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EDGE COMPUTING FOR MOBILE SENSOR NETWORKS

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ABSTRACT

The ever-increasing number of mobile end-user devices and the enormous amount of data processing have been the driving forces behind the growth of mobile cloud computing By integrating cloud computing capabilities into the mobile environment, MCC technology makes it possible for mobile users to make full advantage of cloud resources [2–8]. It is possible to meet the processing requirements of mobile devices by using resources at cloud providers other than the mobile devices themselves to host the execution of mobile applications. This is accomplished by offloading the computation data to the clouds. Mobile cloud computing is a kind of cloud computing infrastructure in which data processing and storage are performed off-site using mobile devices. The name "mobile cloud" alludes to this concept. Cellular core networks may be used by mobile user equipment (UEs) in order to get access to cloud computing services. Therefore, the elastic processing power and storage that is offered by the clouds can support a wide variety of applications that are designed for mobile user equipment (UEs) that have limited resources. By transferring computational tasks from user equipment (UEs) to infrastructure-based cloud servers, MCC has the potential to reduce the amount of energy that UEs use and improve the performance of mobile applications. During the course of the last several decades, cloud computing has seen rapid expansion as an efficient computing platform. This expansion is mostly attributable to the growing processing and computational requirements of various client devices. Considering the significant developments that have been made in networking and communication technologies, users are expecting higher quality standards in addition to the enormous computing requirements.

Keyboard: *networking , communication, technologies, Monetary edge computing*

INTRODUCTION

During the course of the last several decades, cloud computing has seen rapid expansion as an efficient computing platform. This expansion is mostly attributable to the growing processing and computational requirements of various client devices. Considering the significant developments that have been made in networking and communication technologies, users are expecting higher quality standards in addition to the enormous computing requirements. In order to accomplish this goal, a significant number of scientists and researchers have concentrated their efforts on developing innovative approaches that have the potential to improve the efficiency of computing services and reduce latency. Monetary edge computing (MEC) is a revolutionary idea that promises to deliver ultralow latency, high bandwidth, and real-time access to computer services. In recent years, there has been a great amount of interest in MEC. Moving cloud computing from remote, centralized data centres to the edge of mobile networks, which is closer to end users, is the means by which this objective is accomplished. The principles of cloud computing, mobile cloud computing (MCC), and mobile enterprise computing (MEC) are discussed in this section. It also addresses the causes and situations that push cloud computing to shift from the heart of the network to the perimeter of the network.

Cloud Computing: A Centralized Computing Platform

A rising Internet-based technology that makes online computing services available to a broad variety of users, including personal devices and organizations of all kinds, cloud computing has quickly expanded over the last two decades. Cloud computing is a burgeoning technology that is based on the Internet. This is the definition provided by the National Institute of Standards and Technology (NIST): As a result of the cloud computing architecture, it is feasible to have a shared pool of reconfigurable computing resources (such as networks, servers, storage, applications, and services) that can be swiftly deployed and released with little administration effort or contact with service providers. This strategy makes it possible to have network connectivity that is practical, widespread, and on demand.

Some people call the shared pool of resources the data centre or the central cloud. Both of these terms are used interchangeably. The term "central cloud computing" (CCC) is often used to refer to cloud computing, which is a centralized platform. The cloud computing technology is a feasible means of increasing infrastructure capacity and decreasing expenses overall. This enables customers to enjoy exceptional quality of service (QoS) at a minimum cost. Cloud computing technology is a viable way of enhancing infrastructure capacity. In light of this, the major objective of cloud computing is to optimize the utilization of resources via the consolidation of operations, with the intention of achieving enhanced efficiency and performance capabilities. A number of compelling elements of cloud computing, including its pay-as-you-go service model, scalability, interoperability, and other appealing qualities, accelerate its integration with other cutting-edge technologies and its continuous development.

Motivations for Research

The following three demanding but understudied issues in the corpus of current MEC-related literature serve as the motivation for this thesis, which focuses on the design and optimisation of MEC in three advanced wireless communication networks. These themes are listed below.

- In recent years, MEC has become more popular in cellular networks, with the primary focus being on enhancing the energy efficiency of various cellular-based MEC systems or reducing the latency of these systems. Wireless Power Transfer (WPT) technology has been regarded as a key paradigm for providing true sustainability for mobile communications. This is due to the fact that it assists in overcoming the energy-limited limitations of conventional battery-based mobile devices and fully utilising the benefits of powerful computational resources at the edges. For example, the use of wireless powered communication networks (WPCN) is the means by which the synergy that results from the combination of MEC and WPT may be realised [52–55]. The so-called "double-near-far" impact is a dreadful fact that the existing wireless powered MEC works do not completely account for. This effect occurs when user equipment (UEs) that are farther away from an access point (AP) collect less energy and are also needed to communicate over longer distances. The use of user collaboration technology is a potential method that can be utilised to mitigate the double-near-far effect in wirelessly powered MEC networks and improve the performance of overall systems.

EDGE COMPUTING ON MOBILE DEVICES

In 2014, the European Telecommunications Standards Institute (ETSI) presented the concept of MEC, which is a unique platform that provides information technology (IT) and cloud computing features inside the radio access network (RAN) in close proximity to mobile customers. To put it another way, the purpose of MEC is to relieve resource-constrained user equipment (UEs) of heavy computing workloads and to extend the battery life of these UEs. This is accomplished by offloading and completing the computation-intensive and latency-critical tasks of the UEs at the edge of wireless networks. This is accomplished through the deployment of edge cloud servers, also known as MEC servers, at the wireless access points (APs). In essence, the MEC servers are simply small-scale data centres that are built by cloud computing or telecom carriers. These servers may be co-located with the wireless access points (APs), such as the public Wi-Fi routers and base stations (BSs or routers). Through the provision of the APs with the capability to process and store data, the MEC guarantees that the UEs will be able to establish direct connections with the edge clouds. In comparison to the MCC, the MEC provides four significant advantages in the areas of context awareness, energy savings, latency reduction, and privacy and security enhancement. These advantages are available because the MEC is located in closer proximity to end users. As a result of the attractive advantages that MEC offers, it has gained significant recognition as an essential facilitator in the process of determining the path that subsequent advanced wireless networks will take.

REVIEW OF LITERATURE

Hothayfa Agha (2023) Data has become the lifeblood of modern technology, and as our dependence on it has grown, so too has our need for technological equipment that can connect to their surroundings, gather data from it, and deliver it for processing and analysis. This is also a result of broadband capacity limitations. Due to the growing need to review the research on the issues that arose from the widespread use of edge computing with wireless sensor networks (WSN), the researcher discovered that while many aspects have been addressed by previous studies, some still require additional attention, such as the use of artificial intelligence on the edge (smart edge) and security issues. Many advantages come with using a WSN, including mobility, scalability, real-time response, and overcoming bandwidth limitations.

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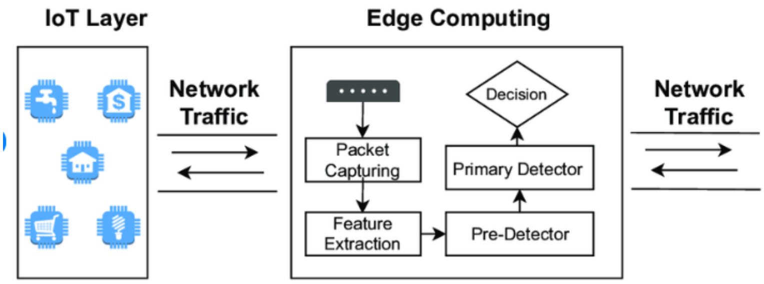
Taha Alfaqih (2022) Wireless sensor networks (WSNs) are completely dispersed, self-configurable, self-organizing systems of nodes that want to communicate data wirelessly across Internet of Things devices. In order to monitor natural phenomena like volcanoes, pressure, sound, temperature, and pollution, heterogeneous and homogeneous sensors are placed across a given region and then transmit their data to a central point for analysis and decision-making. WSN deployment is often used in challenging environments that need for effective data collecting, such as disaster regions, battlegrounds, combat zones, and volcanic zones. WSNs do, however, confront several difficulties, including latency, multitasking, and data quality. In conflict zones and catastrophe situations, this study suggests an effective method for handling various data gathering tasks that take use of mobile edge computing (MEC) technique-enabled WSN. First, we create a unique data gathering system (WSN) by integrating WSN and MEC.

Anindita Raychaudhuri (2021): As the most recent mobile apps improve, so does the development of mobile user equipment. However, customers are unable to utilise these devices to run computationally demanding apps due to the restricted battery life. This one accelerated mobile cloud computing's (MCC) development. Rather of having a large amount of data to store and analyse, MCC has a lot of delay. Mobile edge computing is a fresh and promising idea that has been proposed to address the latency issue. Two very promising areas of wireless network research are mobile edge computing (MEC) and wireless sensor networks (WSN). The concept of Sensor Mobile Edge Computing (SMEC) was created by the merging of MEC and WSN. Energy efficiency is one of the main issues facing the developing area of sensor mobile edge computing, however. In MEC, services are rendered at the mobile network's edge with the goal of lowering latency, which may enhance user experience. Prior to this, MEC concentrated on offloading calculations from mobile devices to base stations.

Mubashir Husain Rehmani (2016) notes that the availability of a large pool of cloud resources and services has made it feasible for a number of novel computer applications, including virtual reality and smart surroundings. But the tight delay requirements of the delay-sensitive applications turn exhilaration into a problem. The low latency, location awareness, and mobility support needs are not met by the cloud computing paradigm. In this context, Mobile Edge Computing (MEC) was established to use the resources available in edge networks to deliver cloud services and resources closer to the user. We provide the definitions of the MEC provided by researchers in this study. Furthermore, by talking about several applications, the MEC's motive is underlined. Along with the benefits presented by MEC, certain significant research problems are also addressed in the context of MEC. A synopsis of the approved articles for our MEC Special Issue is given. Lastly, we outline the most important ideas and provide a summary to wrap up this study.

PROPOSED ARCHITECTURE

Recent years have seen an increase in the number of autonomous monitoring applications that make use of drones, which are often referred to as unmanned aerial vehicles (UAVs). Thus, integrating UAVs to WSNs may boost the systems' remote surveillance capabilities. Thanks to the advancement of unmanned aerial vehicle (UAV) technology, monitoring systems have improved their remote sensing platform by adding characteristics such as mobility, productivity, and cost efficiency, among other benefits. However, the amount of contribution that unmanned aerial vehicles (UAVs) provide to wireless sensor networks (WSNs) may be affected by a variety of parameters, such as the time, location, the speed of the communication channel used by the UAV, and the route. Data that has been detected will be stored on a cloud server for later use, which will make the next generation of wireless sensor networks (WSNs) more advantageous. Consequently, prior to the data being transferred to the cloud server, the data processing techniques and approaches that are now in use will either be replaced or found a new application in the field of data processing inside the scope of this thesis work, we provide a one-of-a-kind edge-based architecture that encompasses data management, processing, and retrieval from unmanned aerial vehicles (UAVs) operating inside a heterogeneous Wireless Sensor Network (WSN) installed in a remote location In order to explain the concept and demand of integrating end-to-end secure communication between unmanned aerial vehicles (UAVs) and low power Internet of Things devices in a real-world practical scenario, we have taken into account a smart agricultural use case that has been located in a remote location with a range of sensors. As an additional point of consideration, we have taken into account the fact that this agricultural region is difficult for humans to reach and requires constant monitoring. the communication protocols and system model of the proposed architecture are described in detail. These protocols and models were used in the process of collecting data with remote field locations.



ANALYSIS OF SIMULATION RESULTS

In the next part, we will investigate the results of the MATLAB simulation that was executed. As a consequence of this, the research was broken up into four distinct parts in order to investigate the elements that influenced the outcome of the simulation. In order to analyse the connection between the overall flight period of the drone and the number of sensor nodes that it is able to cover while collecting data, the simulation was designed to study the relationship. Taking into consideration the drone that we used for the creation of the prototype, we investigated the manner in which the number of sensor nodes changed throughout the course of a flying cycle that lasted for twenty half minutes. Furthermore, the extra general parameters that were employed in order to get the simulation findings are shown in Table 3, Chapter 4. Alterations have been made to the following essential parameters in order to conduct an analysis of the outcomes of the simulation:

- Impact of drone speed (S);
- Impact of sensor distance (D);
- Impact of BLE data rate (RBLE);
- Impact of sensor data rate (RS);

EFFECT OF BLE DATA RATE

In light of the fact that Bluetooth Low Energy (BLE) communication was used to create the interface between the drone and the sensor node, it is essential to analyse the implications of BLE data rate. The simulation graphs for the different kinds of sensor node arrays are shown in Figure 31. When we take a look at the actual process of data collection, we see that the BLE communication rate has a significant impact on the amount of time that the drone must wait in order to reach a sensor node. In the event that there is a low BLE data rate between the drone and the sensor node, the drone will be required to wait for a longer period of time at the sensor node. As a consequence of this, there is a need for a decrease in the total number of sensor nodes that may be covered in a single flying cycle. As a consequence of this, a higher number of sensor nodes will get data gathered from them during a single flying cycle. This is because the BLE transfer rates between the drone and the sensor node are increased.

In order to explore the influence that the BLE data rate has on the total number of sensor nodes that the drone is able to traverse in a single flying cycle, we adjusted the BLE data rate (RBLE) to 2 kbps, 4 kbps, 8 kbps, 12 kbps, and 16 kbps while maintaining the other parameters at their default values. During the process of putting the simulation work into action, each and every kind of sensor node array that was taken into account also went through the simulation process. As shown by the charts illustrated in Figure 31, drones with higher BLE data rates are able to collect data from a greater number of sensor nodes than those with lower BLE data rates. On the other hand, the curves in Figure 31 have a tendency to overlap with BLE data rates that are higher than 8 kbps. The fact that this is the case suggests that when the data rate is higher than 8 kbps, the total number of sensor nodes that may be covered is about similar. Additionally, when the BLE data rates increase, the curves begin to exhibit a linear pattern. These results are consistent across all three sensor node arrays that were investigated.

When comparing the graphs that correspond to the different arrays of sensor nodes, the performance of the circular and square arrays of sensor nodes is better to that of the linear array. This is the case when comparing the graphs. As a result, the greatest number of sensor nodes that a drone is capable of covering during a flying time of twenty-five minutes is around seventy-five, provided that the BLE data rate is sixteen kilobits per second.

Therefore, if the BLE communication rate between the drone and the sensor node is high, we may deduce from the results of the simulation that the drone is able to collect data from a greater number of sensors.

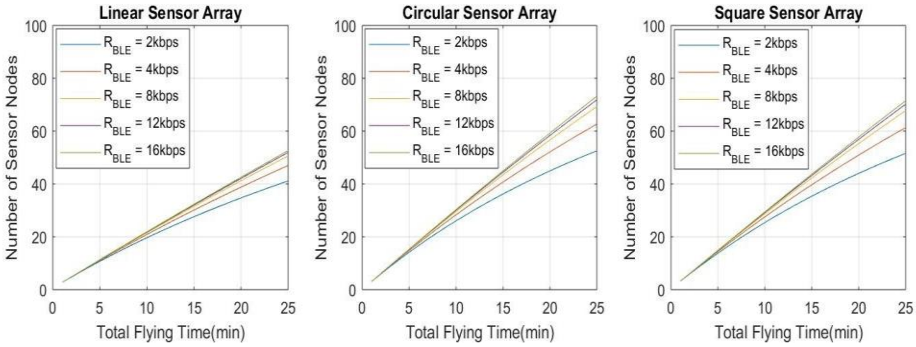


Figure 1 The effect of the BLE data rate

Effect of data rate from sensors

The rate at which the sensor node generates data has a considerable influence on the overall functioning of the system. mainly due to the fact that a sensor produces less data when the data rate of the sensor node is reduced. The drone is able to collect those smaller amounts of data at the sensor node more quickly than it could acquire bigger volumes of data. This is because of the outcome of the previous sentence. In light of this, drones that have lower sensor node data rates are able to collect data from a larger number of sensor nodes in comparison to drones that have higher sensor node data rates. When contrasted with the conclusions that we obtained from the BLE data rate, the effect of sensor data rate produces results that are contradictory.

A representation of the outcomes of this experiment's simulation may be seen in Figure 32. Twenty bytes per minute, forty bytes per minute, sixty bytes per minute, eighty bytes per minute, and one hundred bytes per minute were the data rates (RS) that we changed for the sensor nodes while keeping the other parameters the same. Additionally, we made the assumption that the single built-in sensor of a sensor node generates data at a rate of twenty bytes per minute. The maximum number of sensor nodes that a drone with a flight length of 25 minutes is capable of covering is around 75, and the sensor data rate is 20 bytes per minute.

Within a way that is analogous to the case that came before it, circular and square arrays performed better than linear sensor nodes arrays. The findings of the simulation may lead us to the conclusion that the drone is capable of collecting data from additional sensors [15]. This is because the sensor data rate is low while the simulation is being run.

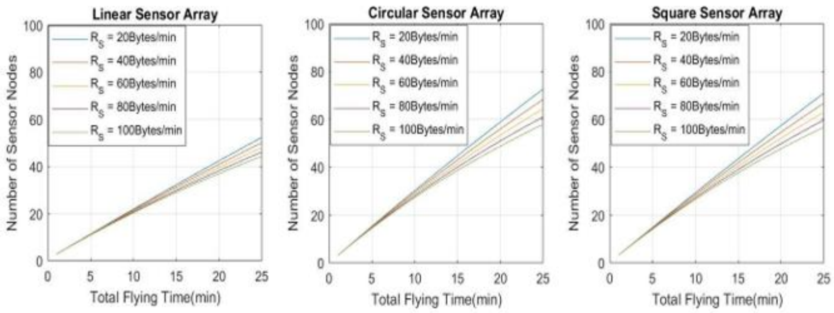


Figure 2. Effect of data rate from sensors.

EFFECT OF SENSOR SEPARATION

The configuration of the system that has been proposed is strongly influenced by the distance that exists between two sensor nodes. Additionally, if the sensor array is composed of neighboring sensor nodes, the drone will be able to access a greater number of sensor nodes in the actual world. Because of this, in order to determine whether or not this phenomenon is true, we conducted simulated experiments in which we altered the distance (D) between two sensor nodes to 50 metres, 100 metres, 150 metres, 200 metres, and 250 metres. As was the case in the three circumstances that came before it, we did not modify any of the other characteristics, precisely as we did in Table 3, Chapter 4. The findings of the simulation that were linked with this scenario are shown in Figure 34.

According to the findings of the simulation, the number of sensor nodes that may be covered throughout the process of data collection is increased when the distance between two sensors is relatively close to one another. Additionally, when the distance between two sensor nodes rises, the gap between curves in the simulation output plots reduces and becomes linear. This occurs because the space between curves is linear.

When we analyse the graphs that correspond to the different arrays of sensor nodes, we find that the performance of circular and square arrays of sensor nodes is much higher than that of linear arrays.

EXPERIMENTAL FINDINGS

The experimental results that we extracted from the prototype implementation are shown here. These findings are presented in this section. A prototype approach allowed us to achieve real-world uploading and downloading data rates between the Raspberry Pi and Waspmote. This was accomplished by using the

Waspmote. We carried out the experiment twenty times for each and every event in order to determine the parameters of the experiment. In addition, in order to get the findings of the performance research, we determined that the flying height of the drone should be set at ten metres above ground.

During the process of uploading data, we made sure that handler 0x0038 from the Waspmote's BLE user services profile was set to send the data from the accelerometer sensor to the Raspberry Pi. One transmission attempt is limited to a maximum of twenty bytes of data, which is the maximum amount of data that may be transferred. In addition, the data from the accelerometer sensor that Waspmote sends out is encoded, and in order for it to be used, it must be decoded on the Raspberry Pi. The Raspberry Pi goes through the process of decoding this data, and 112 bytes are taken from them. It is because of this that we consider these 112 bytes to be the maximum amount of data that may be sent in a single transmission. We were able to code handler 0x0020 during the period of data download, which is the communication that takes place between the Raspberry Pi and Waspmote. In this case, we took into consideration a delay of ten seconds in the transfer of data packets from the Raspberry Pi to the Waspmote over Bluetooth Low Energy (BLE). Due to a buffer capacity restriction, the Raspberry Pi is only capable of sending a maximum of 74 data packets to the Waspmote. Each of these data packets contains 20 bytes, and it takes a total of 74 seconds for these data packets to be transmitted. The maximum amount of data that can be sent causes the Waspmote buffer capacity to become full, at which time the Raspberry Pi will no longer able to get data.

In the following table, , you will find a summary of the actual data rates from the trials.

Data Rates for the Tests, Table 1

Data Rate Parameter	Value
Data transfer rate from Waspmote to Raspberry Pi (*RUL*)	672 Bytes/min
Data transfer rate from Raspberry Pi to Waspmote (*RDL*)	148 Bytes/s

According to the results shown in Table 4, the rate at which data is downloaded from Raspberry Pi to Waspmote is lower than the rate at which data is uploaded from Waspmote to Raspberry Pi. Because of the limitations imposed by the Waspmote software, the download data rate was much lower.

CONCLUSION

Within the context of a wireless sensor network (WSN), this thesis research provides a novel edge-based remote monitoring architecture for low power Internet of Things (IoT) sensors. Consequently, the proposed architecture provides secure end-to-end communication via the use of unmanned aerial vehicles (UAVs) between various wireless sensor networks (WSN) and the central cloud, which helps with the administration, processing, and data retrieval tasks that are performed from a remote location. With the help of this thesis work, the major objective is to develop a systematic, labor-saving, cost-effective, and energy-efficient architecture for remote monitoring in a heterogeneous wireless sensor network (WSN). In the architecture of remote monitoring, drones or unmanned aerial vehicles (UAVs) are used to substitute human labour in the process of data collection. For the purpose of demonstrating the potential viability of the proposed architecture, we took into consideration a smart agricultural software application. A wide variety of other use cases, such as environmental monitoring, wastewater management, disaster warning, anomaly detection in sensor networks, mobile crowd sensing applications, and so on, might potentially make use of the same architecture.

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