and throughput data (the global traffic of WiMAX from the wireless channel to data link layer via a physical layer of

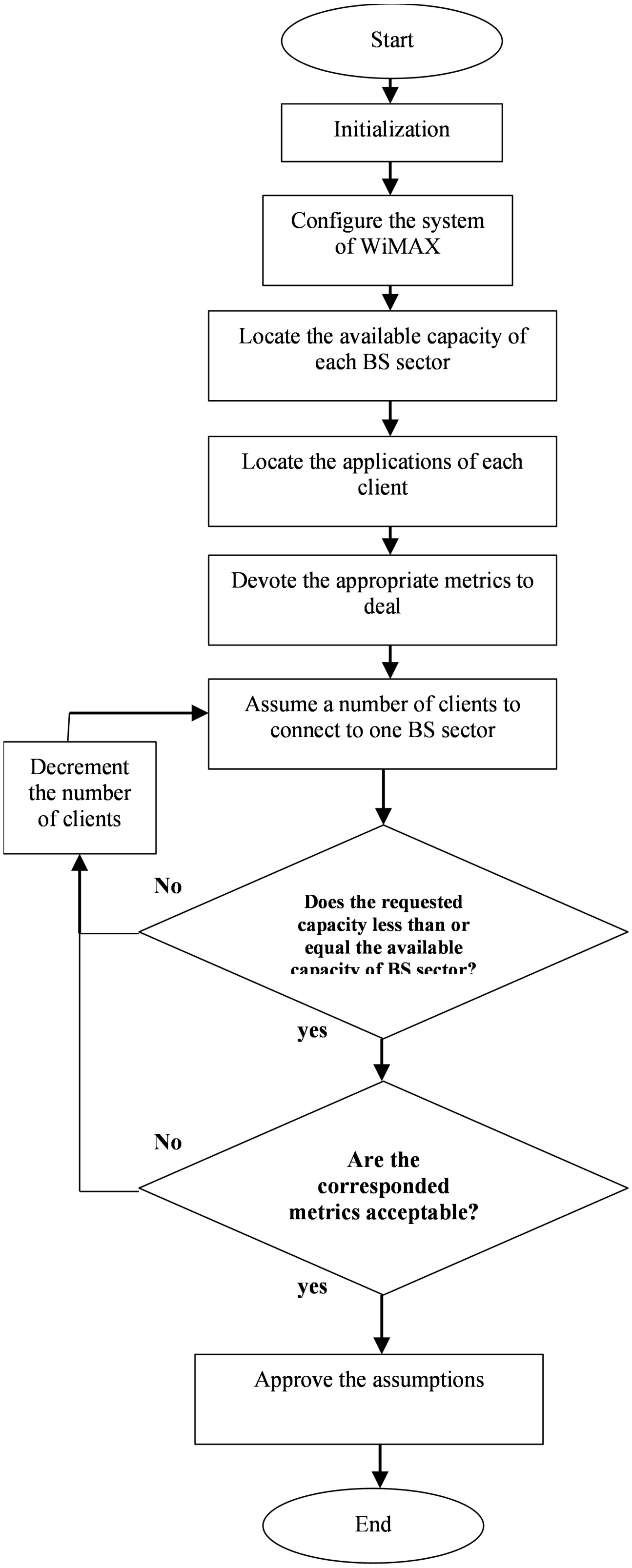

Fig. 3. Flow chart of the suggested methodology.

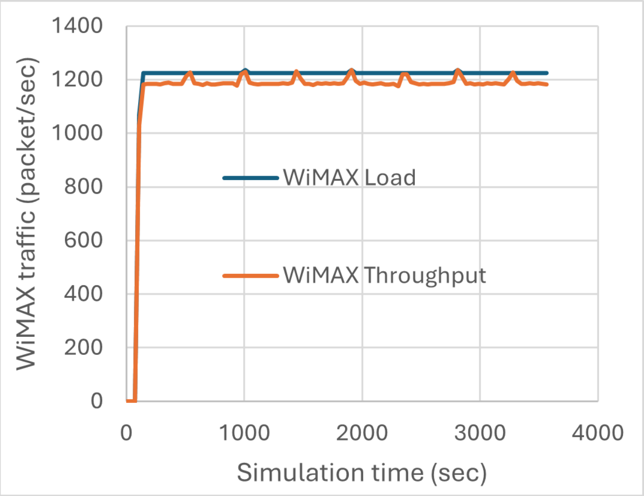

Fig. 4. Traffic of the WiMAX system in the case of connecting 6 sites to one BS sector.

WiMAX at the receivers). The result is collected in the case of connecting six local sites to one BS sector and each site sends four types of real-time data: water flow, water level, water pressure, and video surveillance applications. In general, Fig. 4 explains that the WiMAX system could handle all sent traffic (Load) approximately. Hence, the system compensates the sent data and it receives these data successfully. Moreover, the result demonstrates that the maximum packet loss ranges between 41 packet/sec as a maximum magnitude and zero packet/sec. Hence, the packets lost could be estimated by subtracting the amount of throughput form the load that shown in Fig. 4. It is concluded that WiMAX system could handle the applications data efficiently in such case. Fig. 5 explains the transmitted bytes per second from each sensor (water level, pressure, and flow water) in the water station at three different sizes: 9.6Kbps, 116Kbps, and 250Kbps. The data is sent every 15 minutes.

At each water station, three types of sensors produce data to the data center of the water directorate. In the case of 250Kbps, Fig. 6 shows the end-to-end delay of all sensors of one of the water station sites. The delay ranges between 51.6 msec to 56.1 msec. That is, the latencies of the different applications are close due to the sent data of each sensor being similar to others with similar conditions. Fig. 7 illustrates the overall transmitted, received, and lost bytes of 6 water station sites, these sites of water stations are linked to one BS sector. In general, the most of transmitted bytes are received correctly. The magnitude of lost bytes is very low about 4.3 percent of the transmitted bytes. Where the lost bytes could be estimated by ((traffic sent – traffic received)*100). In the context of video surveillance applications, Fig. 8 explains the transmitted byte/sec per each camera. It is noted that each

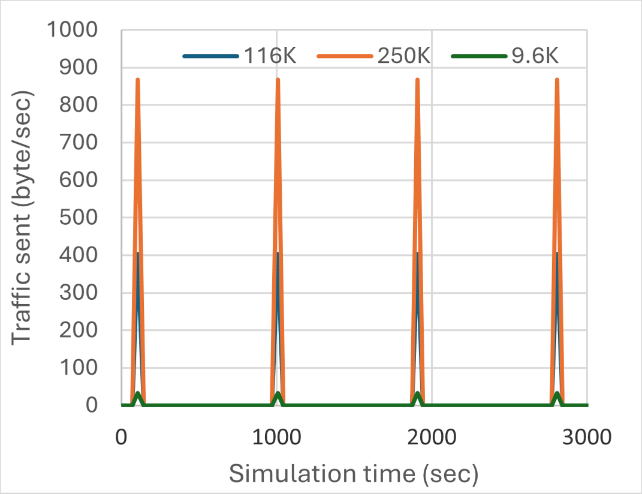

Fig. 5. Transmitted bytes of each water sensor are at multi sizes.

client of video surveillance sends 1024 byte multiplying 200 frames per second (204.8Kbyte/sec).

Fig. 9 shows the received traffic of video surveillance application in the server of the water control center. the results indicate that the received traffic at the server of the water control center of video surveillance for 6 clients per one BS sector is 9.8M bit/sec (6 clients *1024 packet size*200 frame per second *8 byte = 9.8M bit/sec).

Fig. 10 explains the effect of the private cloud on the overall delay (end-to-end delay) of the system in comparison with the case of the public cloud. It is obvious that the delay decreases about 49msec.

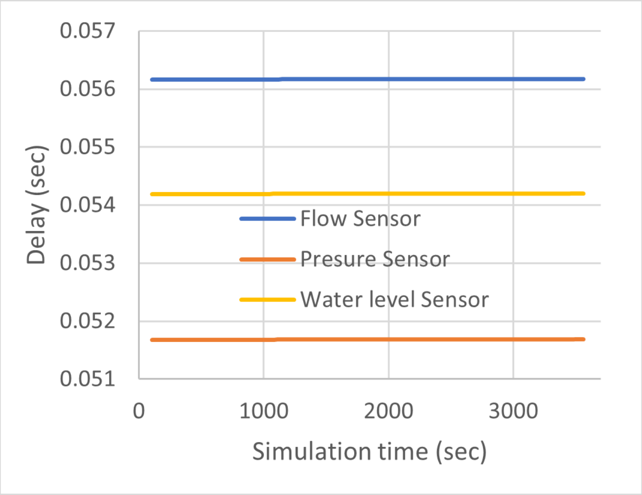

Fig. 6. Delay of the sensor data.

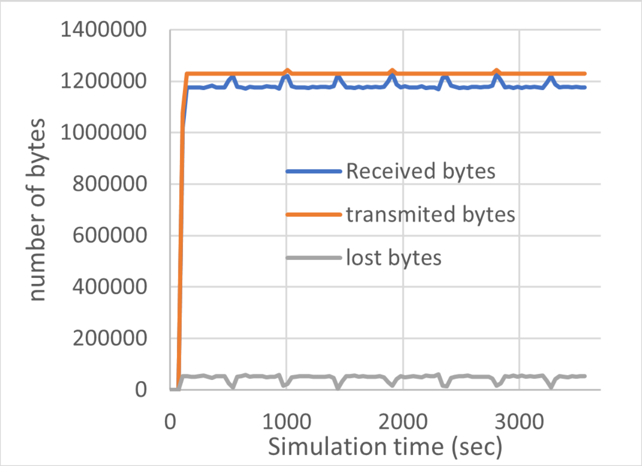

Fig. 7. Overall transmitted, received and lost data of the group (6 sites) of water stations.

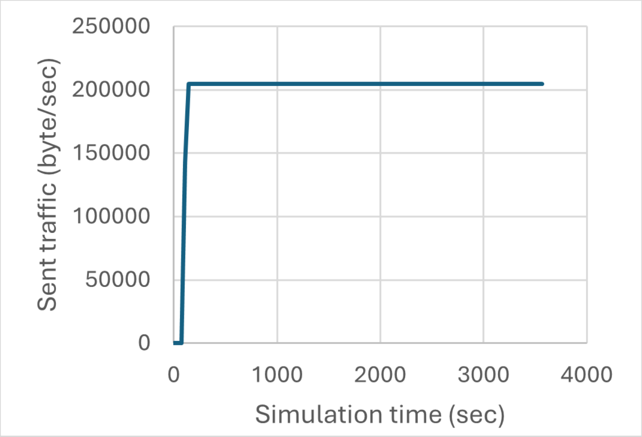

Fig. 8. Sent traffic of video surveillance client.

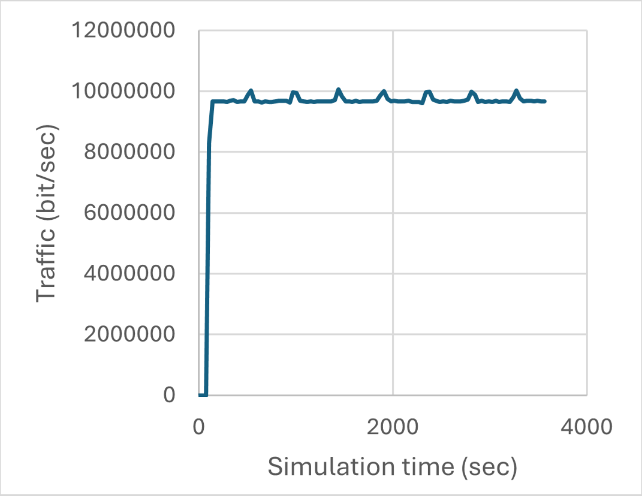

Fig. 9. Received traffic of video surveillance application at the control and monitoring center.

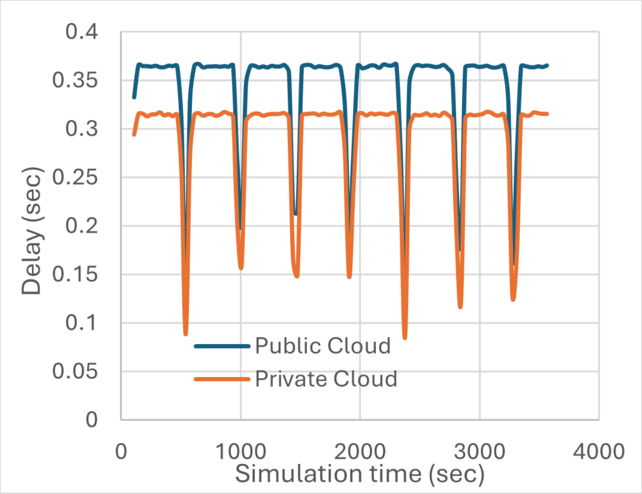

Fig. 10. End-to-end delay of six sites from sensors to control and monitoring center.

VII. CONCLUSION AND FUTURE WORK

The results indicated that the system of water network could address the demand BW of all sites of water stations correctly. Moreover, most of the transmitted bytes are received successfully. This infrastructure of the communication network can absorb 100 sites of water stations sites by six base stations, each base station has three sectors. The nominal sector covers 6 sites of water stations. The results proved that the system of communication supports various kinds of frequency rates per sensor (9.6Kbps, 116Kbps, and 250Kbps). In addition, the processing of data at the data centers of the directorate of water can be implemented using the cloud computing to take advantages of computing without owning specific servers to process the data, providing the metric of availability, and the expansion to compensate for more created water stations. In the context of a control and monitoring center, cloud computing offers services regarding processing and analyzing. However, the private cloud could provide an advantage in the delay of about 50msec compared to the public cloud. Finally, the process of developing the infrastructure of the water section will be addressed as a future work in terms of handling extra sensors to check the quality of water in addition to enhancing the security of this vital structure.

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CONFLICT OF INTEREST

The authors have no conflict of relevant interest to this article.

REFERENCES

[1] A. Ayadi, O. Ghorbel, M. BenSalah, and M. Abid, “A framework of monitoring water pipeline techniques based on sensors technologies,” *Journal of king saud university-computer and information sciences*, vol. 34, no. 2, pp. 47–57, 2022.

[2] B. F. Kim, R. E. Santo, A. P. Scatterday, J. P. Fry, C. M. Synk, S. R. Cebron, M. M. Mekonnen, A. Y. Hoekstra, S. De Pee, M. W. Bloem, *et al.*, “Country-specific dietary shifts to mitigate climate and water crises,” *Global environmental change*, vol. 62, p. 101926, 2020.

[3] N. Nagabhatla, M. Cassidy-Neumiller, N. N. Francine, and N. Maatta, “Water, conflicts and migration and the role of regional diplomacy: Lake chad, congo basin, and the mbororo pastoralist,” *Environmental Science & Policy*, vol. 122, pp. 35–48, 2021.

[4] Z. B. Mohammed, “Evaluation the quality of raw and treated water for number of water treatment plants in baghdad, using a water quality index,” *engineering and Technology Journal*, vol. 33, no. 6, pp. 1429–1441, 2015.

[5] R. A. Salih, I. I. Ghdhban, and A. K. A. Wahid, “Evaluation of a number of water treatment plants in kirkuk governorate using the water quality index,” *Tikrit Journal of Engineering Sciences*, vol. 25, no. 1, pp. 49–59, 2018.

[6] M. A. I. Al-Hashim, “Analysis and evaluation of the potable water network and water quality in al-diwaniya city,” *Diyala Journal Of Engineering Sciences*, pp. 191–204, 2012.

[7] M. F. A.-D. Ahmed, “Evaluation of ground water quality status by using water quality indices at basheqa region, iraq,” *Tikrit Journal of Engineering Sciences*, vol. 23, no. 2, pp. 54–64, 2016.

[8] M. R. AL-Hamdany and N. Mazin, “Study of drinking water quality for some water purification plants and pipes network in mosul city,” *Iraqi journal of Science*, vol. 56, no. 3C, pp. 2563–2573, 2015.

[9] Y. Al-Khashab, R. Daoud, M. Majeed, and M. Yasen, “Drinking water monitoring in mosul city using iot,” in *2019 International Conference on Computing and Information Science and Technology and Their Applications (ICCISTA)*, pp. 1–5, IEEE, 2019.

[10] M. J. M. AL-Ubaide and A. A.-A. Altalib, “The effect of magnetized water with certain intensities on salts leaching efficiency from agricultural soils,” *Al-Rafidain Engineering Journal (AREJ)*, vol. 27, no. 2, pp. 166–177, 2022.

[11] A. J. R. Alves, L. T. Manera, and M. V. Campos, “Low-cost wireless sensor network applied to real-time monitoring and control of water consumption in residences,” *Revista Ambiente & Água*, vol. 14, no. 6, p. e2407, 2019.

[12] A. J. R. Alves, L. T. Manera, and M. V. Campos, “Low-cost wireless sensor network applied to real-time monitoring and control of water consumption in residences,” *Revista Ambiente & Água*, vol. 14, no. 6, p. e2407, 2019.

[13] T. Wongmeekaew, S. Boonkirdram, and S. Phimphisan, “Wireless sensor network for monitoring of water quality for pond tilapia,” in *2019 Twelfth International Conference on Ubi-Media Computing (Ubi-Media)*, pp. 294–297, IEEE, 2019.

[14] I. Skarga-Bandurova, Y. Krytska, M. Shorokhov, O. Suvorin, L. Barbaruk, and M. Ozheredova, “Towards development iot-based water quality monitoring system,” in *2019 7th International Conference on Future Internet of Things and Cloud Workshops (FiCloudW)*, pp. 140–145, IEEE, 2019.

[15] C. Zhou and P. Jiang, “A design of high-level water tank monitoring system based on internet of things,” in *2020 7th international forum on electrical engineering and automation (IFEEA)*, pp. 769–774, IEEE, 2020.

[16] D. Sekhwela, P. A. Owolawi, T. Mapayi, and K. Odeyemi, “Water quality monitoring with notifications system,” in *2020 2nd International Multidisciplinary Information Technology and Engineering Conference (IMITEC)*, pp. 1–6, IEEE, 2020.

[17] C. Feng, J. Yuan, Y. Sun, and J. You, “Design of water quality monitoring system,” in *2020 International Conference on Artificial Intelligence and Computer Engineering (ICAICE)*, pp. 264–267, IEEE, 2020.

[18] V. Lakshmikantha, A. Hiriyannagowda, A. Manjunath, A. Patted, J. Basavaiah, and A. A. Anthony, “Iot based smart water quality monitoring system,” *Global Transitions Proceedings*, vol. 2, no. 2, pp. 181–186, 2021.

[19] J. P. García-Martín, A. Torralba, E. Hidalgo-Fort, D. Daza, and R. González-Carvajal, “Iot solution for smart water distribution networks based on a low-power wireless network, combined at the device-level: A case study,” *Internet of Things*, vol. 22, p. 100746, 2023.

[20] V. Muthukumar, V. Selvakumar, M. Nalini, and B. Chitradevi, “Cloud-based smart water management system,” in *2023 International Conference on Sustainable Computing and Smart Systems (ICSCSS)*, pp. 1633–1638, IEEE, 2023.

[21] H. Huang, “Smart grid communication infrastructures: Big data, cloud computing, and security,” *Archives of Clinical Psychiatry*, vol. 49, no. 7, 2022.

[22] S. L. Qaddoori and Q. I. Ali, “An efficient security model for industrial internet of things (iiot) system based on machine learning principles,” *Al-Rafidain Engineering Journal (AREJ)*, vol. 28, no. 1, pp. 329–340, 2023.

[23] Q. I. Ali, J. M. Abdul-Jabbar, *et al.*, “Design and implementation of real-time voice streaming evaluation platform over wireless sensor network (vowsn),” in *2018 International Conference on Advanced Science and Engineering (ICOASE)*, pp. 233–238, IEEE, 2018.

[24] D. Bakken, *Smart grids: clouds, communications, open source, and automation.* CRC Press, 2014.

[25] M. Y. Thanoun, “The impact of length of frame on the performance of video application in wimax system,” *Al-Rafidain Engineering Journal (AREJ)*, vol. 26, no. 2, pp. 158–163, 2021.

[26] S. A. Ayoob, F. S. Alsharbaty, and A. Alhafid, “Enhancement the heavy file application of 802.16 e cell using intra-site comp in uplink stream,” *Journal of Engineering Science and Technology*, vol. 17, no. 3, pp. 1721–1733, 2022.

[27] M. Ergen, *Mobile broadband: including WiMAX and LTE.* Springer Science & Business Media, 2009.

[28] C. So-In, R. Jain, and A.-K. Tamimi, “Capacity evaluation for ieee 802.16 e mobile wimax,” *Journal of Computer Networks and Communications*, vol. 2010, no. 1, p. 279807, 2010.

[29] F. S Al-Sharbaty and A. Jabbar, “Improving wimax capacity of a cell by applying relay stations and adaptive antenna systems,” *Al-Rafidain Engineering Journal (AREJ)*, vol. 19, no. 1, pp. 8–21, 2011.

[30] S. C. Mukhopadhyay and A. Mason, “Smart sensors, measurement and instrumentation,” *School of Engineering and Advanced Technology, Massey*, 2013.

[31] F. Persia, D. D’Auria, and G. Pilato, “An overview of video surveillance approaches,” in *2020 IEEE 14th International Conference on Semantic Computing (ICSC)*, pp. 287–294, IEEE, 2020.

[32] Q. Wang, X. Chai, Y. Wang, D. Liu, M. Chen, Y. Li, X. Liu, and O. Bai, “A high data rate, multi-nodes wireless personal-area sensor network for real-time data acquisition and control,” in *2017 First International Conference on Electronics Instrumentation & Information Systems (EIIS)*, pp. 1–5, IEEE, 2017.

[33] R. H. AlSheikh, R. M. Hagem, and O. H. Salim, “A survey on smart monitoring system of environment based on iot,” *Al-Rafidain Engineering Journal (AREJ)*, vol. 26, no. 1, pp. 146–158, 2021.