Editorial

5G Mobile Services and Scenarios: Challenges and Solutions

Yousaf Bin Zikria [1], Sung Won Kim [1,]*, Muhammad Khalil Afzal [2], Haoxiang Wang [3] and Mubashir Husain Rehmani [4]

[1] Department of Information and Communication Engineering, Yeungnam University, 280 Daehak-Ro, Gyeongsan, Gyeongbuk 38541, Korea; yousafbinzikria@gmail.com
[2] COMSATS University, Islamabad, Wah Campus, Wah Cantt 47010, Pakistan; khalilafzal@ciitwah.edu.pk
[3] GoPerception Laboratory, Cornell University, Ithaca, 14850 NY, USA; hw496@goperception.com
[4] Waterford Institute of Technology, X91 K236 Waterford, Ireland; mshrehmani@gmail.com
* Correspondence: swon@yu.ac.kr; Tel.: +82-53-810-4742

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Abstract: The Fifth generation (5G) network is projected to support large amount of data traffic and massive number of wireless connections. Different data traffic has different Quality of Service (QoS) requirements. 5G mobile network aims to address the limitations of previous cellular standards (i.e., 2G/3G/4G) and be a prospective key enabler for future Internet of Things (IoT). 5G networks support a wide range of applications such as smart home, autonomous driving, drone operations, health and mission critical applications, Industrial IoT (IIoT), and entertainment and multimedia. Based on end users' experience, several 5G services are categorized into immersive 5G services, intelligent 5G services, omnipresent 5G services, autonomous 5G services, and public 5G services. In this paper, we present a brief overview of 5G technical scenarios. We then provide a brief overview of accepted papers in our Special Issue on 5G mobile services and scenarios. Finally, we conclude this paper.

Keywords: 5G; immersive 5G service; intelligent 5G service; omnipresent 5G service; autonomous 5G service; public 5G services

1. Introduction

We are now heading towards the fourth industrial revolution, which is based on digital revolution and marked by emerging technology breakthroughs in artificial intelligence, quantum computing, robotics, nanotechnology, biotechnology, etc. [1]. This new wave of technological revolution is changing the way we work, live, and communicate with each other. We can see emergence of unprecedented applications and services such as artificial intelligence, smart home, autonomous vehicles, drone-based delivery systems, smart cities, smart factories, etc. The co-existence of machine and human centric services will diversify the future wireless environments with the cost of challenges. In the near future, mobile communication will penetrate every part of society and create a multidimensional, user-centric information ecosystem. In addition, a fully mobile and connected society is expected, which will be characterized by an incredible amount of growth in connectivity, traffic volume, and a much broader range of usage scenarios [2]. The traditional business model of mobile communications has been disrupted by Mobile Broadband (MBB) service, enabling unprecedented user experiences and making a deep impact on every aspect of people's life and work. Accompanying the large-scale commercialization of 4G, the fifth generation of mobile communications (5G) is expected to be commercialized around 2020 and has become a central point for global research and development. Regardless of advanced 4G network, it is difficult to provide mobile

services that need high speed, high reliability, rapid response, and energy efficiency. Existing 4G networks cannot deliver instant cloud services, enhanced Vehicle-to-Everything (eV2X), Internet of Things (IoT) [3], tactile internet [4,5], and robots and drone communication, considering the quality of experience (QoE) to mobile users. These characteristics have become vital necessities for future services in the 5G era. The recent research on 5G services and their technical requirements have been performed by the International Telecommunication Union-Radio communication Sector (ITU-R), the Next Generation Mobile Networks (NGMN) Alliance and the 3rd Generation Partnership Project (3GPP). In the ITU-R Working Party (WP) 5D, 5G is defined by the name of International Mobile Telecommunications-2020 (IMT-2020) [6].

Based on end users' experience, several 5G services are categorized into five groups. The new 5G services are as follows: immersive 5G services, intelligent 5G services, omnipresent 5G services, autonomous 5G services, and public 5G services. As mobile multimedia content streaming and social networks have become more widespread, the demand for mobile traffic has continuously increased. Table 1 summarizes the five service categories of 5G. In addition, new types of multimedia services such as augmented reality, virtual reality, etc., which all require huge traffic volumes, have emerged [7].

The vision of 5G is to provide super ultra-low latency user experience, fiber-like access data rate, connect more than 100 billion devices and deliver a consistent experience across diverse scenarios with enhanced energy and cost efficiency.

Table 1. Summary of five service categories of 5G.

Categories	Services
Immersive 5G Service	Massive Contents streaming Virtual Augmented Reality Telepresence
Intelligent 5G Service	Crowded Area Service User-centric Computing Edge/FOG Computing
Omnipresent 5G Service	Smart Personal Devices/Health Smart Building/Grid Smart City/Smart Factory Systems
Autonomous 5G service	Smart Transportation/Teleoperation Drone-based 3D connectivity Robot-based Service
Public 5G Services	Private security and Public Safety Disaster Monitoring Emergency Service

2. 5G Technical Scenarios

This section presents 5G vision and requirements, and summarizes the main technical scenarios, challenges, and key enabling technologies for 5G. The key features and core technologies are extracted to form 5G concept. IoT and Mobile Internet will become the main driving force for the evolution of mobile communications towards 2020 and beyond. In the future, 5G will need to fulfill diverse service requirements in all aspects of life such as work, leisure, and transportation. Ultimate service experiences include Super Ultra-High Definition (S-UHD) videos, augmented reality, virtual reality, cloud desktop, edge cloud computing, and online gaming. Moreover, 5G will penetrate the IoT and achieve Internet of Everything (IoE) to accomplish diverse service requirements of transportation, manufacturing, medicine, and other vertical industries.

5G will solve the challenges stemmed from the drastically different performance requirements in a wide range of diversified scenarios, where different Key Performance Indicators (KPI) such as user experienced data rate, traffic volume density, latency, energy efficiency, and connection density might be challenging. Four typical technical scenarios of 5G are derived from the main application

scenarios, service requirements, and key challenges of mobile internet and IoT: high-capacity hot-spot scenario, low-power massive-connections scenario, seamless wide-area coverage scenario, and low latency high-reliability scenario [8,9]. Along with this, the above-mentioned technical scenarios have key issues, which are given in Table 2.

Table 2. 5G Technical Scenarios and Key Issues.

Technical Scenarios	Key Issues
High-capacity hot-spot	Traffic volume density: Tens of Tbps/km^2 User experienced data rate: 1 Gbps Peak data rate: Tens of Gbps
Low-power massive-connections	Connection density: 106/km^2 Low power consumption and low cost
Seamless wide-area coverage	100 Mbps user experienced data rate
Low latency high-reliability	Air interface latency: 1 ms End-to-end latency: ms level Reliability: nearly 100%

Further use cases are expected to emerge, which are currently not anticipated. For future 5G, flexibility will be necessary to adapt to new use cases that come with a wide range of requirements [10]. The research forums and other external organizations wishing to contribute to the future development of 5G are encouraged to focus especially in the following key areas [11]:

(a)   Spectrum related issues [12]
(b)   Traffic characteristics [13]
(c)   Radio interface(s) and their interoperability [14]
(d)   Access network related issues [12]

3. A Brief Review of Articles of this Special Issue

In this Special Issue, we have accepted papers in the domain of 5G Mobile Services and Scenarios.

Most existing approaches for categorizing 5G services are presented from the perspective of network operators and service providers [15]. However, Yu et al. [16] categorized with the aim of maximizing the satisfaction of end-users. The megatrends in the upcoming 5G era are analyzed. Then, the new 5G services are classified on the basis of these trends, with the consideration of end-users' experience. Essential technical requirements for realizing the 5G services are suggested. In addition, a competitiveness analysis on 5G services/devices/network industries and the current condition of 5G technologies have been explained in the paper.

Afrin et al. [17] explored the challenge of mapping the heterogeneous requests from Remote Radio Heads (RRHs) to Baseband Processing Units (BBUs) while considering the both aspects, i.e., end-user QoE and service providers' profit. In the proposed work, a multi-objective non-linear programming solution is developed, with focus on the maximization of QoE and profit-aware resource allocation. Two computationally viable scheduling algorithms, named first fit satisfaction and first fit profit algorithms are developed for the optimal tradeoff between the QoE and profit. The simulation results, carried out on CloudSimSDN, show the performance improvements in terms of user QoE, QoS satisfaction, average waiting time, and service provider profit.

Ali et al. [18] studied the IEEE 802.11ax High-Efficiency Wireless local area network (HEW) as the foundation technology for the 5G networks on unlicensed bands (5G-U) [19]. The paper identifies the future use cases of HEW deployments in 5G-U networks, and highlights the challenge of performance degradation in case of high number of Wireless Local Area Networks (WLANs). The authors proposed a self-scrutinized Channel Observation-based Scaled Back Off (COSB) mechanism to handle the high-density contention problem. The performance efficiency of the proposed solution is analyzed

through the analytical and simulation results, and is compared with the binary Exponential Back Off (BEB) mechanism. The proposed mechanism guarantees the enhanced QoE (high throughput and low delay) in a high-density environment by reducing the number of collisions during the channel access mechanism.

Sodhro et al. [20] examined the integration of Fog computing and 5G based IoT devices [21,22]. The author highlighted the shortcoming of Fog computing in terms of less storage capacity and more power drain. Unlike other related literature, the paper investigates the quality of service (QoS) domain of communications between IoT and Fog computing. The authors proposed the Transmission Power Control (TPC) based QoS optimization algorithm (QoS-TPC). The proposed Fog-IoT-TPC-QoS architecture considers the static and dynamic behavior of the channel. Importantly, a comparison with the conventional adaptive TPC (ATPC), Team Game (TG) and constant TPC methods is shown in the proposed work. However, the proposed work carry certain limitations including requirement of high Received Signal Strength Indicator (RSSI) values, and high delay and jitter values.

Song et al. [23] discussed the challenges and the possible performance degradation of Transmission Control Protocol (TCP) due to path heterogeneity in highly integrated 5G systems [24]. The paper presents a performance analysis model for the TCP over multiple heterogeneous paths, with the consideration of link quality asymmetry (both delay and bandwidth). The accuracy of the proposed model is obtained by the comparison of simulation study with field experiment. The authors developed the interesting conclusion that the delay asymmetry between the multiple links is more dominant factor in the performance of TCP. The proposed model, no doubt, can provide guidance to the design of novel Concurrent Multipath Transfer (CMT) solutions for 5G mobile services.

Li et al. [25] proposed a theoretical model for partitioning and allocating an arbitrarily divisible application, i.e., Optical Character Recognition (OCR), among a group of available resources, with the objective of reducing the completion time. The effectiveness of the proposed model for partitioning and allocating divisible applications in opportunistic computing environments is demonstrated through both the simulations and real experiments. The proposed work only focus on the benefit of offloading in terms of completion time, and the inclusion of the incurred energy consumption is suggested for the future work.

Khalid and Yu [26] evaluated the 5G based Cognitive Radio Networks (5G-CRN) [27] as one of the potential candidates for enhancing the spectrum utilization efficiency. The paper highlights the need of efficient handover management for the 5G-CRN as multi-tier network layout for 5G requires the Primary User (PU) to be more active. This paper focuses on the formulation and analysis of the sum utilization of spectrum policy for multi-channel scenarios under different PU and Secondary User (SU) co-existing network topologies, with the aid of sensing and handoff capabilities. The proposed work demonstrates that the different sets of channels, PU activities, and sensing outcomes have a significant impact on the sum utilization of spectrum associated with a specific network topology.

Tanoli et al. [28] investigated experimental performance analysis of Cooperative Communication (CC) [29] over Direct Communication (DC) in the lab environment to overcome channel fading and to improve channel capacity. The experimental setup is built using Universal Software Radio Peripheral (USRP) and Laboratory Virtual Instrument Engineering Workbench (LabVIEW). A text message is transmitted by using Phase Shift Keying (PSK) modulation schemes. The setup uses Amplify and Forward (AF) relaying mode and two time slot transmission protocols. The Maximum Ratio Combining (MRC) technique is used for combining Signal to Noise Ratio (SNR) at the receiver. The CC can significantly enhance the system performance in terms of reliability and channel capacity. Due to the high data rates and cost effective solutions, CC is considered as one of the most efficient technique, and it can be exploited for the 5G wireless networks as well. In this paper , extensive experiments are carried out for capacity gain of CC over DC in a lab environment. Experimental performance analysis shows that CC significantly improves the performance of the system than DC. Experimental analysis also shows that the increase in the transmit antenna gain results in improving the SNR at receiver. High SNR provides more channel capacity by using higher order PSK modulation. The performance

of CC significantly increases the system reliability and the channel capacity of the system with and without obstacle environment. It is also analyzed that channel capacity increases by placing the relay at center between source and destination.

To alleviate the spectrum scarcity problem in 5G networks, traditional mobile data offloading schemes from Long-Term Evolution (LTE) to WLANs have been revised by the third-Generation Partnership Project (3GPP) in release 13, which is known as LTE-WLAN Aggregation (LWA) [30]. Bajracharya et al. [31] proposed a user-offloading algorithm for Evolved Node B (eNB) hardware that smartly allocates the deprived LTE User-Equipment (UEs) and assigns the LWA service to an optimal number of UEs without degrading the QoS for existing WLAN UEs. With LWA, UEs supporting both LTE and WLAN can utilize both LTE and WLAN links simultaneously. Thus, UEs under the coverage of an LWA network will be surrounded by multiple standards, such as LTE, WLAN, and LWA, along with cells of different sizes and coverage. Providing the LWA service to all UEs unconditionally may lead to serious intra-cell unfairness, degradation of system-level QoS, and a reduction in system resource utilization. Hence, to resolve this issue, two important challenges need to be addressed: Which LTE UEs should be transferred, and how many LTE UEs need to be transferred. The proposed LWA admission control mechanism for eNBs finds the optimum number of LTE UEs for LWA activation. It addresses two important challenges: which LTE UEs should be transferred, and how many LTE UEs need to be transferred. Through numerical simulations, this paper proves that the proposed algorithm contributes to maximizing network throughput and performance by optimally assigning LWA service to poor UEs without degrading the QoS of existing WLAN UEs. The paper shows that the proposed scheme maximizes the throughput performance of the whole network.

A Smart Grid (SG) [32,33] is a modernized electric grid that enhances the reliability, efficiency, sustainability, and economics of electricity services and plays a vital role in modern energy infrastructure. The core challenge faced by SGs is how to efficiently utilize different kinds of front-end smart devices, such as smart meters and power assets, and in what manner to process the enormous volume of data received from these devices. Furthermore, cloud and fog computing provide on-demand resources for computation, which is a good solution to overcome SG hurdles. Fog-based cloud computing has numerous good characteristics, such as cost-saving, energy-saving, scalability, flexibility, and agility.Resource management is one of the big issues in SGs. This paper proposes a cloud–fog-based model for resource management in SGs. The key idea of the proposed work [34] is to determine a hierarchical structure of cloud–fog computing to provide different types of computing services for SG resource management. In this paper, four load balancing algorithms, namely Particle Swarm Optimization (PSO) , Artificial Bee Colony (ABC), Ant Colony Optimization (ACO), and the proposed Hybrid Artificial Bee Ant Colony Optimization (HABACO) algorithm, are used to manage SGs resources optimally in a cloud and fog based environment, and their results are compared with each other. For this purpose, two scenarios are considered. Four load-balancing algorithms are implemented in both scenarios. Simulation results show that the overall performance of HABACO is better as compared to the other techniques presented in Scenario 1. In Scenario 2, the performance of the proposed algorithm is also found to be better as compared to PSO, ABC, and ACO. From the numerical results, the paper concludes that, in Scenario 1, the response time of proposed algorithm outperformed PSO by up to 60%, ACO by up to 90% and it enhances its efficiency by up to 36% in the case of the ABC using two VMs in Scenario 1. The proposed algorithm also outperforms the other algorithms in terms of average processing time: 7.8% as compared to PSO, 7.07% as compared to ABC and 66% as compared to ACO for average processing time using one fog server and two VMs. In this manner, the proposed HABACO algorithm outperforms its counterpart algorithms due to its capability of finding the both global and local optimal solutions.

Named Data Networking (NDN) [35] is an innovative paradigm that provides the location independent data communications in which client's requests are satisfied regardless of the content's location. In fact, this concept provides unique and location-independent content, in-network caching and name-based routing. These features give NDN the potential to become a key technology for

data dissemination in IoT. The NDN concept has abilities to mitigate the significant communication overhead caused by the distribution of commonly accessed contents. The Information-Centric Networking (ICN) [36,37] concept is used to decrease the substantial communication overhead caused by the dissemination of analogously accessed contents. In-networking caching arranges a content replica that is cached at different locations to increase the availability of the desired data. Caching is a crucial component that makes ICN more beneficial than the present Internet architecture. It significantly minimizes the huge volume of data traffic and diminishes the bottleneck caused by publishing data in a unique location. Moreover, caches reduce the distance required for data retrieval. The cache performance totally depends on cache management schemes, which are divided into two mechanisms, namely, content placement strategies and replacement policies. Naeem et al. [38] addressed the caching strategies with the aim of recognizing which caching strategy is the most suitable for IoT networks. The simulations indicate the impact of different popularity-based caching strategies; of these, periodic caching is the most appropriate strategy for IoT environments in terms of a stretch that results in decreasing the content retrieval latency and improving the cache-to-hit ratio. Moreover, it is useful for all smart city applications, as it reduces the latency and improves the content response time.

Cisco first introduced the term fog computing. The aim is to provide data storage, processing, and analysis capabilities at the edge devices instead of the cloud. Consequently, it improves the efficiency and performance of the overall system by reducing network load and delay. Integration of fog computing and IoT opens up new research venues, challenges and opportunities for the practitioners and researchers [39–41]. Dealing with the issue of energy crisis in SG is a challenging task. Load management using load balancing is one of the technique to cater this challenge. Virtual Machines (VMs) on the physical system is one of the techniques to manage resources efficiently and is also feasible for SGs management. Bakhsh et al. [42] addressed the issue of dynamic VM placement to reduce the computational cost, increase the system performance and reduce the delay for SG. Optimized Response Time Policy (ORTP) is used to route the request to fog. Thereafter, First Come First Serve (FCFS) or Ant Colony Optimization (ACO) policy assigns the request to the VM. The result shows that proposed system improves the overall system in terms of response time, processing time and the computation cost. It is interesting to see comprehensive analysis and evaluation by applying Best Fit (BF), First Fit (FF), First Fit Decreasing (FFD), and Best Fit Decreasing (BFD) heuristic algorithms in the future work.

4. Conclusions

Twelve papers in this Special Issue provide state-of-the-art research trend in the area of 5G Mobile Services and Scenarios. The papers present interesting discussion and novel ideas for the readers. The Guest Editors would like to show appreciation to authors and thank all the anonymous reviewers for providing constructive feedback to improve the overall quality of all the accepted papers. We would also like to thank Editor-in-Chief Prof. Dr. Marc A. Rosen and Managing Editor Leanne Fan for the invaluable help and productive advice in finalizing this Special Issue.

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Abbreviations

The following abbreviations are used in this manuscript:

3GPP	3rd Generation Partnership Project
5G	Fifth Generation
5G-CRN	5G Based Cognitive Radio Networks
5G-U	5G Networks on Unlicensed Bands
ABC	Artificial Bee Colony
ACO	Ant Colony Optimization
ATPC	Adaptive Transmission Power Control
BBUs	Baseband Processing Units
BEB	Binary Exponential Back Off
BF	Best Fit
BFD	Best Fit Decreasing
CC	Cooperative Communication
CMT	Concurrent Multipath Transfer
COSB	Channel Observation-based Scaled Back Off
FCFS	First Come First Serve
FF	First Fit
FFD	First Fit Decreasing
HABACO	Hybrid Artificial Bee Ant Colony Optimization
ICN	Information-centric Networking
IIoT	Industrial IoT
IMT-2020	International Mobile Telecommunications-2020
IoE	Internet of Everything
IoT	Internet of Things
ITU-R	International Telecommunication Union-Radio communication Sector
KPI	Key Performance Indicators
LabVIEW	Laboratory Virtual Instrument Engineering Workbench
LTE	Long-term Evolution
LWA	LTE-WLAN Aggregation
MBB	Mobile Broadband
MRC	Maximum Ratio Combining
NDN	Named Data Networking
NGMN	Next Generation Mobile Networks
OCR	Optical Character Recognition
ORTP	Optimized response time policy
PSK	Phase Shift Keying
PSO	Particle Swarm Optimization
PU	Primary User
QoE	Quality of Experience
QoS	Quality of Service
RRHs	Remote Radio Heads
RSSI	Received Signal Strength Indicator
SG	Smart Grid
S-UHD	Super Ultra-high Definition
SU	Secondary User
TCP	Transmission Control Protocol
TG	Team Game
TPC	Transmission Power Control
USRP	Universal Software Radio Peripheral
VM	Virtual Machine
WLANs	Wireless Local Area Networks

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