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REVIEW

Mobile Cloud Computing and Wireless Sensor Networks: A review, integration architecture, and future directions

Chhabi Rani Panigrahi[1] | Joy Lal Sarkar[2] | Bibudhendu Pati[1] | Rajkumar Buyya[3] | Prasant Mohapatra[4] | Abhishek Majumder[2]

[1]Department of Computer Science, Rama Devi Women's University, Bhubaneswar, India

[2]Department of Computer Science and Engineering, Tripura University, Agartala, India

[3]School of Computing and Information Systems, University of Melbourne, IEEE, Australia

[4]Department of Computer Science, University of California, Davis, US

Correspondence

Chhabi Rani Panigrahi, Department of Computer Science, Rama Devi Women's University, India.
Email: panigrahichhabi@gmail.com

Abstract

In today's fast advancing world, sensors are used in various applications to provide complete data about different objects present around us. The sensor data when integrated with Mobile Cloud Computing (MCC) is used for further computation to provide useful results advanced warning, forecasting, planning, and plethora of other applications in this uncertain world. Few works have been proposed where sensor nodes are integrated with Wireless Sensor Networks (WSNs) which give a new direction in modern research for developing new technologies which help the users for fast access of sensory data over mobile devices. Herein, a systematic literature review of both MCC and WSNs are conducted and subsequently assimilated them via an architecture which is efficient and achievable within short time-span for a variety of applications. The MCC applications are reviewed from two main perspectives that are energy and information management. The communication aspect in MCC and WSNs has been discussed and the need for integration between the two has been justified in this work. The work done on mobility management in MCC and WSNs is reviewed. Also, the challenges in MCC-WSNs integration along with the comprehensive analysis and findings of the review are identified. Finally, the conclusion and specific future direction of research in this area are provided.

1 | INTRODUCTION

The current world has undergone a big revolution with the introduction of Smart Mobile Devices (SMDs) like smart phones, tablets, laptops, etc., which can accomplish different types of activities using intelligent applications that can be run independently on the cloud [1]. The current Year on Year (YoY) growth of mobile devices is more than 50% and their number has already surpassed the total world population [2]. Mobile access has taken over the fixed Internet access [1]. Also, the popularity of the mobile devices can be gauged from the fact that their number has already surpassed the number of desktops across the globe in 2014 [3]. National Institute of Standards and Technology, USA (NIST) defines [4] cloud computing as follows: "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable resources (e.g. networks, servers, storage, applications and services) that can rapidly be provisioned and released with minimal management effort or service provider interaction." MCC comprises of mainly three components—mobile device, cloud, and network [5].

When mobile devices are integrated with the cloud, it can leverage the huge potential of the cloud for computation and storage purposes [5–20]. However, a particular mobile device is at the centre which initiates the computation and various other mobile devices are well connected in a network to perform the execution of a task that is logically split amongst them. In case the computation task is very huge and cannot be taken care by a network of SMD's, then the offloading approach is followed, wherein the task is executed completely in the cloud and only the final results are sent back to the mobile device for the user [21]. WSNs are very important in today's world as they are used widely to monitor various parameters in the environment and based on these observation values corrective action can be taken for the betterment of the society. For example WSNs are used to monitor the climatic conditions of temperature, rain, etc. [22–33]. Sensors also find a variety of usages in military and industrial applications, and are typically micro devices which can be embedded at various places and not detectable with a common eye. They transmit huge amounts of data to the sink node which is used to collect the data from several nodes and subsequently sends it to the cloud for processing and extraction of useful information for the betterment of the society [34–50].

MCC and WSNs work together on the principle of using the sensors of various types (like temperature, humidity, chemical, optical, etc.) to generate data that will be consumed by MCC for further processing. Transfer of sensor data to the cloud is done using the offloading approach which thereby helps to utilise the immense computing and storage power of the cloud. Hence, the researchers are actively working in this field and continuously coming up with various techniques to integrate both MCC and WSNs in an effective manner [38, 42, 51, 52]. WSNs would put the data in the cloud from where one would pick it up for further processing. However, MCC may look at various mechanisms of pulling the data for further processing. A few strategies of data pulling by MCC from the cloud where WSNs put the data depend upon the need of data by MCC based on the demand of the particular user. Many of the sensors available today are fitted with non-rechargeable batteries having limited energy and hence the need of judiciously using the energy of the sensors [53–69]. Integration of MCC and WSNs has become very important for various reasons such as increasing usage of mobiles across the globe and to make use of the cloud which has enormous resources at the same time. Offloading is an important mechanism to process large chunks of complex data using the power of cloud computing and subsequently displaying the result in a mobile device . It enables the power of cloud (compute resources, storage, networks, applications, and services) to be used effectively to do the work and also the display in the mobile devices (smart phones, tablets, etc.), seamlessly without the user knowing about it. Hence, cloud computing compensates for the power of the mobile and user is able to get all the information and his work done for a cheaper price [70]. Various applications of this type such as mobile cloud learning, gaming, health-care, etc. are gaining popularity day-by-day.

1.1 | Contributions and the organisation of the study

In a nutshell, the study covers the following salient points.

- A comprehensive overview of MCC and WSNs along with their architectures is presented.
- An overview of MCC applications with respect to energy management along with the problems faced with existing approaches without WSNs and subsequently the solutions of MCC applications with WSNs is reviewed.
- A few research challenges have also been brought into limelight with respect to the integration of MCC and WSNs.
- Also, the information management and communication aspect in MCC and WSNs has been discussed. The need for integration between the two has been elucidated (see Figure 1).
- An architecture of MCC-WSNs integration has been proposed by considering the mobility scenario.
- Towards the end, we have made an overall comparison of the MCC-WSNs integration with respect to both energy and information management.

Herein, in Section 2, the overview of MCC and WSNs is presented. The MCC applications for energy management and information and communication management are presented in Section 3 and 4 respectively. A brief comprehensive analysis and findings of the survey is given in Section 5. Finally, Section 6 concludes with specific research directions in this field.

2 | OVERVIEW OF MCC AND WSNS

This section covers the basic idea about MCC and WSNs.

2.1 | Mobile Cloud Computing

We think about cloud computing being the mother of computing power having vast resources for computation and storage which are dynamically provisioned on-demand, immensely elastic and used on a pay-per-use basis. On a much smaller scale, similar to a child who much depends on his mother, we can pack small amount of computation power into a SMD and still use it for our needs. MCC combines this small power from various devices combined together into a network which then helps to accomplish a bigger task. However, by no means can MCC beat the humongous power of the cloud, and also it is not intended for this purpose as well. Instead, MCC cleverly leverages the power of the cloud on a need basis when the computational task grows large by using the mechanism of offloading. The results are returned to the mobile user from the cloud via the mobile device and this process is transparent to the user [51]. The various layers in the MCC architecture as include:

- User Interface layer, which consists of several SMDs like smart phones, tablets, etc.
- base station of the mobile network, which is the connection between the mobile device and the Internet.

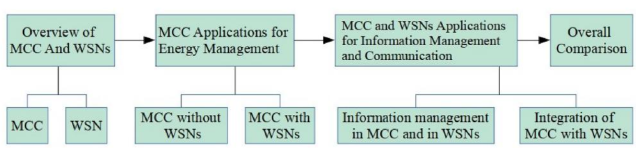

FIGURE 1 Review methodology used here

- Internet which helps to connect to the cloud where immense computation and storage takes place.
- Cloud helps in doing the intensive computations and has services of different types (IaaS- Infrastructure as a Service, PaaS- Platform as a Service, SaaS- Software as a Service, etc.), which are then passed to the mobile device [45]. Either public, private or hybrid cloud can be leveraged for this purpose.

2.2 | Wireless Sensor Networks

Sensors have been popular since long time 1970s, when wired sensors were used and are connected to a central location [71]. Today almost all sensors are wireless in nature. WSNs however gained popularity around in 2000 and combined the sensor devices along with the wireless networks in order to propagate the data to computers for useful analysis for mankind. WSNs consist of networks of nodes which operate in a cooperative manner using various sensor devices to collect different types of information from the environment thereby enabling interaction between computers and the environment [72]. Subsequently, gathered data from sensors is passed for analysis to the computing engine or the cloud and displayed to the user using a mobile device or fixed Personal Computer (PC). Sensors find a variety of usages in almost different types of applications such as smart homes, health care, smart grid [73], smart agriculture, and fire detection, etc. The sensors are of different categories such as physical (for temperature, moisture, pressure, etc.), chemical (for pH value, large organic compounds, etc.), biological (for micro-organisms, monitor pulse rate, etc.) and various other types. In WSNs architecture, there are many wireless sensors and there is a sink node where the data is accumulated and ultimately transmitted to the cloud. A typical WSNs node consists of the following components:

- Battery, that provides the power to the sensors
- Memory unit to store the data collected
- Sensor unit which is typically an electrical or mechanical device to sense and capture a typical parameter
- Radio transceiver device used to send the data captured
- Processor unit which does the task of doing slight computation on the data, if required

The different network topologies [74] applicable to WSNs for communication are given as below:

Star network where there is a single central sink node which collects from/sends information to the various remote nodes. It is very important that the central node should be in the radio range of the remote node(s) as there is total dependency on the central node for the data. *Mesh network* in which each and every node is connected with each other. It is more reliable than *Star network* as it has built in redundancy, which allows for multi-hop communications and hence information reaches the destination node via a different route in case any specific connection is broken in the network. *Hybrid network*, which combines the features of both star and mesh network. It is robust and also helps to maintain power consumption of each of the nodes to a minimum, as the low power nodes do not forward messages but the powerful nodes would only be capable to forward messages and have multi-hop capability. This topology has been implemented by networking standard—ZigBee. The main features of WSNs include:

- Scalability as several nodes are connected to a particular network
- Self-healing where a sensor node typically does self-rectification of its own issue
- Low complexity
- Low cost of sensor devices as the node is not a very complex and huge device
- Energy efficient sensor unit

The different applications of WSNs in various domains but not limited to, are listed below:

- Monitoring regions by deploying sensor nodes over a certain area and thereby gathering data on various parameters (such as heat, humidity, pressure of a region) and reporting to the base station where suitable action to be taken on the basis of the collected data is decided (like alarming fire stations etc.)
- Traffic monitoring and alerting drivers of congestion of specific routes. This is achieved by the help of WSNs which collects information about traffic movements and dissipates to drivers via Internet websites or radio stations
- In medical domain, WSNs help to monitor patients by conveying information like heart rate, ECG and other health parameters to a doctor or nurse who can then pro-actively prescribe drugs or take appropriate medical actions. On the contrary, doctors and nurses can also be tracked in the hospital and can rush to render immediate help in emergency situations.
- Environmental tracking where various environmental conditions of mother Earth are tracked using the environmental sensor networks (an area of WSNs especially directed towards research of the Earth).

2.3 | Mobility management in MCC and WSNs

Kim et al. [75] proposed a technique to offer the consistent sub-RRH and sub-MEC server flexibility help of communications and routing services with centralised control [76] through a vehicular Cloud Radio Access Network (vCRAN) with Remote Radio Heads (RRHs) and Mobile Edge Computing (MEC). Chen et al. proposed a method which provides complete information flexibility, control and an immediate and secure interaction with its client focussed on a data-centred and diverse network transfer. Hu et al. [77] focussed on connectivity control in cloud computing platforms relying on the connectivity-driven network's recognition/finder detaching approach for providing active relocation among IP subnetworks with a virtual environment avoiding disruption of service. In a subsequent stage, the author introduced the MOBaas, a clouded predictor of accessibility and connectivity resources, that could be implemented, used and provided on-request with OpenStack Framework [78] to forecast positions of a singular/community device devices. In order to minimise the adverse effects of large variations in vehicle positions on vehicle cloud activities [79], the authors suggested an effective Artificial Neural Network (ANN) design flexibility detection. To enhance the processing of information acquired in theWSN structured in clusters by means of a leach method, authors suggested two network topologies with adjustable paused times to allow the detection of cluster heads and information gathering for an optimised Mobile Sink route and a query of tabu and model ripple protocols was utilised [80]. Kaur et al. [81] suggested to pick the cluster head through not only of the remaining potential, as well as of an approximate cluster time [82]. Rajesh et al. [83] suggested optimising clusters via versatility and energy-savvy clustering techniques for power conservation, balancing of charging and lifespan development of the handheld sensor. Cayirpunar et al. recommended to classify an active device, death device, peripheral output, packages forwarded to access point, and remaining power a cost effective flexibility grouping information distribution model (MMCDD). In order to illustrate the effect of different displacement trends on the WSNs lives, authors developed a hybrid optimization method using Gaussian and spiral connectivity [84]. Hyunsook et al. [85] suggested a diverse slot distribution to minimise the vacant spaces depending on the expected residential period among the cluster head and representatives to promote stability and increase the lifespan of its network and lessen the amount of departing devices. In order to overcome the standard routing problem of all WSNs and MWSNs techniques utilising MH-LEACH-R [74] method and the firefly optimization principles, Laroui et al. [86] suggested a modern scheduling algorithm for mobile wireless sensors.

3 | MCC APPLICATIONS FOR ENERGY MANAGEMENT

In this section, problems with existing approaches for MCC applications without WSNs, solutions of MCC applications with WSNs and also the future research direction are highlighted. Table 1 shows the summary of MCC applications for energy management. On the other hand Table 2 shows the summary of MCC applications with WSNs for energy management.

3.1 | Problems with existing approaches for MCC applications without WSNs

3.2 | Information management in WSNs

For managing information over sensor nodes, WSNs follow two approaches namely *warehousing approach* and *distributed approach* [95].

MCC is catching up at a larger scale as the number of mobile users is growing at a fast pace. SMDs are becoming chip which is very good for the user but comes with certain limitations like less computational power, lesser battery life, lesser storage capacity and less network bandwidth. Under these limitations, sometimes we may not be able to run computationally intensive programs or store huge data on a SMD. Hence, we need the approach of offloading the large computation or huge storage requirement to a cloud which is dynamically elastic, ubiquitous, and cheap [96]. The existing approaches for MCC without WSN's are categorised as below:

- Mobile and cloud integration
- Offloading for resource utilization

In the mobile and cloud integration approaches, it is not possible to get the data upon which the analysis needs to be done. Hence, we only have the cloud services (like IaaS, PaaS, and SaaS), but the mobile device does not send any data and hence no computation or storage from the cloud is used. The services are only ornamental in nature and even there is no communication between the mobile and the user. Also, using the mobile and cloud integration, we overcome obstacles in computing related to performance, battery life of mobile, storage, availability, scalability in the cloud, etc. Using WSNs, we are able to provide data from sensors for the computation in the cloud. Hence, the user will now have to manually feed in all the data, which is practically impossible and subject to errors. For example, in the Health-care domain, if WSNs is missing then MCC cannot get the data from WSNs and it is not possible to process the health data of the patient on a real time basis and it may result in sudden death as the situation would deteriorate and no medication can be prescribed by the doctor on lack of physical data of the patient.

Also, if we consider any military application then no data will be received in the absence of WSNs and hence no intelligent analytics or inferences will be made. This will result in loss of lives as the military may be taken by surprise by the attacking party. Hence, it becomes very essential for the MCC to be tagged along with sensors so that they constantly provide data and useful information which will help the user. Also, in the absence of WSNs, the offloading approach will not give any substantial benefit. The offloading approach problems are as follows:

In remote places where the Internet connectivity is not good, it becomes very slow to do the offloading activity. Also, there is a possibility of instability of the wireless network connectivity which causes problem and delay in response of the application which has offloaded the task to the cloud. As battery life of the mobile devices is very less, there is a possibility of breakdown of the offloading process in the middle while sending data to the cloud or receiving data processed by the cloud. The different types of offloading techniques are listed below [96]:

- *Static offloading*: The application written in any specific language (like Java, .Net, etc.) is analysed and partitioned during development time and certain parts are run by SMD

TABLE 1 Summary of MCC applications for energy management

MCC Applications	Features	Underlying Services Used
eTime [87]	• Provide energy efficient transmission between cloud and the mobile devices using the Lyapunov optimization technique • Based on the bad or good connectivity the transmission of data consider delay- tolerant and prefetching friendly applications	Sina App Engine (PaaS)
ThinkAir [88]	• Method level code offloading approach • Dynamic resource allocation and also the parallel execution	Great Computer Language Shootout
Dream [89]	• Dynamic resource and task allocation Policy • Used Lyapunov optimization • Energy saving algorithm	Android OS
Partition scheme [90]	• Program is divided into the client and server tasks by which consumption of energy by the program can be minimised	Linux OS, Lucent Orinoco
Task allocation [91]	• Proposed an energy cost model • Divide the responsibility of processing the data between the server side as well as handheld	Mediabench programs
Secure communication [92]	• Considering the computation offloading of the consumption of energy for multimedia applications	Linux FreeS/Wan 1.96
Remote processing [93]	• Increases the battery power of mobile devices by using remote processing based on the Markovian decision approach	StrongARM SA-1110 processor
Offloading Computation/ Compilation [94]	• Works for java based mobile devices and the offloading technique supports for both compilation of bytecode-to-native code and execution of methods	Java based mobile device, 750 MHz SPARC server

TABLE 2 Summary of MCC applications with WSNs for energy management

MCC-WSN Applications	Scheme	Future Research Direction
Collaborative location-based sleep scheduling [51]	CLSS 1, CLSS 2	• Design with handoff mechanism by considering cloudlets when mobile users locations frequently change • Use dynamic sleep scheduling technique which fully depends on the user request
Data processing framework [42]	Apriori	• Use scheduling technique when sensor nodes work otherwise sleep
Reliability of sensory data using MCC [52]	TPSS (TPSDT, PSS)	• Use distributed clouds where sensor nodes efficiently offload the data to the local cloud
Virtualisation of sensor device using mobile cloud [7]	Mobile sensor device virtualisation	• Consider a case when mobile devices have limited battery life

(e.g. few Java methods which are computation intensive are offloaded and run on the cloud and few simple methods run on the SMD).

- *Dynamic offloading*: Here, different modules (e.g. Java methods) can be offloaded to the cloud while the application is running. After that the application is run on the cloud and the result is then transferred to the SMD. In absence of WSN, there is no use of offloading approach. Although we may come up with a very good strategy for computation or storage, in absence of data which we get real time from the user, it will not be possible to start the computation at all and hence no offloading approach/technique will be required.

Li et al. [90] proposed a partition scheme about the energy efficiency where the program is divided into the client and server task. The idea behind this is that for dividng this the consumption of energy by the program is minimised. Li et al. [91], proposed a task allocation approach where the responsibility of processing the data between the server side as well as handheld has been divided. Li et al. [92], proposed a secure communication where they consider the computation offloading to reduce the consumption of energy for multimedia applications. Rong et al. [93], used the remote processing based on the Markovian decision approach to improve the battery power of mobile devices. Chen et al. [94], proposed an approach which supports JAVA language. This offloading technique supports for both compilation of bytecode-to-native code and execution of method. Hara et al. [97], proposed an approach that decides where software components across the resources will be deployed and also how various kinds of systems are involved. In Ref. [98], Xian et al. proposed a scheme which is based on the timeout and is maintained for executing program on the client and program is offloaded to the cloud if compilation is not completed before the timeout. Seshasayee et al. [99], considered a set of techniques for running various applications across multiple and cooperative systems while performing the power actively. Hong et al. [100], proposed an offloading mechanism based on different parameters to save energy for content-based image retrieval. Cuervo et al. [101], proposed an approach named as MAUI which provides runtime decision that which method needs to be executed remotely.

A thorough study has been made by Namboodiri et al. [102], based on the energy consumption factor of mobile devices for different type of applications, to determine which applications should be running on the cloud and which are suitable for running on the mobile device only. Also, the GreenSpot algorithm suggested by the authors helps to understand whether running an application in the cloud is beneficial or the local mobile version. In Ref. [103], authors have laid stress on the fact that offloading is definitely beneficial for MCC. Song et al. [103], suggested a novel model - Energy Efficient Cooperative Offloading Model (E2COM) for striking a balance between the energy and traffic in case of MCC. Also, authors designed an Online Task Scheduling (OTS) algorithm which can set a balance between energy consumption and data traffic on the Internet by correctly setting the tradeoff coefficient. Reference [104], a practical approach has been followed to identify code offloading limitations and subsequently an elegant solution and architecture to resolve the issues has been proposed. The authors have followed the 3—W's and 1—H (what, when, where and how) approach for offloading of the code and the obtained results have been given. In Ref. [105], an offloading system for MCC has been prototyped that takes into account many cloud resources. Also, an algorithm about offloading decision has been proposed that provides runtime decisions for code offloading (upon giving inputs of the cloud resources). Also, real time experiments have been conducted for algorithm performance evaluation.

Zhang et al. [106], found out that offloading approach in which at most there is one shift from mobile to cloud for computation purpose is very energy efficient, along with collaborative execution between them. Balasubramanian et al. [107], have done a comparison between different mobile networking technologies like 3G, GSM, and WiFi. Also, a new protocol TailEnder has been developed for reduction in energy consumption of common mobile applications (for 3G and GSM), and evaluated with different applications and found to be more energy efficient.

Xia et al. [108], proposed an offloading approach to save energy of SMDs and also to improve the performance of applications by reducing execution time as it now runs on the cloud. Also, an architecture has been proposed along with the algorithm for deciding the offloading of application. Experimental results have also been shared. Noble et al. [109], discussed about Odyssey, which was the Linux OS (Operating System) that consumed very less power when running on laptops. The SMD's which run a variety of applications consume lots of energy and hence energy has been a primary concern for mobile run applications. This necessitated the usage of OS in SMD's which are energy saving and conscious such that they use it wisely, typical examples are ErdOS [110] and Cinder [111]. In Ref. [112], Chameleon is the software in which, applications will have to adjust the energy factor based upon conditions. Noble et al. built the Odyssey OS [113]. In ECOSystem, OS distributes energy to different applications in a justifiable fashion. CIST [114] focusses on the energy requirements of the application and uses Dynamic Power Management (DPM) [115] in order to solve energy when applications are running. In Odyssey and ECOSystem, a hybrid approach is followed where OS and application work together to deal with the energy consumption minimisation factor. In Ref. [116], Snowdon talk about the Koala platform which tells the amount of energy consumed by different running applications.

Shu et al. [87] presented eTime mechanism which helps to transfer the data between the mobile and the cloud in an efficient manner by pulling over mostly used data when the connection between the mobile and cloud is really good. In this work, authors have demonstrated that nearly one-third of the CPU and network energy of SMD can be saved during MCC using their algorithm: DREAM, and also proposed an architecture. In Ref. [117], that authors have come up with mCloud algorithm which tells whether offloading of the computation task should be carried out or not and hence helps to achieve cost reduction. In Ref. [88], ThinkAir framework has been proposed which enhances the power of MCC by running the methods of a programme in a parallel fashion on different VMs.

3.3 | Solutions of MCC applications with WSNs

The architecture of MCC along with WSNs is shown as in Figure 2. The description of the various components of MCC along with WSNs are as follows.

- The sensors can be of different types such as static, mobile video, biological, etc. These mainly do the task of sensing the data, processing, and storage of data [118, 119]. However, the power of computation and storage is minimal in a sensor, and hence the need for offloading to the cloud.
- The radio transceiver does the task of both transmitting and receiving data, and this term was originated in 1920s.
- The cloud does the computation and storage of the programs and data, using its vast power and hence able to does the computation faster and delivers results.
- The mobile users interact with the cloud for results which are useful for them. Also, the mobile user through the approach of offloading is able to leverage the cloud for computationally intensive jobs. For example in military applications, the sensors on the ground sense the movement

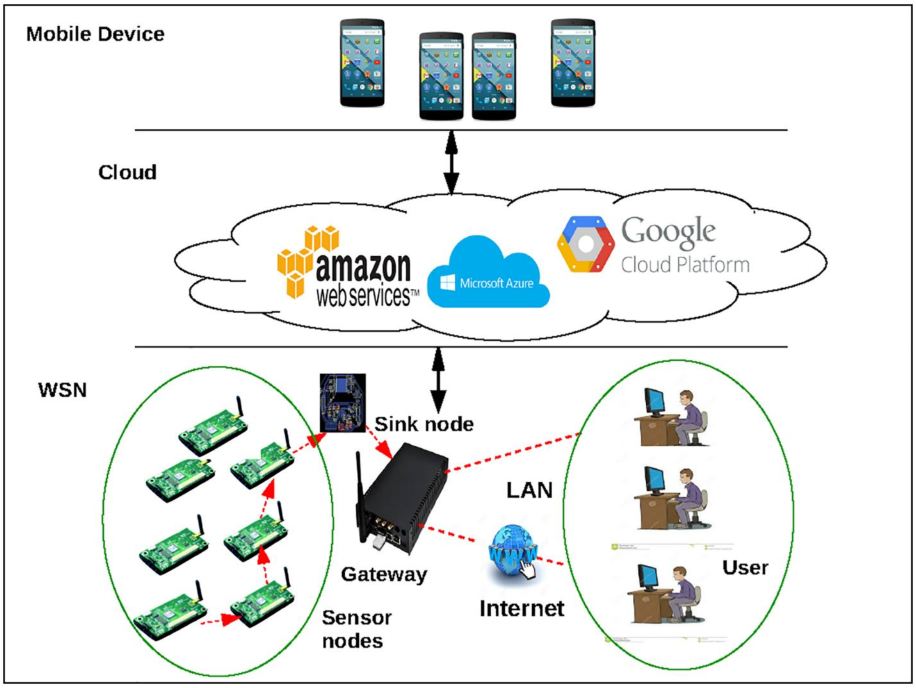

FIGURE 2 Overview of MCC-WSNs integration [52]

of the people in the sensitive areas, and is then sent to the cloud via the radio transceiver, after which it is processed by services of the cloud dealing with image processing, optical character recognition and intelligent algorithms. Such application is used to track the infiltration of enemies from bordering countries thereby guarding the borders and ensuring safety in the country. Also, in health-care, use of sensors has increased tremendously. By the help of WSN's, the patient's data like Heartbeat, ECG, pressure, etc., is transmitted to the cloud where it is processed and available to doctors and patients via their mobile devices, so that corrective drugs are prescribed to the patients in timely manner. Also, on the contrary, the doctors and nurses can have the physical condition of the patient(s) in their mobile and can rush to them in emergency. Hence, it allows to track the doctor in case of any emergency as well as monitor the physical condition of the patients.

Guillaume et al. [120], presented taxonomy of the different issues in MCC and also suggested various approaches to mitigate them. Zhu et al. [51], have emphasised on the integration of MCC and WSNs based on the assumptions that the mobile users will mainly request data of the nearby geographical regions only and also the sensors possess limited power. To this effect, authors have suggested two approaches, CLSS1 where the sensor is turned on or off depending on the location thereby saving good amount of energy and CLSS2 emphasises on the performance factor of the integrated WSNs. In Ref. [7], an architecture has been proposed depicting the use of sensors which are present in the human body for the monitoring of various body parameters which will ultimately help the doctors to make a sound decision for the well-being of the patient.

In Ref. [34], a cloud architecture has been proposed which helps to store data as well as performs computation on the cloud. An efficient Home Energy Management System using cloud and sensors has been proposed [37]. A novel framework has been proposed in Ref. [38] for providing meaningful data to the user by extracting the data features that are really desired by the user. This involves recommendation of data as well as data prediction besides monitoring the traffic of data flow between the MCC and WSNs. Ali et al. [40], are concerned about the rising medical costs, typically US spending of 2.3 trillion USD (16% of GDP), and have developed a low cost authentication scheme which prevents loss of data thereby enabling complete patient body information from body worn sensors for further processing analysis.

Zhu et al. [42], proposed a robust integrated framework which reduces the storage requirements at the sensor end and the gateway takes care of doing various activities for further processing of the data from sensors. In Ref. [52], an approach of TPSS which includes both Time and Priority Selective Data Transmission (TPSDT) and Priority-based Sleep Scheduling (PSS) approaches for energy saving. In TPSDT, the sensor data is transferred selectively based on time and usefulness to the user. In PSS, first time and priority characteristics are incorporated into the process and subsequent action is determined. In this work, we present an architecture which depicts the approach of integration of MCC and WSNs based on the following concerns

- Battery life is less for sensors in WSNs
- Type of requests from mobile users (mainly localised in nature)
- Delivery of more reliability in data transfer across the network
- Provide secure mode of communication and transfer of information to the cloud and also back to the mobile user.

For achieving the above, we need to do the following:

- The sensors should be present in a cluster and generally greater than one in the same vicinity.
- At any point of time only one or more than one (but not all) sensors are active (this will depend on the type of data to be sensed which will be decided by the Intelligent Sensor Controller (ISC)) and sends the data forward to the MCC. This activity will therefore be able to save valuable sensor power and also ensure that central control and routing of data forward to the MCC is done by the ISC for different wireless sensors. 3) Reliability is achieved using a Reliable Message Layer (RML) component. It collects the data from the various ISC's and ensures that data packets reach the cloud. Only after it ensures that all transmitted data has reached the cloud (it gets acknowledgement from the cloud about quantity of data received at cloud end) it stops re-transmitting the data and also deletes it locally from RML.
- WSNs also play a major role in case of driverless cars, wherein the real-time signals are picked up and sent to the MCC for further processing using intelligent algorithms so that the next course of actions can be planned and smooth rolling of the driverless cars if possible.
- WSNs are also used in case of military operations to detect the movements of enemies in the vicinity. The image signals are sent across to the MCC wherein they are analyse and the appropriate alerts are used to fix corrective security actions. WSNs also find usage the healthcare, wherein the patient's body signals are analysed using MCC and the doctor can then recommend the right treatment which is save his/her life.
- Security needs to be ensured all the way from the sensors up to the point where the data reaches the cloud. This will ensure that sensors are not captured by the hackers and also the overall WSNs will be protected. This can be achieved using encryption techniques for sensor data and various other mechanisms.

3.4 | Challenges

There are a lot of research challenges when MCC is integrated with WSNs and are described as follows:

1. To design architectures which are specific to various domains, such that they can effectively leverage the MCC-WSN integration and can also efficiently utilise the power of the cloud for complex applications. We need to look at seamlessly delivering results on the mobile devices and delivering data for computations using the WSNs. Then it will be a real benefit to mankind.
2. The WSNs may use multihop for forwarding the data to the sensor gateway. This process is done by the intermediary sensor nodes which are close to the gateway. But, WSNs suffer due to less battery power of sensor nodes. So, a proper mechanism is required which can balance the network lifetime.
3. The mobile devices have limited battery life. The data which is generated by sensor nodes is available to the mobile devices based on the mobile user requests but for continuously collecting the data from the networks mobile devices consume energy. Sometimes it creates huge problem for battlefield condition. So, there is the need of an energy efficient technique which can save the energy of such devices.
4. For improving the lifetime of WSNs, the sensor nodes require a unique sleep scheduling technique. The existing techniques depend on the mobile users location. To predict user location is a challenging task in these techniques.
5. For improving energy efficiency of mobile devices sometimes they connect to the local cloud (cloudlets) for processing the data. In such scenario, WSNs should be designed in such a way that it will efficiently connect with the local cloud. This technique is required for distributed environment.

4 | MCC AND WSNS APPLICATIONS FOR INFORMATION MANAGEMENT AND COMMUNICATION

In this section, first the approaches for information management in WSNs and then the approaches for information management in MCC are highlighted. Then the needs for integration of MCC with WSNs are identified and the approaches for information management in MCC with WSNs are discussed. Lastly, authors tried to identify the future research directions in this aspect. Tables 3 and 4 show the Summary of WSNs and MCC applications for information management.

Warehousing approach is a centralised approach where based on the different user queries, the sensor nodes collect the data and send to the central database as shown in Figure 3. One of the major disadvantage of warehousing approach is that as sensor nodes collect huge amount of data so it creates the bottleneck problem on the server because for transferring large amount of data and waste the resources. The warehousing approach is not acceptable in quality of no-historical queries as it is related to the delay of time for the results. There are different centralised approaches namely poTree [120, 121], pasTree [122, 123] etc. are available in the literature. In Refs. [123, 124] authors proposed a spatiotemporal sensor data model which is basically built upon location of the sensor nodes. The sensor nodes may be fixed, mobile, or agile. Both the techniques use centralised approach. Aurora [125] and RTSTREAM [126] are data stream management system. RTSTREAM works based on the real-time data stream query

TABLE 3 Summary of WSNs applications for information management

WSNs Applications	Centralised Approach	Distributed Approach
RTDM [22]		✓
S2S [54]		✓
PoTree [120,121]	✓	
PasTree [122,123]	✓	
Spatiotemporal Heat index [124]	✓	
Aurora [125]	✓	
RTSTREAM [126]	✓	
Gutierrez and approach Servigne [127]	✓	
Donet al. [128]	✓	
Neto et al. [129]		✓
Chagas et al. [130]		✓
Goncalves et al. [131]		✓
Mathiason et al. [132]		✓
Gupta et al. [133]		✓

TABLE 4 Summary of MCC applications for information management

Mobile Cloud Computing Applications	Features	Underlying Services Used
Information mangement system for healthcare [134]	• The proposed technique monitors the patients activity and sends the information to the doctor without visiting the hospital	Android OS, Amazon's S3
Data management using MCC [135]	• Hospital management system using MCC by keeping the patients data	Android OS
Data management using Using surrogate object [136]	• Uses Cloud-caching technique based on surrogate object that can store the necessary data across several surrogate objects to the cloud	Surrogate Object-based Cloud Caching (SOCC) mechanism
Emergency management syatem using MCC [6]	• Proposed CPS, CRS to choose best available networks	Amazon EC2, jclouds multi-cloud toolkit Java APIs, SIGAR Java API, RESTful web service
Firechat [137]	Peer-to-peer Communications	Android OS
Disaster management system using MCC [138]	• Used genetic algorithm • Used the problem of travelling salesman	Android OS, Google Maps

model which can manage large amount of data stream by considering the periodic queries deadline. In Refs. [127] and [128] authors proposed a centralised data management system which basically works with sptiotemporal data.

In distributed approach, it overcomes the problem of central database by considering the local databases where, a sensor node itself acts as a local database. The consumption of energy can be minimised by using distributed approach because the sensor nodes locally calculate the limit of transferring data in order to serve the query request from different users. Like warehousing approach, data are stored in the central databases and a sensor node plays a vital role for serving as a part of data base. The architecture of distributed approach is shown in Figure 4. There are a lot of advantages of distributed approach over warehousing approach. The distributed approach increases the lifetime of the networks by minimising the energy consumption as well as time delay.

There are a few distributed approaches have been proposed [129–133]. Fernandes et al. [129], proposed an integration technique between database management technology as well as sensor networks. The proposed technique is built upon concurrency control and in-network processing. Joel [131], proposed a distributed technique which mainly focusses on optimising the delay of dissemination of sensor data. The proposed technique is built upon 4-teir namely WSN layer, data layer, transport layer, and client layer where, each layer plays several roles. The WSN layer is dealt with the data acquisition, the data layer and transport layer deal with the presentation and transmission respectively and finally the client layer is dealt with the consumption. Gupta et al. [133],

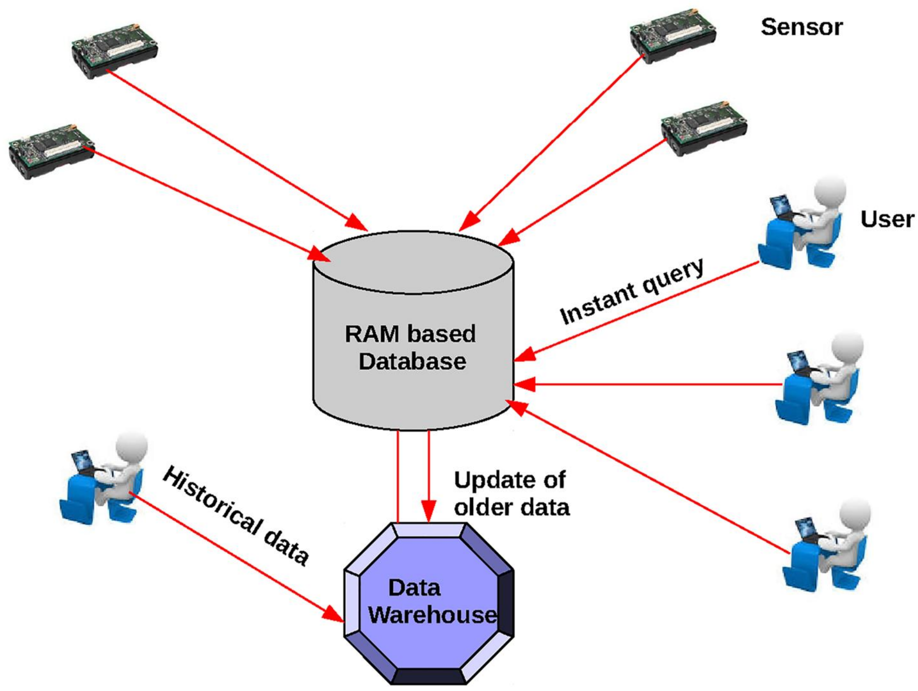

FIGURE 3 Warehouse architecture

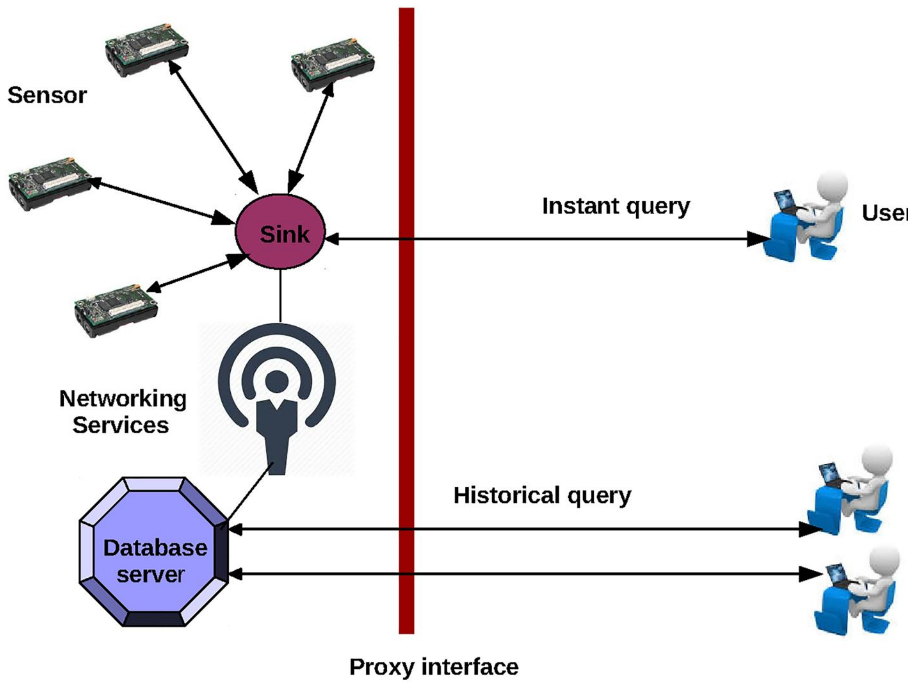

FIGURE 4 Distributed architecture

proposed a distributed technique which is built upon the clustering technology where different sensor nodes in the network form a cluster and from each cluster a cluster-head is selected. The different cluster-heads then are responsible for transmission of data to the sink nodes. The proposed technique was built upon for processing the real-time data. Sarkar et al. [22], proposed a novel approach for handling real-time database management in WSNs with the help of assembly line scheduling algorithm. The work of each sensor node is fixed which is based on the predefined deadline and from each sensor node finally the data come across to the sink nodes. Panigrahi et al. [54], proposed a novel approach for source to sink node communication based on the coalition formation of different sensor nodes. Jiang et. al [139] proposed the use of

WSNs in an underwater scenario where we have difficulties in monitoring WSNs. In case of preventive maintenance to be done on existing vehicles, aircrafts etc.,the WSNs sends real-time signals about the important engine parts and whenever there needs a possibility of breakdown in the near future, the engineers are notify to replace the parts in advance so that any major accident can be avoided during the operations process of the engine. In the case of smart city we use different sensors which help in creating intelligent across the different units in the city for example in an airport we are able to get real-time data of the climatic conditions, traffic conditions and thereby take precautionary measures which aim to improve the safety and robustness of the passengers and airport stuffs [140, 141].

4.1 | Information management in MCC

MCC plays an important role for managing information and there are a few work that have been proposed [134–136]. Mohamed et al. [136], proposed a Surrogate Object model which is a distributed platform. The proposed technique is built upon 2-tier namely mobile host as well as stationary hosts. The mobile devices are connected to the Mobile Networks Services(MNS) and utilise cloud services with the help of Internet Service Providers(ISPs) as shown in Figure 5. From Figure 6 it is clear that MCC is fully utilised on the basis of intelligent sensor controller where through the Reliable Messaging Layer (RML), the data can transmitted to the cloud.

The Surrogate Object is used to serve as a representative of each individual mobile host which can minimise the transfer of wireless data. The proposed technique is fully developed for the distributed mobile platform. Somasundaram et al. [134] proposed a medical image data management technique using MCC technique. The proposed technique is developed by usig android OS. The technique monitors the patients' activity and sends all information to the doctor without visiting the hospital.

Doukas et al. [135] proposed a technique which is used for medical applications and was developed for information management for mobile health-care. Mitra et al. [6], proposed a technique which is used for emergency situations. The proposed technique was built based on the Cloud Probing Service (CPS), and Cloud Ranking Service (CRS) for choosing the best cloud for data communications. The system uses anchor point for running CPS and CRS. The emergency vehicle used is used as a local cloud. The proposed technique efficiently selects the best available networks by considering the Relative Network Load (RNL). Authors used Amazon web services as a public cloud. There are several techniques have been proposed for managing the emergency situations [138].

Firechat as proposed in Ref. [137] can work without networks connectivity by considering the mesh networking technology. The proposed application automatically switches on the bluetooth service for sending the data from one device to another when there are no networks available. For getting the data from the sender, the same application should be installed on the receiving side. Shanmugam et al. [142] proposed a data management system for mobile cloud paradigm using Surrogate Object. The proposed work was built upon the cloud caching technique. The method can store the necessary data across several surrogate objects in the cloud. The advantages of this work is that users can share and process their data at different mobile devices with the help of cloud environment.

For every user and their various separate tasks, a generic multi-user MCC are considered [143]. The computational data and communicative resources are shared with the cloud by the mobile users through offloading. In a traditional MCC, a wireless access point is used to offload the tasks, whereas a

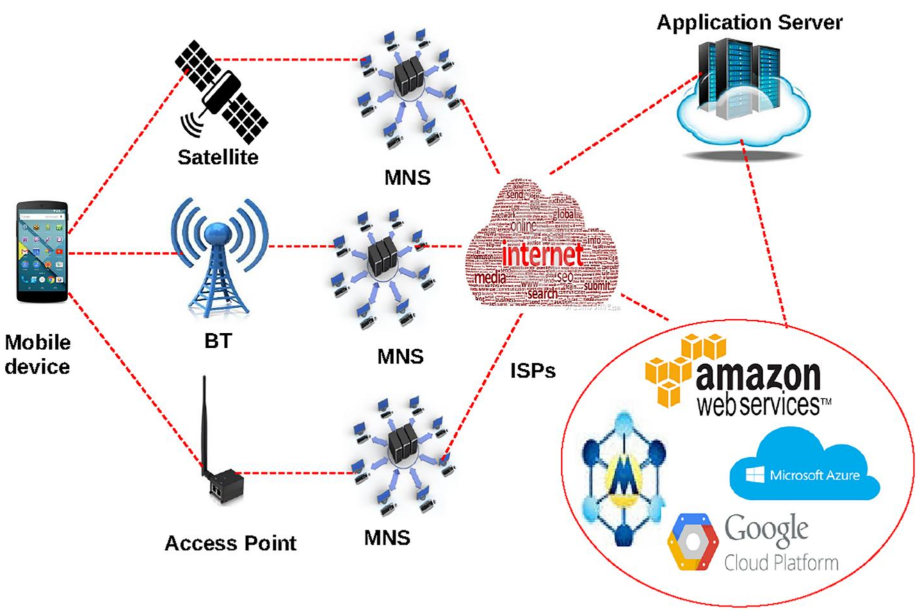

FIGURE 5 MCC with MNS and ISPs

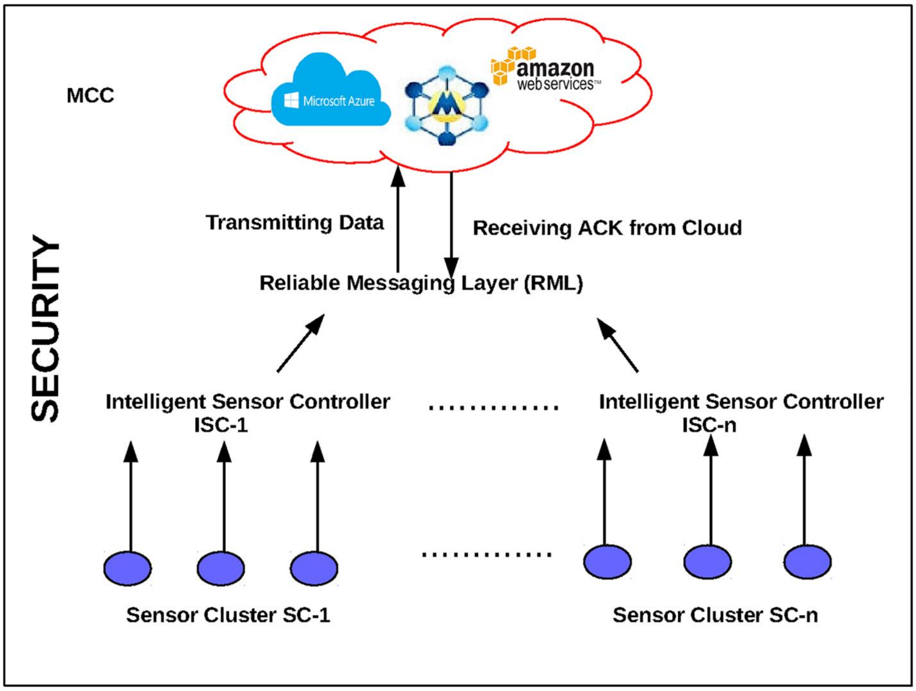

FIGURE 6 MCC with Intelligent sensor controller

Computing Access Point (CAP) handles the both computational service provision and network access gateway. To avoid the delayed service to the users and to reduce the computational and energy costs, the communication and computational resources along with offloading choices are collectively optimised. NP hard is an optimization problem to define the non-convex quadratically constrained quadratic program. After the improvement of binary offloading selection and excellent communicative resource allocation, the Separable Semidefinite Relaxation (SDR) is used to propose the MUMTO which is a powerful closed-form solution when CAP is not exists. The combined MUMTO SDR and MUMTOC algorithms along with CAP are proposed to fix the difficult problems of the CAP which is a best optimal solution and works locally. To improve the performance, a low cost system is introduced by considering and not considering the CAP. The proposed simulation outputs gives the best performance with less constraints for different specifications with cost effective use of CAP. The efficient way to boost the mobile battery life, the mobile application tasks need to offload to the cloud and execute there [144]. An energy efficient scheduling of transmission amount is presented in Ref. [144] and which should run on mobile devices. The objective of this work is to preserve the mobile device energy by perfect alteration of the transmission rate. We proposed an altered Lyapunov optimization concept for MCC scenario rather than a common dynamic programming (DP) approach. In our proposed approach, in every time slot the exact channel gain is measured and expressed the transmission rate, which deviates the channel gain forecast of subsequent time slots. But, the DP algorithm requires stochastic wireless channel information. In comparison with DP algorithm, our proposed approach saves the energy up to 30%. The author of Ref. [145] considered Heterogeneous MCC (HMCC) which consisting of WLAN, non-task offloading Mobile Devices (NTMDs), task offloading MDs (TMDs), local cloudlets, remote servers and cellular networks. Remote cloud servers are used to offload the task in TMDs but NTMDs uses the traditional cellular network. Remote cloud servers alone is used to evaluate the MCC's disconnection probability, whereas HMCC uses remote cloud servers along with cloudlets. The evaluation resulted with necessary information for finding the different parameters of the system and how it is influencing the disconnection probability. The evaluation result shows that, the MCC system's disconnection probability is decreased with inherent limitation due to the use of remote cloud servers. We show that cloudlets will overcome this problem of inherent limitation. Anyhow, the cloudlets running costs and its deployment leads a trade off. The MCC with enhanced computational power is the best option to lower the power consumption of mobile device for its huge applications. The dynamic scenario problem of MCC with random offloading with multiple mobile user is examined in this work [146]. A stochastic weighted potential game with minimum one Nash Equilibrium (NE) is prepared for self interested user's task offloading selection process. We measured the performance of NE to propose an analytically derived multi user stochastic learning approach to attain by NE with assured convergence rate. We performed a simulation experiment to verify and validate the efficiency of the proposed approach in a dynamic scenario. MCC is a best model to improve the computational power and reduce the energy consumption of SMDs when task offloading to the cloud. The challenging task is to accomplish low energy task offloading in a tough constrained application within its completion time.

This study considers the resource scheduling (eDors) strategy with low energy consumption dynamic offloading process to cut down the application's energy utilization and its completion time. Based on the constraint completion time bound and task dependency demand, An Energy Efficiency Cost (EEC) minimisation problem is formulated from eDors problem. A distributed eDors algorithm is proposed with combination of transmission energy allotment, clock frequency management and offloading decision. The mobile device's offloading choices depending on transmission energy, clock frequency and next ancestor's maximal completion time. Finally, we prove that the fine-tuning of SMDs CPU clock frequency in local computing and accommodating transmission energy in cloud computing based on wireless channel settings, the eDors approach is dramatically shortened the EEC and we presented the real testbed's empirical results. The reservation system assures the multimedia application's quality of service (QoS). The prior Resource Reservation and Allocation (RRA) setting provides the symbolic diminish of the overall provisioning cost in MCC. But, the resource requirement of the mobile users' undecided features leads a challenge for the RRA. The cloud Virtual Machine Resource (VMR) and Radio Resource (RR) drives the mobile application's QoS of voice IP or video in MCC. So these resources are needed to allot together.

4.2 | Need for integration of MCC with WSNs

In recent scenario, sensor nodes are used everywhere for collecting necessary information. WSNs help to collect important data from places where sometimes it is very difficult to go there. Recently, offices, hospital, school etc. WSNs take a vital role. On the otherhand, MCC creates huge interests among users for collecting necessary information from the cloud. Different users use different applications without any extra memory requirements. That means users can view their information in the mobile device where the necessary information has been stored in the remote locations. There are several scenarios where, it is useful to integrate MCC with WSNs and are described as follows:

- To process huge amount of data which are collected by sensors need sufficient storage. The emerging cloud computing technology solves this problem of storing and processing of those data.
- The sensory data should be available to the users as and when required. The mobile devices can fulfil this requirement where users send request to the cloud for their necessary sensory data and according to the request the necessary data will be available to the mobile device from the cloud.
- Sensor nodes have limited energy so it is efficient to process the sensory data in the cloud and users can use based on their requirements.

4.3 | Information management in MCC applications with WSNs

It is essential for WSNs that the sensor nodes must connect with the cloud for processing of data and also for the high storage. There are several works have been proposed those deal with the connection of cloud with WSNs. In Ref. [44], Wang et al. proposed an approach where for connecting the sensor nodes with the cloud authors used the dynamic proxy as well lightweight component model. Authors used lightweight model for enhancing the performance of Loosely-coupled Component Infrastructure (LooCI) middleware. Table 5 shows the summary of MCC applications with WSNs for information management.

In Ref. [45], Ahmed et al. proposed an approach where the sensor nodes are connected to the cloud. There are three different layers namely SaaS, PaaS, and IaaS have been used in cloud for retrieving data from the sensors to the cloud data centre or different query requests from the WSNs. In Ref. [46], Lee et al. said that non-static computational tasks for monitoring environment as well as modelling can be performed using WSNs. Authors used Amazon web services for connecting WSNs with Amazon Elastic Compute Cloud (EC2).

In Ref. [47], Lounis et al. mainly focussed on the security by using cloud for encrypting and decrypting the necessary information. Another work [51] has been proposed which mainly focussed on the MCC-WSNs integration. The proposed work increases the battery life of sensor nodes by considering the sleep/awake technique where based on the locations of mobile users sensor nodes periodically maintain sleep/awake state whereas authors indicated that this was the first technique which works on sleep scheduling technique of sensor nodes with respect to the MCC-WSNs integration. In Ref. [42], Zhu et al. proposed a data processing framework which mainly focussed an critical issues for MCC-WSNs integration. In Ref. [52], reliability of sensory data is used to make a difference for sensory data and reliability of WSNs. In Ref. [148], Das et al. proposed an approach for mapping sensor data with the server. In Ref. [149], Jeong et al. proposed a technique for virtualisation of sensor devices for mobile cloud. In Ref. [150], Shah et al. focussed on health-care based applications which are running on the mobile devices. In Ref. [151], Chen et al. proposed an approach which can reduce the delay time when increasing the rescue requests by considering the multicloud platform. In Ref. [152], Xue et al. proposed an approach for exchanging the sensory data using the unstable mobile architecture. A disease-oriented healthcare monitoring approach was proposed with the help of Wireless Body Area Networks (WBAN) and with multiple Health Cloud Service Providers (H-CSP) to serve the pervasive medical services inclusive of supervised expanded traffic load [153]. To enhance the computing complication and network traffic load, the Social Network Analysis (SNA) is used with the consideration of various disease categories and critical indicator of WBANs. Enhanced traffic load and lowered computational complication were assured with the construction of Disease-centric Patient

TABLE 5 Summary of MCC applications with WSNs for information management

Applications	Features	Future Research Direction
Collaborative location-based sleep scheduling [51]	• Works based on the mobile device location • Sensor nodes maintain awake or asleep state • Considers scalability and robustness • Increases the WSNs lifetime	• Develop a scheduling technique when users are dynamic • Develop a conflict-free scheduling algorithm which runs on the base station for which the tasks will be assigned from mobile user to a particular sensor node • Using data filtering or data compression method, unwanted sensory data can be minimised
Data processing framework [42]	• Consider the critical issues for MCC-WSNs integration • Increases WSNs lifetime by minimising the traffic load • Minimises the sensor storage requirements	• Develop a system when cloud is distributed for each sensor gateway which may serve as a cloudlet
Reliability of sensory data using MCC [52]	• Consider the critical issues which makes a difference for sensory data and reliability of WSNs • The data transmission takes place based on the priority • Consider sleep-scheduling based on the priority	• Based on the cloud data optimization consider the query processing rate as well as the guarenteed work-flow latency
Mapping a sensor node with server [148]	• Monitor patients based on the resource allocation framework	• Use cloud based model which will satisfy all domains for mapping between server and mobile nodes
Virtualisation of sensor device using mobile cloud [149]	• Mobile cloud system stack • Using cloud, the mobile users data from remote location can be accessed	• Develop a system which will support sensor device drivers for all mobile users
Remote health monitoring system [150]	• Health-care application run on the mobile devices • Sensor data can be accessed from the cloud	• Develop an approach where the patients are moving around and generate huge amount of data
Rescue service architecture [151]	• Broadcasts the emergency data • Prediction of disaster • Planning for evacuation	• Reduces delay time when increasing the rescue requests by considering the multi-cloud platform
Data exchange of sensor [152]	• To exchange the sensory data using the unstable mobile architecture	• Design scalability of networks with multiple actors

Group (DPG). Anyhow, the QoS of WBANs is not only defined by DPG model. To enhance the forecast delay in packet delivery and throughput in network, the author of this work, framed an H-CSP from DPG as a cost model to a powerful map of critical WBANs. Blood bleeding and infiltration are a dangerous problem while intravenous supervision and dialysis process. Severe infiltration may cause sepsis, infection and harms tissues while drip and drugs. A few minutes of blood loss or bleeding may drop 40% of the blood quantity of adult and can leads mortality. To identify the blood loss and bleeding, Wu et al. [154] proposed an alarming device with incorporating the cloud computing, Bidirectional Hetero Associative Memory (BHAM) network and adjustable sensors. The two array arrangement of adjustable sensors is helping to find the liquid loss as well as smooth substrate is fabricated with screen-printing approach. An embedded device or tablet was used to build the virtual warning system based on BHAM network. This cloud and wireless network based early warning system detects the hazard levels and intimated to the remote mobiles or monitors. The feasible warning system is verified by experimental results. The healthcare model gets innovated through vast changes in WBAN and vast number of User Equipment (UE). Anyhow, UE devices need a specific battery power, fidelity and capacity which leads the warning system a problematic one to run the computation intensive works in an efficient manner [155]. The objective of this work is to increase the computational capability of the UE devices with the help of mini Coordinator Based Mobile Edge Computing (C-MEC) servers. The energy requirements, system difficulty, computation assets is shifted to C-MEC from UE due to its constant power supply and which is feasible. Primarily, the mobility architecture and system model need to prepare. Secondly, many transmission techniques need to evaluate with inclusive of proposed mobility aware joint task offloading mechanism. Various performance techniques are evaluated on MEC for its average working time, numerous running tasks and power usage of the MEC. The result shown that the proposed offloading technique is beneficial with minimum latency and effectively balance the energy usage rather than conventional relay oriented schemes. For the latency concern, multi-user MEC were used in Ref. [155]. The data was compressed and offloaded. Definite MEC helps to compress the data, allotment of resource and optimised offloading concepts. Simulation of convex optimization shown that proposed method outperforms with baseline algorithms. The industry and academic community got attraction when WSNs jointly with sensor-cloud (SC) and send the sensor data ubiquitously to the users. The authors in Ref. [156] has reviewed the green SC problem and applications of SC and resolved with Multi-Method Data Delivery (MMDD) model. MMDD considers the following transmission as cloud → SC users, WSN → SC users and cloudlet → SC users. MMDD accomplish the minimal transmission cost and lower transmission time for the SC users compared to specific data transmission from cloud to SC users.

4.4 | Challenges

There are a few research challenges in MCC-WSNs integration which are described as follows:

1. The main component of WSNs is the sensor nodes which collect the environmental data and processed. The integration of MCC-WSNs makes advantage for sensor nodes as they can offload the data to the clud and hence prolonging their network life. One of the main challenges here is that sometimes it is quite difficult to establish connection between cloud and the sensor nodes.
2. WSNs use the radio resources where the bandwidth may become very poor as compared to the number of mobile or cloud users. A recent survey indicates that the number of mobile users are increasing day-by-day. On the other hand, WSNs also produce huge amount of data which creates demand for high bandwidth.
3. Recently, some of the MCC techniques use multicloud platform for faster communication as well as to improve utilization and for that the WSNs is designed in such a way that it supports all domains of MCC.
4. The important concern for collecting data from the sensor nodes is delay where sensor nodes produce data continuously or based on the user requests. Hence there is the need for a technique which will reduce the delay for collecting the data by the mobile users.
5. During handoff, mobile devices should efficiently collect the data from the WSNs. Sometimes MCC works with heterogeneous access networks before starting handoff mechanism for choosing best network and is done by using the Relative Network Load (RNL).
6. We need to ensure that the analysis of the data from the WSNs is done intelligently using latest Artifical Intelligent (AI) techniques of machine learning and deep learning algorithms. Using these algorithms to create models will definitely prove to be useful and helped in verity of ways.
7. In the event that a sensor changes its position due to certain climatic conditions it may not be able to send correct data for analysis to the MCC. In this case, the intelligent algorithms should smartly identify the bias and out-layer data and make recommendation accordingly.

4.5 | Proposed architecture

There are a number of challenges when MCC is integrated with WSNs [38]. Figure 7(a) shows the proposed architecture where a mobile device connects with the local cloud and the local cloud connects with the public cloud. The sensory data from the WSNs is sent to the local cloud and based on the user requirements mobile devices collect data from the local cloud. This scenario is useful in case of emergency conditions. The mobility scenario is shown in Figure 7(b) where mobile devices connect with local cloud for collecting data from the WSNs but at certain time due to the unavailability of local cloud mobile devices conect with the public cloud. If mobile users move from one position to another, the mobile users send requests to the new cloudlet. If mobile users do not obtain cloudlet data in the past cloudlet then they can access this data from the new cloudlet.

5 | COMPREHENSIVE ANALYSIS AND FINDINGS

Fast installation and dynamic topology of UAVs, an air-ground integrated mobile edge networks (AGMEN) where UAVs can be used for supporting the MEC system. AGMEN of this type aims to offer MEC facilities efficiently and is omnipresent. Initially, authors presented the functionality and elements of UAV. Then, from the viewpoints of connectivity, processing and cache, they explored the processes, core problems and existing research developments of AGMEN in particular. At last, certain relevant testing recommendations for AGMEN were addressed [157]. Shafique et al. [158] introduced IOT innovations with a bird 's eyes that covers its patterns, application scenarios, problems and opportunities in the mathematical/design industry. The study also described the latest 5G-IoT situation in depth and thoroughly. The article explores the latest case studies of 5G-IoT enabled by advancement in artificial intelligence, the engine and deep learning, current 5G projects, 5G service quality standards and their structured problems. This article offers an in-depth overview of these primary supporting technologies. Finally, the study addresses the difficulties of introducing 5G-IoT because of the huge data speeds that even the cloud enabled and IoT powered edge computing systems need [159]. The barriers to SIoV protection security are listed in this article. The article examined also the security risks and considerations, important to the protection of personal data, such as personal privacy, actions and intervention, correspondence, data and images, emotions and opinions, place and location, and interaction, in the SIoV setting. The study also addresses block chain-based strategies to protect the SioV′ s protection. Qiu et al. [160] suggested an architectural design composed of detecting, connectivity, cloud computing and software in four layers of Heterogeneous Internet of Things (HetIoT). The state-of-the-art study and apps of HetIoT is then debated. This guide also offers some potentially flexible ideas for sustainable HetIoT problems, such

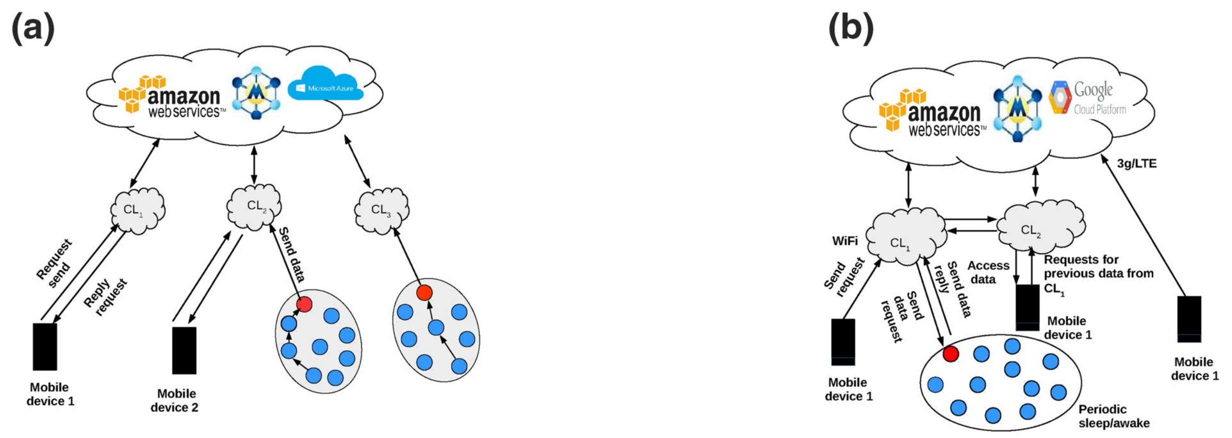

FIGURE 7 (a) Architecture of MCC-WSN integration. (b) Mobility Scenarios of mobile user

as self-organization, huge amount of data transfer, privacy security, data replication and large-scale HetIoT production [161]. Osanaiye et al. identified the architectural design for fog computing and explored its numerous facilities and implementations. Then addressed protection and privacy concerns in fog computing, which concentrated on the provision of facilities and infrastructure. Finally, the course of future studies was illustrated. In addition to addressing the safety issues of the essential infrastructure (CI), Sajid et al. presents the best approaches and guidelines to enhance and sustain stability. Finally, this work quickly discusses the potential course of science in order to protect the vital CPSs and enable the group to recognise the research gaps [162].

The exiting survey work is focussed on particular domains such as IoT, healthcare, security etc., while this work includes the numerous work related to MCC and WSNs and their integration.

MCC helps to perform computation and storage using SMD's integrated together and also by offloading to the cloud. The energy aspect needs to be managed in an optimum manner such that offloading decision is taken keeping in mind the dual factor of complexity of programs versus the energy taken to offload the programs to the cloud. Energy in SMD's is limited and hence there is a need to optimise it for different types of operations like computation, and offloading. WSNs contain a group of sensors which work together to provide input data and these sensors have power sources which have its small life span. It is of utmost importance that sensors data be effectively utilised and we take all measures for doing effective energy management in sensors (like only activating the sensor to active state when required to transmit data upon a particular action or event). It is possible that WSN is integrated with the cloud. This helps WSN to send data to the cloud directly which can be used for computational purposes.

However, we need to ensure that in this case, WSN should not spend much energy in uploading data to the cloud, as it will then shorten the life of the battery. The advantage of this approach is that the up-to-date data will be always available in the cloud and hence it can feed data to those applications which need real time data (like medical applications). On the other hand SMD's also send data/code to the cloud for computation purposes and this approach of offloading is generally preferred as this will help to save energy of the SMD. In offloading, it is recommended that the energy saved due to this process of moving the computation/data to the cloud is greater than the energy required for communication of data and code packets up to the cloud. The factors that are responsible for battery power consumption in SMD's are:

- Local computation on a SMD
- During offloading, the source code and data packets sent to the cloud from SMDs need power for communicating to the cloud
- Also, in case we are doing backup operations of the SMD (as a preventive measure) either to the cloud or local backup's, it involves energy.

Both MCC and WSNs need to be effectively integrated to produce information or results which can be used for the benefit of mankind. As both of them possess limited energy, it is of fundamental importance that it should work with these devices keeping this energy factor in mind. When WSN is integrated with MCC, it pumps data to MCC which is then further processed keeping in mind that least energy should be used in this computation. The offloading to the cloud is very important as this will help in large computations as well as save energy of the SMDs. Also, we need to ensure that the sensors provide data in the required format and this can be achieved by testing the sensors at regular basis and replacing the faulty ones. Information management also plays an important role in MCC. The SMD will offload information by way of packets of data and code to the cloud where these will be processed and the results will be conveyed back to the mobile device. In another case, the SMD will first offload the data and code to the cloudlet where processing will be carried out (or offloading to the cloud will happen in case there is requirement for more resources). In case of WSNs, the information from individual sensor is aggregated at the sink node initially. Subsequently, the data and code will be transferred to the cloud for computation or storage purposes and ultimately the results are transferred to the SMD. When MCC and WSN are integrated together, the information is off-loaded to the cloud via the SMD and results are sent back to the mobile device in an asynchronous manner. In order to ensure that accessibility of the SMD and the cloud remains available at all times, it is very necessary to have reliable communication mechanism between them. This can be achieved by using a communication network that is up and running at all times.

Security factor should also be kept in mind for the applications where WSN and MCC work together (like health care applications, military applications and others). Sensor data should be authenticated properly before it is consumed by the different cloud applications. Also, attacks by hackers and spurious programs should be avoided and proper security mechanisms need to be built in place.

Guo et al. [163] implemented online, inexpensive wireless surveillance application architecture, production and field deployment using Arduino Board ZigBee, and Python for near real-time landslide surveillance, which provides noticeable is alerted of potential landslide default. Linderman et al. [164] demonstrated the shortcomings of the Structural Health Monitoring (SHM) Common Analog to Digital Converter (ADC) Framework and provides a firmware approach for delay—tolerant remote end points. Abdelhakim et al. [165] implemented a modern, time critical power efficiency device, the mobile access coordinated wireless sensor network (MC-WSN). Jondhale et al. [167], in order to achieve first position estimates of the single reference movement in 2-D within the WSN, that is often improved with Kalman Filtering function (KF), the GRNN was suggested to be the counterpart to this conventional RSSI solution. In order to evaluate hazard in industrialised activities with signal transmitting properties in a traditional home, workplace and production context, an algorithm dependent on a real-time big data gathering (RTBDG) array focussing on an interior WSN was proposed [168]. Guo et al. [169] suggested an algorithm named fault-tolerant task allocation algorithm (FTAOA) assignment for WSNs in favour of reliability systems by utilising main/restore concept. In order to improve the IoT sensor node battery life [170], the IoT/WSN software introduced an effective real-time data collection model called RDCM. The RDCM is exceptionally efficient when contrasted with similar approaches in power usage. Ayad et al. [170] discussed MCC concept, Open Source OS, single cloud development, Face-Recreation as MCC Technology with face identification techniques in real-time situations. Ayad et al. [171] implemented a new strategy to GPU enhancement for real-time face recognition. The findings of the software produced indicate that the Smartphone GPU cloud storage proposed improves both facial sensing device speed and efficiency. Authors in Ref. [85], introduced a method which uses flexible virtualisation to build multi-mobile, web service MCC testbed communities. Authors presented two case studies to illustrate how programmers may build quite practical experimental models for evaluating and analysing software and MCC solutions.

6 | CONCLUSION

This survey article delves into the various aspects of MCC and WSN integration with respect to energy and information management. These factors are of utmost importance for healthy running of the MCC and WSNs ecosystem. Also, the authors have discussed about the different layers of WSNs and its various applications in daily life. The use of robust techniques in case of analysis of the data received by WSNs and processing successfully using the MCC for various applications in the field of military, healthcare and other domains has been highlighted. There is a tremendous potential of using applications through the integration of MCC and WSNs which has been also discussed. The authors have thoroughly run through the research work that has been carried so far in the field of MCC-WSNs' integration and have suggested an intelligent technique that can be incorporated in the future. The problems of current MCC applications have also been highlighted wherein WSNs is not used. On the other hand, the authors also discussed about MCC solutions which are integrated with WSNs. There are a few study issues that need to be understood by new researchers as to which are the MCC-WSNs techniques that are sufficient enough to provide better communication? or do we need any other specialised techniques that can be used directly for various domains such as IoT, healthcare, etc.? The future research directions have also been explored which will be useful to mankind in a variety of applications.

ORCID

Chhabi Rani Panigrahi https://orcid.org/0000-0002-4015-4587
Joy Lal Sarkar https://orcid.org/0000-0001-7017-1057
Bibudhendu Pati https://orcid.org/0000-0002-2544-5343
Rajkumar Buyya https://orcid.org/0000-0001-9754-6496
Prasant Mohapatra https://orcid.org/0000-0002-2768-5308
Abhishek Majumder https://orcid.org/0000-0001-8451-0451

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