The Role of 5G Wireless Communication System in the Metaverse

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***Abstract*—The metaverse is a virtual world that is based on numerous technologies. One of such technologies is the wireless communication system. Specifically, 5G wireless communication will have a role to play in the development of the metaverse. Since the metaverse has features that require certain service requirements, it is necessary to analyze the specific benefits that 5G has to offer. The aim of this paper is to discuss the features of the metaverse, the service offerings of 5G standards of communication, and how 5G can help make the metaverse a reality.**

***Index Terms*—Metaverse, wireless communication, networking, virtual reality**

I. Introduction

THE term "metaverse" was originally coined by *Neal Stephenson* in his science-fiction 1992 novel titled *Snow Crash*. In 2018 a science-fiction movie titled *Ready Player One* also portrayed the idea behind the metaverse. Metaverse is a virtual online world that allows avatars of real people to connect. It can also be defined as a virtual world that mirrors the real world [1]. There are numerous definitions for the metaverse. Most of the definitions of metaverse claim that it encompasses different technologies including the Internet and virtual and augmented realities [2]. However, based on the expectations and requirements of the metaverse, it encompasses much more. The metaverse promises to exploit these different technologies to enable an advanced kind of internet application that combines the virtual and real world into one space.

Technologies such as wireless communication and networking will be a key support system for the metaverse [3]. The evolution of digital communication began with the first generation (1G) networks which only supported voice services. 2G came with improved voice and text messaging properties with low data rate services. One gap which was not resolved by 2G was the need for mobile internet access. This was rectified by the 3G network services. The 3G standards provided both rapid data services and higher capacity for voice services. The not so outdated 4G mobile communication systems introduced mobile multimedia with high capacity and high rate data service. Every generation of communication network revolves around a set of use cases. The 5G communication system had the prospects of providing ultra-reliable and low-latent communications, massive machine-type communication and enhanced mobile broadband.

A. Contributions

The 5G wireless communication standards are designed to enable low-latent and highly reliable communication systems. Wireless 5G communication has already laid a solid foundation for the integration of virtual reality (VR), augmented reality (AR), mixed reality (MR) and digital twin (DT), among others [4]. However, is 5G technology ready for what the metaverse entails and requires? Can the current wireless communication systems support the metaverse?

The objective of this paper is to analyze the requirements of the metaverse, the role that 5G connectivity has to play, and how it can support the requirements of the metaverse.

B. Road map

The rest of this paper is organized as follows. In Section II, a brief overview of the concepts and features of the metaverse is discussed. The devices necessary to access the metaverse are also discussed. In Section III, the 5G standard and its requirements are discussed. Section IV analyzes the potential of 5G wireless communications to support the metaverse, while Section V concludes the paper.

II. Brief Overview of the Metaverse and Its Service Requirements

The metaverse refers to a three-dimensional virtual world that allow virtual characters to interact with each other [2]. These characters can be virtual humans or avatar representations of real humans. This section will dissect some of the concepts of the metaverse, the necessary devices, and the features of the metaverse.

A. Concepts of Metaverse

1) Avatar: The conventional understanding of an avatar is that it is a computer icon that represents the character of a person in a game. However, it is much more. In the metaverse the avatar is similar to the concept of digital twin. It is the digital form of a human. The avatars in the metaverse replicate the movement and gestures of the human [5].

2) Extended Reality (XR): Extended reality (XR) is an umbrella that includes VR, AR, and MR. While VR allows remote control of virtual objects from the real world, AR allows the control of real objects using virtual control. With AR, virtual objects can be overlaid on real objects. MR integrates VR and AR and creates a union of the virtual and real world,

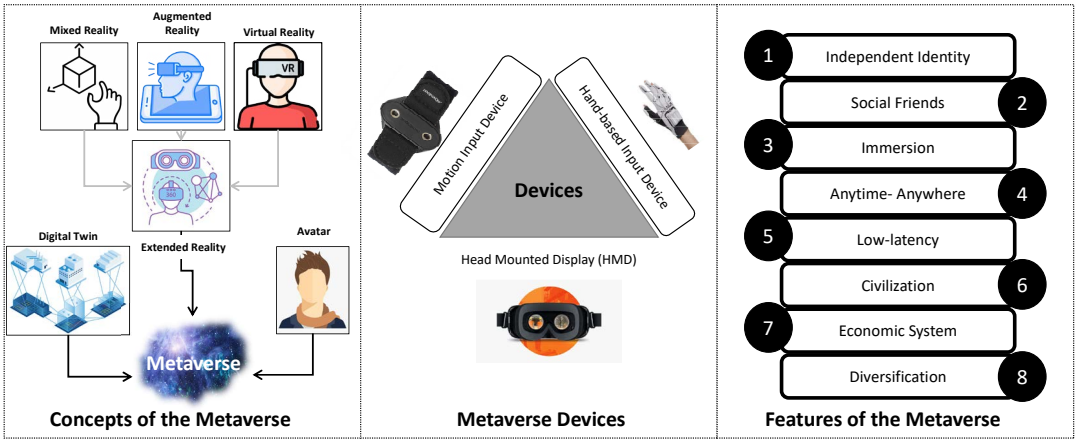

Fig. 1. Summary of the Concept, Devices and features of the metaverse

so that users can seamlessly interact from one world to another [5].

3) Digital Twin: Digital twin is the virtual or digital representation of an object or scenario that exists in the real world. For a digital twin to exist, there has to be a physical object in the real world, equipped with the necessary sensors to allow for the replication into the digital form.

B. Metaverse Devices

To successfully access the metaverse and begin interaction with other avatars, certain devices are very necessary. These devices fall into three categories: (1) head mounted devices (HMDs), (ii) motion input devices, and (iii) hand-based input device [5].

1) Head mounted displays (HMDs): HMDs are VR headsets that utilize technologies like accelerometers, gyroscopes and magnetometers with a head mounted display and provide virtual images for the user. While VR uses HMDs, AR uses a special type of glasses that help visualize virtual objects in the real world. HMD provides a good level of immersion, unlike AR glasses. These devices track the movement, orientation and position of the users head and projects the adequate image for the specified direction.

2) Motion-input device: Motion-input devices help to monitor user motor movements and enable easy interaction with the virtual world. Meta Company is currently working on a wrist-based band that can read motor movements [1].

3) Hand-based input device: Hand-based input devices such as VR haptic gloves enable one to feel virtual objects as if they were real. Haptic devices create virtual pressure using its active haptic and give the texture feel of real objects using its active haptic.

[1]https://businesstech.co.za/news/mobile/595156/meta-working-on-other-devices-for-the-wrist/

C. Features of Metaverse

According to Roblox, an online gaming platform, there are currently eight metaverse features. These include civilization, independent identity, immersion, anytime-anywhere, social friends, economic system, low latency, and diversification [6].

1) Independent identity: To enter the metaverse and interact, it is necessary to have an identity. This is the basic requirement for the metaverse.

2) Social friends: One of the sole goals of the social metaverse is to connect with people. When you connect with people, you can make friends.

3) Immersion: To further enjoy the experience and feel like you are close to the next person, there must be a reasonable level of immersion.

4) Anytime-Anywhere: There should be no restriction on location, so that regardless of where you are and what time you are, you can access the metaverse.

5) Low latency: To have a worthwhile experience, low latency is also very necessary, otherwise reactions, interactions, speech signals, and responses will be very slow and delayed. There must also be low friction, allowing you to access any location instantly.

6) Civilization: There is a need for safety and stability in the metaverse. People need to be able to enhance digital civility while networking.

7) Economic system: For the metaverse to embody attributes of the real world, it is necessary that there be a vibrant economy, in which people can create and sell services, thereby making a living, regardless of their occupation.

8) Diversification: To continuously engage metaverse users, it is important that there is a variety of content available to them.

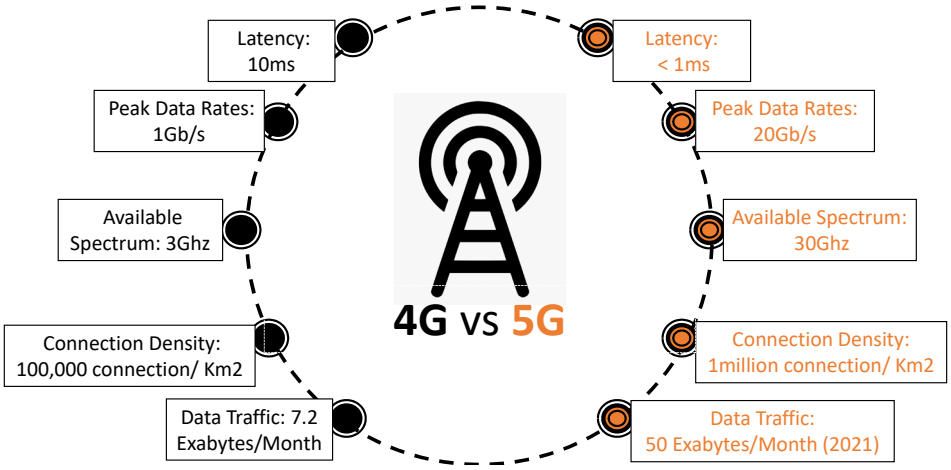

Fig. 2. Differences between 4G and 5G communication systems

To realize all features of the metaverse, there needs to be considerable advancement in the communication technologies available.

III. Brief Overview of the 5G Requirements

This section describes the 5G communication characteristics, which have been grouped into three communication services namely: Enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (uRLLC) and Massive Machine-Type Communications (mMTC) [7].

A. Enhanced Mobile Broadband (eMBB)

One key characteristic of the 5G communication standard is that mobile broadband services are enhanced to achieve uniform coverage with increased data rate demands. To enable this, the data rates increased from 1Gb/s in the previous 4G technology specification to 20Gb/s in IMT-2020 systems that work under 5G. Thus 5G provides higher user data rate link, enabling data rates that are 10 to 100 times more than that offered by 4G. Another feature of this communication service is that the quality of experience(QoE) in 5G systems is much better and faster, compared to 4G, as the user-experienced data rate is 10-times more [8].

B. Ultra Reliable Low Latency Communications (uRLLC)

One main performance measures of 5G is latency. 5G systems have to deliver services with a service latency that is lower than 1ms, while transmitting at 300miles/hour [7].This latency requirement was a huge leap from the previous 4G technology which was pegged at 10ms. with this standard, so many real-time systems such as autonomous vehicles and VR/AR systems will be a success. The second offering of this service is that 5G systems should be able to deliver services that have over 99.999% availability, even in extreme scenarios. Such systems should be ultra-reliable and have a system delay that is less than 5ms. All of these are aimed at helping to reduce energy consumption by more than 90%. This is 10 times less than what the 4G communication system offers [8].

C. Massive Machine-Type Communications (mMTC)

The last but not least of the service characteristics of 5G is that it can support an expanded number of devices enabled by the wireless network. With an extended coverage area, it can deliver efficient transmission of little payloads over a massive number of devices. With such massive connectivity, more devices that are up to 10 to 100 times more than that supported by the 4G communication systems [7], [8].

Fig 2 summarizes the difference between the 4G and 5G communication systems

IV. Potential of 5G Wireless Communication to Support the Metaverse

A. Why Choose 5G Technology ?

The current 5G standards were adapted to meet the demands of wireless communication of industries, improving performance in numerous applications and scenarios [9]. The metaverse also has numerous scenarios and employs diverse technologies which all enable much of the contents within the standards of 5G to form a support for the metaverse. For example, some of the capabilities requirements of the metaverse include low latency, high reliability, large connections, large bandwidth, and low power consumption [10].

Devices are like the portals between the virtual and physical world. Today, we use certain devices, such as keyboards and touchscreens, to access digital devices. This also applies to the metaverse. Metaverse devices have the task of translating information from the physical to the virtual world and vice versa. Access to the virtual world of the metaverse and the inherent haptic interaction is enabled using XR devices. Moreover, the function of sensing the environment is done using a plethora of sensors, all form the internet of things

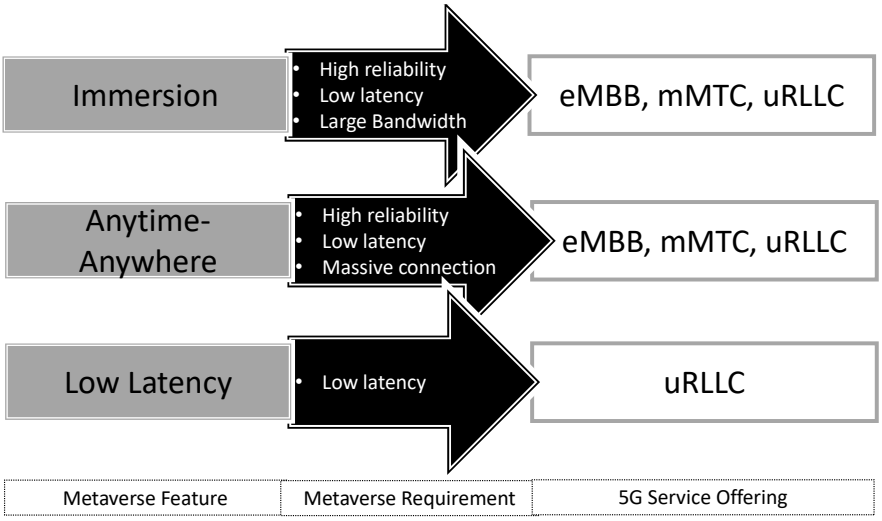

Fig. 3. Potential of 5G as a support for metaverse

(IoT). Such sensors include lidar sensors, volumetric capture cameras, gloves, haptic devices, motion wristbands, etc. All of these devices have one common requirement to be able to achieve the desired service with adequate comfort and cost: They need a reliable and secure network. These devices need to be linked to the least possible latency. Computational tasks need to be offloaded away from these devices to the edge in order to achieve balance [11]. This means that data will continuously flow back and forth between AR/VR devices and the edge/cloud within some amount of milliseconds, at a low latency and high data rate. Thus it is paramount to utilize a wireless connection that is not only reliable, but also secure and low latent. The only technology that has been proven to be able to achieve these is the 5G.

Furthermore, though there are a couple of wireless connectivity solutions such as Bluetooth, WiFi, and cellular technologies. All of these fail to include certain critical elements for ubiquitous access. While WiFi can offer the required data rate, it suffers from network congestion and would lead to very high latency, once numerous devices are connected. In a similar vein, Bluetooth fails with regards to reliability, data rate and coverage. Although WiFi7 proposes to address the congestion issues of WiFi, the range offered isn't close to that offered by cellular technologies. The 5G offerings are much more with respect to range, reliability, latency, data rate, etc [12].

B. 5G Standards and The Metaverse

The evolution of the 5G standard has resolved many of the specific tasks of the metaverse. One of such tasks is XR, which is an umbrella that encompasses all other realities (VR, AR, MR), and is the main interface for the combination of the virtual and real world for the metaverse. XR research in the 5G standard began in 2019 at the 86th plenary meeting of the 3GPP RAN that was held in Spain [13]. At this meeting, the 3GPP standard experts presented the R17 5G evolution standard, which consisted of a total of 23 projects that covered three main directions: capability refinement, network intelligence, and business extension. *Qualcomm* proposed an evaluation research project on how 5G NR can support XR [4], [14]. XR poses a huge challenge to 5G networks, since it requires low latency, high reliability and large bandwidth. As a result novel network optimization methods are required to meet up with the requirements.

Three specific features of the metaverse will place higher demands on wireless communication networks. These include: Immersion, anytime-anywhere, and low latency [3].

1) Immersion with 5G: For an adequate sense of immersion to be realized, the virtual world will exist as an alternative to the real world and this virtual world will be accessed through a door made accessible by VR, AR, and MR, among other devices. Thus, not only does device performance need to be enhanced, but the communication that occurs between edge, cloud, and device needs to be achieved wirelessly, putting forward specific requirements for the existing 5G network. This feature of immersion will require a network that is highly reliable, allows massive connectivity, and at a low latency. These can be addressed by the 5G eMBB, nMTC, and uRLLC solutions.

2) Latency with 5G: Another feature of the metaverse is low latency and high synchronization, enabling users to have a smooth and real-time experience. Synchronization of the real world with the virtual world requires a highly reliable communication network. This is a critical feature of the 5G network, as it promises to provide Ultra-reliability and low-latency communication (uRLLC).

3) Being anywhere at anytime with 5G: Finally, the metaverse promises that people can be anywhere at anytime and easily access the metaverse, thus breaking the barriers that time and space can create. To realize these, the metaverse needs to be connected to the network at all times. This feature of spatio-temporality will require a network that is highly reliable, allows massive connectivity and at a low latency. These can be addressed by the eMBB, nMTC and uRLLC solutions of 5G.

In addition, for the metaverse to be successfully deployed and pervasive, the following non-connectivity issues have to be addressed: application interfaces (APIs) must permit developers access to 5G, and integrating APIs into busniess logic must be seamless. Borrowing a leaf from the success in the standardization of the internet, there is need for uniform standards for telco companies in 5G deployment and building metaverse ecosystem standards [3], [15].

V. Conclusions and Future Works

This work presents the concepts and requirements of the metaverse and how 5G can be an enabler to its realization. The metaverse promises to be the future of web 3.0 with high demand for full connectivity and reliable user experience. To this end, the 5G service offering and standards are touted to meet these demands. However, 5G service provision alone can not guarantee the full implementation of the metaverse. It is a future research direction to investigate the role of metaverse ecosystem players and the coming 6G network as 5G comes with its own challenges of spectrum availability, and network densification.

Acknowledgments

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