Green Mobile Cloud Computing for Industry 5.0

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1 Introduction

Mobile Cloud Computing (MCC) integrates mobile computing and cloud computing, which brings the facilities of using cloud services to the mobile users [1–4]. With the rapid increase in the usage of smartphones, the demand for storage and access to various applications also increases. However, mobile devices face multiple challenges: limited storage, limited battery life, limited computing power, bandwidth, etc. [1]. In such a scenario, MCC has fulfilled the users' demands. Cloud computing provides three types of services: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). Cloud is a virtualized, shared resource or infrastructure that can compute, analyze, and warehouse large amounts of data. Cloud serves the client on an "on-demand," "pay as you use" basis. The elastic nature of the cloud helps the client to get the desired service according to the requirements. Various cloud providers such as Amazon EC2, Microsoft Azure, and Google Cloud Platform provide ubiquitous service along with elastic storage and immense processing facilities in an "on-demand" and "pay as you use" fashion.

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D. De et al. (eds.), *Green Mobile Cloud Computing*,
https://doi.org/10.1007/978-3-031-08038-8_1

In MCC, the mobile devices are the thin clients. In MCC, mobile users can offload their data and applications inside the cloud. We define MCC as [1, 2]:

The data is offloaded to the cloud in MCC for processing and storage. However, nowadays, cloudlet and intermediate fog devices are also used for offloading [5–7].

The advantages of MCC are listed as follows [1].

- ***Extension of battery lifetime***: The large-scale data processing or exhaustive computation inside the mobile device drains the battery quickly due to high power consumption. As in MCC, the data processing and storage occurs outside the mobile device, the battery life is increased.
- ***Extension of storage capacity***: MCC provides storage facilities to the user based on the requirement. Dropbox Amazon's simple storage service is an example of the storage supplied to the user. Google photos, flicker are photo-sharing applications. On Facebook also, the users can share images.
- ***Extension of processing power***: Various power intensive applications like online gaming, transcoding, on-demand multimedia services, etc., require provision of high processing capacity. In this case, task offloading can be a solution.
- ***Low probability of data loss***: As in MCC, the data and applications are maintained in multiple computers, the likelihood of losing data are more pessimistic.
- ***On-demand service***: The cloud provides on-demand seamless service to the user from the cloud. The user does not need to install dedicated hardware or software as everything is available in the cloud on a "pay as you use" basis.

This chapter will discuss MCC's architecture, applications, and future scopes. The rest of the chapter is organized as follows: Section 2 discusses the architecture of MCC. Section 3 briefly describes various applications of MCC. Section 4 discusses about various simulators. Section 5 explores the future research scopes of MCC. Section 6 demonstrates green MCC, and finally, Sect. 7 concludes the chapter.

2 Architecture of MCC

This section discusses the service-oriented architecture, agent-client architecture, and collaborative architecture of MCC.

2.1 Service-Oriented Architecture

The service-oriented architecture consists of mobile network, Internet service, and cloud service, described as follows [1]:

- ***Mobile network***: The mobile network consists of mobile devices such as mobile phones, tablets, laptops, etc., and the network operators. The mobile devices are connected to the network operators by the base station, access point, etc.

The network operators provide a wide spectrum of services like authentication, authorization, and accounting (AAA) that use the home agent (HA) and the subscribers' data stored in the database.

- ***Internet service***: The Internet service links the mobile network with the cloud. The users receive the cloud services through high-speed Internet connectivity.
- ***Cloud Service***: The cloud controller receives user requests, processes them, and provides service accordingly. Several servers inside the data center are connected with the high-speed network and high-power supply. The data center is responsible for delivering infrastructure and hardware facilities for the cloud. At the top of the data center layer, Infrastructure as a Service (IaaS) provides storage, network components, servers, hardware, etc., to the clients on a "pay as you use" basis, e.g. Amazon EC2 and S3. An elastic cloud service represents an infrastructure that expands and shrinks dynamically according to the demand of the user. The Platform as a Service (PaaS) provides the users an integrated environment or platform for building, testing, and deploying various applications, e.g. Microsoft Azure and Google App Engine. The Software as a Service (SaaS) provides multiple types of software solutions to the users on an "on-demand" basis without dedicated installation at the client site. The software and associated data are hosted on the cloud. The application service providers provide the SaaS.

2.2 Agent – Client Architecture

In the agent-client architecture, mobile agent like cloudlet connects the mobile devices to the cloud [5]. Figure 1 presents the agent-client architecture. The remote cloud is usually at a long distance from the mobile device; hence, the latency is a significant issue. For time-critical applications, latency is an important concern. Cloudlet is such an agent that, by containing the cache copies of data stored by the cloud, meets the user need of low latency [5]. Cloudlet is well connected to high-speed internet, and the users can offload their data and computation to the nearby cloudlet instead of the remote cloud [1, 5]. Small cell base station such as femtocell is famous for its use in the indoor region for better signal strength [8]. Therefore, the user may be connected to the cloud through the femtocell. Nowadays, femtolet and small cell cloud enhanced eNodeB (SCceNB) can also be used which can provide communication and computation facilities simultaneously [9–11].

2.3 Collaborative Architecture

Smartphones have their computing, storage, networking, and sensing abilities. Several smartphones' data and computing resources are collaborated in this architecture, and a smartphone cloud is generated [1, 12]. The mobile applications utilize

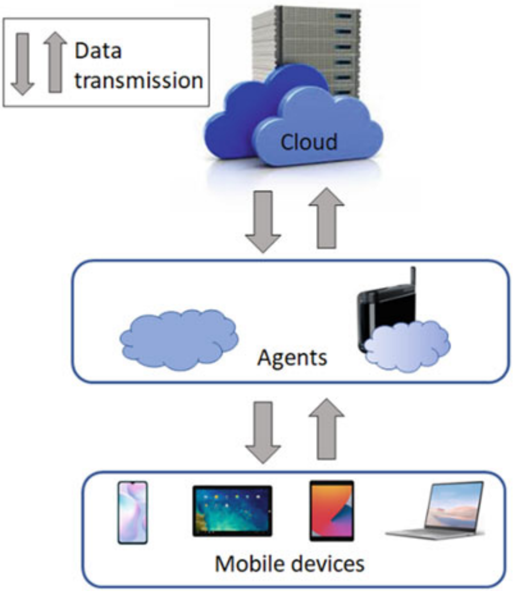

Fig. 1 Agent-client architecture of MCC

the resources of the smartphone cloud; this, in turn, overcomes the limitation of offloading to the remote cloud.

2.4 Fog-Edge Architecture

Nowadays, the intermediate devices between the mobile and cloud participate in data processing, such as access point, switch, router, etc. [7]. These intermediate devices are referred to as fog devices. In mobile edge computing architecture, edge server is used with the base station in case of cellular network, and cloudlet is used in case of WLAN (Wireless Local Area Network)/WMAN (Wireless Metropolitan Area Network) to bring the resources at the network edge for faster service provisioning [13, 14]. The edge/fog computing-based MCC architecture is presented in Fig. 2. Usually, the edge-fog-cloud architecture is famous for various types of applications [15–21], where large scale data processing is performed inside the cloud. In contrast, fog and edge devices are used for primary data processing purposes.

3 Applications of MCC

There are several applications of MCC discussed as follows.

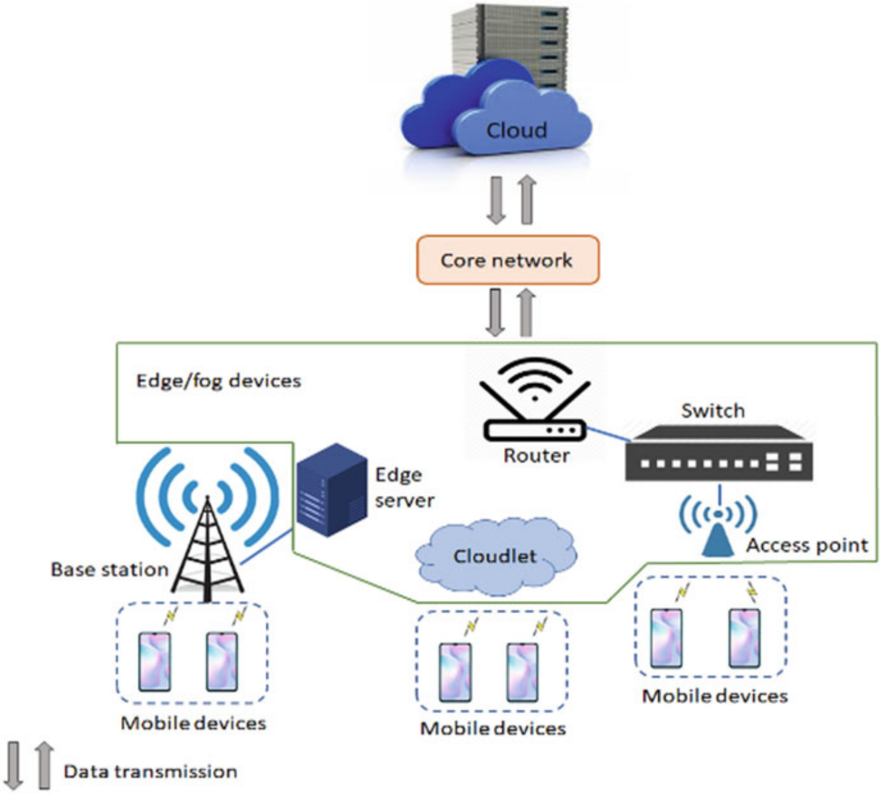

Fig. 2 Mobile Cloud-Fog-Edge computing-based architecture

3.1 Mobile Learning

Mobile learning is an e-learning method in which learning opportunities are provided to people who may not be at a predetermined or fixed location [1]. Here, the learning is provided through mobile technologies, and the social and content interactions occur through personal mobile devices. This is an e-learning system with mobility because the learner may move physically during the e-learning process. Therefore, portable devices such as laptops, notebooks, tablets, and mobile phones are included here to enhance portability and interactivity. However, conventional mobile learning systems have several limitations such as low data transmission rate, limited resources, high cost, etc. The use of the cloud in mobile learning has dealt with these difficulties by providing ample storage, processing power, etc. GeoSmart is a cloud-based mobile application for learning used as an online education system [1]. A cloud-based real time mobile learning strategy is discussed in [22].

3.2 Mobile Commerce

The mobile version of e-commerce is known as mobile commerce, where every utility of e-commerce is available through mobile devices [1]. Here, for computation and storage purposes cloud is used. Mobile commerce is nothing but delivering e-commerce abilities to the customer's hand, anywhere, through wireless technology [1]. There are a lot of examples of mobile commerce such as advertising, shopping, ticket purchasing, transaction, payment through mobile devices. Various mobile applications are available for online shopping, ordering food, flight booking, railway reservation, online payment, etc. However, privacy and data integrity are crucial issues because sensitive information such as the user's bank account details, credit card details, debit card details are involved. Usually, public key infrastructure (PKI) protects users' access to outsourced data.

3.3 Mobile Healthcare

Mobile health monitoring is a popular application of MCC, where e-health care is provided through mobile devices [16–21]. Low power and high precision sensor nodes are used to form a body area network to collect the health parameter values, and the health data analysis is performed inside the cloud. Based on the study, healthcare advice is provided to users through mobile devices. Intermediate fog devices can be used to process the data for faster health service provisioning. In [17, 18], small cell base stations are used for preliminary health data analysis. In [16], a route to the nearby health center is suggested based on the user's mobility information and the health data. Nowadays, various mobile applications are also available such as Samsung Health, Google Fit, etc. For epidemic trends monitoring the use of the cloud for data analysis also plays an important role [20].

3.4 Mobile Game

In mobile gaming, game execution occurs partially or fully in the cloud, and the game players interact with the screen interface of the mobile devices. In [23, 24], computation offloading strategies are discussed. Game can also be offloaded if involves exhaustive computation. The offloading can reduce the energy consumption of the mobile device while accessing various games. Cloud-based mobile gaming has been discussed in [25], in which the game rendering parameters are adjusted dynamically according to the players' demands and communication constraints.

4 Simulators of MCC

In Table 1 we have listed some simulators of cloud computing, fog computing, and networking.

5 Research Challenges of MCC

Industry 5.0 delivers a vision of the industry that intends efficiency and productivity goals. It reinforces the contribution of industry 5.0 to sustainable smart cities and societies. MCC faces various challenges towards implementing Industry 5.0, where are highlighted in this section.

5.1 Mobility Management

In MCC, the clients are mobile devices which can frequently move from one location to another, and connection interruption is significant. Hence, mobility management is a considerable challenge in MCC to maintain the Quality of Service. Here, localization is substantial and is achieved using either GPS, RFID, ultrasound RF, etc [26, 27]. The social interaction between the users is monitored using audio signals and walking traits of individuals using phone compass and accelerometer. In this case, multiple meetings obtain various routes, and the optimal path is selected. Virtual compass is another method in which short range protocols such as Bluetooth Wi-Fi are used to form a 2D reorientation of the nearby device. Peer-to-peer message passing is used to compute the distance using signal strength and pass the information about the device's adjacent nodes and spaces. In XMPP-based peer-to-peer method GPS is used, and only the known contacts or friends' locations are visible. Mobile Collaboration Architecture (MoCA) has been proposed in [28] to support mobility management that uses component and proxy migration. Here, the users' locations are monitored, and an application proxy is switched to a more suitable place. Through researches have been performed on mobility management, novel intelligent methods are still required for optimal path finding to a destination while the user is on the move. Drone mobility is challenging for proper path planning in mobile edge networks.

5.2 Offloading Method

Usually, in offloading to the cloud, communication is performed using Remote Procedure Call (RPC), Remote Method Invocation (RMI), and sockets between

Table 1 Simulators and their inventors along with their sources

Simulator name	Source
CloudSim	https://github.com/Cloudslab/cloudsim/releases (Accessed 30th October 2021)
CloudSim Plus	https://github.com/manoelcampos/cloudsimplus (Accessed 30th October 2021)
Containernet 1.0	https://github.com/containernet/containernet (Accessed 30th October 2021)
Containernet 2.0	https://github.com/containernet/containernet/releases/tag/v2.0 (Accessed 1st November 2021)
Containernet 3.0	https://github.com/containernet/containernet/releases/tag/v3.0 (Accessed 1st November 2021)
Containernet 3.1	https://github.com/containernet/containernet/releases/tag/v3.1 (Accessed 1st November 2021)
Distrinet	https://distrinet-emu.github.io/installation.html (Accessed 2nd November 2021)
Mininet	http://mininet.org/download/ (Accessed 2nd November 2021)
Mininet CE	https://github.com/mininet/mininet/wiki/Cluster-Edition-Prototype#vision (Accessed 2nd November 2021)
Maxinet	http://maxinet.github.io/ (Accessed 2nd November 2021)
GPUCloud Sim	https://git.ce.aut.ac.ir/lpds/gpucloudsim/tree/master (Accessed 2nd November 2021)
GreenCloud	https://download.uni.lu/GreenCloud/greencloud-v2.1.2.tar.gz, https://greencloud.gforge.uni.lu/vm.html
	Online Version
	http://greencloud.uni.lu/ (Accessed 3rd November 2021)
ACE	https://bitbucket.org/manarjammal/ace-availability-aware-cloudsim-extension/wiki/Home (Accessed 3rd November 2021)
ECSNeT++	https://github.com/sedgecloud/ECSNeTpp (Accessed 3rd November 2021)
	Dependencies
	https://inet.omnetpp.org/, http://www.grinninglizard.com/tinyxml2/
RECAP Simulator	https://recap-project.eu/simulators/ (Accessed 9th November 2021)
iFogSim	https://github.com/Cloudslab/iFogSim1 (Accessed 9th November 2021)
iFogSim2	https://github.com/Cloudsla/iFogSim (Accessed 9th November 2021)
YAFS	https://github.com/acsicuib/YAFS (Accessed 12th November 2021)
DewSim	https://github.com/cmateos/mobileGridSimulator (Accessed 12th November 2021)
Network Simulator-ns-2	https://sourceforge.net/projects/nsnam/files/latest/download, https://www.isi.edu/nsnam/ns/, https://www.isi.edu/nsnam/ns/ns-build.html (Accessed 3rd November 2021)
	Dependencies
	http://www.tcl.tk/, https://sourceforge.net/projects/otcl-tclcl/files/ (Accessed 3rd November 2021)
Network Simulator-ns-3	https://www.nsnam.org/releases/ (Accessed 3rd November 2021)

the requesting device and the executing device. However, in the case of mobile devices, these services need to be pre-installed, which is a disadvantage. Hyrax is a Hadoop-based smartphone application ported on the android platform [1]. In this case, a cluster of mobile devices is used as the mobile cloud and resource provider. Hyrax Tube is an application that permits users to search multimedia files based on time, locations, and quality [1]. Hadoop distributed file system (HDFS) maintains multimedia data and threads executable on mobile devices [1]. In [29], a virtual cloud computing provider has been discussed. In [30], a framework named "Cuckoo" has been proposed based on the java stub/proxy model to improve the performance in offloading and reduce battery usage. In this case, the task is offloaded to any resource that runs a virtual machine (VM). Another critical issue in offloading is VM migration, where the memory image of a VM is transferred from one server to another server without interrupting the execution. Clone cloud is a VM migration method where a resourceful server is used to offload part of an application [31]. MobiCloud is another approach that uses mobile ad hoc networks and cloud computing [32]. Each node serves as a service broker or provider based on its available resources and computational ability. Though researches are going on offloading, mobility-aware, energy-efficient, and fast offloading is an emerging issue.

5.3 Security and Privacy

As the cloud is used for offloading data and computation, security, trust, and privacy are significant parameters in MCC [33–35]. The transmission and storage of personal data and applications to the remote cloud raise security and privacy concerns. The following issues are needed to be considered while offloading takes place to the cloud [1]:

- The cloud service providers should maintain external audits and security certifications.
- Cloud service providers should have recovery management schemes for protecting data and services in case of disaster or technical fault.
- The data are stored in a shared space inside the cloud; hence, the data of individuals should be maintained separately implementing encryption methods.
- Local privacy is also an essential factor because the exact physical location of the user's data is not transparent.
- Investigative support is also required because multiple customers are logging and maybe co-located data, and it is hard to predict any illegal or inappropriate activity.
- This is to be ensured that if the cloud company leaves the business, the users' data would also be safe and accessible.

Mobile devices may be affected by viruses and worms. Thus, installation and use of the security software is required to protect against threats. Moreover, most mobile devices use GPS-enabled location-based service that discloses the user's present location, which may be a privacy concern for a few users. Though researches are going on security, privacy, and trust. Nowadays, blockchain has become another emerging area of interest [36]. Federated learning-based MCC provides a privacy-preserving ecosystem [37]. Hashing and symmetric parameter function can be used to implement impersonation resistant biometric-based authentication [34]. The energy-efficient and secure hybrid (EESH) algorithm utilizes voltage scaling to decrease energy utilization [35]. A malicious data detection (MDD) algorithm makes EESH more secure using blockchain.

5.4 Cost and Business Model

We divide the cloud cost into ownership cost and utilization cost. The total cost of ownership determines the costs of owning and managing an IT infrastructure. In cloud computing, the ownership cost determines the commercial value of cloud investment, including service, power, cooling, facilities, software, real estate, and maintenance costs. The utilization cost denotes the cost of using dynamically elastic resources by a user. The cost and analysis of the benefit of offloading are also essential. In [3], Spectra's method has been discussed, where resources are monitored continuously, and a trade-off between application offloading and performance, quality, and energy consumption is maintained [3]. To achieve the best placement of the resource "self-tuning" is used. Here, the users' demand of available resources is carried, executed, and the profile history of the surrogates is maintained. In [3], Chroma has been discussed, which uses "tactics" and monitors resources, and performs history prediction for estimating cost. Here, a trade-off is maintained between the attributes such as speed and power consumption based on the utility function. Serialization-based cost-benefit analysis has been performed in [24], where the authors have considered the network and application's characteristics and the device's energy consumption. To take decisions regarding offloading, the relative speed, network bandwidth, utilization of surrogate, latency, task complexity, and input/output size can be considered. The comparison of energy usage between the cloud and mobile devices is performed using parametric analysis [1], where network bandwidth, mobile device and cloud speed, data amount transmission, etc., have been considered. In MCC, two types of service providers are involved: Mobile service provider (MSP) and Cloud service provider (CSP) [1]. When a mobile user is receiving service from the cloud, both the service providers are involved. Hence, an appropriate business model is required to decide how the profit will be divided between the MSP and CSP.

5.5 *Deployment of Agents*

In agent-client architecture, the agents such as cloudlet, femtolet, SCceNB, etc. are used to provide low latency and high bandwidth access to the network [1]. However, in agent-client architecture, the deployment of agents is a vital issue. The agent's processing power, storage, and networking capacity need to be decided. On the other hand, resource requirements based on various applications are required to be decided. The clustering of users, resource demands of individuals and groups of users, user's level of satisfaction, cost minimization, management policies, trustworthiness, etc., are also essential factors. In [5], a proxy server-based computation offloading method has been discussed where the optimum cloudlet is selected based on latency and power consumption to offload the computation. In [38] selection of cloudlets to offload has been decided based on the type of application. In the case of femtolet and SCceNB, the interference is another factor that needs attention because they are small cell base stations. In the case of the small cell network, densification is a significant concern, and interference mitigation is a challenge [39]. Hence, the allocation of femtolet/SCceNB is another research scope.

5.6 *Context-Aware Service Provisioning*

Various attributes such as user's location, acceleration, direction of movement etc., need to be considered while providing cloud-based service to a mobile user. This contextual information plays a vital role in delivering convenient and timely service to the user. The context element has four layers [1]. The first layer denotes a device's currently monitored context, including environmental settings, service context information, user preference settings, etc. [1]. The second layer deals with the types of functional or non-functional gaps between the contexts of two consecutive services. The third layer deals with the causes of gaps between different interfaces and implementations of a single device, which may happen due to the mismatch of service level, service component level, service interface level, and component instance level. The fourth layer contains adapters required to remove the causes. Context-aware service provisioning is a three-tier architecture [1]. The user tier includes mobile devices in which the applications are executed. The agent tier adapts service based on the context. Finally, the service tier deploys the services. The contextual information is acquired, processed, managed, and delivered by the context management architecture (CMA) [1]. The context quality enabler controls the supply of contextual information to the mobile cloud [1]. The role of contextual information for identifying resources and risk assessment is another future research scope.

5.7 Mobile Data Management

Users' data such as chat logs, photos, contacts, videos, financial documents, records, users' login credentials, etc., are sensitive information. The storage of these information in the cloud raises various questions concerning security, privacy, data interpretability, portability, trust, etc. [1]. Moreover, a tremendous amount of data transfer to the cloud faces bandwidth and network connectivity problems, especially if the user moves [1]. Data portability and interoperability are other significant concerns in MCC. A mobile database may not provide all features of a traditional database. Traffic management is another primary research scope of MCC.

5.8 Energy-Efficiency

Mobile devices have limited battery life. Hence, the execution of specific applications inside the mobile device may result in high energy consumption of the mobile device that in turn drains the device's battery life. MCC offers application offloading for saving energy. However, communication with the cloud during offloading also involves energy consumption due to data transmission. The offloading of a simple task may result in high energy consumption than executing locally. Hence, the decision-making regarding offloading is crucial. An energy-efficient software, that makes use of an energy profiling tool customized for mobile applications [40], maps the power usage to a specific code component in the application and the operating system. Another software-based approach has been proposed for energy profiling in [41]. The energy consumption incurred by computation, communication, and overall infrastructure management contributes to the cost of system energy [42]. Energy harvesting in MCC is another future scope [43, 44].

5.9 Resource Management

As mobile computing and cloud computing technologies are integrated, the resource requirements estimation, resource allocation, and resource sharing are vital issues in MCC. Nowadays, edge/fog computing and dew computing have come into the picture. In [45], the authors have used game theory in resource pricing and offloading decisions for edge computing scenario. Developing intelligent resource management strategies for edge/fog/dew computing and MCC is a significant research scope in MCC.

5.10 Integration of MCC with IoT

Internet of Things (IoT) deals with connecting identified embedded devices within an Internet infrastructure to create a computing environment [46, 47]. IoT has become a principal component in designing intelligent solutions for daily life such as smart homes, smart cities, intelligent transport, smart health, etc. While mobile users are involved, the objects' status-related data is collected by the sensors/actuators. The data processing and storage will happen inside the cloud. However, in edge-fog-cloud architecture, the edge/fog devices can also participate in data processing. However, the decision regarding which data will be forwarded to the cloud, which will be processed inside the intermediate devices, the security of the data, mobility management, and spatio-temporal data analysis, etc., need to be focused in the IoT-MCC framework.

Along with these issues, other research scopes are also there such as intelligent health care [48], use of opportunistic delay-tolerant network [49], etc.

6 Green Mobile Cloud Computing

Green Mobile Cloud Computing (GMCC) refers to energy-efficient mobile cloud computing [1]. Here, 'green' refers low energy consumption. During the execution of resource-intensive applications, the energy consumption of the mobile device may be higher, and it will drain the battery of the device. On the other hand, energy-efficient mobile network design and providing good quality service to the mobile subscribers is a challenge. For energy-efficient mobile network designing, the use of small cells has been discussed in the existing research works [50, 51]. From the mobile device's perspective, an energy-efficient strategy for application execution inside the mobile device is a vital issue. MCC provides the facility of storing data and executing applications outside the mobile device. However, the communication with the cloud incurs energy consumption of the mobile device. Hence, the implementation of an energy-efficient offloading strategy is essential. In MCC, a green data center can also play a vital role. The various components regarding GMCC are therefore summarized as follows.

Green Data Centre The number of data centers in the backhaul is increasing to fulfill the requirement of online data storage and computations of users. Green data centre is significant to achieve GMCC [52]. Storing and maintaining a vast amount of data and executing calculations at the server side also incur tremendous energy consumption. By switching on/off devices, hardware, and software depending on the user demand and traffic load, can save energy. For energy saving the inactive network links can also be switched off.

Green Cellular Network A tremendous amount of energy is consumed to operate the base stations in a conventional cellular network. Green cellular network is vital for GMCC [53, 54]. The small cells come into the picture for energy-efficient cellular network design and providing good coverage. Firstly, microcell base stations have come, later picocell base stations, and then femtocell base stations have arrived. Switching on/off the base stations depending on the traffic can save energy. User-density-based base station allocation can also be vital in developing green cellular networks. In [10, 11], the authors have discussed the small cell base stations with storage and computing capability. The users under such small cells can offload their data and applications inside these small cells.

Green Mobile Devices For energy-efficient, i.e., green mobile devices, the energy demand, user requirement, traffic pattern, and resource requirements are considered. Energy saving of mobile devices is also important in GMCC [55, 56]. User-requirement-based dynamic resource allocation can improve resource utilization and reduce energy wastage. MCC allows users to offload data and computation inside the remote cloud servers. In computation offloading, the computation-intensive tasks migrate from mobile devices to the cloud, and after execution, the result is sent to the mobile device. The motivation is to overcome the mobile device's resource limitation and save battery life by reducing energy consumption. However, communication with the cloud also requires energy consumption. In this perspective, the decision making regarding whether to offload or not and whether to offload the application fully or partially, these queries appear. For example, suppose a mobile device has to offload a computation C. The energy consumption in communication (E_{offc}) and the energy consumption in local execution (E_{locc}) are compared. If $E_{offc} < E_{locc}$, then offloading is beneficial concerning the device's energy consumption. Few applications require partial offloading concerning the energy consumption; in that case, the decision regarding which portion will be offloaded and which amount will be locally executed, is vital. Nowadays, fog/edge computing has come to the scenario that brings the facility of offloading and partial processing closer to the mobile device.

Green Mobile Application and Services The design of energy-efficient mobile applications and services is another significant aspect of GMCC. Efficient data transmission is also required for energy-efficiency [57]. The use of data compression reduces the amount of data transmission that will help to reduce the energy consumption of mobile applications and services. The data volume is reduced. Thus, the energy consumption for data processing is also reduced. Green IoT applications is also an emerging issue [58–60].

7 Summary and Conclusions

This chapter discussed the architecture, applications, and research scopes of MCC. MCC enables mobile users to use the cloud resources "on-demand" and "pay as you go" basis. Mobile users can offload their data and applications inside the cloud instead of storing data and executing applications locally inside the mobile device. The execution of resource-specific applications and storage of a vast amount of data inside the cloud overcomes the limitations of mobile devices such as resource limitation, limited battery life, limited processing power, limited storage capacity, etc. There are several applications of MCC, such as mobile commerce, mobile learning, mobile health care, mobile game, etc., which have been highlighted in this chapter. We have discussed on green MCC. Finally, future research challenges of MCC have been highlighted.

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