# SMEC: Sensor Mobile Edge Computing

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**Abstract** The development of mobile user equipment progresses cooperatively with the advancement of the latest mobile applications. Still, the limited battery capacity prevents users from running computationally intensive applications on their gadgets. This one stimulated the evolution of Mobile cloud computing (MCC). Instead of its ample data storage and processing capability, MCC suffers from high latency. To deal with the latency problem a novel promising concept known as mobile edge computing has been introduced. Mobile edge computing (MEC) and wireless sensor networks (WSN) are two ever-promising research domains of the wireless network. The integration of MEC with WSN has given birth to Sensor Mobile Edge Computing (SMEC). However, sensor mobile edge computing is an emerging field, and energy-efficiency is one of the major challenges of this field. In MEC, services are provided at the edge of the mobile network for reducing the latency that in turn can improve the quality of user experience. Previously MEC focused on the use of base stations for offloading computations from mobile devices. However, after the arrival of fog computing, the definition of edge devices becomes broader. SMEC is a fusion of mobile edge computing and wireless sensor network. SMEC is an architecture where the sensor nodes capture the status of environmental objects and the collected data are sent to the cloud through the edge devices which participate in data processing also. This chapter discusses sensor mobile edge computing, its architecture, and its applications. The future scopes and challenges of SMEC are also addressed in this chapter.

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## 1 Introduction

A Wireless Sensor Network is a group of low powered tiny sensor nodes intended for monitoring and recording some physical or environmental conditions at different locations [1]. WSNs can be used in forest fire detection, industrial process monitoring, air pollution measurement, different medical applications, and many more such different areas. Cloud computing (CC) is the delivery of computation, software, and storage as service to the users in a virtualized and isolated environment. In the past decade, Mobile Cloud Computing (MCC) has emerged as a new archetype of computing due to the popularity of mobile devices and the epidemic rise of mobile applications [2, 3]. MCC overcomes the computational and storage limitations of today's smart mobile devices. Although an intrinsic drawback of MCC still exists that is propagation delay. The growing computing capacities present on smart devices call for the decentralization of Cloud computing services to avoid latency issues and fully utilize handy computing abilities at the network edges [4].

Driven by the vision of the Internet of Things (IoT), Mobile Edge Computing (MEC) is becoming a new trend in computing that addresses the issue of propagation delay and can provide latency-critical mobile applications [5–11]. For the period of the last four decades, the development of wireless communication networks took place based on the requirements of applications and transformed every facet of our lives [11]. A summary of Wireless Communication evolution is shown in Fig. 1.

Edge computing introduces technologies that allow computation to be performed at the network edge. Therefore computing is possible near data sources also. Before going to the discussion on the integration of WSN with MCC and MEC, we define mobile cloud computing, fog computing, and mobile edge computing.

**Definition 1: Mobile Cloud Computing**
MCC is a paradigm where the storage as well as the processing of data happens outside the mobile device. The applications of MCC have moved away from the data storage and computational power from mobile phones and into the cloud, which in turn brings mobile computing and applications not just to smartphone users but to a huge number of mobile subscribers (Mobile Cloud Computing Forum (MCC-forum, 2011)).

**Definition 2: Fog Computing**
Fog Computing is an infrastructure where the devices present between the end node and cloud servers take participation in the processing of the data, which in turn reduces the latency.

**Definition 3: Mobile Edge Computing**
MEC is a new technology that offers cloud computing capabilities and information technology services within the mobile access network of mobile users.

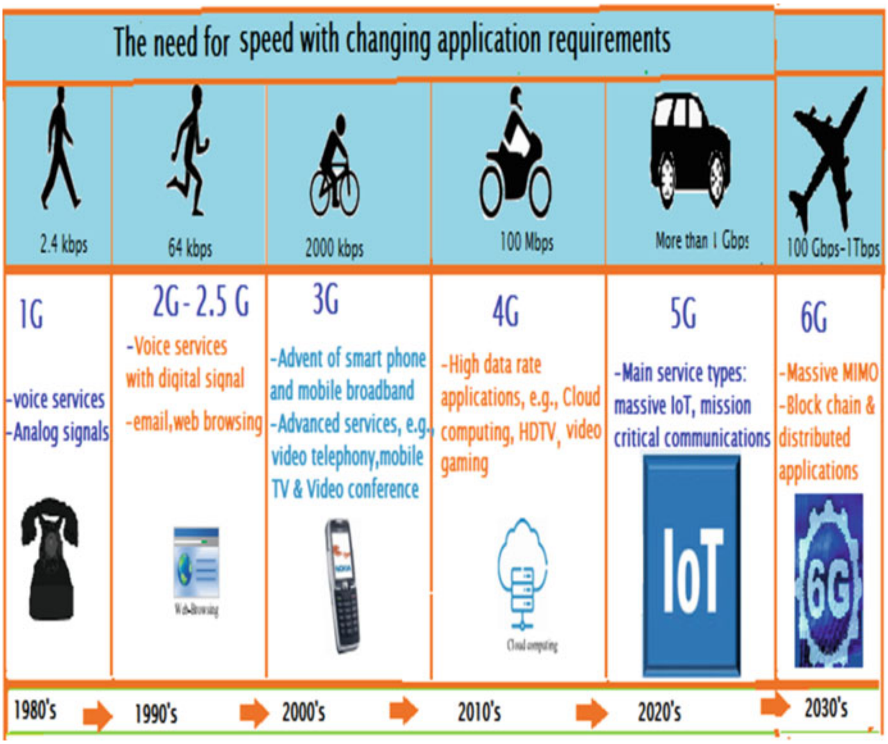


**Fig. 1** Evolution of Wireless Communication during the last four decades [11]

## *1.1 WSN with MCC*

Mobile cloud computing is a technology that offers unlimited functionality, mobility, and huge storage capacity through heterogeneous network connectivity. The integration of WSN and MCC draws significant attention from researchers due to its data gathering, storage, and processing capability in a single integrated infrastructure. The main advantage of WSN-MCC integration is the utilization of effective cloud computing infrastructure for storing and processing a huge amount of sensory data and ultimately offering processed data to the end-users [12–17].

## *1.2 WSN with Mobile Edge Computing (MEC)*

Most of the time MEC gets along with cloud computing for supporting and enhancing the end devices' performance. It is possible by pushing cloud resources such as to measure, set of connections, and storage space to the edge of the mobile network. An edge device can be any device that has the computational power and ability to network between data sources and cloud-based data centers, for example, a smartphone can be an edge device which is present between the cloud and body sensors. MEC directly connects the user with the nearest edge network able to provide cloud services [11]. According to recent research, the basic motivation of MEC is to offer computationally intensive applications using resource-limited mobile devices. As a result, it will be able to fulfill the end-users requirements which are latency-sensitive and involve high computation. Among the key characteristics of mobile edge computing proximity and lower latency are the most important characteristics to be mentioned [3–6].

The comparison of MCC with edge computing is provided in Table 1. As observed from the table the deployment in MCC is centralized wherein EC the deployment is distributed. The distance of user equipment from the cloud is higher than the edge device, which results in higher propagation latency while using the cloud. However, in the case of the cloud the storage and computational power is high in comparison with the edge device.

## *1.3 Research Motivation*

The integration of WSN with MCC provides lots of advantages but faced some critical issues which should be taken care of seriously. In [12] authors identified some critical issues regarding WSN-MCC integration which are as follows:

- Over-burdened intermediary sensor node: In WSN sensor nodes are generally equipped with a non-rechargeable battery. It follows multi-hop data communication from source nodes to gateway nodes via intermediary nodes. As a result, intermediary nodes become overburdened. Therefore energy efficiency is a prime concern to make the sensor network operative.

**Table 1** Comparison of MCC and Edge Computing [4]

| | MCC | EC |
|---|---|---|
| Deployment | Centralized | Distributed |
| Distance to UE | Long | Short |
| Latency | High | Low |
| Computational Power | Immense | Limited |
| Storage capacity | Huge | Limited |
| Advantages | Resource constraint mobile devices get additional capacity | Reduces latency in computational tasks |

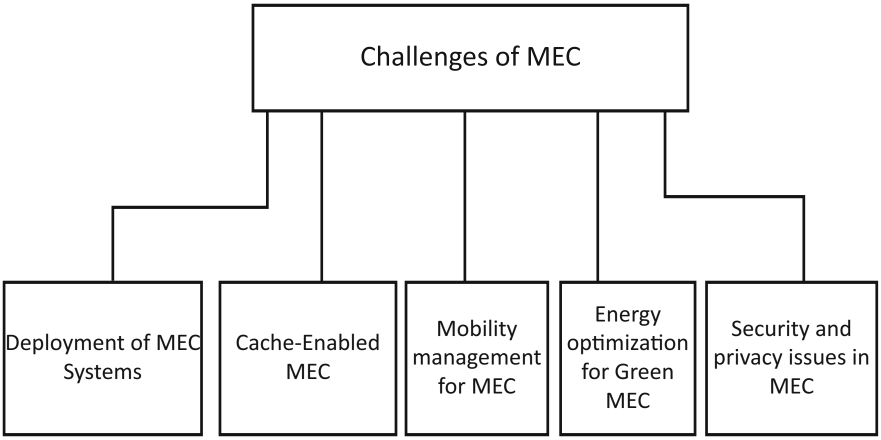


**Fig. 2** Challenges of MEC

- The bottleneck of traffic and bandwidth: With the dramatic increase in the number of mobile and cloud users the bandwidth of wireless networks may turn into a bottleneck situation. Besides, high bandwidth is required for multimedia data transmission. Therefore optimization of traffic and bandwidth demand is also an important issue.
- Delay of processing: In WSN the data collected from sensors are offered to end-users based on the need of the applications or users. In that case for some applications, the delay is unavoidable which affects the network performance. Therefore it is desirable to make use of the processing capability of the cloud to empower the WSN for tackling this type of issue.

The primary motivation of MEC is the decentralization of cloud computing services to make it available at the network edges and avoid latency issues. To accomplish this lot of challenges are being faced which are shown in Fig. 2.

As observed from the figure, there are several challenges in MEC such as deployment issue, cache-enabling, mobility management, energy optimization, security, and privacy, etc.

## 2 Related Work

In this section, we will focus on the existing works in IoT, cloud computing, fog computing, and edge computing applications of the sensor network.

### 2.1 IoT Applications

The emergence of IoT also termed as Internet of Everything enables the global network of people, processes, data, and things worldwide. WSN is an important part of IoT, and it is mainly accountable for collecting and reporting data. WSNs bring IoT applications more effectiveness and makes it more competence [18, 19]. A large amount of sensory data and its real-time processing is a big challenge for the practical implementation of large scale IoT systems. Edge computing is one of the promising solutions in this respect. But the deployment of an edge node is a fundamental problem. To address this issue authors proposed a deployment approach for edge servers intended for large-scale IoT [20]. They have shown that their proposed approach can significantly reduce the number of edge nodes and improves throughput. Day by day MEC is becoming a key enabler of consumer-centric IoT applications and services that demand real-time operations [21]. As IoT performance mainly depends on the lifetime and coverage area of WSN, designing an efficient method that conserves nodes' energy and reduces the number of dead nodes becomes important issues [22, 23]. Therefore clustering is one of the efficient methods to solve these problems in WSN [24, 25].

With the evolution of IoT, a massive number of sensor-based applications are going to be materialized. Therefore, the deployment of sensors and their mobility is a big concern to fulfill their job competently. In this respect, authors have presented an exhaustive review of existing mobile sinks that support sensors' mobility in the context of IoT applications [26]. The concept of the Green Internet of Things (G-IoT) is considered to play an extremely important role in providing smarter and sustainable cities [27].

### 2.2 Cloud Computing Applications

In recent days, cloud computing frameworks have become increasingly popular in both academia and industry. At the same time, a significant increase in the usage of smartphone platforms has been noticed worldwide. Therefore Mobile Cloud Computing emerges as a current state of the art technology providing unlimited functionalities in many useful applications [28]. The two closely related emerging technologies IoT and Big Data have matured convincingly to allow smart cities to materialize [29]. Due to the fast increase in the number of smart cities, their sustainability needs to be achieved through transformational urban systems design which may vary from system to system. Big data and Cloud computing play an important role in this perspective [30]. In [31] authors presented a new concept and its technologies that are related to the integration of MCC and context-aware applications. They have introduced CAOS, an android-based framework to illustrate how context-aware apps may be improved with MCC features like data and computing offloading. In [32] authors introduced a new medical big data clustering algorithm in a cloud computing environment. With the help of cloud computing technologies, the need for ubiquitous healthcare services is becoming possible day by day. Besides, big data analysis technologies have shown great possibilities for improving the quality of healthcare services. In [33] authors proposed a medical primary diagnosis framework that is outsourced to the cloud server in an encrypted manner. As a result, it can preserve confidential medical data from an unauthorized user.

## *2.3 Fog Computing Applications*

Traditional cloud computing is facing severe network challenges like network bottlenecks high latency to meet the massive requirements of IoT applications. The circumstances where traditional cloud-based solutions are not appropriate, edge and fog computing is considered the key enabling archetype which brings the cloud resources to the edge of the network [34]. Recently fog computing has emerged as a platform that handles massive data caused by IoT environments and provides networking services between IoT devices and traditional cloud computing [35]. Fog computing has come out as a new paradigm for a large group of applications that are delay-sensitive including smart city, healthcare service, intelligent transportation system, the personalized recommendation of banking products, Block-chain enabled applications, and many more [36–44]. Fog computing provides innovative solutions by bringing resources closer to the user and offer low latency solutions for data processing. Authors proposed a new framework called HealthFog intended for automatic Heart Disease analysis by integrating deep learning concepts with Fog computing [36]. HealthFog delivers healthcare as a fog service using IoT devices and capably manages the health data.

In urban areas, smart cities are already a reality and therefore have attracted the attention of many researchers. In [37] authors presented a hybrid edge-fog-cloud computing architecture for monitoring environmental parameters and traffic flow in a city with very limited infrastructure. In [38] authors presented a comprehensive literature review of the existing work already been done in the area of fog computing applications in smart cities.

## *2.4 Mobile Edge Computing Applications*

According to recent research, the main objective of Mobile Edge Computing is to provide computationally intensive applications using resource-limited mobile devices. MEC servers are small-scale data centers; therefore it is very important to develop innovative approaches for obtaining green MEC. Several approaches are already there for designing green MEC [45–56]. MEC is a furnishing solution to

**Table 2** Major contributions of existing publications on MEC

| Serial no. | Major contributions | Reference |
|---|---|---|
| 1 | Architecture &Computation offloading | [5–11, 62–64, 67–69, 77–80] |
| 2 | Resource allocation | [57–63] |
| 3 | Green MEC | [45–56] |
| 4 | Mobility management | [26, 65, 85] |
| 5 | MEC for IoT applications | [66, 72–77, 81–89] |
| 6 | Security & Privacy issues | [75–76, 79, 111–116] |
| 7 | MEC with 5G Technologies | [11, 70, 89] |

facilitate augmented reality (AR) applications on mobile devices [57, 58], video stream analysis service [59], Cloud-based vehicular networks [60].

For full utilization of the MEC paradigm, few key points should be based on application-oriented which are (1) decision on computation offloading; (2) allocation of computing resources within the MEC, and (3) mobility management. Several researchers have tried to focus on these above mentioned key points along with the other key points like the architecture and model of MEC, its mathematical frameworks, energy efficiency for a better solution [61–69]. MEC facilitates numerous mobile applications like video stream analysis, augmented reality, Vehicular network, gaming and IoT applications [70–89].

The major contributions of existing publications on mobile edge computing are summarized in Table 2. The comparison between Cloud, Fog, and Edge computing concerning processing response is shown in Fig. 3.

## 3 The Architecture of Sensor Mobile Edge Computing (SMEC)

Sensor Mobile Edge Computing (SMEC) is an integration of a sensor network with mobile edge computing. The four-layer architecture of SMEC is presented in Fig. 4.

SMEC architecture contains the following components:

- Sensor nodes
- Mobile device
- Cellular base station with edge server (in case of the cellular network)
- Cloudlet (in case of Wi-Fi)
- Cloud

The sensor nodes after collecting the object status send the collected data to the mobile device. The mobile device is connected with the base station (cellular network) or cloudlet (WMAN/WLAN). In the case of a cellular network, a cellular base station is used along with an edge server. The edge server is connected with the cloud. In the case of Wi-Fi i.e. Wireless Local Area Network (WLAN) or Wireless

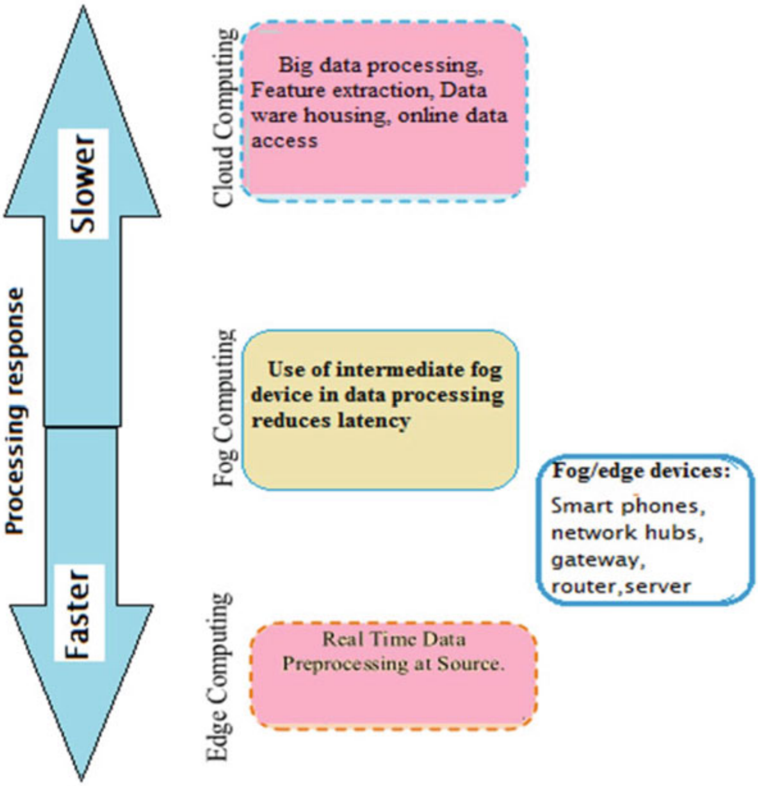


**Fig. 3** Comparison between Cloud, Fog and Edge computing

Metropolitan Area Network (WMAN), cloudlet is used. Here, cloudlet offers the storage and computation facilities. The cloudlet is connected with the cloud. In SMEC the mobile device after receiving the sensor data performs preliminary processing on the data and sends them to the edge server through the base station, or to the cloudlet. The data is processed inside the edge server/cloudlet, and then according to the necessity, the data is forwarded to the cloud.

### *3.1 Advantages of SMEC over SMCC*

The advantages of SMEC over SMCC are listed in Table 3.

As observed from the table due to the use of MCC the deployment is centralized in SMCC, where the deployment in SMEC is distributed as edge computing is used. In the case of SMEC, the latency is lower than the SMCC as the distance of the end node from the remote cloud is higher than the edge device. The computational

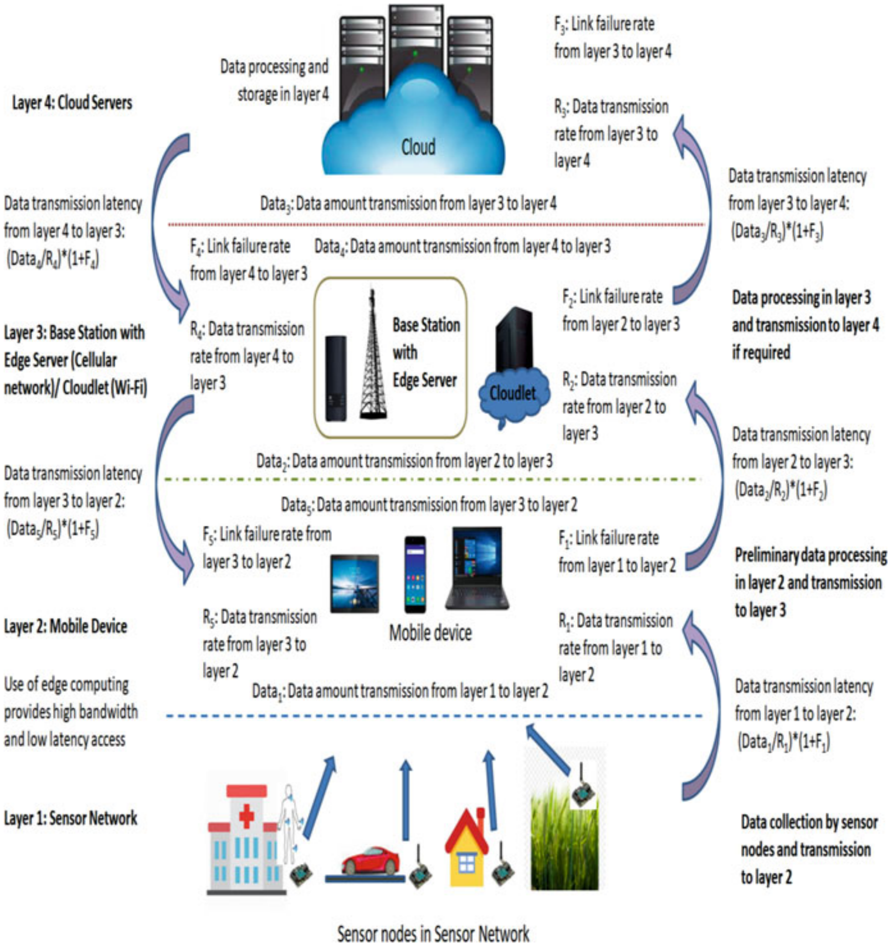


**Fig. 4** Four-layer Architecture of SMEC

**Table 3** Comparison between SMCC and SMEC

| | SMCC | SMEC |
|---|---|---|
| Deployment | Centralized | Distributed |
| Latency | High | Low |
| Computational Potential | Immense | Restricted |
| Storage capability | Huge | Limited |

power and storage of the cloud are higher than the edge device, the computational power and storage are higher in SMCC than SMEC.

### 3.1.1 Definition of SMEC

Sensor mobile edge computing is defined as an integrated architecture which is the combination of mobile edge computing and wireless sensor network where the sensor nodes capture the status of environmental objects and the collected data are sent to the cloud through the edge devices. MEC connects the user directly to the nearest cloud service enabled edge network which provides high computation, low latency, and avoid bottleneck situation.

## *3.2 Latency in SMEC*

In SMEC, the storage and computation execution related to the sensor data takes place inside the edge device. To calculate the latency the data transmission, propagation, computation execution, and queuing latencies are calculated.

The data transmission latency in SMEC is given as [78],

$$L_{st} = \sum_{i=1}^{h} \left(1 + U_{fi}\right) \frac{S_{tui}}{R_{ui}} + \sum_{j=1}^{k} \left(1 + D_{fj}\right) \frac{S_{tdj}}{R_{dj}}, \tag{1}$$

Where $U_{fi}$ is the failure rate in the uplink, $S_{tui}$ is the sensor data amount transmitted in the uplink, $R_{ui}$ is the sensor data transmission rate in the uplink, between the communicating devices for hop $i$, $D_{fj}$ is the failure rate in the downlink, $S_{tdj}$ is the sensor data amount transmitted in the downlink, $R_{dj}$ is the sensor data transmission rate in the downlink, between the communicating devices for hop $j$, h is the number of hops in uplink and $k$ is the number of hops in the downlink.

The computation execution latency is given as [78],

$$L_{sc} = \frac{I}{I_c}, \tag{2}$$

Where, $I$ is the number of instructions to be executed for the computation and $I_c$ is the instruction execution speed of the computing device.

The propagation latency is given as [78],

$$L_{sp} = \frac{D_p}{S_p}, \tag{3}$$

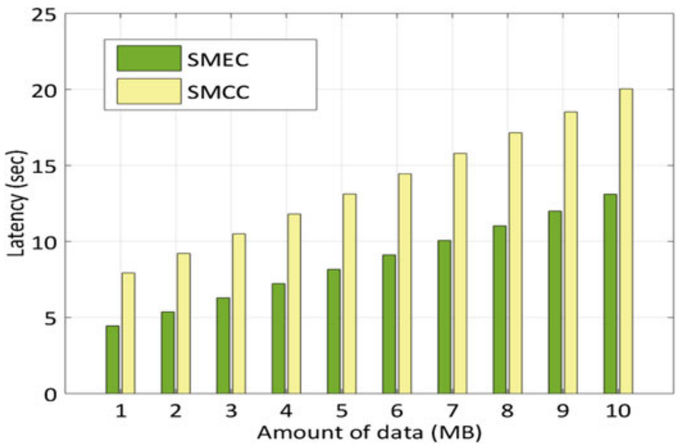


**Fig. 5** Latency in SMEC and SMCC

Where, $D_{rs}$ is the distance covered between the requesting and serving node, and $D_p$ is the propagation speed.

If the queuing latency is denoted by $L_{sq}$, the total latency is given as [78],

$$L_{smec} = L_{st} + L_{sc} + L_{sp} + L_{sq}. \tag{4}$$

In Fig. 5 the latency in SMEC and SMCC are compared. This is observed that by bringing the computation at the network edge the latency has been reduced by ~40% than the cloud-based SMCC framework.

In the next section, we have focused on the applications of SMEC.

## 4 Application of SMEC

Different applications of SMEC are discussed as follows.

### *4.1 Vehicular Network*

In Vehicular Adhoc Network (VANET) the use of edge computing has been highlighted in [79]. It has been shown that by using edge nodes as an intermediary interface amid vehicle and cloud, the latency has been reduced. A Software Defined Network (SDN) with MEC has been presented in [80] which are intended for establishing the VANET routing path for paired vehicles. In [80] it has been demonstrated that this method provides better throughput.

### 4.2 Augmented Reality Service

Augmented Reality (AR) presents a virtual environment through which the users observe the real world with virtual objects composited with the real world [81, 82]. With AR a user will be able to work with real 3D objects with their information acknowledged visually from a mobile device. For example, a civil engineer wishes to develop a children's house inside a playground. AR allows him to select the correct place to build the house inside the playground with the help of his mobile device camera. The sensor plays an important role in AR. In SMEC with the help of sensors, virtual reality can be provided to the user to view the real world with virtual objects superimposed with the real world.

### 4.3 Home Monitoring

A smart room generally contains a computer system with huge storage and processing power to control the activities of the devices within the room. This is expensive as well as introduces overhead to a single device. If SMCC based smart home, the activities can be controlled by the server itself with a cloud environment. In [83] the use of fog computing in the smart home has been demonstrated. In SMEC the computing and storage resources are placed close to the network edge and the delay, jitter, and energy consumption of the user device can be reduced. Recently several researchers have presented IoT based solutions for smart home monitoring [84, 85].

### 4.4 Healthcare

In smart health care, health sensor devices capture the health status, and the sensor data are stored and processed inside the cloud servers. After processing the data, the health status of the user can be detected [86–89]. In [86], the use of an edge-based framework in time-critical applications has been shown, where health care has been considered as a case study. By bringing the processing facility closer to the network edge, the delay which is a vital parameter for health care can be reduced. In [87], mobility data analytics has been integrated with health care service, for advising users regarding nearby health center.

# 5 Future Scope

## 5.1 *Bio-inspired SMEC*

Bio-inspired computation has started a new era towards the solution of different energy aware, time-critical computational problems in wireless sensor networks. Sensor mobile edge computing is an emerging field that can provide high-quality solutions using resource-limited mobile devices. Mobile edge computing addresses the issues of latency, the limited battery power of mobile devices and security, etc. In recent days Bio-inspired algorithms are getting much attention for providing the best solution in different areas specially WSN, IoT, Fog computing, and Cloud computing [90–107].

In [90] authors presented a hybrid routing algorithm combining ACO and FSOA which addresses one significant issue namely energy consumption of WSN and extends network lifetime. So the concept of applying a hybrid bio-inspired algorithm can also be useful for green SMEC. In [91], a hybrid algorithm has been presented combining improved Bat algorithm and LEACH. In this paper, it was shown that the improved BA has stronger optimization ability that can reduce energy consumption and is able to enhance the lifetime of WSN considerably. In [92] authors presented a cat swarm optimization-based approach which optimizes the energy distribution for the WSNs in real-time. In [93] authors proposed a Chicken Swarm Optimization Algorithm (CSOA) based cluster Size Load Balancing technique for IoT-based sensor networks. In this paper, it has shown significant improvement in terms of network lifetime, overall energy consumption. One GSO-based energy-efficient sensor movement approach is presented in [94] which attempts to optimize both the energy and coverage of mobile WSN at a time. Therefore it will also be effective if it is applied for implanting green SMEC. In [95], the authors presented the MFO based energy-efficient clustering protocol which extends the stability period of the network and optimizes energy consumption. Hence this algorithm can also be useful for green SMEC. Recently bio-inspired algorithms are showing good results in energy optimization in diverse areas specially WSN and IoT which are summarized in Table 4.

## 5.2 *Big Data Analytics in SMEC*

Big data analytics in SMEC is another major challenge. SMEC has various application areas like VANET, healthcare, where a large amount of data generation takes place and the analysis of the huge amount of data is required. In [108] big data reinforcement learning method has been proposed along with an integrated paradigm for better performance in smart city applications. In [109] big data analytics in health care has been focused. An edge computing paradigm has been proposed for big data processing and an optimized model for estimating

**Table 4** Contributions of bio-inspired algorithms in energy optimization

| Bio-inspired Algorithm | Journal name (publication year) | Area |
|---|---|---|
| Ant Colony Optimization | Journal of Cleaner Production (2019) | Vehicle routing |
| | The Journal of Supercomputing (2018) | WSN |
| Bat Algorithm | Swarm and evolutionary computation (2019) | Vehicle routing |
| | IEEE Communications Letters (2018) | WSN |
| Cat Swarm Optimization | International Journal of Distributed Sensor Networks (2015) | WSN |
| Chicken Swarm optimization Algorithm | Journal of Network and Computer Applications (2019) | IoT |
| | IEEE Access (2019) | WSN |
| Fish Swarm Optimization Algorithm | Sensors (2018) | WSN |
| Glowworm Swarm Optimization | Simulation Modelling Practice and Theory (2016) | WSN |
| Moth flame Optimization Algorithm | Wireless Personal Communications (2019) | WSN |
| Particle Swarm Optimization | Wireless Personal Communications (2019) | WSN |

epileptogenic network [109]. In [110] a MEC based system has been used alongside a big data-driven scheduling method to achieve communication efficiency.

## *5.3 Security and Privacy Issues of SMEC*

While integrating WSN with MEC then security becomes a major challenge. The security threats in the edge-cloud computing framework have been studied in [111]. In [112] the authors have proposed a fog-based storage framework to deal with the cyber threat. As a large number of mobile users are present, then privacy is another issue. Here, the assessment of each mobile node is also very important [113] along with the assessment of invulnerability [114]. In [115] an intrusion detection system has been discussed based on a decision tree. Security and privacy issues of MEC for heterogeneous IoT are the most promising future research areas [116].

### 5.4 Dew Computing Based Context-Aware Local Computing

In [117, 118] authors introduced dew computing architecture intended for real-time context-aware service framework. It has been observed that the end-users can get advantage from this framework through data sensing, computing in the IoT environment [118].

### 5.5 Resource Management

Resource allocation in mobile cloud computing is a major challenge [119]. Similarly, in MEC also resource allocation and management are major factors. In SMEC the deployment of edge servers for optimal service provisioning as well as resource management is a vital challenge. As multiple users are present and their requirements are also different and most importantly the users have mobility, the resource allocation, release, VM migration, delivery of required service with minimal latency are key challenges.

## 6 Conclusion

This chapter provides a discussion on the architecture and working model of sensor mobile edge computing. The use of edge computing provides lower latency concerning the cloud-only system, which we have shown in theoretical results. The applications of sensor mobile edge computing in health care, smart home management, vehicular network, augmented reality have been discussed. The future research directions of sensor mobile edge computing have been also illustrated where resource management, big data analytics, security, bio-inspired sensor mobile edge computing have been considered.

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