5G: The Next Wave of Digital Society Challenges and Current Trends

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***Abstract*—The Internet that can easily connect global landscape is a fundamental component for business and communication. In the next decade, wireless network 5G will provide native support for a new kind of network infrastructure deployments, including the ultra-dense networks, multiple Radio Access Technology co-existence, direct Device to Device communication and many others. This article explores the new trends and challenges in the new digital wave. Further, it highlights the research areas in each feature and discusses the new approaches to handle huge populated devices demand.**

***Index Terms*—5G; Multi-RAT; Ultra Dense Network; MIMO; Context-Aware.**

I. INTRODUCTION

The evolution of mobile communication from simple voice to current sophisticated communication etches a need and support for a massively advanced technology to create a totally connected network society. The development of 3G and 4G technologies had been primarily served to satisfy data services over the Internet. However, today's era of diverse applications and demand from a huge population for data is pressing towards a more promising wireless network in terms of data rate, speed, efficiency, Quality of Experience (QoE) and battery life. To satisfy these diverse requirements, a new digital wave, the Fifth Generation (5G) is set to be deployed by early 2020 [1, 2].

The 5G technology is the next generation ultra-broadband network infrastructure integration of multiple Radio Access Technologies (RAT) for massive mobile data traffic focusing on massive capacity. The 5G technology emerges to introduce advanced feature technologies to cater 1000 times more service to users [3, 4]. Specifying their vision for the 2020 projects, the International Telecommunication Union (ITU) stated the requirements of the 5G technology as summarized in Table 1.

Table 1
Requirements for 5G Technology [1]

Parameter Standards	Forecasted
Data Rate	1-19 Gbps (resp 100s of Mbps)
Capacity	36TB/month/user (resp. 500 GB)
Spectrum	Higher frequencies & flexibility
Energy	~10% of today's consumption
Latency reduction	~ 1ms (e.g. tactile internet)
D2D capabilities	NSPS, ITS, resilience
Reliability	99.999% within time budget
Coverage	>20 dB of LTE (e.g. sensors)
Battery	~10 years
Devices per area	300.000 per access node

The 5G technology is not just broadening the horizon of technical aspects like increasing the coverage, speeding up the data rate or increasing the spectrum frequency, it is going to be a revolution in a communication of interfacing diverse application and more prominence to the artificial intelligence-based applications.

Changing the telecom landscape enables the technology drive towards human-centric, leading to machine-centric to redefine new challenges to mobility. The air interface, spectrum, and network devices are the main building blocks of wireless technology. However, there is a paradigm shift from the last decade to the next decade on how these categories are emphasized. In the last decade, more focus was given to the air interface and spectrum to have coordinated multi-point receivers and transmitters, 3D or full dimensional Multiple Input Multiple Output (MIMO), new modulation and coding schemes, more licensed and unlicensed spectrum, and sharing of unlicensed spectrum. However, the next decade is focused on the last category of the network devices and Information Technology (IT) for telecom. IT for telecom includes features like cell densification, WLAN offloading, integrated multiple RAT operations, Device-to-Device (D2D) direct communication, joint scheduling and non-orthogonal multiple access. Figure 1 depicts the transformation from the last decade to the next decade. The next decade will focus on the utilization of available network resources supporting more and more device-to-device communication. The control is from virtual cloud based systems and artificial intelligence based approaches [5, 6].

The new horizons are featured in 5G to support smart grid, cities and homes, and e-health applications. These applications require a different type of communications to acquaint into a single wireless technology to support voice and Internet services.

Visionaries of the 5G technology have laid the foundation by dividing the whole system into five Horizontal Techniques (HT), namely the mobile networks, massive multi-antenna systems, context-aware approach, interference and mobility management, air interface with adaptability for new applications and device-to-device communications. Focusing towards the network and transport functionality of the system, all applications are looking towards smart mobility service to be a promising one, which aids to be the foundation for all new applications envisioned on it [7, 8]. Table 2 summarizes the cutting edge between the current and the 5G network.

To enable all new horizontal features, the 5G wireless technology needs to be an ultra-broadband network worth rethinking, reconstructing and redesigning of approaches in mobile networks. The fundamental theory for 5G should be based on massive capacity and massive connectivity. The

new horizontal features mentioned above will enhance the connectivity and is expected to provide a hyper response. In reality, all these feature deployments are accompanied by many challenges from both the network and user perspectives. The subsequent sections explore these features, capabilities and challenges.

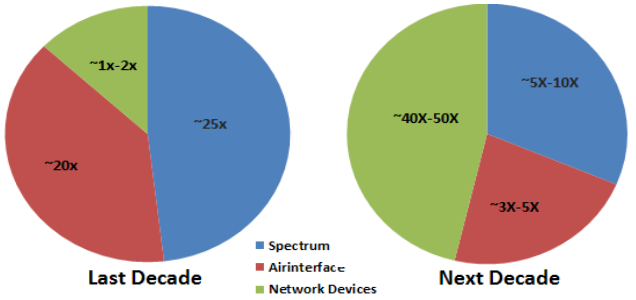

Figure 1: Transformation from last decade to next decade

Table 2
Specifications of Current and 5G Technology Features

	Current Generation	5G
Development	2010	2015
Data Bandwidth	200Mbps-1Gbps	1Gbps and above
Standards	Single unified	Single unified
Technology	Unified IP, seamless combination of LAN,WAN,PAN and WLAN	Unified IP, seamless combination of LAN,WAN,PAN,WLAN and WWWW
Service	Dynamic information retrieval, diverse devices	Dynamic information retrieval, diverse devices with AI capabilities
Multiplexing	CDMA	CDMA
Switching	All Packet	All Packet
Core Network	Internet	Internet
Web Standard	WWW(IPv4)	WWWW(IPv6)
Handoff	Horizontal and Vertical	Horizontal and Vertical
Others	HetNet, Relay, SON, V2V	Massive MIMO, Ultra-dense HetNet, SDN/NFV

This paper is organized as follows. Section 2 describes all the horizontal features of 5G and open research challenges. Section 3 describes the other features that are going to drive the next generation digital wave. Finally, Section 4 concludes the discussion.

II. Horizontal Features Driving 5G Network

Horizontal features are the new paradigm approach towards the upcoming complete wireless digital wave. Its fundamental goal is to provide anytime connectivity with user's satisfaction of service and efficient network resource utilization. These features are a new thought of connecting and decentralizing the services into multi-tier and controlling the applications with more AI-based approaches.

A. Ultra-Dense Networks

With the heterogeneity feature to satisfy the exponential growth of traffic that is expected to explode 500 times more than the current by 2020 [9]. The main motivation in 5G is towards energy efficiency, cell coverage and hyper-fast response. All these requirement's demands are hard to be achieved by a macro base station. Hence, the next generation digital wave needs a holistic approach to handle heterogeneous environment significantly. The macro base stations are further divided into micro-, femto- and pico-smaller base stations to offload the traffic [10]. The concept of small cells enables better network resource utilization and cost efficient to attain better Quality of Experience (QoE) for the users [11, 12]. Figure 2 outlines the typical ultra-dense network scenario.

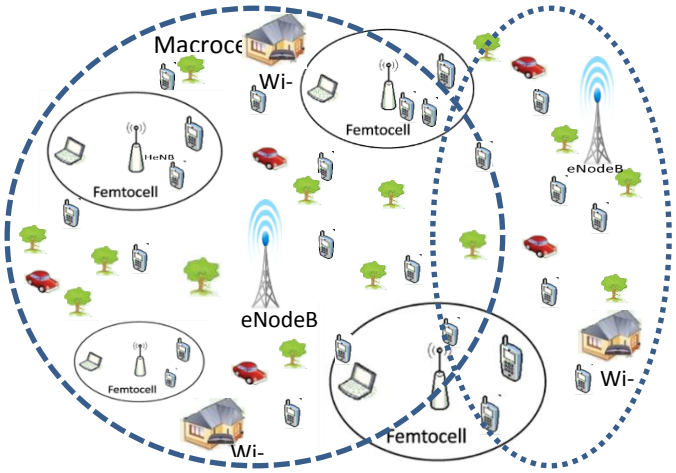

Figure 2: Heterogeneous Multi-RAT Environment

The small base stations require less power; consequently, the energy efficiency problems are resolved. This context possesses a win-win opportunity to the users and the operators.

Due to the random close deployment of multi-RAT access points, there is a frequent handover, which may result in a dynamic on-off of carrier selection. Frequent handovers will not only degrade system performance, but also consume power. Hence, it is an open research area to introduce intelligence in handling unnecessary handovers in the ultra-dense network.

B. Device to Device Communication

Earlier, Device-to-Device (D2D) communication was confined to devices pairing manually between each other through Bluetooth and Wi-Fi unlicensed bands. There was no issue of security, interference and power due to the low intensity communications.

The direct D2D communication is another promising technology to improve network capacity and user experience in the future 5G networks for local services in cellular backhaul networks. The direct D2D communication allows User Equipment (UE) to communicate with nearby UE without the intervention central base stations. D2D enables applications like voice-service, file sharing, context-aware applications and video-steaming [13, 14].

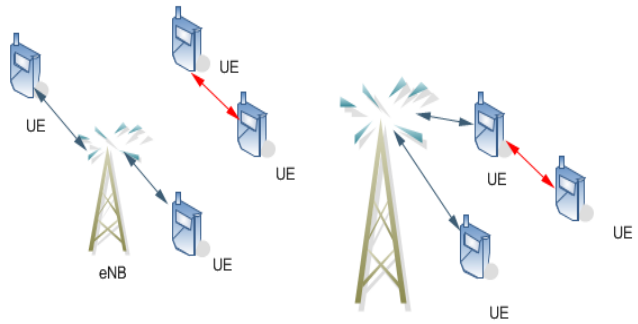

Figure 3: Device to Device Communication

Figure 3 depicts the D2D communication scenario both using the base station and offloaded direct D2D communication. The D2D communication offloads the traffic from the macro central base station to D2D local direct communication enhancing the coverage and capacity [15]. The close deployment of devices co-existing with central base stations and local D2D communication, definitely resolves load issues, but interface challenges may crop up. There are three major open research challenges in D2D communication: Firstly, the interference of management needs with the dense deployment of devices and the cellular base stations co-existence. The performance of the direct D2D communication should be better than the service through central base stations without interrupting the services of a core cellular network. Secondly, the direct D2D communication is a hop between the UE to UE, but the multi-hop is still an open research avenue toward attaining better throughput in cellular networks. Finally, the heterogeneity and multi-RAT environment postures for diverse research and design aspects to be addressed in D2D communication.

C. Massive Multi Input Multi Output

On a path to meet the exploding demand, additional spectrum band and high spectrum efficiency approaches are required. The new spectrum bands alone may not satisfy the 500-fold increased traffic and device communication. Hence, advanced MIMO techniques need to be incorporated to attain high spectral efficiency using available bands by multiplexing them intelligently.

The MIMO concept was introduced by 3GPP in LTE-Advanced, but 5G infrastructure needs massive MIMO technique to serve massive devices without congestion. The massive MIMO antenna deployment is illustrated in Figure 4.

Massive MIMO is based on spatial multiplexing, depending on the uplink and downlink information from base stations and comprises multiple antennas that associate a user to an antenna in highly dense network [16], receiver and transmitters. The heterogeneous network scenarios design should consider user association schemes to base stations[16]. The max-RSS based scheme may bias the user towards macro-base stations forcing imbalance in the traffic.

A large number of antennas deployed should have proper interplay between the user and the associated antenna associated to avoid high power consumption and complex signal processing. The main challenges for massive MIMO are adopting intelligent and efficient schemes too.

Numbers of antennas are increased massively from 8 to 64

Figure 4: Massive MIMO

D. Heterogeneous Multi-Rat Environment

There will be numerous devices and interconnected networks that drive the heterogeneity feature by enabling different cell sizes and access points of diverse RAT to provide the smooth operating environment [17, 18]. Hence, it is essential to set up heterogeneous infrastructure for future Internet.

Multi-RAT is an environment, which comprises more than one RAT in an integrated environment [19, 20]. It comprises both licensed and unlicensed (Wi-Fi) technologies that co-exist with each other. The implementation of vision multi-RAT in small cells and WLAN is to balance the load and attain high spectral efficiency along with uniform user experience. The 5G devices are designed for multi-interface to different RAT. Figure 2 illustrates the typical heterogeneous multi-RAT environment.

The challenge encountered by multi-RAT is the appropriate RAT selection to serve the diverse application. The max-RSS and SINR based will not be efficient to the emerging complete wireless technology. Hence, research in context-aware multi-criteria based RAT selection is an open research area towards better performance.

III. Other Drivers to 5G Wave

A. Context-Aware Services

Context is the concept that requires the system to sense dynamically and react to the changes in the context. A recent definition of context is defined as ‘any information that can be used to characterize the situation of an entity, where an entity can be a person, place, or physical or computational object’. The definition of context is further extended to be related to context-awareness or context-aware computing and defined as ‘the use of context to provide task relevant information and/or services to a user, wherever they may be[21]. This technique comprises the components, namely the mobile terminal, network and user preference contextual information for wise decision making [22].

Definitely, the evolution of horizontal techniques discussed in the previous section enables physical and technical drive. However, to achieve hyper-response and uniform user experience in ultra-sense network a context-aware action is required. For instance, the handover in between the RAT is traditionally based on max-RSS approach, which is not adequate and efficient for the 5G wave environment. A context-aware approach would be more appropriate towards a better performance.

B. Mobile Cloud Computing

Mobile cloud computing is another evolving technology that enables adaptability and scalability for mobile devices. This integrated technology provides cost efficient services for computing and storage for applications over the Internet. Mobile cloud computing enhances plug and play approach along with context-aware service to mobile devices [23].

Radio access network as a service functionality is emerging for partly centralized controlling with a cloud platform enhancing storage and processing abilities [24]. The coordination of the densely deployed small cells with multiple RAT co-existences needs a rapid computing and switching ability to handle mobile devices.

C. Software Defined Network

The densely deployed small cells need a platform to connect RAT network as a service platform. Hence, operators need a strong and simplified network management while saving cost.

The concept of virtual network management and operation, which can be implemented by Network Function Virtualization (NFV), and Software-Defined Networking (SDN) are the main elements of network design to support the new chunks of wireless communication in the future. SDN enables adequate resource control towards enhanced QoS. The control plane and user plane may be handled separately and efficiently in the new architecture. In the wake of attaining all the 5G technology bandwidth, there will be inevitable challenges in the future [25].

IV. Conclusion

In this article, we first reviewed the different features and capabilities of the upcoming new digital wave 5G. The new horizontal features to support 1000 fold that increase connected devices are highlighted and the challenges encountered in real deployment are explored in brief. With the application features, there is a need for controlling and making decision according to the context-awareness. Additionally, a need for virtual software defined network is of essence for coordinating dense network.

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