Current Status, Challenges, and Solutions to Improve Wired/Wireless Fixed/Mobile Broadband Internet

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June 07, 2024

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***Abstract*—In this paper, we raise five questions and find solutions: What are the positive and negative effects of broadband Internet? Which type of Internet access is preferable? Which one of them needs more attention? How much and what kind of developments affect the Internet? What solutions are there to improve the current situation? First, fourteen advantages and positive effects of broadband Internet in every corner of life are presented. Second, fifty criteria are extracted for comparing wired and wireless broadband Internet. The third task, they are compared by describing the characteristics of optical fiber-based fixed and fifth-generation-based fixed/mobile broadband Internet access. Fourth, issues that directly and/or indirectly affect the global development of broadband Internet are outlined. The fifth task elicits twenty items on balanced sustainable development and strategic planning of broadband Internet. Finally, we propose ten solutions to improve the current state of global broadband Internet, reduce the digital divide in the world, and decrease the negative social effects of broadband Internet.**

***Index Terms*— Broadband Internet, Fixed, Mobile, Wired, Wireless, Fiber-To-The-x (FTTx), Fifth Generation (5G).**

I. Introduction

INTERNET supports a high number of nodes to transfer information from one node to the other [1]. It is the global system of interconnected networks that uses Internet protocols to communicate between networks, users, and devices, even consists of a group of smaller networks [2]. This network includes private and public, governmental and non-governmental, academic and non-academic, and commercial and non-commercial subnets, linked by wired (two-pair/coaxial copper or optical fiber cable), wireless (radio or light waves) networking technologies, and a combination of them [3], [4].

Today, the economic, industrial, communications, cultural, educational, health, medical, and social development of the countries is dependent on the Internet. The new applications and services of digital media require broadband Internet access. Broadband refers to the high-speed data transfer and a large range of services, applications, and capabilities such as configurations and technologies that require high bandwidth of frequency and high-speed data transmission between interconnected elements. Thus, broadband Internet access can be measured by the usefulness of such access to subscribers (persons, homes, businesses, industries, and institutions) and the applications and services that use broadband Information Communication Technologies (ICTs) [5], [6].

The possibility of providing new services in the digital media and the high speed of the service delivery using optical fiber as the most suitable cable platform for reliable, symmetrical, and high-speed data transmission in both upstream and downstream links and 5G standard of wireless cellular communications with mobility are serious concerns and requests of Internet users [7]. These two technologies are complementary to each other and with their convergence, broadband Internet access can be provided all over the world from anything to anything, whenever, wherever, for fixed and mobile applications to transfer and exchange broadband (high-speed) information and supporting broadband digital Internet-based services and applications [8]-[10]. Hence, there are five questions as

1. What are the positive and negative effects of the broadband Internet and its progress on human life?
2. Which of the two types of fixed wired and fixed/mobile wireless Internet access is preferable and why?
3. In upgrading and expanding services based on broadband Internet, which wired or wireless access needs more attention, and what are the trends of users and operators?
4. How much and what kind of developments in scientific, technical, economic, and social fields affect the Internet?
5. What solutions are there to improve the current situation and accelerate the expansion and development of broadband Internet, locally in the countries and globally in the world?

The remainder of this paper is organized as follows. In Section II, broadband Internet and its benefits are presented and fifteen criteria are introduced to evaluate and compare different types of broadband Internet access. Section III presents the three fixed and mobile Internet access scenarios in more detail, and compares optical fiber-based and 5G-based broadband Internet. Important factors in the balanced development and strategic planning of broadband Internet are presented in Section IV. Moreover, it introduces ten solutions to improve the current state of the broadband Internet in the world. Finally, Section V draws our conclusions from this research.

The Manuscript received on February 15, 2024.

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II. Broadband Internet

Broadband means a large bandwidth that can carry multiple signals at a wide range of frequencies, support different types of Internet traffic, and allow multiple data streams to be sent. A connection or connectivity is high-speed if it can connect multiple devices simultaneously to enable streaming and access to modern applications [8]-[10]. The terms *broadband* and *high-speed* are mostly interchangeable when the Internet meets or exceeds Federal Communications Commission (FCC) standards. The FCC defines basic broadband as a transmission speed of at least 25Mbps downstream and 3Mbps upstream. The Infrastructure Investment and Jobs Act (IIJA) considers 100Mbps downstream and 20Mbps upstream as the minimum rates for broadband Internet [11], [12]. It is possible to find proper situations for all types of high-speed communications, various types of sending and receiving broadband information, and providing services that require high-speed data using broadband Internet with wired access using an optical fiber or wireless access using 5G cellular or satellite.

Broadband Internet access is rapidly changing the way people live, work, and even play and have fun [13]. According to the ITU report [14], [15], which examines the economic effects of fixed and mobile broadband and data from 139 countries in the time interval 2010-2020, a 10% increase in fixed and mobile broadband penetration increases Gross Domestic Product (GDP) per capita in developed countries by 0.77% and 1.5%, respectively. Based on the European Telecommunications Network Operators' association (ETNO) report [16], communities, where 50% of the population has a Fiber-To-The-Home (FTTH) connection with a speed of at least 1Gbps, have 0.9% to 2% higher per capita GDP than communities without an optical fiber broadband network.

Broadband investment is the main driver of countries' growth and development. Although it is difficult to fully quantify this, the importance of broadband connectivity in the social and economic development of countries is undeniable [14]. The global broadband subscription market alone was worth more than $356 billion at the end of 2021, accounting for between 2% and 7% of a country's GDP [15]-[17].

Countries have set up national broadband plans to create greater penetration of connectivity, and accordingly, the global population of unconnected people is predicted to decrease from 45% in 2019 to 27% in 2026 [18], [19]. The higher the broadband maturity of a country, the greater its ability to improve digitalization and increase the absorption of economic impacts. However, the benefits of broadband go beyond those that directly lead to revenue generation. For example, according to a World Bank study [20], educated people's chances of finding a job increase by 7% to 13% if they have access to broadband Internet, especially through optical fiber.

A. Positive Effects of Broadband Internet

According to Fig. 1, we can point to the positive effects of wired and wireless broadband Internet in different urban and non-urban, individual and social, and local and global aspects of modern human life.

1. *Global communications*. Cross-border communications and cooperation will be facilitated, and global trade relations and cultural exchanges will be strengthened.

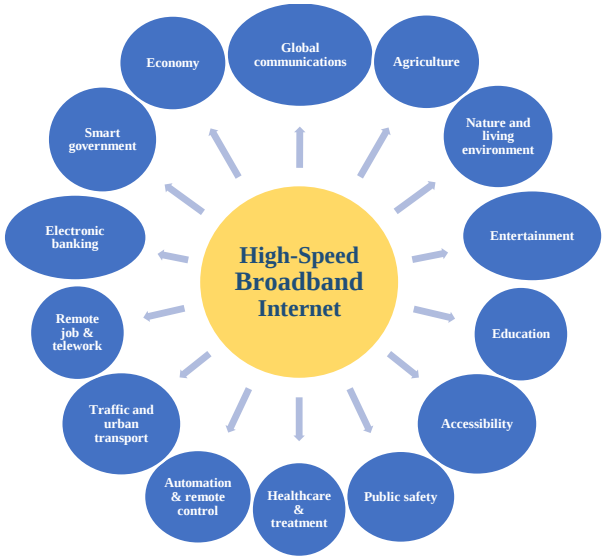

Fig. 1. Positive effects of broadband Internet.

2. *Economy*. It accelerates commerce, promotes innovation, and enables new markets to aid economic development.
3. *Smart government*. Citizens can do all administrative and business matters through the Internet with no need to travel.
4. *Electronic banking*. It becomes possible to do banking and financial transactions using electronic and mobile banking without the need to be physically present in a bank or financial/credit institution.
5. *Remote job and telework*. It expands the possibility of telecommuting and flexible work schedules that benefit both employers and employees.
6. *Traffic and urban transport*. Using location and status information of stations and traffic lines makes transportation planning practical and traffic control intelligent.
7. *Automation and remote control*. It facilitates a more efficient and comfortable life by using smart devices and home, and industrial and office automation systems [21, 22].
8. *Healthcare and treatment*. Telemedicine enables online diagnosis and treatment, improved patient care and access, and data sharing among healthcare professionals. The high-speed Internet increases the amount of information contained in the healthcare marketplace [23].
9. *Public safety*. Wireless broadband is essential for the cooperation of police, fire, health, and other government agencies in both normal and emergency cases.
10. *Accessibility.* High-speed Internet is an important tool to meet the needs of people with disabilities. Through various broadband-based applications and technologies, they have access to new smart devices that improve their quality of life.
11. *Education*. It provides access to online learning resources, virtual classrooms, and worldwide educational collaborations by improving and leveling the access for interested people.
12. *Entertainment*. Enriching possible options for leisure and entertainment, it enables high-quality gaming, video streaming, and interactive virtual media experiences.
13. *Nature and living environment*. It promotes paperless transactions and virtual meetings that reduce the consumption of natural resources and harmful environmental impacts.
14. *Agriculture*. It gives farmers real-time information on weather, markets, planting and harvesting, and productivity.

B. *Broadband Internet Performance Evaluation Criteria*

15 criteria are considered to evaluate and compare various types of broadband Internet access. They are divided into two categories as shown in Fig. 2 and Fig. 3. The first category includes download and upload speeds, subscription fees, mobility and comfort, users' willingness (desire to access), effective range, and data volume, which are important to users. Also, the second category includes security, reliability, interference, latency, jitter, packet loss, establishment and setup time, and link observation and maintenance, which are important to operators directly and users indirectly.

All system parameters and performance metrics depend on the type of access, the channel used, technology, etc. Hence, in the aforementioned criteria, the effect of system parameters including transmit power, transceiver loss and gain, working frequency, bandwidth, noise level, interference, and threshold level of the receiver is visible.

III. Broadband Internet Access

Broadband Internet access can be classified as wired or wireless, fixed or mobile, short or long coverage, low or high data speed, radio wave signal or light, low or high subscription fee and cost of service usage, and fast or slow deployment and startup. There are various platforms like two-pair, coaxial, and optical fiber cable in wired and Wireless-Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMAX), 3G/4G/4.5/5G, Low Earth Orbit/Geostationary Earth Orbit (LEO/GEO) satellites, and balloons in wireless. Optical fiber and 5G cover a high number of users and support different services of the broadband Internet, and LEO satellite is a new candidate, especially for rural and remote areas.

A. *Fixed Broadband Internet Based on Cable*

Fiber-To-The-x (FTTx) broadband Internet is of interest to many countries [24], [25]. Its advantages are as follows:

- High bandwidth and speed with symmetrical connectivity;
- Low dependencey of service quality on the distance;
- Placing a large number of cables together;
- High security;
- Corrosion resistance and long life of cables;
- Thinner and lighter than two-pair and coaxial cables;
- No need for frequent replacement.

The disadvantages of this access are as follows:

- High cost of establishment and setup;
- Different cabling compared to copper cable;
- Lack of optical fiber in many areas;
- Need a different modem;
- High fragility and low bending of cables.

Realization and expansion of FTTx network in Fiber-To-The-Node (FTTN), Fiber-To-The-Cabinet (FTTC), Fiber-To-The-Business (FTTB), and Fiber-To-The-Premises (FTTP) or FTTH types, is of special interest. As presented below, they differ in the type of channel, speed in establishment and setup, data speed, and cost.

- *FTTN*. From the network to the cabinet that is far from the access node (more than 300 meters) is of optical fiber cable and from the access node to users is of copper (twisted-pair or coaxial) cable. If the end user is far from the cabinet, the quality of the provided service will be greatly reduced.

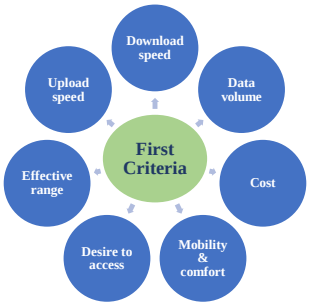

Fig. 2. Criteria of the first type.

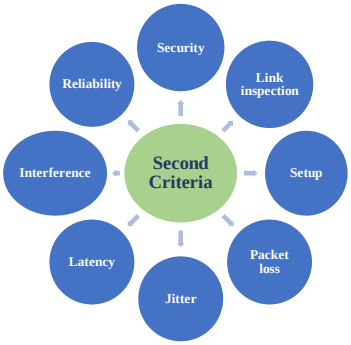

Fig. 3. Criteria of the second type.

- *FTTC*. The channel from the network to the cabinet, which is close to the home/office is more than 300 meters of optical fiber, and in most cases, copper cable is used from the cabinet to the user. This type of Internet platform offers sufficient speed for home use and is cheaper than other types of FTTx, but the downloading and uploading speed is limited [26].
- *FTTB*. The channel from the network to the cabinet and from the cabinet to the building is fiber optic. In the building, wired or wireless access using a modem can be given.
- *FTTP or FTTH*. It is a newer generation, the cable from the network to the cabinet and from the cabinet to the office (or home) is fiber. Currently, the fastest home broadband Internet available has a speed of 1Gbps, and the upload speed can be as fast as the download speed [27], [28].

B. *Mobile/Fixed Broadband Internet Based on 5G Cellular*

5G supports high-speed data transfer, low latency, high reliability, high availability, and high connection density. Based on 5G, data speeds on mobile and fixed broadband Internet access can reach 20 Gbps, allowing users to enjoy access to files, services, and applications. The latency will be ten times lower than 4G and it will be able to remote actions in real time.

5G offers a positive experience in smart cities and IoT. By sharing the information of the sensors of the cars and those of the city, and then exchanging data, the quality of life in cities can be improved and the navigation of the autonomous car can be facilitated by choosing better routes, reducing the number of accidents, find available parking spaces, etc. 5G networks are expected to effectively support typical applications such as enhanced Mobile Broad-Band (eMBB), Ultra-Reliable Low Latency Communications (URLLC), and massive Machine-Type Communications (mMTC) [29]-[33].

In summary, the 5G features are:

1. Improved connectivity between multiple devices;
2. Connect a much larger number of different devices;
3. Enhanced Internet experience in streaming and gaming;
4. High reliability;
5. Increased availability;
6. High energy efficiency;
7. Virtual networks implementation and network slicing;
8. Configure subnets to do connections for specific needs.

These features come at the cost of the following downsides:

1. Faster battery drainage, when streaming high volume of data;
2. Limited coverage, spotty in some, not available in all areas;
3. Expensive infrastructure of new base stations and equipment;
4. Signal interference from trees, buildings, and obstacles.

5G is divided into low (less than 1GHz), mid (1GHz-6GHz), and high (24GHz-40GHz) frequency bands. The low-band offers lower speeds with greater coverage, the mid-band has a balance of speed and coverage, and the high-band offers higher speeds with smaller coverage. Besides, frequency bands for 5G-New Radio (5G-NR) are divided into two different frequency ranges. Range 1 from 410MHz to 7125MHz and range 2 in millimeter waves from 24.25GHz to 71GHz. Moreover, frequency bands 600MHz, 700MHz, 800MHz, 900MHz, 1.5GHz, 2.1GHz, 2.3GHz, and 2.6GHz are considered for traditional coverage applications and new specific usages such as IoT, industry automation, and critical use cases [34], [35].

C. Broadband Internet Based on Satellite

GEO satellite Internet experiences high latency and power loss, LEO satellite Internet requires handover between the satellites of the constellation, and the cost of both of them is high. However, they are of interest for sparsely populated areas where wired networks and 4G/5G cellular coverage are not possible and are not economically justified for operators.

Starlink is being tested and launched as the latest satellite technology to provide broadband Internet [36], [37]. It is SpaceX's LEO satellite constellation that provides high-speed Internet access to underserved areas of the world and is a great choice for people living in remote areas [38, 39]. Compared to Starlink, fiber-based Internet is more reliable because it uses a wired connection. The limitation of capacity and power in fiber optic is not so worrying and it has higher speed and lower latency and jitter than Starlink. While Starlink offers faster speeds and more reliable services in clear-sky situations, 5G supports high-speed and wide-coverage Internet that is more widely available than Starlink and generally costs less for urban areas [36]-[42]. Starlink's upfront costs for equipment and service fees are significantly higher than 5G and FTTx plans.

Starlink is currently in the testing phase, it has many energy and bandwidth issues, its coverage will be limited to areas with a clear sky, it can be affected by weather (snow, rain, and ice), and some of the bottlenecks will be determined later [36, 38]. Moreover, Starlink is only available in limited areas, so there may be some bugs [40]. For users in areas with limited FTTx and 5G coverage, in remote/rural areas [41], it may be the best.

D. Comparison of FTTx and 5G Broadband Internet

FTTx and 5G networks are widely used. For users who have access to FTTx and 5G networks, higher speeds and lower costs make them more attractive options. Businesses must also consider the long-term implications of their choices [43]-[45]. TABLE I and TABLE II compare FTTx and 5G based on the criteria of the first and second types, respectively. Technical and functional comparison with more detail is as follows:

1. *Data speed/volume.* 5G can reach a maximum downstream speed of 20Gbps and an upstream speed of 10Gbps, while the data speed in FTTx can reach 1 petabit (10^{15} bits) per second (practical speed of 100Gbps) symmetrically for upload and download links. In FTTx, upload and download rates can be equal and the highest speed is for FTTH, FTTB, and FTTC, respectively [24]-[26]. Mostly data volume is unlimited in FTTx but limited in 5G. During peak hours, wireless networks will be slower, but fiber optic connections will not change much download or upload data speed [43]-[45].

TABLE I
COMPARISON OF FTTX AND 5G BASED ON THE CRITERIA OF THE 1ST TYPE

Criterion	Technology	
	FTTx	5G
Download rate	100Gbps	20Gbps
Upload rate	100Gbps	10Gbps
Subscription cost	High	Average
Mobility and comfort	Average	High
Desire to access	High for fixed users	High for mobile users
Effective range	70km	10m/3km
Data volume	Unlimited	1TB per month

TABLE II
COMPARISON OF FTTX AND 5G BASED ON THE CRITERIA OF THE 2ND TYPE

Criterion	Technology	
	FTTx	5G
Security	High	High with cryptography
Reliability	High	Average
Interference	Low	High
Global average latency	9ms	28ms
Global average jitter	3ms	9ms
Packet loss	Insignificant	Average
Setup time	Average	Low
Required link observation	High	Low

2. *Effective range.* Wireless connections can only feed a limited area, and when the user moves too far from the coverage area of the base station or modem, they drop the connection or start experiencing signal instability. This is not the case with optical fiber, and regardless of how far the user is from the signal source, it always receives a strong signal. 5G-Home (5G-Mobile) can reach up to 10m (3km), but signals passing through fiber can have acceptable quality up to about 70km.
3. *Users desire to access.* 5G broadband Internet is welcomed due to the possibility of high mobility and high download speed while users' need for high data speed in broadband and symmetrical applications promises the growth of FTTx. Hence, it is necessary to create access points with a coverage radius of 100m to 300m in countries with no or limited optical fiber [43]-[45], and accelerate setup and access to 5G broadband Internet to meet the mobility needs of users.
4. *Mobility and comfort.* Subscribers are looking for 24/7 connectivity and want a seamless connection wherever they are, which is an inherent advantage of wireless Internet.
5. *Cost.* Wireless connection is significantly cheaper than optical fiber because Internet service providers must install fiber optic cable to establish a connection. FTTx is cheaper for subscribers due to no limit on the amount of data available while 5G is more cost-effective to distribute and more expensive to access.
6. *Security.* 5G requires encryption because data is transmitted over a wireless medium. In the fiber-based Internet, the majority of the transmission medium is optical fiber, and data requires less encryption. Hence, both provide users' data security, but a 5G connection requires more data protection due to its reliance on wireless radio waves [43], [44].
7. *Reliability.* Fiber-based Internet is immune to the wear and tear seen in copper cables. In the 5G Internet, if the distribution and position of the base stations are properly designed, which guarantees reliable communication, the failure is only caused by the connections of the parties.
8. *Interference.* With fiber optic connections, there is greater resistance to interference, while adjacent and cochannel interference is highly influential in 5G cellular connections.

9. *Latency.* FTTx has a lower latency than 5G, which is more suitable for latency-sensitive applications like business, stock market, and gaming, while 5G with 3-4 times the latency of fixed Internet is great for completing activities like video broadcasting, Internet browsing, and using cloud applications. The technology used in FTTx can affect the latency [43]-[45].
10. *Jitter.* This shows latency changes. Applications such as the stock market and online games are very sensitive to it. On average, jitter is much lower in FTTx-based fixed Internet connections than in 5G connections.
11. *Packet loss.* It depends on the quality of the communication link. The more stable and lower the random fluctuations, the lower the packet loss. Hence, FTTx fixed Internet is more suitable than 5G fixed/mobile Internet, because, it does not experience random propagation changes.
12. *Setup time.* 5G Internet does not require cables to install, but FTTx Internet connections are more time-consuming and difficult to establish and set up because fiber or copper cables are to be run from the home/building to the cabinet and service provider. After making the connections, the Internet can be accessed directly or via a Wi-Fi modem.
13. *Link observation.* Maintenance and inspection of the channel and connections are important in FTTx, but in 5G, since it has an air transmission channel, only the inspection and maintenance of the connections are necessary.

IV. Sustainable Broadband Internet

The Internet has positive and negative effects on various aspects of life. Areas with broadband Internet can attract investors, become a place for tech workers, and boost the local economy. The unavailability of broadband services and data speeds sufficient to meet the minimum needs of today's human beings in suburbs, rural, and remote areas, creates unequal economic opportunities and the digital divide [46]. Hence, alignment towards a unified, coherent, and sustainable Internet should consider [47]-[49]:

1. Policymaking in the field of ICT and their compliance;
2. Regulatory mechanisms in the digital and the Internet;
3. The possibility of using the Internet without discrimination;
4. Supporting innovative Internet-based businesses;
5. Creating a safe and inclusive digital environment;
6. All ages, genders, and races benefit from digital evolution.

A. Balanced Development and Strategic Planning

Three main factors in Internet technology and global digitalization are the increase in the number of Internet users and devices, the dramatic adoption of Internet-based services requiring high data rates, and the emergence of various broadband Internet-based services. Each wired and wireless broadband Internet platform has its own advantages and disadvantages, and none of the two platforms alone is responsible for all conditions, scenarios, and services. In some applications only one platform and in some of them both platforms can be used. In some other applications, these two platforms must interact with each other to provide services.

Ten important items in choosing wired/wireless fixed/mobile access are the type of connection, data speed and volume, information security, mobility, flexibility, cost, speed of establishment and setup, observation and maintenance, coverage area, and interference. A wired connection has higher reliability, more security, and less interference while a wireless connection has higher mobility, more flexibility, faster setup and provision of services, and ease of adding users, devices, and equipment to the network.

In broadband networks that provide high-speed Internet services based on sustainable quantitative and qualitative development, foresight, strategic and management planning, and compatibility and friendliness with the environment, attention to the following points is necessary:

1. Accelerating the macro plans to achieve high bandwidth;
2. Creating direct and indirect employment opportunities;
3. Helping to make the digital economy and business based on the Internet platform more effective;
4. National and global added value in scientific, cultural, educational, social, medical, and environmental fields;
5. Network integrity and accessibility;
6. Making changes and expanding the network and services;
7. Compliance with territorial geography;
8. Providing services for different fixed and mobile users;
9. Access for urban, suburban, and rural areas;
10. Coverage of all types of services;
11. Acceptable data download and upload speeds and volume;
12. Decreasing latency, jitter, and packet loss;
13. Lowering subscription, service, and maintenance costs;
14. Decreasing costs of updating devices and software;
15. Improving security and defense against cyber threats;
16. Benefiting from optical fiber platforms in smart homes and cities, IoT, and future broadband services;
17. High durability of fiber optics against corrosion;
18. Reduction of electromagnetic radiation and interference;
19. Environmental pollution as little as possible;
20. Reducing damage to nature to provide electrical energy.

B. Ten Solutions to Improve Global Broadband Internet

The development of different countries will be dependent on high-speed fixed and mobile broadband connections. The new services and applications help the development of broadband Internet while broadband Internet can pave and accelerate the development of new technologies. A critical problem is unacceptable connections in areas with low-speed Internet as the world moves towards the Metaverse and IoT. So, the development of wired/wireless fixed/mobile broadband Internet is important in reducing the emerging digital divide.

Broadband access guarantees strong economic development. FTTx and 5G technologies play a major role in this direction and their deployment is commercially viable in densely populated and urban areas [50], [51]. Infrastructure costs have limited how FTTx and 5G can deliver effective broadband Internet services to rural areas [51]. Due to the small population and economy, the communication infrastructure of rural areas lags behind their urban counterparts [52-54].

By addressing the problem of the digital divide and the need for strong economic development, broadband Internet penetration significantly reduces civic engagement, political participation, and non-profit involvement in public affairs [55], [56]. An important question is, “How does it affect global social capital and interactions that enable people to work more effectively together to pursue common objectives?”

As demonstrated in Fig. 4, ten solutions to improve the current conditions, upgrade the broadband Internet network, and solve the associated problems related to the digital divide and social impacts of broadband Internet are as follows:

1. *Governments' attention and operators' focus on balanced wired/wireless fixed/mobile broadband access.* Balanced and stable development of broadband Internet makes it possible to achieve and enjoy the benefits below:
   - New job opportunities;
   - Improving the penetration rate of broadband Internet;
   - Providing high-quality services and applications;
   - Increasing average data upload and download rates;
   - Average latency and jitter reduction;
   - Making new high-speed/low-latency services;
   - Achieving high economic added value;
   - Increasing subscriber satisfaction.
2. *Sharing infrastructure and convergence of fixed and mobile broadband Internet*. Because of reducing costs and increasing broadband coverage in a joint manner, governments and network operators are growing infrastructure sharing [57]. Moreover, Fixed and Mobile Convergence (FMC) Internet allows fixed and mobile networks to work together to provide complete, reliable, and inexpensive services. FMC provides a variety of quality services to fixed and mobile users regardless of terminal, network, application, and location [46]. It is also useful for operators, especially in places where one platform cannot provide services while it can be created by another platform. It means subscribers can get a wide range of services at a reasonable price [58].
3. *Data transfer from wireless 5G to wired FTTx.* In locations with optical fiber, mobile users covered by 5G who are fixed or have limited mobility, transmit and receive data over optical fiber infrastructure. In this way, the following four advantages can be obtained:
   - Increasing the speed of downloading and uploading data;
   - Releasing the occupied frequency channels;
   - Removing interference and radio pollution;
   - Reducing latency and jitter.
4. *Special attention to new digital technologies requiring high rate and low latency.* The new digital technologies that require broadband Internet are IoT, Sixth Generation (6G), Metaverse [59], Augmented Reality (AR), Virtual Reality (VR), video streaming, and online gaming [60]. Their expansion requires the existence and access to broadband Internet and ICT. These technologies encourage operators to put more efforts into their development and broadband Internet [61]-[64].
5. *Establish and increase the number of data centers around the world*. High latency and jitter are due to latency from multiple transmission and delivery environments, and connections to distant data centers. The increase and distribution of data centers around the world adjusted with the number of users and Internet penetration rate can be a suitable solution.
6. *Support of governments in the development of fixed and mobile broadband Internet and creation of incentive aspects.* The costs of upgrading the mobile network from 4G to 5G and the high time and costs of creating the basic infrastructure of the optical fiber-based network are the factors that prevent and slow down the development of broadband Internet. With the support of the government, it can be solved and the process accelerated. To encourage operators to provide fixed and mobile broadband services and to interest domestic, office, and business fixed users in using stable, reliable, and inexpensive FTTx broadband Internet, financial and spiritual incentives and tax exemptions are needed because the investment return time in these platforms is longer than existing 4G/4.5G wireless and copper cable platforms.
7. *Integrated terrestrial-satellite networks.* With the growth of global communications and the pervasiveness of the IoT, connectivity to rural and remote areas is considered important for future networks [65]. 6G and beyond will enable a fully connected world, providing ubiquitous wireless connectivity for everyone. The convergence of Communication, Computing, Control, Localization, and Sensing (3CLS) and multi-sensor eXtended Reality (XR) programs change the future networks such that they provide heterogeneous services and unified network coverage for everyone and everything [66], [67]. Hence, integrated terrestrial-satellite networks provide broadband access to all users worldwide [68].
8. *Virtualized Fiber Wireless (V-FiWi) broadband access networks.* It effectively integrates heterogeneous Virtual Networks (VNs) originating from the Service Provider (SP) into the same Substrate Network (SN) provided by the Infrastructure Provider (InP). It plays a key role in providing distinct requirements between wireless frontend and fiber backhaul subnets to enable heterogeneous resource allocation between them [69].
9. *Dynamic spectrum reuse using Cognitive Radio (CR).* Networks are positioned as a preferred paradigm for addressing spectrum capacity challenges with next-generation networks driving the intersection of multimedia, broadband, and broadcast service. CRs solve these issues through spatiotemporal access to the dynamic spectrum in in-band and out-band classes, underlaying and overlaying scenarios, and various low, mid, and high frequency ranges in 5G and 6G. Also, spectrum efficiency is improved by using CR learning models, network densification architectures, massive Multi-Input Multi-Output (MIMO), and beamforming [70], [71].
10. *Solve the social impacts of broadband Internet.* This issue needs solutions because high-speed Internet replaces offline activities such as civic partnership, political participation, and face-to-face interactions.

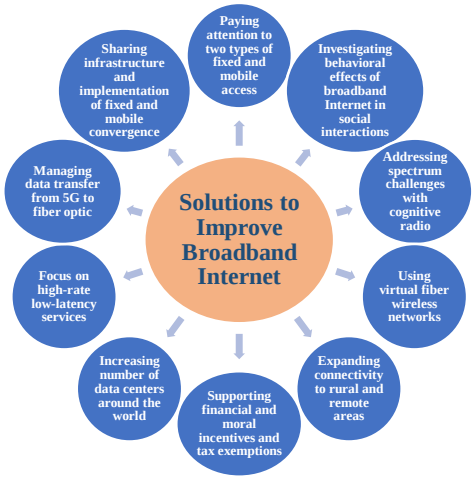

Fig. 4. Ten solutions to improve global broadband Internet.

V. Conclusion

High speed and good quality broadband networks are needed to support a large number of applications to help the following objectives in line with the digital world and virtual space:

1. Sustainable and balanced development;
2. The convenience of citizens' lives based on online services;
3. Internet-based services in a fair way around the world;
4. Internet business boom;
5. Electronic government and banking;
6. Virtual education;
7. Services based on video streaming;
8. Online interactive games;
9. Metaverse and applications based on AR and VR;
10. Internet of Things.

The quality of service of Internet-based applications, the concern of operators, and the satisfaction of subscribers can be measured and evaluated based on various criteria, such as download and upload speeds, packet loss, network latency and jitter, availability, reliability, security, establishment and setup time, and subscription cost. These differ in wired and wireless networks and fixed and mobile scenarios, because end-to-end distance, network bandwidth, hardware configurations, end-user problems, and physical issues are different.

With the cooperation and constructive interaction of two fixed and mobile platforms, it is possible to achieve high-speed Internet with low latency and gain the benefits of two platforms. Therefore, sustainable and balanced development will be implemented with infrastructure sharing and convergence of wired/wireless fixed/mobile networks and using the advantages of 5G and FTTx platforms and satellite networks.

Although the Internet has several positive effects, high-speed Internet access significantly reduces civic and political participation, and broadband penetration destroys several dimensions of social capital. It creates destabilizing democracies and delegitimizing state institutions, with wide-ranging effects on the psyche, and exacerbating digital inequalities. Hence, to find an optimum stable broadband Internet, the following items need more attention:

1. Connecting all people and protecting human rights;
2. Accelerating the access of communities to the Internet;
3. Internet integration and preventing its fragmentation;
4. Data governance and privacy protection;
5. Applying advanced technologies and artificial intelligence;
6. Creating safety, security, and responsibility.

Acknowledgment

This work was supported as an extended version of the output of the technical-functional observational project entitled “Broadband Internet in the World,” by the ICT Research Institute (ITRC). We would like to thank our colleagues for the help and support they provided.

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