EDGE COMPUTING ENABLED WIRELESS SENSOR NETWORK REQUIREMENT: A SURVEY

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(Received 10th June 2022; accepted 28th August 2022)

Abstract. Data has become the lifeblood of current technology, and with the expanded reliance on technology, the need has increased for technical devices to connect to the surrounding environment and collect data from it and send it for analysis and processing. This is also due to limited bandwidth capacity. In view of the increased need to survey the research that focused on the challenges that appeared with the wide spread of the use of edge computing with the Wireless sensor networks (WSN), the researcher find that many aspects have been covered by researchers, but some of the aspects need to work on them furthermore like using artificial intelligence on the edge (smart edge) and security challenges. the use of a WSN provides many benefits like overcoming bandwidth limitation, scalability, real-time response and mobility. The interest in making the processing take place at a node and not in a central server or on the cloud is due to the slow development in communication technology compared to the growth of processing technology, so the price of the bandwidth package still costs a large amount compared to the price of data processing at the edge of the network. The growth of the battery development sector that lasts for a long time has made new horizons grow new ideas in using the wireless sensor network in a more efficient manner and in more fields.
Keywords: *wireless sensor network, edge computing, cloud computing, real-time, IoT*

Introduction

The rapid development of using technology in all fields of life led to extensive usage of real-time systems where sensors collect physical quantities and send them to control unit for processing and later for decision making depending on the value of the processed data (Ali et al. 2017). Any real-time system should have a sensor(s), if the application requires a lot of sensors like monitoring soil humidity at many checkpoints at the farm means that all of these sensors have to send their data to center point then to datacenter where data can be processed, analyzed and stored for future use. Data sent wirelessly because this network will be more applicable, hence the need for WSN (WSN) arises to satisfy the increasing need for automation application to read word physical status, since the first WSN established at 50’s to secure the Pacific Ocean from Soviet warship, it used a lot of hydrophones to listen to the sound made by these ships to track down their route. This network is the first ancestor of WSN and it is still working till now but for civil purposes (Weir and Center, 2006). At 80’s with the spread of internet, many applications have been purposed to make our life easier and safer (Ali et al. 2017). Along with the spread of WSN’s, many issues and challenges faced the designer (Yik et al., 2008), the researchers will try to give a general overview on the studies which tried to overcome these challenges using the modification of network properties or improving routing protocols or the programs that manage the network, also we will take a look at the research which depends on edge computing as a solution to these challenges and improve its performance.

eISSN: 2716-6341
www.qjoest.com

Moving towards Edge computing as a solution to many issues because the hunger in the data collected through many sensors did not a combined by increasing in Bandwidth between cloud and data source to accommodate the amount of data been sent. The principle is straightforward: If you can't get the data closer to the data center, get the data center closer to the data. This idea improves the scalability of the network exponentially Edge computing addresses three principal network limitations: bandwidth, latency and congestion or reliability. Some examples include retail environments where video surveillance of the showroom floor might be combined with actual sales data to determine the most desirable product configuration or consumer demand. Other examples involve predictive analytics that can guide equipment maintenance and repair before actual defects or failures occur. Still other examples are often aligned with utilities, such as water treatment or electricity generation, to ensure that equipment is functioning properly and to maintain the quality of output (Shi et al., 2016). Through the investigation of this paper the authors will prove that the use of Edge computing instead of fog computing or cloud computing will pave the way for new era of using WSN extensively in the near future. Many researchers proved that the use of Edge computing is the solution for many challenges faced by the implementation of WSN but the researchers did not find a comprehensive survey covering Edge computing Enabled WSN. In this paper the researchers will highlight the benefits of merging WSN with edge computing technology and some applications that prove this direction.

Using cloud computing to place all the raw data for processing, analyzing and storage led to the emergence of many challenges. Since the WSN applications now covering more and more of our daily life especially what is related in IoT applications, the amount of data collected is increasing tremendously sending of raw data to the datacenter placed on the cloud or on fog servers increase bandwidth usage which may result latency, security and congestion challenges. The use of Edge computing will reduce the burden on required bandwidth and network status (congestion). This is done by moving some cloud capabilities (storage and processing) to the edge server near to the data generation source, therefore, just information can be sent to the cloud instead of raw data (Lv et al., 2021; Huang et al., 2020a; Xhafa et al., 2020).

Discussion

Edge computing requirements

To design a robust Edge computing enabled WSN, some requirements should be satisfied, which include: system security, real-time application support, efficient resource management, energy consumption, system cost, heterogeneous handling of hardware, ability to support mobility, system scalability, system support for artificial intelligence, system availability and ability to avoid malfunctions, researches are studied and classified into 10 classes , in each one researchers proposed a solution to fulfill one requirement to deploy Edge computing enabled WSN.

System security

Any reliable system has to be secured. in case of cloud computing enabled, the cloud has enough capabilities to run the most sophisticated security algorithm, but in Edge computing enabled WSN the lake for adequate resources and processing speed or memory and the fact that data is distributed, making it vulnerable to hackers. The requirement of secure system must be met which are: availability, reliability, confidentiality, and data integrity. Since the data are exposed to the attacker, it needs immediate action to eliminate the risk, LocKedge which is a mechanism to detect multiple attacks has been proposed to identify attacks in less time than methods that use deep learning algorithms (Huong et al., 2021). The increasing numbers of WSN devices led to increasing the targets of intruder attack, deep learning algorithm is used in a new way to predict data transmission and the process of offloading to detect a cyber-attack to detect cyber-attacks has high sensitivity and high accuracy (Gopalakrishnan et al., 2020). Edge gateway to support security services is proposed to deals with resource limitations in edge computing pose challenges in the field of data security to provide an acceptable level of security with a low latency that can be suitable for real time applications (Jin et al., 2020). Using a lightweight authentication system in edge computing servers an edge computing framework is designed to implement a secure healthcare system based on a software-defined network so that Patient data collected from low-power devices is not vulnerable to security threats (Li et al., 2020a).

The security of high-end computing should not be underestimated because edge devices face real security problems. So that a visualization of the edge nodes dealing with different types of things into various virtual networks is accomplished to enhance the security of edge computing (Zhang et al., 2020a). A wireless edge network model is proposed to provide security during the interaction between edge server nodes via time factor, it also provides power-saving and balance control (Jiang and Tseng, 2021). A model has been built to collect secured data using edge computing server, where data coming from all directions is analyzed to check the reliability of this data, in addition to choosing most secured path to send outcoming data, energy conservation and security are achieved in WSN when this model is deployed (Wang et al., 2020a). Privacy and security of the location of the node is being protected by developing two protocols to enhance trilateration and multiliterate algorithms based on philler's harmonic encryption scheme. The proposed protocols secure location information of the node, which sends the information to base station then it sent from base station to edge server to calculate the ciphertext and produce the encrypted location of node (Jiang et al., 2019).

Real-time application support

In real-time applications, the matter of response time is necessary when application is soft real time systems and fatal when we are talking about hard real-time system, using cloud enabled WSN will introduce a latency issue as well as congestion which reduce the performance of the system dramatically (Trinks and Felden, 2018). The distributed nature of edge computing made it suitable for real-time applications due to the neglection of the traveling time from data source to the could then processing the data for the decision to be made (Ananthanarayanan et al., 2017; Nastic et al., 2017). An edge computing platform is proposed where mobile edge nodes devices are physically deployed on a transit bus to support for transit network systems across edge analytics platforms using the application trial method (Cao et al., 2017). Power transmission efficiency and lack of reliability are important problems at present and to optimize the framework and propose an efficient heuristic algorithm based on the simulated annealing strategy. To find the efficiency, multiple edge computing servers were used in the simulation of the proposed system (Huang et al., 2018). Augmented reality (AR) / Virtual reality (VR) applications require research, Discussion of the networking challenges encountered by the AR/VR community in a real-world environment to Analyzing AR/VR network interactions of head mounted displays (Shannigrahi et al., 2020). To meet the requirements of delay intensive and resource hungry applications in 5G, an edge computing-based photo crowdsourcing (EC-PCS) framework is proposed by using a photo pricing mechanism by jointly considering their freshness, resolution and data size (Yu et al., 2020). An algorithm is proposed to locate the position of a robot precisely Extended Kalman Filter (EKF) and realize it using Edge computing instead of cloud computing to achieve real-time position control and to reduce bandwidth usage (Ullah et al. 2021).

Efficient resource management

Resources in Edge computing are much more limited than these placed on the cloud since Processor and memory constraints of high-end devices. In addition, these devices can be heterogeneous in terms of structure and the functions entrusted to them. Since the resources are limited, it is very important that the usage of the very effective to make a full benefit from them (Hong and Varghese, 2019). Some studies took place to deal with problem facing implementation of Edge computing in WSN. Optimizing the allocation of edge nodes in physical environment using a multitiered mobile edge computing system is studied to find a solution improves the pseudorandom resource allocation by proposing a parametric Bayesian optimizer, it is implemented for hardware resource allocation (Šlapak et al., 2021). Currently there is no resource management system able to deliver all features for the edge that made cloud computing successful so classification has been Introduced to measure the features of missing mechanisms in resource management systems which provided a list of the features required to operate and use edge computing resources, and investigate how an existing IaaS manager satisfies these requirements (Cherrueau et al., 2018).

Collaborative technology to share resources with nearby devices is used to satisfy IoT applications needs to allocate resources in line with decentralization and privacy requirements by Proposing a new technology to support real-time IoT applications through decentralized resource management (Avasalcai et al., 2019). Also, the loss of connection in a mobile edge computing system extensity studied to improve the success rate of task processing in the system using the Kalman filter to predict the movement of users within the system (Ojima and Fuji, 2018). Due to, making resource management difficult in Mobile edge computing, a placement algorithm that can satisfy QoS was proposed to reduce energy and user costs at non-significant loss in performance (Zakarya et al., 2020). The increasing use of WSNs is related to overcoming the challenges of technical equipment. The sensors associated with WSNs provide us with huge amounts of data, which may not be supported by the current network capabilities if all this data will be sent to the main data center. A new protocol has been proposed for managing clusters, each of which has an edge server that will manage data coming from its nodes. The proposed model undergoes a black widow optimization (BWO) based clustering technique to select the optimal set of cluster heads (CHs) effectively. Besides, the CBR-ICWSN technique involves an oppositional artificial bee colony (OABC) based routing process for optimal selection of paths. A series of simulations take place to verify the performance of the CBR-ICWSN technique and the results are examined under several aspects (Vaiyapuri et al., 2021). An algorithm for resource allocation based on edge computing is proposed. It is designed to support Multichannel Multiinterface, in order to obtain the benefits of these kinds of networks. Traditional resource allocation algorithm support just single interface networks (Liu and Zhu, 2021).

Energy consumption

One of the main determinists in WSN is how much each node consumes therefore task allocated to each node must be limited to the amount of power that this node has. Node that takes the role of WSN router has to work continuously without interruption, in case power break down, a battery must be provided to resume working without interruption. After a while, the battery may go nearly to end, this must take into consideration, so computing and storage power can be transformed to the cloud to reduce energy consumption (Chang and Wu, 2021). The limited energy allocation mechanism in edge-software defined WSNs (ESDWSNs) makes the energy consumption of different nodes unbalanced so an energy allocation optimization (EAO) algorithm is proposed for solving the problem of energy consumption by establishing a novel three-layer network architecture based on the edge computing and software defined technologies (Li and Xu, 2019). An energy consumption minimization scheme that adjusts both the offloading ratio and CPU operating frequency of the device is proposed to maximize the battery lifetime of smart devices which are very sensitive to the energy consumption using a Dynamic Voltage and Frequency Scaling (DVFS) technique under delay constraint (Yoo et al., 2020). a scheduling strategy through balancing the resources of virtual nodes that reducing the power consumption is proposed to reduce the power consumption for the providers of the edge nodes while meeting the resources and delay constraints, this done by verifying the effectiveness of their algorithm, they used the iFogSim simulator as an experimental platform (Fang et al., 2020). Analyzing the computing and transmission energy consumption is performed to study the limitation of power capacity of mobile devices becomes the bottleneck of edge computing by proposing a systematic approach that could balance the power consumption between computation and communication (Kuo and Wang, 2019).

Multiple data collection algorithm using edge computing is proposed to check the validity of the data and send just the valid data to the cloud by dividing nodes into clusters, and every cluster, checks the validity of data of associated nodes and send valid data to cloud (Li et al., 2020b). A bio-inspired algorithm is proposed to balance the energy of nodes inside the clusters by choosing the node of maximum energy to send data. Management has done via edge computing server, this algorithm is a development of clustering algorithm, and the purpose of development is to handle with heterogeneity of energy level of WSN nodes (Agbehadji et al., 2020). The Joint bandwidth allocation and energy consumption (JBAEC) algorithm has been proposed, which will determine the amount of data sent by the nodes depending on the amount of energy that those nodes have within the cluster, and also depending on the available bandwidth, where the bandwidth limitation has been treated so that the transmission is a function of the energy level of the node and also according to available bandwidth (Li and Song, 2020). genetic algorithm and ant colony algorithm are deployed together to choose the node so that the load is balanced to make network life longer and to have highly reliable parallel computation of WSN with energy conservation and load balancing (Wen et al., 2022). Genetic algorithm and simulated annealing is used to solve the challenge of localization in WSN, also quantum tunnel effect is used in which the energy barrier can be quickly penetrated from local optimum to global optimum, so that the calculation is simplified and the computation speed is increased (Cao et al., 2019).

System cost

The data transmission network may be costly to use, enhancement system by adding more resources have to add cost to the system, cost can be fixed or variable, so tradeoff between additional cost and improvement must be done to decide the necessary addition should be done (Buyya and Srirama, 2019; Hassan et al., 2018). The use of edge computing for fixed systems can reduce the cost of data transmission and processing cost in the long run due to initial hardware costs. In systems whose peripherals are mobile, the cost becomes one of the challenges in which the feasibility study is carried out, and therefore the cost may be greater (Hassan et al., 2018; Shi et al., 2016) a Cloud Assisted Mobile Edge computing (CAME) framework is proposed to minimize mobile edge computing delay and cost by Applying queueing network and convex optimization theories, in which cloud resources are leased to enhance the system computing capacity (Ma et al., 2017). A replication management system which includes dynamic replication creator, a specialized cost-effective scheduler for data placement to reduce data access costs while meeting deadline constraint by using data scheduling for the workflows is modeled as an integer programming problem (Shao et al., 2019). During peak load times, edge servers have limited capabilities to support the required response so a mechanism is suggested to reduce the computational cost in mobile edge computing while reducing the power consumption of mobile devices by using of optimization methods to match the power required to transmit information and the computing necessary to achieve the desired response (El Haber et al., 2018). Minimizing the long-term system cost through the elastic microservice deployment, the container based microservice deployment is formulated as a stochastic optimization problem to minimize the system cost while maintaining the system QoS and stability using algorithm that makes the microservice deployment plan greedily without the future knowledge of the system and users (Zhao et al., 2020).

Heterogenous handling of hardware

Due to heterogeneous nature of resources in WSN like the type of data representation, storage capabilities, processing capabilities, peripheral devices, such as sensors, Internet of things and wearable devices. Edge node may face a challenge in managing this diversity so it must be taken into account that this diversity when designing Edge computing WSN (Sabella et al., 2019). A fine-grained processing framework that normalizes tuple non-classification is implemented to enhance false-positive function and assembles IoT sensory tuples with the in-memory capacity to rectify compression failovers for non-classification at the level of data encapsulation because of heterogeneous IoT devices (Koo and Qureshi, 2021). A model for reasoning about distributed computing at the edge with support for heterogeneous hardware is presented to explore the implications of distributing application computation across a network of heterogeneous compute platforms using a case-study of an object detection and tracking system (Cooke and Fahmy, 2020). A heterogeneous multi-layer mobile edge computing (HetMEC) is proposed using task offloading, cognitive radio, pricing, scheme design, and network congestion control for HetMEC because conventional

MEC suffers from the insufficient utilization of computing and transmission resources through the entire network (Zhang et al., 2020b).

Ability to support mobility

Providing computational capabilities using mobile node is one of the challenges (Buyya and Srirama, 2019), but this can be done using Mobile edge computing (MEC). Many applications can be realized using MEC including temporary storage of some data in addition to the possibility of processing that data. Mobile edge computing technology can be implemented in 4G mobile network systems and is expected to be strongly supported in 5G and 6G systems (Al-Turjman and Al-Turjman, 2019). H-Container, which migrates natively compiled containerized applications across compute nodes featuring CPUs of different ISAs is introduced to Integrate H-Container into Docker, allowing the migration of containers between hosts of different ISAs integrate H-Container into Docker, allowing the migration of containers between hosts of different ISAs because Server program natively compiled for one Instruction Set Architecture (ISA) cannot migrate to another when a client changes its physical location (Barbalace et al., 2020).

System scalability

One of major benefits of using is computing is the scalability of network (Aruna and Pradeep, 2020). Due to rapid development of applications using WSN, adding new nodes to satisfy the demands made Edge computing enabled WSN is the best solution because of the possibility of adding multiple edge computing nodes when needed and in any location (Khan et al., 2019). To accelerate the execution of an object identification service for mobile users a Design and experimental evaluation of a scalable two-tier Edge Computing architecture is implemented to realize location-based services in a smart city context by deploying Google-powered TensorFlow framework as the object-recognition service (Spatharakis et al., 2020). Techniques to realize a scalable, fog/edge-based broker architecture that balances data publication and processing loads to meet the response time requirements of real-time applications so that a proposed solution learns a latency prediction model for a set of co-located topics on an edge broker (Khare et al., 2018). A novel computation task model and formulated the system utility maximization problem is proposed to investigate the optimal tradeoff between user experience and consumptions of communications and computation resources in MEC, where each computation task is scalable with different service levels, corresponding to different user experiences (Gao et al., 2019). Exploits Cloud and Edge scalable virtual resources to improve the delivery video contents at different quality resolutions to support the provisioning of videos to heterogeneous end user devices in different contexts (Galletta et al., 2018). Mission critical software defined WSN is proposed to be agile and scalable and can work in industrial environment or in security surveillance. Software defined network is used to combine the hierarchical cloud and edge computing technologies. Based on the MC-SDWSN architecture, a novel centralized computation offload strategy in sensor network application is proposed to show the feasibility (Xu et al., 2019).

System support for artificial intelligence

As WSN main function is to collect data, this data should be processed and analyzed which is done mainly using Artificial intelligence (AI), this is now a fact that any WSN should have some kind of intelligence algorithms to process and analyze the data been collected. In case of algorithm placed on cloud, processing power can handle most sophisticated algorithms, but that would be with high delay due to network and congestion latency. A smart edge can be introduced as an edge node can handle AI algorithms with available resources in the edge which has the ability to meet the demands of artificial intelligence service for edge devices associated with it (Wang et al., 2020b; Zhou et al., 2019). Training phase with big data is accomplished on the cloud, and then AI parameters are copied to the edge node. To address the issues of Deep Learning in edge computing, practical implementation methods and enabling technologies, namely DL training and inference in the customized edge computing framework via a survey was presented about deep learning and its potential to be supported by edge computing (Wang et al., 2020b). An intelligent algorithm is proposed and realized in a logistic warehouse where the edge node responds in a fixed time to any data type and any data complexity, also the edge node has the intelligence to decide if the data need to be processed in the cloud or in the edge node (Wang et al., 2020c).

System availability

On the contrary with cloud computing, edge computing is not too reliable because error may occur, so al alternative working plan must be ready when this happens to avoid system collapse (Vance et al., 2019). To address the issue of reliable edge computing on dynamic high-churn edge systems a solution is implemented in Python 3, and tested it on the set of edge devices and developing a deviceless pipeline-based approach (DPA) to establish workflows in which stages of the analysis pipeline are completed on edge devices (Vance et al., 2019). To address the reliable workflow scheduling problem over mobile edge computing environment a Krill-based algorithm is developed to solve workflow scheduling problem by formulating the workflow scheduling problem as an optimization problem which takes the reliability of resource into consideration (Peng et al., 2019). Stochastic Petri net models of edge servers and cloud clusters is proposed to address the failures and recoveries problems in the edge computing by designing a simulation-based optimization approach for reliability aware service composition (Huang et al., 2020b). A task merging strategy based on mobile program component call graphs to minimize the computational complexity of the program partition is proposed to guarantee the reliability of the offloaded computing using a new shadow component scheme (Dong et al., 2019). Multi-access edge computing (MEC) is used to reduce the latency of communication and computations of the received data from nodes, taking into consideration the constraint of the network, a scaling law has been calculated which is for both communication and computation latency regarding network loads and resource parameters. The deduced scaling laws quantify the trade-offs between computing latency, network coverage, and stability (Chen et al., 2021). *Table 1* shows the distribution of research studied, and its classification according to the challenge covered by the study.

Table 1. *Classification of researches according to the challenge they cover*.

Edge computing enabled WSN deploying challenges									
System security	Real-time applicatio n support	Efficient resource managem	Energy consumpt ion	System cost	Heterogene ous handling of	Ability to support mobility	System scalabilit y	System support for	System availabili ty and

		ent			hardware			artificial intelligie nce	ability to avoid malfunct ion
9-16	17-24	25-32	33-42	43-49	50-53	54-56	57-63	64-66	67-71

Conclusion

Many researchers contributed in pushing towards the new era of WSN by proposing a new method adaptive to the use of edge computing with WSN, where the edge can hold the processing and storage responsibilities. The use of Edge computing instead of Edge computing pose some challenges as well as benefits, in this paper the contribution of the researchers is to classify papers according to what requirement they studied to overcome its challenges. Papers are studied and mentioned as how they did, why they did it and what they did to analyze the contribution belong to which requirement. The conclusion of this research that some of the requirements need to be studied further and algorithms shall be improved to adapt the limited resources especially AI and security techniques.

Acknowledgement

This paper is self-funded.

Conflict of interest

The authors have declared no conflict of interest with any parties involved in this research study.

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