



The Fifth Generation Fixed Network (F5G): Full-Fiber Access Embracing the Gigabit Era

Chandra Bhushan Sah, Prabha Shastri, Babu R. Dawadi*

Department of Electronics and Computer engineering, Pulchowk Campus-Institute of Engineering, Tribhuvan University

Abstract

The rapid rise of the digital economy is aided by the new generation of information networks. Optical Fiber networks are foundation stone of cost-effective sustainable mode of communication of our society by leveraging high bandwidth, low latency, reliability, security, stability, enabling long-term economic growth through cutting-edge services and applications for industries, business and users. F5G intends to lay the groundwork for a systematic structure to the growth of fixed networks, including generational planning and pushing the technology's innovations and expansion into as many industries as feasible through Fiber-To-The-Everywhere-and-Everything. Fixed networks have become a crucial public infrastructure in the growing global digitization process, and their development level is an essential metric for evaluating a country's overall strength. This article introduces the trend for F5G networks along with recommendations for their development.

Keywords – F5G, Fiber-to-everywhere, Gigabit access, Digital transformation, Optical transport network

1. Introduction

The new generation of information network has entered in the gigabit era of communications, and fixed networks alongside in collaboration with mobile networks, plays a crucial role in this evolution. Therefore, both fixed access and wireless networks have advanced to the fifth-generation networking. Even though fixed networks are less visible to end users, while it offers higher bandwidth, full experience and greater availability than wireless networks. These advantages will keep appealing for proper development and investment in full fiber access solution employing cutting-edge technologies. Only upon advancement of fixed networks will be able to embrace the promising future applications like telemedicine, ultra-high-definition video streaming, cloud services that requires high bandwidth and low latency, online education, work & gaming, augmented/

*Corresponding author

Email: baburd@ioe.edu.np (B. Dawadi)

virtual reality and many more. Next generation fixed networks are critical infrastructure for accompanying and facilitating the global deployment of 5G/Wi-Fi6 wireless networks, that could be hard to implement without 5G fixed network (F5G). F5G is being designed and developed to offer unparalleled benefits to fixed network communications.

The 5G fixed network, in comparison to preceding generation, offers a full-fiber connectivity, ultra-high bandwidth and the new experience. Fiber is regarded as one of the essential elements in the new era of communication [3]. It can connect not only homes and campuses, but also to medium and large enterprises running vertical businesses. Network performance and user experience will be even further enhanced by symmetric Gigabit and WiFi-6. Operators will move from traffic-centric to experience-centric services because end-to-end network latency has been decreasing and connection becomes more reliable and stable. With the advent of the digital economy era, the enabling role of digital infrastructure has become more prominent [4-6]. Digital infrastructure will accelerate the digital transformation of traditional industries and promote the development and prosperity of many new industries, new formats and new models of digital economy. Compared with the well-known 5G, F5G is still a new terminology. F5G includes Gigabit broadband access network and all-optical transmission network, providing ultimate connection experience for users in various scenarios such as individuals, families and enterprises, improving overall production efficiency, and building a solid all-optical base to support the rapid development of digital economy and next generation communications [7].

The paper is organized as follows. Section II defines and introduces the F5G followed by development status and trend of F5G in Section III. Section IV presents the role of F5G in industrial transformation and good quality society development. Key features of F5G are presented in Section V, while Section VI presents the F5G development and construction scenario. Section VII concludes the paper.

2. What is F5G?

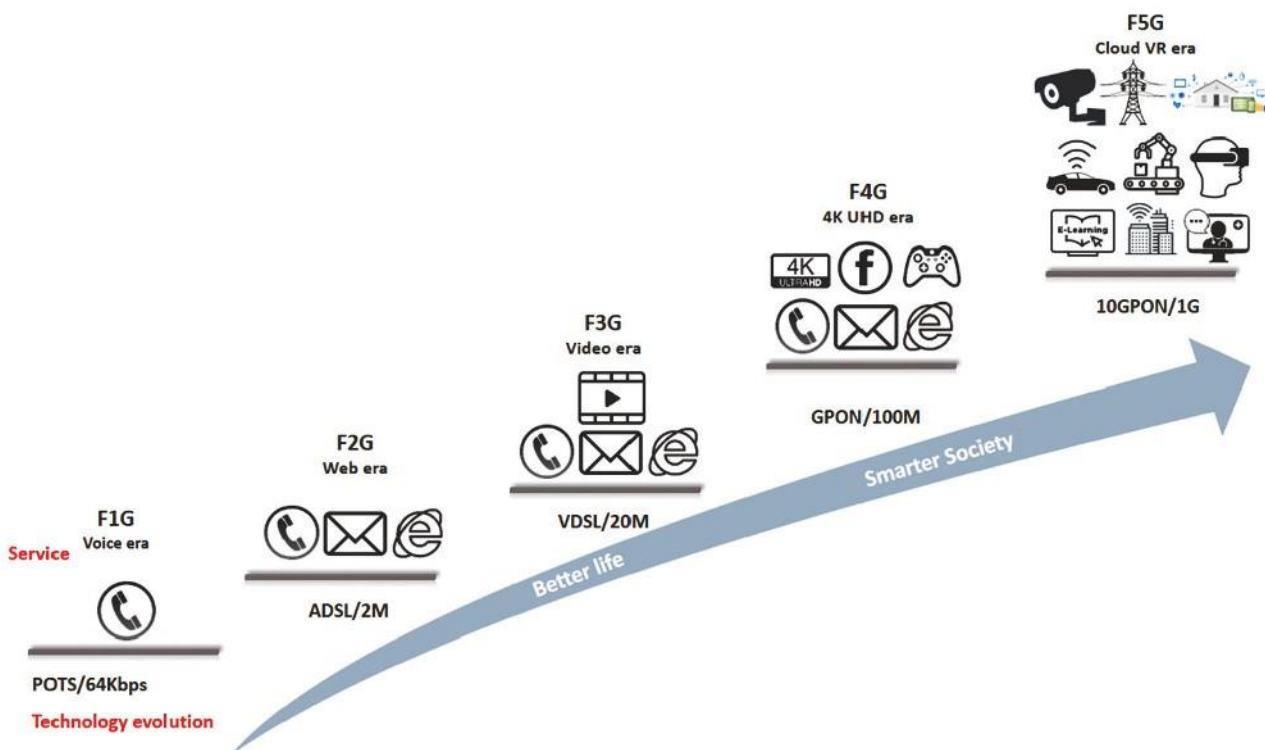


Figure 1: Generational evolution of communication technology

First, In the process of accelerating global digitization, fixed network has become a strategic public and military infrastructure, and its development level has become a comprehensive measure of the country. It is one of the important indicators to show country IT infrastructure power and strength. In recent decades, it has been seen rapid growth and technological advancement in fixed network technology, which has achieved remarkable results. However, compared with the fifth-generation evolution of wireless network industry from fragmentation to integration and standardization between standard organizations (Fig. 1), the 5G fixed network industry has the lack of obvious and standardization uniformity cooperation unity between ITU, IEEE, ETSI, BBF, OIF and other standard organizations. These standard organizations are lacking to reach at one agreement such as synergy between the upstream and downstream cooperation of industrial ecology [8, 9]. In February 2020, European Telecommunications Standard Institute (ETSI) organized online conferences entitled on "Fiber to everywhere" [10]. At the conference, it announced the establishment of the F5G industry working group for the whole world, dedicated to studying the intergenerational evolution and long-term development of fixed networks, and promoting the transition from fiber to the home to all things, pointing out the direction for the development of the industry [9, 10].

The F5G industry working group has the participation of various countries telecommunication operators and industries. F5G network covers gigabit broadband access network based on 10G passive optical network (PON), Wi-Fi 6, and alloptical transmission network based on 200G/400G, next generation optical transport network (NG OTN), optical cross connect (OXC) etc. It has the characteristics of large bandwidth, low latency and highly stable all-optical connection. F5G network not only improves home ultra-high broadband, covering the park (all-optical park) and industrial manufacturing field (industrial light network) extension to support the digital transformation of thousands of lines and industries. F5G is oriented to fixed access scenarios, providing anti-interference and stable optical fiber connections for indoor access services such as individuals, families, enterprises, factories, schools, and hospitals, and providing optical base transport capacity support for 5G. 5G is flexibly deployed for wireless access scenarios, suitable for outdoor or mobile access services. These both F5G and 5G together form a dual-gigabit access network, complementing each other and jointly support the gigabit connection and builds the foundations of coming generation telecommunication.

3. Development status and trend of F5G

Many developed countries have already started to build F5G infrastructure. In this race, China has emerged as leading player. It has established a good foundation for optical fiber network coverage and is at the leading level in the world. As of May 2020, the total number of fixed broadband access users reached 4.62 million, Fiber-to-the-home (FTTH) user access account for 93.1%, 100 Mbit/s and above users account for 86.1%, and it has entered the "all-optical era" [11, 12]. The OTN began to adopt the leading all-optical switching OXC network construction and the network architecture gradually realized MESH networking. The backbone network evolved from the mainstream single-wavelength 100G to 200G, which effectively increased the system capacity and supported dual gigabit network bearing.

Countries around the world are actively exploring the construction of F5G networks. In recent past years, 287 operators in 66 countries and regions officially release F5G gigabit broadband as commercial service [13]. Europe launched the gigabit society back in 2016, according to strategy, it is planned to achieve all major projects such as schools and transportation hubs by 2025, public service providers and digital intensive enterprises achieve F5G gigabit access, all households in Europe can be upgraded to F5G gigabit network. The Digital Europe program designed to promote the EU's cyber security, defense imperial construction, and support digital transformation to realize gigabit society [14]. In 2016, Germany launched "Gigabit Germany strategy" aiming to achieve full Gigabit coverage by 2025 [15]. The UK announced new plans to drive adoption of fiber networks in early 2020. Under this proposal, government will provide £5bn of investment in rural areas. Moreover, In March 2020, the UK government also announced that it would introduce legislation to ensure pre-installation of optical fiber in new houses deployment with Gigabit broadband suitable for the future [14]. Spain released the all-optical policy, which plans to achieve 100% all-optical coverage in 2021. South Korea

began to implement the "Giga Korea (Gigabit South Korea) Strategy" in April 2012, with the goal of reaching 100% gigabit broadband coverage in 2020 [16]. At present, South Korea has achieved more than 95% gigabit coverage, and South Korea KT Company has begun to deploy 10 gigabit broadband network. The United States put forward the idea of gigabit broadband earlier. The population covered by gigabit network exceeds 80 million, which is the highest in the world. However, at present, cable is still the main broadband access.

With the development trend of Internet of things (IoT), the connection scenarios such as data centers, private lines, homes, office and industrial production parks will increase exponentially. F5G network will promote the further extension of optical fiber network coverage deployment, in the one hand, from optical fiber-to-the home (FTTH) will go to fiber-to-the- room (FTTR). On the other hand, it will extend to every scene of the enterprise, to the enterprise desktop, to the machinery and equipment of the factory. It will also cover every data center, and finally move towards fiber light link connecting all things as depicted in Fig. 2.

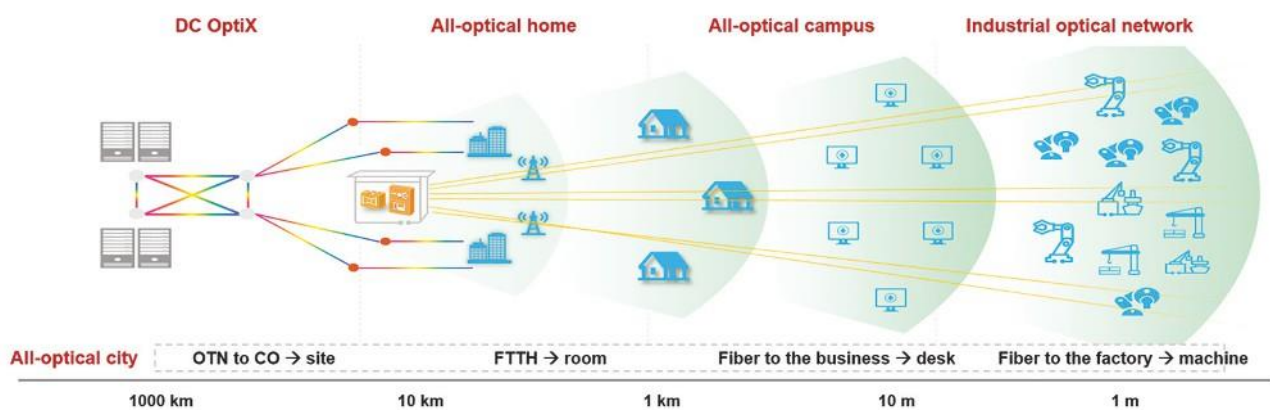


Figure 2: F5G optical fiber network coverage deployment trend

F5G Gigabit broadband network will bring the ultimate experience of ultra-high bandwidth and ultra-low latency. 10G PON has become a mainstream technology with a complete industrial chain. In cooperation with FTTR scheme and WiFi6 equipment, 10g PON can further realize seamless true Gigabit coverage and realize "zero waiting, zero jamming and zero failure" of business. To implement F5G, first and foremost, it is necessary to realize the gigabit home to help the digitalization of the family, afterwards accelerate the process of Gigabit City, and then gradually realize the Gigabit society by bringing up social digital transformation, and carry out the commercial trial of 10gigabit. F5G all-optical transmission network will complete the capacity upgrade of single wave 200g backbone optical transmission network (OTN) and the full deployment of alloptical cross connect (OXC) as soon as possible. The OTN deployment will further sink and evolve from supporting network to service network facilitating high quality dedicated lines.

4. F5g For Digital Transformation Of Industry And Society Development

The fixed broadband has Gigabit access capability, it can not only enrich personal and family information applications, but also provide services for urban operation management, digital village construction, industrial digital transformation Digital upgrading of traditional infrastructure and public services. Which provides high-quality access network capabilities to meet cloud VR, smart home, cloud desktop, safe city, enterprise cloud, online education, telemedicine and intelligent manufacturing. This effectively supports the new growth of digital economy and accelerates the realization of high-quality social and economic development.

During the pandemic in 2020-21, many countries and regions started the home isolation mode, and the demand for online teaching, remote office, telemedicine, home entertainment and other network-based services soared. About 90% of the Internet traffic was carried through fixed broadband, highlighting the key role of optical fiber networks [17]. Online education has continuously increasing requirements for video resolution and user

participation; remote consultation requires comprehensive and real-time transmission of data, images and voice; video conferencing is the main application of remote office. F5G can meet the network requirements of these applications for large bandwidth, low delay and strong stability. It will be a "flexible line of defence" to deal with public emergencies such as epidemic.

Many nations information technology related governing bodies issued the guidance on accelerating the development of virtual reality industry, proposing the development of virtual reality network distribution and application service aggregation platform (cloud VR) with end cloud collaboration. The governing bodies in association with other IT telecommunications department jointly issued the action plan for the development of UHD video industry, which proposed to vigorously promote the development of UHD video industry and applications in related fields according to the overall technical route of "4K first and 8K at the same time". Ultra-high definition 4K/8K, cloud VR and other applications have entered the fast lane of development. Ultrahigh definition 8K single channel requires a stable bandwidth of more than 100 Mbit/s or more, and the ultimate cloud VR experience (24K program source) in the future needs 1.5Gbit/s bandwidth and delay network within 8ms are inseparable from F5G network.

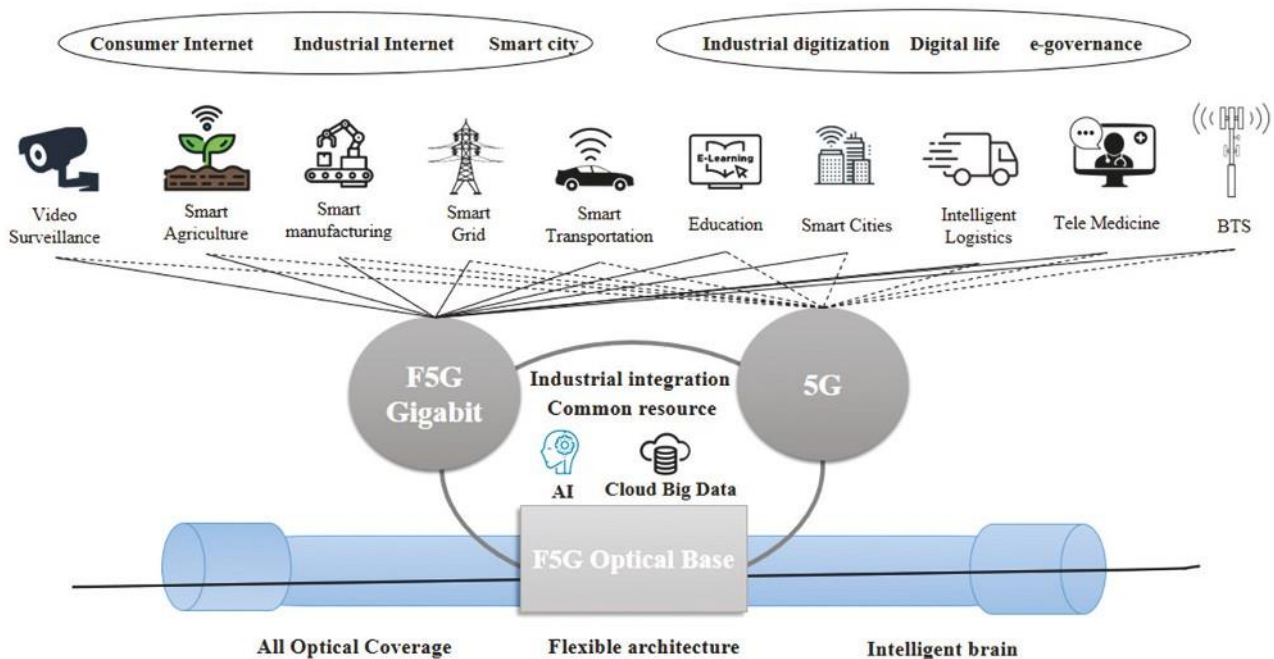


Figure 3: F5G fiber network coverage deployment trend

Fig. 3 depicts the F5G fiber network deployment trend. As a digital infrastructure, F5G directly supports the digital transformation and upgrading of traditional infrastructure, and as an optical base to transmit data and information for 5G, industrial Internet, artificial intelligence, Internet of Things, data centers, etc., it is the core and cornerstone of digital infrastructure. F5G all-optical will realize all-fiber network for people's production and life. It supports digitalization, digitization, and intelligence from consumer Internet to industrial Internet and smart city Internet, from industry digitization to life digitization and social governance digitization and helps the high-quality development of the society.

5. Key features of F5G

F5G facilitates to meet the demand of massive connectivity, high bandwidth and high quality of experience. These can be characterized in a three-dimensional space with feature groups associated with each dimension as shown in Fig. 4, these are (i) guaranteed reliable experience (GRE), (ii) enhanced fixed broadband (eFBB), and (iii) full fiber connection (FFC).

5.1 Guaranteed reliable experience

For better high quality of experience must need to be assured for the new applications that offered by F5G. Optical fiber technologies are the sole way to provide and ensure high-quality of data transmission, low packet loss, and microsecond latency. To improve the autonomous administration and operation of E2E networks and applications, technology advancements in Big Data and AI will be incorporated into the network sector. To fulfil the quality of experience and standards, different types of applications are handling various features differently in the network.

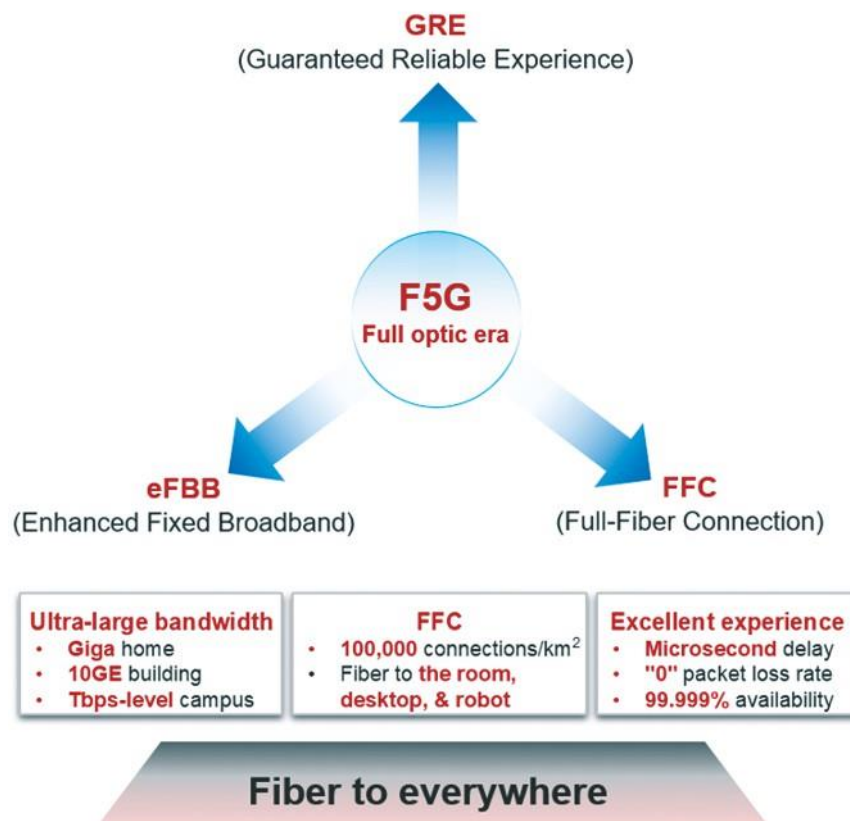


Figure 4: Features of F5G

For home services with high value include ultra-high-definition video, virtual reality, augmented reality, gaming, video communication, online education and home security. These services required milli and even micro-second level of latency in the transportation network. B2B service of the telecommunication operator like vertical industries; they not only require bandwidth and millisecond latency, but also need to assure the time needed for configuration, high precisions for clocking and to commit service level agreement (SLA) to business users.

5.2 Full Fiber Connection (FFC)

To provide ubiquitous connectivity, F5G expands fiber connections beyond Fiber-To-The-Home to a much larger application field, including commercial and vertical customers. As a result, the number of connections has expanded by almost tenfold, allowing for full-fiber connectivity. F5G extends existing FTTH to deliver fiber into each room (FTTR) and provide a full fiber infrastructure for smart homes and enhances the quality of family life in the home access domain. For 5G base stations, optical fiber are the best connecting medium. 5G networks demand a lot of capacity, a lot of coverage, and a lot of latency, all of which can only be achieved

with optical fiber access and transport. The number of base stations required for full-scale 5G deployment will grow by hundreds of times. The 5G base station distribution will overlap with the FTTH ODN network. As a result, sharing the FTTH ODN to carry 5G services is cost-effective.

With F5G, fiber access penetrates even further into industrial firms' production processes, linking fiber-to-the machines (FTTM) and industrial robots. Time sensitive networking may be used to assist the industrial digital transformation because of the high bandwidth, high reliability, low latency, interference-immunity, and high security qualities of fiber networks. Optical fiber can be linked to each smart camera in industrial, real-time traffic light and security video applications to provide high-bandwidth and low-latency transmission channels, enabling high-speed connections to data centers that enable machine vision and aiding the usage of AI technologies in this industry.

5.3 Enhanced Fixed Broadband (eFBB)

Enhanced fixed broadband (eFBB) is an F5G feature group that enables the fixed network to accommodate high bandwidth demands with symmetric access capacity per user more than 1Gbps. For home users, there will be single fiber network connection to enhance home service experience. Customers' wireless experiences from Wi-Fi or by other means would also relies on the connection using optical technologies. To offer an improved customer experience for 10G PON, the in-house connectivity quality must be upgraded from standard Wi-Fi to smart Wi-Fi. Fiber access technology based on XG(S)-PON will be widely used to provide high bandwidth requirement. This network has capability to deliver symmetric gigabit bandwidth upstream and downstream. The Wi-Fi 6 technology is used to overcome the restriction of gigabit connections in the last few meters.

6. Development and construction of F5G

The comprehensive popularization and construction of F5G network with large bandwidth, low delay and stable all optical connection will greatly promote the prosperity of digital economy and the construction of digital intelligent society. Country should comply with the global development trend, firmly grasp the development opportunity of digital infrastructure, and strengthen the strategic direction of "gigabit pilot, application guidance, fixed-mobile synergy, and integration promotion". Nations firmly promotes the largescale deployment of F5G networks, and deepen the transition from gigabit optical networks from home scenario to thousands of industries, laydown a solid foundation for the digital transformation of traditional industries and provide solid support to boost the country economies.

- *Formulate the strategic plan of F5G network:* The F5G network that supports the popularization of gigabit access capacity, should be included in the national key plan of the country for the development of communication industry to implement "network power strategy" and an important part of digital infrastructure. The overall goal and phased indicators of F5G gigabit development ensure the continuous incremental investment in optical networks, accelerate the construction of gigabit cities and strengthen the transformation of rural gigabit networks. Furthermore, build the cornerstone of dual 5G network dual gigabit experience, and form a development pattern in which F5G and 5G complement each other.
- *Accelerate the construction of F5G network:* First of all, Fiber-optic ODN network should be laydown that will give full play to the advantages of home users and small & medium enterprises (SMEs) in F5G network construction and drive the development of digital transformation. As it finishes, should focus on capacity upgrade of single wavelength 200G backbone OTN and full deployment of all-optical OXC, and also make plans to upgrade to 400G network. Promote the 10G PON, Wi-Fi 6 broadband access network and further extend the deployment of optical fiber, from the "last mile" of optical fiber coverage to the "last meter" of homes, campuses, and factories.
- *Cultivate the innovative application of F5G at industries:* At present, the F5G gigabit access capability is

in the initial stage of deployment, and its innovative applications are not yet extensive. It is necessary to promote the deep integration of F5G and the industry, incubate downstream applications, and cultivate the application ecology, encourage the society to carry out extensive practice, and promote the healthy development of the industry with the continuous increase of income and business cycle, give priority to the formation of applications in the livelihood industries such as family, education, medical care, government affairs, and many more. And gradually radiate to thousands of industries such as manufacturing, electric power, transportation, and finance, and improve the society. It will benefit the people's livelihood, strengthen the online and offline integration economy.

7. Conclusion

F5G builds the infrastructure to realize the Fiber-to-the everywhere-and-everything by leveraging ultra-high gigabit bandwidth with ensuring latency and reliability. As the cornerstone of the development of digital intelligent society, F5G has become a global hotspot, connecting everything with optical network has opened a new era of fixed network. It will integrate cloud technologies for control and management, making the technology more future-proof and allowing for the incorporation of AI/ML technologies, as well as modernizing the end-user's services experience. In the 5G era and beyond, the growth of F5G, together with that of mobile 5G, will create a profoundly synergized global network that allows ubiquitous connectivity and astoundingly diversified applications.

Conflict of interest

"Not declared by the author(s)".

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