5G will Popularize Virtual and Augmented Reality : KT's Trials for World's First 5G Olympics in PyeongChang*

Extended Abstract

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Figure 1: KT demonstrates a Virtual Reality Experience of the 2018 Winter Olympics (Press Conference, March 14, 2017)

ABSTRACT

As the telegraph and the Internet served in the previous industrial revolutions, the fifth generation (5G) network works as a general purpose technology (GPT) for the Fourth Industrial Revolution. Virtual and augmented reality, one of the most attractive technologies leading the Fourth is ideal for 5G, benefitting from enhanced bandwidth and latency. KT's attempt to showcase various virtual and augmented reality services for the world's first 5G Olympics in 2018 will be historic.¹ The world will take the first step into the 5G era and get a glimpse of the infinite possibilities of VR/AR.

KEYWORDS

Virtual Reality, Augmented Reality, the Fourth Industrial Revolution, 5G, GPT (General Purpose Technology), KT, 2018 Winter Olympics, ACM proceedings

1 INTRODUCTION

Since Facebook's 2014 acquisition of Oculus Rift in a US\$ 2 billion deal, virtual and augmented reality have continuously captured significant attention and investment from countless global giants such as Google, Microsoft, Apple, Samsung, and Alibaba. However, the current market adoption rate is somewhat disappointing. The actual VR/AR sales in 2016 were below the forecast by market research experts such as Fortune and Goldman Sachs.

Recent surveys on VR/AR point out numerous hurdles for VR/AR's large-scale adoption – expensive hardware, bulky equipment, lack of contents, dizziness, regulation, technical limitations and so on. As for TVs, PCs and mobile phones, the cost of hardware will fall to more affordable levels soon. With the improvement of component technologies and embedded technologies, the equipment and contents will evolve rapidly. Regulation will also find a way to accommodate the increasing needs of VR/AR. The biggest

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remaining problem is the infrastructure which should seamlessly deliver a massive amount of data traffic generated by VR/AR. With massive bandwidth and ultra-low latency, the fifth generation (5G) network will be the catalyst spurring mass use of VR/AR.

This paper examines the characteristics of the Fourth Industrial Revolution and discusses the role of 5G as a general purpose technology (GPT). It also addresses the attributes of VR/AR and looks at the future of VR/AR. It then presents the case of KT which will provide various 5G VR/AR trial services in the world's first 5G Olympics in PyeongChang next year.

2 THE FOURTH INDUSTRIAL REVOLUTION AND THE IMPORTANCE OF 5G

2.1 The Fourth Industrial Revolution

2.1.1 Arrival of the Fourth Industrial Revolution. The past few years have brought a series of game-changing technological innovations in various fields such as artificial intelligence (AI), robotics, the Internet of Things (IoT), autonomous vehicles, 3D printing, cloud computing, biotechnology, and VR/AR. Advances in each technology and the convergence among them have triggered the Fourth Industrial Revolution, which will change the way people live, work, and relate to each other [1]. Previous industrial revolutions, which have centered on improving productivity and connectivity, have created major socioeconomic changes and opportunities. The First Industrial Revolution introduced mechanical production facilities powered by water and steam. The Second used electrical power to open the era of mass production. The Third introduced electronics and information technology (IT) and made automation of production possible. The arrival of the Fourth Industrial Revolution can be characterized by a fusion of technologies among the physical, digital, and biological spheres [1]. Schwab points out that it is distinct from the previous ones because it is evolving at an exponential velocity with unprecedented breadth and depth. These disruptive changes are great enough to transform the entire industrial, social, governmental systems in almost every sector in every country [1, 2].

2.1.2 Industry 4.0 and Digital Transformation. The Fourth Industrial Revolution has been discussed by many business organizations focusing on the industrial changes, and thus is often referred to as 'Industry 4.0.' The core of Industry 4.0 lies in the 'connectivity' between digital and physical systems while the Fourth Industrial Revolution embraces biological aspects as well. Hence, Industry 4.0 is defined as a 'Cyber-Physical System (CPS)' focusing on the end-to-end digitalization of all physical assets and integration into a digital ecosystem [2-5].

Digital technology has penetrated all sectors. The average level of perceived digital penetration across all industrial

sectors in 2016 reached about 33 percent, according to PwC. It is expected to increase up to 72 percent within five years [4, 6]. Billions of people around the world are already connected by mobile devices, and many companies are trying to embrace digital transformation and create opportunities from it. Hence, as the digital penetration deepens, the world will see more unprecedented breakthroughs like Uber, Pokémon Go or Google Earth VR. Digitalization is expected to transform the entire industrial system not only by digitizing products and service offerings, but also by integrating vertical and horizontal value chains. Also, as business models and processes are digitized more and more, customer power with access and involvement will increase as well [4]. Individualization and customization are now becoming key trends of Industry 4.0, along with optimization and extreme automation of production.

2.2 5G as a GPT (General Purpose Technology)

2.2.1 Increasing Demands and 4G Limitations. Powered by the digitalization of the economy and society and the connection between physical and digital worlds, the success of the Fourth Industrial Revolution heavily relies on the connectivity, capacity, and reliability of telecom networks. According to DBS, global mobile data traffic is expected to increase by more than eight times from 3.7 Exabyte (EB) per month in 2015 to 30.6EB per month in 2020, as more people use smartphones and other connected devices [7]. The current fourth generation (4G) telecom services have offered faster broadband internet with lower latency than those of 3.5G or 3G networks. However, 4G faces limitations in meeting the demand of massive data traffic and in serving many advanced technologies. Thus, telecom network providers are already conducting experiments on 5G, and KT is leading the pack with the aim of launching the 5G commercial network in 2019.

2.2.2 5G as an Enabling Infrastructure for Extreme Connectivity. The Next Generation Mobile Networks (NGMN) Alliance defines 5G as "an end-to-end ecosystem to enable a fully mobile and connected society" [8]. Though 5G technical specifications are not yet standardized, 5G is expected to fulfill the following requirements [9]:

- 1 ~ 10 gigabit per second (Gbps) connection to endpoints in the field
- One millisecond end-to-end round trip delay (latency)
- 1000x bandwidth per unit area
- 10 ~ 100x number of connected devices
- (Perception of) 99.999% availability
- (Perception of) 100% coverage
- 90% reduction in network energy usage
- Up to ten-year battery life for low power, machine-type devices

With massive connectivity and ultra-high reliability with millisecond latency, 5G can serve as the enabling

infrastructure for upcoming technologies such as autonomous vehicles, connected wearables, IoT, augmented reality, and virtual reality [7]. As shown in Fig. 2 [10], GSM Association (GSMA) compares mobile operator's future business opportunities. One evolved from the 4G networks and ripened with a more efficient 5G system, and the other newly created by 5G. Whereas business opportunities have focused on the mass market, one of the greatest benefits of 5G is that it can create and spur new additional commercial possibilities by targeting niche segments and even individuals within industry verticals [10].

Figure 2: The 5G Opportunity Framework

2.2.3 5G as a General Purpose Technology (GPT). General purpose technologies (GPTs) are radical new technologies that have significant impact throughout the economy. GPT works as a catalysts for transformative changes in the entire industrial ecosystem. [12, 13]. The steam engine, electricity, and the internet were the main GPTs for the previous industrial revolutions [13]. Recently, 5G has come to be regarded as a GPT since it shares key characteristics of GPTs including pervasive use across many industries and sectors, the innate potential for continual improvement over time, and the ability to spur new advancement [12, 13]. Moreover, 5G is expected to be a future platform for innovation since it is capable and flexible enough to support new and unforeseen services of the future.

International Telecommunications Union (ITU) defines three broad classifications of 5G use cases – 1) Enhanced Mobile Broadband, 2) Massive Machine Type

Communications, and 3) Massive Internet of Things [11]. Some foreseeable use cases for each category are listed in Table 1 [13].

Table 1: 5G Use Cases Framework

	Use Cases (Examples)
Enhanced Mobile Broadband	Enhanced wireless broadband, enterprise teamwork/collaboration, augmented and virtual reality, extended mobile computing, enhanced digital signage
Massive Machine Type Communications	Autonomous vehicles, drones, industrial automation, remote patient monitoring/e-health, smart grid
Massive Internet of Things	Asset tracking, smart homes, smart agriculture, smart cities, energy/utility monitoring, remote monitoring, connected shoppers

3 VIRTUAL AND AUGMENTED REALITY: FUTURE REALITY IN THE 5G ERA

3.1 VR/AR Connecting Physical-Digital Worlds

3.1.1 Defining VR/AR. VR and AR lie within a spectrum of artificial reality, which was first introduced to the public by American computer scientist Myron Krueger in the 1980s. Today, the term embraces a wide range of technologies that blend physical and digital worlds and make users feel artificial experiences as real [14]. Though the lines are not clear, artificial reality technologies can be categorized as VR, AR, and MR as seen in Fig.3 [16]. VR technology allows users to fully interact with computer-generated cyber objects in a simulated environment, whereas AR technology displays overlaid and tailored digital information and image onto a user's physical field of view. MR is a hybrid system which technically belongs to a realm of AR, and it combines real and virtual objects to produce a new environment where users can interact with both objects. [14, 15].

Figure 3: Reality-Virtuality Continuum

AR technology became well-known to the public through popular apps such as Pokémon Go and Snapchat's signature

camera filters. Google Glass is the best-known device for AR while Microsoft HoloLens and Magic Leap are representative examples of MR. Augmented and mixed reality aim to blend digital objects with existing physical reality of users while the users remain present at the location of experience. In other words, users can interact in real-time with his or her physical environment. In contrary, in virtual reality, users do not maintain a presence in the actual environment and are instead immersed in a simulated reality. Sony's PlayStation VR, Oculus Rift, HTC Vive, and Samsung Gear VR are popular devices for VR. Currently, head mount device (HMD) manufacturers produce separate VR or AR/MR devices. However, it is expected that HMD features and functions will be integrated in the near future since they have similar underlying technologies, blurring the lines of VR and AR/MR [14].

3.1.2 VR/AR to Embrace Human Senses. Virtual and augmented reality technologies have evolved to enhance user's digital experience and immersion level. AR and MR try to seamlessly merge the real environment with virtual objects while VR tries to maximize immersive reality in virtual worlds. Seamless integration and full immersion might be achieved when all six human senses are stimulated as they are in the physical world, within the reaction time of the human body.

The way humans perceive reality entails two basic processes, sensation and perception. Six human senses such as vision, hearing, taste, smell, vestibular (balance), and haptics (touch) work as inputs for perception. In order to trick human brain and to interfere its perceptive system, the six senses must be hacked, and computer-generated and artificial sensations should be created [14, 17].

Figure 4: Six Human Senses to Be Simulated

As in Fig.4, vision and hearing are the two most conquered senses thanks to the advanced technologies such as 360-degree video and 3D audio. Also, great strides have been made in haptics and vestibular. Though expensive and cumbersome, haptic gloves and suits are already on the market, and there already are some theme park attractions that combine HMDs and other riding or flying type machines.

Though taste and smell sensory signals seem hard to fabricate, there are many ongoing scientific trials.

3.1.3 Accelerating Technologies Needed. To make the real world and virtual reality indistinguishable, necessary technical accelerators should be ready in the market including gesture recognition, brain-computer recognition, AI, robotics, Big Data, and wearables. The development of each technology boosts others, and they tend to increase the capability of the entire IoT ecosystem [14]. According to Gartner's Hype Cycle 2016, as seen in Fig.5 [18], the necessarily embedded technologies such as brain-computer interface and gesture control devices, and IoT platform are still in the technology trigger stage. They are expected to take more than five years to become mature enough to be adopted in the mainstream market. AI technologies such as machine learning and smart robots are now in the middle of over-excited interest, but they are also probably more than five years away from becoming part of the mainstream.

Figure 5: Hype Cycle of VR/AR and Embedded Technologies

VR/AR technologies are in the stage of enlightenment and show possibilities of mass adoption. In the past three years, many global giants like Facebook, Google, Microsoft, Apple, HTC, Sony, and Samsung have competitively launched 1st generation products, some of which have proved profitable. Though we must wait for more than five years to experience fully immersive VR/AR stimulating all six senses, VR/AR will incessantly develop and expand its applications. It is hard to pinpoint when exactly VR/AR will be pervasive in our lives. However, many industry experts point out that some killer contents with enhanced resolution and sound can trigger the early mass market of VR/AR.

3.2 5G Makes VR/AR a Future Reality

3.2.1 5G Enables Full-fledged VR/AR. The possibility of large-scale adoption of VR/AR heavily depends on network capabilities of higher capacity, lower latency, and consistently high data rate. Richer and immersive contents will require faster response time and more control over real

and virtual objects. Although preliminary services of these types may be delivered through 4G, large-scale adoption and usage may cause congestion and jitters, thus ruining the entire user experience.

Many currently available VR and AR services may fall into categories of video streaming, real-time gaming, or multi-person video calling since they are usually provided with low resolution (less than 4K) in the 4G network and with less than 50Mbps bandwidth. Consequently, current VR services provide a low immersion level and often provoke dizziness. Since human vision sense can be compared as 12K regarding resolution, the large discrepancy between the actual and virtual sights causes discomfort in the form of dizziness, which hinders further immersion. Higher resolution (8K) 360-degree video requires bandwidth from 50 Mbps to 200 Mbps. Fully immersive VR/AR services, powered by AI, gesture control, brain-computer interaction, and IoT platform, will be realized in a 5G network with 1Gbps bandwidth and ultra-low latency (down to ~1ms) as seen in Fig.6 [10].

Figure 6: 5G Supported Matrix

3.2.2 VR/AR Becomes Future Reality. By combining physical and digital objects and connecting to the human sensory system, VR/AR will offer unprecedented experiences and unlimited possibilities. As the technology becomes more affordable, effective and user-friendly, more companies and organizations will find a way to incorporate VR/AR solutions into their business and workflow. Over 150 companies in multiple industries have already deployed or are testing VR/AR solutions, and 52 enterprises among them are listed in the *Fortune 500* [15].

According to Goldman Sachs, as in Table 2 [19], VR/AR software is expected to generate US\$ 35 billion by 2025. Specifically, it is expected that 54% of the revenues will come from entertainment areas such as video games, live events, and video entertainment, while the rest will come from diverse areas including healthcare, engineering, real estate, retail, military, and education. Though not listed below, other business areas such as journalism,

advertisement, tourism, and social networking services also have already started to seek business opportunities in VR/AR. VR/AR will continuously create unforeseen markets and lucrative business opportunities while disrupting or merging existing ones, thus eventually affecting every part of our lives.

Table 2: VR/AR Software Revenue Estimate by 2025

	Software Revenue	Percentage
Video Games	\$11.6bn	33%
Live Events	\$4.1bn	12%
Video Entertainment	\$3.2bn	9%
Healthcare	\$5.1bn	15%
Engineering	\$4.7bn	13%
Real Estate	\$2.6bn	7.4%
Retail	\$1.6bn	4.6%
Military	\$1.4bn	4.0%
Education	\$0.7bn	2.0%
Total	\$35.0bn	100%

Moreover, VR/AR will radically change the way we work by transforming industry value chains and communication methods. With increasing digitization of the overall industrial processes and integration of value chains, VR/AR will become widely adopted in product design, production, distribution, sales, and marketing. According to Merrill Lynch, VR/AR has great potential in boosting productivity (30% faster assembly), reducing costs (25~60% savings on installation & maintenance), and improving outputs (40~90 % accuracy) [14].

Soon, it may be possible for individuals to have a multi-use device which incorporates both VR and AR and serves as the next-generation computing platform. It could be an advanced smartphone or everyday eyeglasses that can unlock and display information and communicate with it. Since millennials (born 1981 ~ 1997) and Generation Z (born 1998 ~ present) will lead the mass adoption and use of VR/AR, the speed and scope of VR/AR spread will become even more difficult to grasp.

4 KT's Hyper-Reality Service Trials for World's First 5G Olympics in PyeongChang

4.1 KT's 5G Vision, GiGAtopia

A global first, KT plans to launch 5G trial services during the 2018 Winter Olympics in PyeongChang and plans to commercialize the world's first 5G mobile service in 2019. Because more than 3.5 billion people watch each edition of the Olympic Games [21], KT's 5G trials can generate surprisingly high interest in 5G. Through the 2018 Winter Olympics, KT will demonstrate its 5G technology and trial services, and the world can see how they actually work.

This historic and ambitious plan is a part of KT's 5G master plan. During the Mobile World Congress 2015, KT declared its 5G Vision, GiGAtopia. GiGAtopia envisions that KT enables a much more convenient life, provides well-being to everyone and creates a new value-innovating convergence world. GiGAtopia will be realized through a 5G GiGA infrastructure that will provide secure connectivity for a tremendous amount of mobile data traffic. It will also enable an innovative cloud platform that will facilitate efficient and rapid deployment of various future services. Convergence services of GiGAtopia can be categorized as hyper-connected convergence services such as IoT, robots, and autonomous vehicles, hyper-knowledge services utilizing big data, and hyper-reality services such as VR/AR and 3D holograms. [20].

4.2 World's First VR/AR Trials in 5G

As a sponsoring telecommunications operator of the PyeongChang Winter Olympics in 2018, KT has put its best efforts to successfully demonstrate the world's first 5G services in the Olympics. KT's first test event was conducted successfully in February 2016, followed by a 5G field test with upgraded services in December. In March 2017, KT held the 'Hello PyeongChang' event in PyeongChang with many key 5G services such as VR/AR/MR services, a 5G autonomous driving bus, and drone delivery. Listed below are the key VR/AR/MR services that KT demonstrated at the time, and which will be delivered in the 2018 Winter Olympics.

4.2.1 Omni Point View. As seen in Fig. 7, the service provides multiple live angle views and 3D virtual services. Through various technologies such as Omni view platform, GPS sensor, and 3D VR, users can choose the desired scene and view real-time video in mobile or enjoy immersive VR with HMD. The service was tested and technically verified during the Cross Country World Cup held by International Ski Federation (ISF).

Figure 7: Omni Point View

4.2.2 360-degree VR Live. To make the exciting and touching moments more immersive, KT will provide 360-degree VR service at diverse zones in real-time so that users can choose the view and enjoy the athlete's virtual presence with HMDs as exemplified in Fig.8. This service was verified during the Four Continents Figure Skating Championships held by International Skating Union (ISU).

Figure 8: 360-degree VR Live

4.2.3 Interactive Time-Slice. The service is designed for users to choose his or her location of interest, time frame, and angle to see the desired scene in 360-degree with mobile devices whenever they want. Figure skating might be a good example for time-slice as shown in Fig.9.

Figure 9: Interactive Time-Slice

4.2.4 Hologram(AR) Live. The service teleports holographic images to and from remote sites. Deploying 5G mobile technology, it will provide an ultra-high quality hologram live, in real-time from multi-sides, as in Fig.10.

Figure 10: Hologram(AR) Live

4.2.5 5G Autonomous Bus. As seen in Fig. 11, the self-driving small bus will be serviced in a 5G network. In the small autonomous driving bus, users will be able to explore and experience many services such as a hologram, 360° VR, and transparent display.

Figure 11: Features of the 5G Autonomous Bus

The success of KT's 5G trial services is significant not only to KT, but also to all others who are seeking the possibilities and opportunities that 5G will open. To the 3.5 billion people watching TV around the world, KT's trial services will provide a chance to discover and experience the unique value of VR/AR services supported by 5G.

5 CONCLUSIONS

The greatest attribute of the Fourth Industrial Revolution is the fusion of technologies connecting physical, cyber, and biological spheres. The virtual and augmented reality shares the core value of the revolution as it blends physical (real) environment with the digital (virtual) environment, attempting to fabricate artificial human (biological) senses. Also, the virtual and augmented reality is mesmerizing in that it promises to transform not only the way we consume content, but also the way we conduct businesses.

As more than three-fourth of the world's mobile data traffic will be video by 2021 [22], the first mass adoption of VR/AR will occur in mobile. However, today's 4G network is not able to deliver most of the network requirements of various VR/AR uses cases, thus limiting and penalizing current user experience. The full potential of VR/AR will be opened with the commercialized 5G network. 5G, as a GPT for the Fourth Industrial Revolution, will pave the way for a new rise of disruptive business models and a new suite of use cases of VR/AR. VR/AR will play a major role in the early 5G era since it can be instantly benefit from 5G's enormous bandwidth capacity, ultra-low latency, and more uniform and immersive user experience.

In this sense, KT's attempt to implement 5G at the 2018 PyeongChang Olympic Games and to showcase various VR/AR trial services is significant. The 2018 Winter Olympics is less than a year away. The result of the years-long efforts by KT under the vision of GiGAtopia will be opened to the world. KT had competed aggressively for the rights of full network coverage of the Olympic Games to demonstrate its prominence as a network company and to prove its early 5G capabilities [23].

The world will watch the very first 5G Olympics and will see how much 5G can change the way we enjoy the event. It will be a historic moment in which the world takes the first step into the 5G era and gets a glimpse of the infinite possibilities of VR/AR. The customer experience of 5G VR/AR services through the Olympics might trigger an exponential increase in demand and encourage the related and supporting industries to move forward.

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