IEEE Internet Technology Policy Community White Paper

OPTIONS AND CHALLENGES IN PROVIDING UNIVERSAL ACCESS

February 2017

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EXECUTIVE SUMMARY

IEEE’s goal of universal Internet access for all global citizens has roots in the IEEE Board of Directors' recently approved position statement on universal access. Although the general support and response for this goal tends to be strongly positive, many obstacles and challenges to providing this commodity for all global citizens still exist. Within the framework of the IEEE Experts in Technology and Policy (ETAP) working group, and under the umbrella of IEEE's Collabratec Internet Technology Policy Community coordinated by IEEE consultant Jared Bielby, a group of industry experts have collaborated to identify and propose solutions to these challenges. After basic needs and electricity are addressed, the six challenges identified include the following: Infrastructure, cost, digital literacy, availability, disinterest, and public policy. Each of these challenges is explored, and various options for solutions are discussed. The advantages of universal global Internet connectivity are many and varied, and providing universal access for all will most likely support the UN’s Sustainability Development Goals.

INTRODUCTION

IEEE's goal of universal Internet access for all global citizens has roots in the IEEE Board of Directors' recently approved position statement on universal access. Although the response to this goal tends to be strongly positive and supportive, many obstacles and challenges to providing universal access for all global citizens remain. Within the framework of the IEEE Experts in Technology and Policy (ETAP) working group, and under the umbrella of IEEE's Collabratec Internet Technology Policy Community coordinated by IEEE consultant Jared Bielby, a group of industry experts have collaborated to identify and propose solutions to these challenges.

Universal access to the Internet, by default, surpasses geographical and political borders, cultures and economy. It excludes any form of discrimination and gives rise to flexible options for connecting the human population, both technically and socially. Internet access, as a concept, also evolves in much the same way as the Internet itself evolves and will in time also be intimately connected to the Internet of Things (IoT). From its humble beginnings as a closed communication network of the U.S. Department of Defense, as well as a number of Universities, to the hub of global communications everywhere form banking to entertainment, the Internet grew from a small project to a massive communication network that encompasses so much more than a mere repository of information. The Internet opened up new spaces for interaction that transcended traditional borders of citizenship, making way for the advent of the global netizen and allowing new interfaces for interacting with the world around us. The Internet is indeed a global system of interconnected (computer) networks—accessing the Internet has become the central function of the computer for many people.

BACKGROUND

The Internet had a limited role in the not-so-distant past. It was mainly relegated to browsing purposes. In many developing countries, "cyber cafés" were prevalent, popular for being one of the only options for accessing the Internet. However, rapid technological advancement has ushered in novel methods of Internet communication through portable devices, especially cheaper-to-acquire mobile phones. Many users now take for granted the process of accessing and using the Internet in their daily and routine tasks and are dependent on its functionality, from on demand phone calls to life-hacking videos to chatting with friends and colleagues on social media.

One of the signifiers of modern-day communications is its exponential advancement in accessibility and efficiency among devices used to access the Internet, represented by the evolution of the computer itself, an iterative progression from home computers to wireless portable devices. Likewise, users view each new application release as a mechanism towards advancing, if not extending, their currently applied version of the traditional Short Messaging Service (SMS). An abstraction of the intricacies of technology tends to shield users from comprehending the underlying infrastructure of such communications, and most users are oblivious to the nature and complexity of the processes involved in their dependence on the Internet for communication. While such abstraction is not without its problems and poses questions of sociological and educational accountability, the layered process also poses advantages in terms of universal access, as it can hasten widespread Internet adoption.

The following white paper is the result of an intensive collaborative research project addressing options and challenges for providing universal access. However, before delving into the challenges and solutions of universal Internet access, certain assumed foundations must first be acknowledged and established as the necessary basis for exploring the question of universal access from.

BASIC NEEDS AND ELECTRICITY

MASLOW'S HIERARCHY

In many areas of developing countries around the globe, citizens are focused on the tasks of obtaining water, food, and shelter. From Maslow's hierarchy [1], these needs are basic and fundamental, and each level, bottom upward, must be satisfied before any of the above levels of needs can be adequately met.

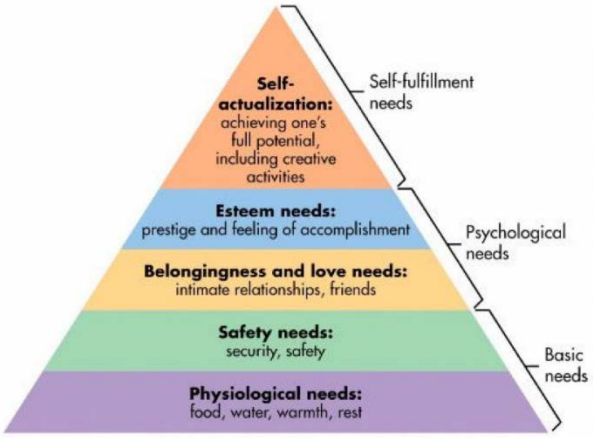

FIGURE 1. MASLOW'S HIERARCHY OF NEEDS
Source: (Maslow, 1943)

Clean water, proper sanitation, and sustainable farming are often given higher priority over educational/literacy directives and access to the Internet. The question is asked in discussions around providing Internet access whether the infrastructure for meeting basic survival needs should be addressed first (i.e., water and power resources), or should Internet access be primarily provided to enhance the building of that basic infrastructure. As to many dilemmas, the answer is "both."

ELECTRICITY

As society evolves, and countries develop, the need for and dependence on electricity has become evident. Some would consider electricity a basic need, along the lines of physiological and/or safety needs. Electricity has become assumed in developed countries where most people take it for granted, until of course it becomes temporarily unavailable due to power outages, natural disasters, or other events. Obtaining Internet access includes the assumption that there is a safe and reliable source of electricity nearby that would enable the use of computer information technologies that provide Internet connectivity. Routers, networks, laptops, and mobile phones are all dependent on a source of electricity. As such, the utility of power must be in place before the goal of Internet access for all is explored. Options to provide electricity via renewable energy sources include using solar panels, wind turbines, or other technologies. A portable solar PV array to charge mobile phones is another solution to providing connectivity.

HOW INTERNET ACCESS COULD HELP MEET BASIC NEEDS

Although access to the Internet has not been recognized as a human survival need on the same level as oxygen and water, it is a very valuable tool for satisfying all of the levels of needs in the above hierarchy. Knowledge from the Internet can explain ways to clean and/or desalinate drinking water. It can provide information about irrigation and crop choices for farmers, which in turn will satisfy the physiological need for food for the farmer, his/her family, and possibly other village members. Nutrition and dietary information from the Internet could assist with developing diets for specific nutritional or medical needs. Medical information from the Internet might assist doctors and other medical personnel in their diagnosis and care of their patients. Weather information and natural disaster warnings and recovery information

obtained from the Internet could significantly contribute to the comfort, security, and safety of global citizens. Communication through Internet channels could improve any emergency disaster relief efforts that might be critical to survival. The benefits and advantages of Internet access are wide-ranging and continue to expand on a daily basis.

UN SUSTAINABLE DEVELOPMENT GOALS AND HOW INTERNET ACCESS HELPS MEET THEM

In January, 2016, the United Nations adopted 17 Sustainable Development Goals (SDGs) agreed upon by 150 member nations as a model for ending poverty and for furthering global development [2]. Information and Computer Technologies (ICTs) will form the infrastructure that enables the implementation of these goals in the timeframe set forth by the UN. Three pillars outline the development of the goals: economic development, social inclusion, and environmental protection.

The International Telecom Union has clearly outlined [3] the criticality of an ICT infrastructure as necessary to meeting these goals. One clear requirement of implementing ICTs as the infrastructure is that of providing Internet access to every individual worldwide.

The United Nations Broadband Commission in its "State of Broadband 2015" report [4] has outlined the current spread of global Internet access, confirming that in developed countries 82% of individuals are connected to the Internet, while in the developing world, only 35% of individuals are connected. A separate classification designated under the term the Least Developed Countries [ref of list] has only about 9.5% of individuals connected to the Internet. Despite the poor access rate, the more pressing point of concern is that the growth of Internet Access is in fact slowing down. Roughly 56% of the individuals in the world are still not connected. The biggest concern is that Internet access growth in the LDCs is progressing at a slower rate than either developed or developing countries.

Of the 17 UN Sustainable development goals (SDGs), almost all of them require universal Internet access and ICTs for their necessary development. Below is a summary of the UN SDGs with an explanation of how ICT/Universal access enables meeting them:

1. *No poverty*: Accurate information services that are directly accessible by the end-stakeholders will allow equal access to economic resources, efficiently execute property right records, and give individuals access to

mobile banking and micro-financing that can be used to rid poverty by providing opportunity. The other issue in developing countries and least developed countries is leakage of economic aids and services or inability to deliver development resources to the targeted recipients. ICT and Internet access, through efficient information systems, reduce the leakages, and thus accelerate the development.

2. *Zero Hunger*: With Internet access, farmers can access information and services at much lower cost. Universal Internet access will enable e-commerce opportunities that will allow farmers timely and cost efficient access to markets to procure seeds, fertilizer, equipment, etc. Farmers having interconnected markets will enable new business models to access farm equipment as needed at lower and affordable cost points. Farmers will have access to markets to sell their produce to manage supply and demand of agriculture products, fostering more availability of food products and more reasonable costs. Additionally, accessing weather information, disease information, fire information, and water information via the Internet will assist farmers with planning sustainable agriculture and improving productivity.

3. *Good Health and Wellbeing*: Telemedicine requires secure and reliable Internet access. With availability of telecommunication networks, health workers can communicate with patients and monitor medical conditions remotely. With the ratio of health workers being lower in less developed countries, this will enable the health workers to improve their reach. After this is established, then, with the availability of IoT-based cheaper and more efficient medical monitoring equipment, medical care can be provided remotely either at home or at remote medical centers. Additionally, much more rapid access can be provided to data identifying epidemic outbreaks, as well as enable remote diagnosis services and provide reminders to patients. With analytics and other newer AI based tools, medical providers can routinely respond more quickly to medical epidemics and pre-identify an epidemic before it spreads.

4. *Quality Education*: With reliable and robust universal Internet access, electronic books, and teaching materials, students and teachers will be able to prepare and learn remotely at any time. With virtual reality and augmented reality being available at cheaper price points, their use in education will explode in the coming years. This will significantly improve the quality of education of the students. With access to vast amount of information and interactive access to experts and remote counsellors, educational systems will be able to increase their reach.

5. *Gender Equality*: One of the critical goals for sustainable development, especially in developing countries, is gender equality. The effort is not only aimed at ending gender inequality but empowering women to participate in social and economic spheres, results in a multiplying effect on development. Since most women traditionally spend more time at home, having Internet access at home or in their communities is critical. There is clear evidence that women in both developing and developed countries empowered by information access online have made major improvements in not only their own progress but their society's progress. Internet access for women has proven to be a major factor in bringing about gender equality.

6. *Clean Water and Sanitation*: ICTs enable the decentralization of water management. For example, it was previously necessary to staff all water processing centers, creating a minimum viable size. Transducers and IoT have changed that. With ICT and newer control systems based on IoT rapidly becoming more affordable, discovery, monitor, and control of water resources will become affordable for everyone. These technologies will also enable more equitable distribution of resources and will keep end users informed about any disruptions and change. With more affordable control systems the water management can be controlled more locally along with leveraging the larger area data to make more informed local decisions. Control systems will reduce the distance travelled for accessing these resources. With the availability of newer control systems based on more interconnected devices, waste disposal systems will become cheaper and more efficient. These control systems will also enable higher extraction of recyclable resources.

7. *Affordable and Clean Energy*: ICT and Internet access will enable reduction of energy consumption by using smart grids and smart home control systems. These smart systems will enable control of energy consumption as well as more distributed clean energy generation. More renewable energy generation requires better monitoring of energy generation and consumption so that the supply and distribution targets are kept in balance in real time. Technology and efficient communications help in keeping the end users informed and educated in energy supply resources, thus helping end users make better choices in their energy sources and cost. Remote operations of systems and services made possible by universal access will also prevent energy consumption that would have been required due to the required travel.

8. *Work and Economic Growth*: Computer skills have already become mandatory for those seeking employment or running even a medium-sized business. Today, with the widespread growth of e-commerce, many

financial and business transactions are conducted online. Financial inclusion today not only means having a bank account, but a lot of businesses today are expected to provide online transactions for clients. In addition, electronic payments require clients to have Internet access. With credit cards, debit cards, e-wallets and digital payment interface becoming commonplace, all business organizations—large, medium or small—must have electronic transaction access. To minimize tax evasion, money laundering, and illicit trades, many governments are setting goals to increase more transactions by online and electronic means, thus requiring individuals and businesses to have Internet access.

9. *Industry, Innovation, and Infrastructure*: Today basic infrastructure not only includes road, water and sanitation, electricity, and housing, but also Internet infrastructure, as many services in urban areas require Internet. Most industry and research organizations need interconnectivity to reduce inequality with customers, suppliers, and partners, as well as other co-locations due to globalization. Additionally, innovation requires that individuals have access to the infrastructure to be connected if they want, not only at work locations but also at home and in public spaces. Smart cities require Internet availability at every location—both static and mobile. With newer technologies like automation and machine learning, unnecessary repetition of tasks can be eliminated as can hazardous working conditions. This may lead to a fear of job loss but in fact it will free labor resources towards an ability to focus on jobs that require more complex problem solving. On the other hand, virtualization reduces infrastructure costs and energy loss in sharing of ICT resources.

10. *Reduce Inequality*: Internet is a great leveler—it gives a single individual the same power as the most powerful governments. Social media has also amplified that voice of each individual--enabling ideas to be freely expressed irrespective of their authors. Access to information through the Internet has also broken the cost and censorship barriers, even when governments attempt to erect barriers to keep control of policymaking. Internet access has provided a platform to empower citizens.

11. *Cities*: Smart cities, including smart censors, require Internet access as their backbone. People living in smart cities require universal access to access services in their area.

12. *Sustainable Consumption and Production*: Sustainability in production and consumption is attained through product-specific improvements such as: customization, dematerialization and virtualization. All sectors of an economy –including agriculture, mining, production, construction, transportation, supply chains, smart urban and rural buildings, and other

infrastructure, can benefit from information access across interacting boundaries. Smart cities and smart infrastructure can have IoT-based information exchanges with machine-to-machine exchanges. Innovative ICT applications including cloud computing, machine learning, predictive analytics, smart grids, smart metering, and smart appliance can enable sustainable consumption and production. This access would require much smarter Internet infrastructure.

13. *Climate Change*: Understanding climate change requires data collection and monitoring. Today, climate action requires collecting and analyzing these data on a larger and larger scale. First, nations as well as individuals must react to the changes that have been set in motion, which requires information dissemination to minimize the consequences of climate change. Internet is the most cost effective medium for this purpose. The other area where Internet is critical is in managing sustainable development. Active information technology can assist individuals and localities in making sustainable choices, such as using renewable and carbon-free energy.

14. *Life Below Water*: Monitoring as well as stakeholder access to the Internet will increase accountability of using lake and marine resources. Satellite and other information collection will ensure enforcement of marine regulation.

15. *Life on Land*: Conservation of forest and forest life can be monitored by Internet-connected infrastructure. If indigenous peoples have Internet access, they can be critical assets in conserving forest flora and fauna. The Internet can also assist in providing effective forest management through use of monitoring devices and rapid information dissemination.

16. *Peace, Justice and Strong Institution*: Citizens can become more confident in their government with the transparency and ease of participation provided by universal access. When all the facts on the table are easily scrutinized by any legitimate stakeholder, the transparency gained will significantly improve peace and stability.

17. *Partnerships for Goals*: Universal Internet access can forge partnerships using all forms of media, such as data, voice, and video. Universal access is also key to enabling collaborative work. Today, our world is smaller in every way, and Internet is the primary medium through which to forge partnerships.

OVERVIEW OF CHALLENGES

After basic needs and electricity have been met, six options and challenges have been identified as barriers and/or obstacles to universal Internet access. These include:

Internet Network Infrastructure:

We must determine an appropriate infrastructure that will connect the unconnected. Issues include network design choices, technology choices, and integration issues that exist between current systems in place and future infrastructure choices.

Cost of Infrastructure and Service:

Cost is a major issue in two areas—the cost of the infrastructure and the cost of the Internet service provider (ISP). If there is an existing infrastructure at a certain location, it must be determined whether it is feasible to maximize its use to provide connectivity for all of the local population. It may instead be more logical to use newly constructed or newly implemented infrastructures. The capital expenditures as such include installing, operating, and troubleshooting for the chosen infrastructure. In addition, an Internet service provider must be put in place for these areas and regions. Costs must be determined for them, and accountability established for who will ultimately bear the future costs of the sustaining the system.

Universal Education, Digital Literacy, and Content:

Even if the entire global population was to have access to the Internet, is must be asked whether local populations have the expertise and knowledge needed to effectively and efficiently use their access. Even after providing the infrastructure and the technologies needed to connect via laptops, mobile phones, or other information communication technologies (ICT), we must still ensure that everyone who desires access also possesses the skills needed to use these ICTs. Furthermore, we would want to provide insight to the local populations as to how they can find relevant data on the Internet. The content must be relevant to their daily lives for them to want to access the Internet. In many parts of the world, most of the Internet is not available in the local population's language and/or dialect, so both the content and the language must reflect local needs in order to be useful.

Location and Availability:

Some remotely located areas of the globe raise unique and difficult challenges for Internet access. What new innovative technologies and trending business models can be used that would reach the remotest locations around the globe?

Disinterest:

In light of all of the challenges and obstacles, a sample of the global population will still choose not to access the Internet for any number of reasons. Commonly accepted values should not be forced on any particular population or individual, particularly when those values conflict with a local population's value system. Providing educational sources to increase awareness of the digital divide and the benefits of Internet connectivity, while still maintaining individual freedom of choice, might be the solution for those disinterested in connecting to the Internet.

Public Policy:

Governmental regulations and local public policies might inhibit connection to the Internet, or they might provide selective content for their citizens. Should there be a creation of National Universal Access Policy from National Governments in addition to the building of a publicly funded infrastructure for accessing the Internet assisted by National Governments and the World Bank? Or is this an area where it would be unwise to force a particular practice on all citizens? The public policy aspect of universal Internet access is currently evolving, and solutions for this challenge are becoming evident.

CHALLENGE AND SOLUTION: INTERNET INFRASTRUCTURE

Internet access is important to reach every person and to eliminate any potential barriers to access to information and services on the web. Rapid population growth is affecting the economic development cycle that requires "critical Internet infrastructure" to attract the most highly skilled workers or dynamic firms. All of the below aspects are significant enablers to economic growth, delivery of services and improvements for the quality of life for all global citizens. Specifically, Internet infrastructure is of primary importance for:

1. *Citizens*: In 2012, the UN Human Rights Council unanimously decided that a connection to the Internet is one of human rights the same as free speech, cultural identity, and security to improve quality of life [5].

2. *Education*: Internet access is very important to all levels of education (pre-school through post-doctoral). Students can have access to online learning classes even if they are miles away from the school [7]. Also, while research via print-based resources is time-consuming and limited by access, Internet-based resources are both faster and provide a wide variety of choices at once.

3. *Government Information and Services*: Internet access plays a significant role in politics and government functions by facilitating information and service access. The UN defined e-government as "the utilization of the Internet and the world-wide-web for delivering government information and services to the citizens [8]." E-government increases the government functions' transparency and allows citizens to interact with legislators to make timely contributions to the decisions that affect them.

4. *Healthcare*: Internet access is a very useful communication tool between patients and their health providers, especially in emergency cases [9]. Also, Internet access allows health providers to monitor their patient activities.

5. *Social Impact*: Internet access is the cornerstone of connecting people (professional and non-professional) using many social networks such as Facebook, Twitter, LinkedIn, and IEEE's Collabratec, thereby making the entire world a small village [10].

6. *Economy*: Internet access has made economic activities more efficient, faster growing, and less dependent on geographic constraints and limitations [11]. For example, market advertising, GPS-based products delivery, and Internet-based trading are boosting economies significantly.

ELECTRICITY AND ACCESS IN RURAL AREAS

One of the challenges to universal access pertains to the lack of a significant infrastructure available to parts of the population. Even in countries that have a developed infrastructure, there are still areas that lack Internet connectivity because the area also lacks the electricity infrastructure. One of the identified challenges to providing universal access to all is the lack of a reliable and dependable source of electricity for those living in areas of energy poverty. According to the International Energy Agency in 2016,

approximately 1.2 billion of the world's population still lacks access to electricity. Approximately 80% of these live in rural areas. Access to the Internet is difficult but not impossible for this group of the globe's population.

In Central America, Asia, Africa, and other regions and countries that have low electrification rates, one of the solutions to providing these residents with electricity is through the use of renewable energy sources in the form of off-grid or micro-grid electrification systems. The difference between off-grid and micro-grid is the possibility of being connected to the country's traditional infrastructure. A micro-grid system would be able to connect to the traditional electric grid; an off-grid system lacks this electrical connectivity component.

Using solar panels, wind turbines, or geothermal technologies, the off-grid system could provide a source of electricity limited in recurring energy costs for those living in rural and/or remote areas. Some business models used to implement these systems include a Non-Governmental Organization that would procure all of the necessary supplies, personnel, and logistics to make an off-grid system a reality in rural remote villages. But once the system is in place, how do the residents connect to the Internet? If the rural area is geographically located near a local mobile service coverage, then the residents could use their smartphones to connect to the Internet.

Mobile phones were being used prior to the NGO's installations of the renewable energy off-grid system. Where did the electricity come from to recharge the mobile phone batteries? One solution was for one village resident to collect all of the phones and take them to the nearest charging station. This could be an hour to three hours away. However, solar-powered keychains are arriving on the market that contain a handheld solar PV array, and these can be used to charge small batteries. With wireless 4G or LTE connections, these residents can be connected to the Internet.

OPTIONS FOR INFRASTRUCTURE

Internet infrastructures can be divided into two main categories: wired and wireless. Wired infrastructures include Digital Subscriber Line (DSL), Broadband over Powerlines (BPL), Cable modem, and fiber optic. Wireless technologies include satellite and cellular networks such as 4G/5G, LTE, etc. Also, Internet infrastructures can cover three kinds of areas (urban (> 50,000 people), semi urban (< 50,000 people), and rural) according to Census Bureau's urban-rural classification [12].

In rural areas, providing basic infrastructure for access is a challenge. Whereas, improving efficiency of existing infrastructure is another challenge to incorporate maximum number of users. ICT industry has gone through a rapid change and is attracting more and more Internet users. User demands are also increasing day by day in terms of bandwidth and service innovation. Infrastructure, on the other hand, is not expanding with the same proportion and is one of the challenges in providing Universal Access.

The existing Internet model consists of two entities: infrastructure providers and service providers. In this model, infrastructure is used to lay out the grounds for service providers to offer their services to customers. As ICT industry has rapidly grown, existing infrastructures have been unable to keep up with increasing bandwidth demands [13]. Thus, they have no capability to incorporate the additional traffic that will be generated by increased number of users. At the same time, changing the whole infrastructure is too expensive.

To solve this problem, ICT researchers proposed the concepts of virtual networks [14]. These virtual networks lie on top of existing infrastructure, providing higher bandwidth, improving security, and handling more diverse traffic requirements. Deploying fiber optics on existing electronic infrastructure is the best example of this virtualization.

In 5G networks, with the emergence of more stakeholders in the Internet, the service provider is subdivided further into: virtual network providers, virtual network operators, and service providers, shown in Figure 2 below. Emergence of more stakeholders in the current Internet will improve the capacity and capabilities of the network; hence, the satisfaction level of existing users will increase, attracting more people to join the Internet community.

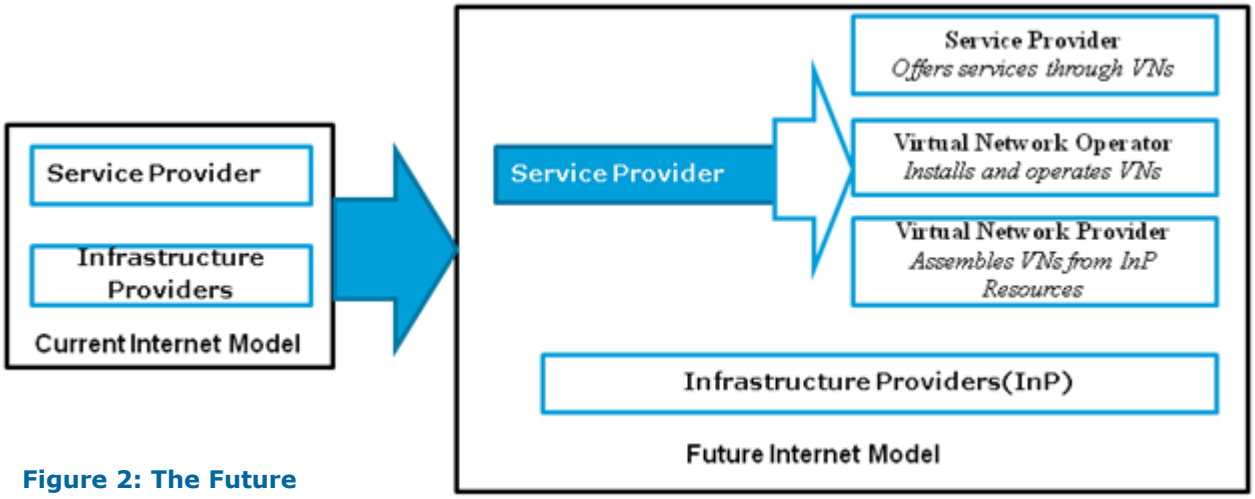

Figure 2: The Future Internet Model

Countries like South Korea and Japan are already on the way in achieving the goal shown in Figure 2. This expansion is reinforcing better quality, lower rates, and increased interest in obtaining access. Other countries can follow these examples to adopt technologies to expand their infrastructures.

CHOOSING TYPES OF INFRASTRUCTURE

Choosing a technology for Internet infrastructure will depend on many factors such as the area (urban, semi urban, and rural), kinds of required services (such as voice telephone and home entertainment), cost and availability [15]. Some details about various countries' Internet infrastructures are shown in Figure 3.

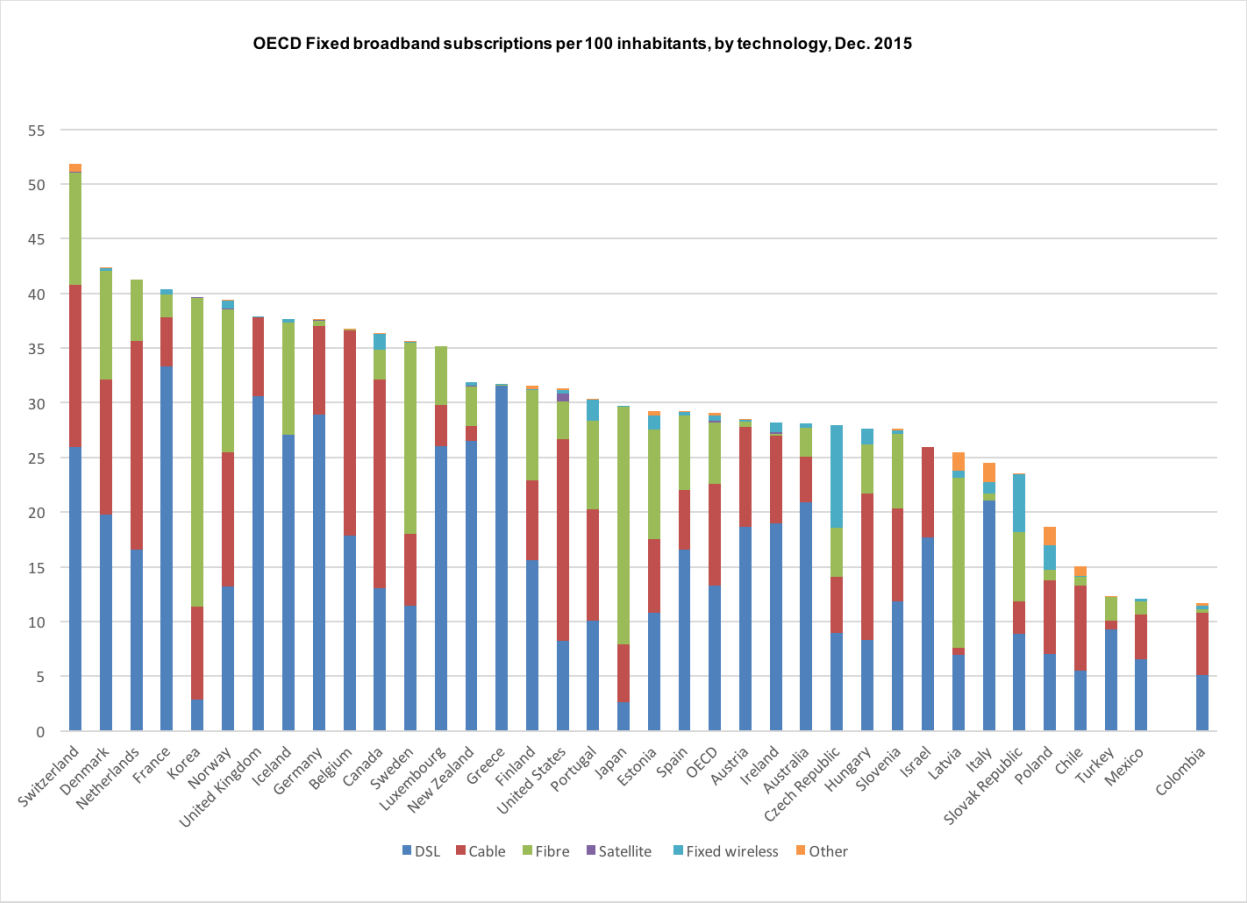

Figure 3. OECD Fixed broadband subscriptions per 100 inhabitants, by technology, Dec. 2015.
Source: OECD, Broadband Portal [16]

WIRED

Wired infrastructures include:

1. *Digital Subscriber Line (DSL):* DSL is a wired technology that uses copper telephone lines to transmit data over a variety of speeds depending on the distance between house/business and the closest telephone company facility [17]. This kind of technology is appropriate to all types of areas. There are two types of DSL: Asymmetrical DSL (ADSL) and symmetrical DSL (SDSL). ADSL is used for residential customers, and SDSL is used for business customers and provides high bandwidth. SDSL can be divided into two types: High data rate DSL (HDSL) and very high data rate DSL (VDSL).
2. *Broadband over Powerlines*: Broadband over powerlines is a wired technology that uses the existing low-voltage electric power distribution network [18]. This kind of technology is appropriate to rural areas and provides comparable speeds to DSL and a cable modem.
3. *Cable Modem*: Cable modem is a wired technology that uses coaxial cables that deliver TV services [19]. This kind of technology is more appropriate to urban and semi urban areas.
4. *Fiber Optic*: Fiber optic is a wired technology that converts electrical signals into light, then transfers the light over transparent glass fibers [20]. This technology is very fast, and data transmission speed reaches to hundreds of Mbps. This kind of technology is appropriate to urban areas as shown in Figures 4 and 5.

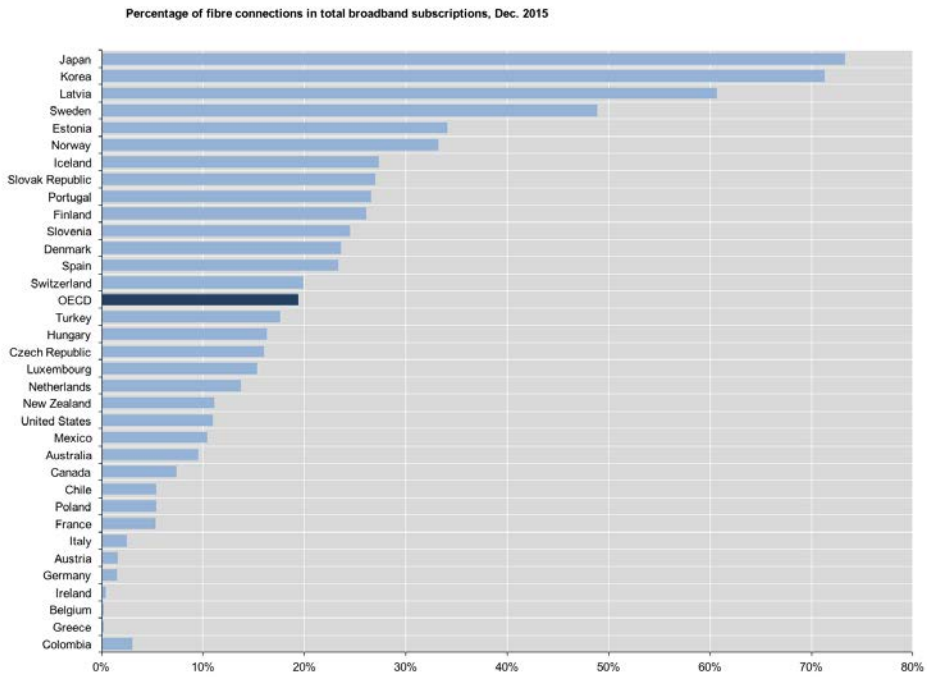

Figure 4. Percentage of fiber connections in total broadband among countries reporting fiber subscribers, Dec. 2015.
Source: OECD, Broadband Portal [16]

WIRELESS

Wireless infrastructures include:

1. *Wireless*: Wireless technology uses radio frequency to transfer data that built on top of IEEE 802.11 standards [21]. There are wide ranges of specifications of this standard, including 802.11a, 802.11b, 802.11g, 802.11n, and 802.11ac. The first widely accepted standard was 802.11b, known more commonly as Wi-Fi, and runs on the public 2.4GHz spectrum and is capable of data speeds of up to 11Mbps over a range of up to 150m.
2. *Satellite*: A wireless technology that succeeded in providing a faster and more reliable Internet service, especially in remote or sparsely populated areas such as rural areas, than the standard public system telephone network (PSTN) [22]. However, the downstream and upstream speeds of satellite technology depend on many elements such as natural obstacles, weather conditions, and location (line of sight) to the orbiting satellite. Satellite service can be worked in two modes: asynchronous and synchronous. Asynchronous refers to the upstream and downstream speeds as being different. Whereas, synchronous refers to the upstream and downstream having the same speed. The main challenge of wireless technology is that many cell sites are required to cover rural and low population areas; a costly venture. Most investors have focused on urban areas since they can maximize their profits in high population areas.
3. *Mobile Wireless*: A wireless technology that uses microwave signals to transfer data and Internet over cellular towers [23]. Mobile is appropriate to provide services to highly mobile customers as shown in Figure 5.

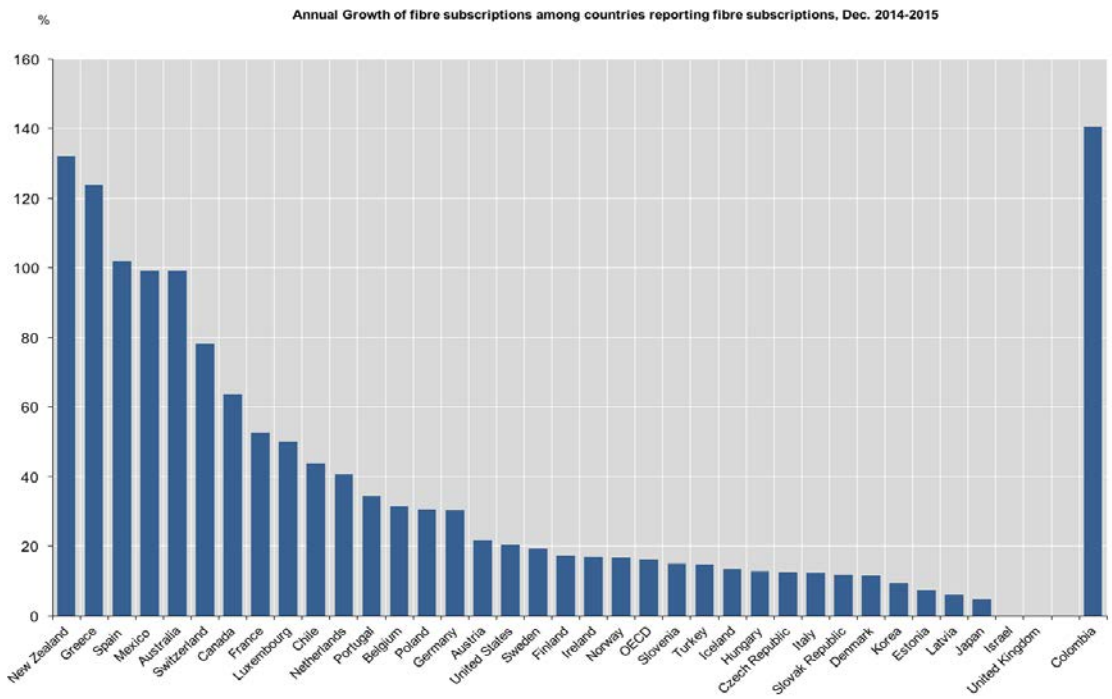

Figure 5. Annual Growth of fiber subscriptions among countries reporting fiber subscriptions, Dec. 2014-2015.
Source: OECD, Broadband Portal, www.oecd.org/sti/broadband/oecdbroadbandportal.htm

CHALLENGE AND SOLUTION: COST

DIFFERENT BUSINESS MODELS TO LOWER THE COST OF INTERNET ACCESS

Internet access has become an essential utility and an integral part of our lives. Many of us could not imagine a day spent without it. However, more than half of the world population is still completely offline, and cost is one of the primary reasons for this discrepancy. The Worldwide Internet Users Pyramid shows 4 billion people at the bottom of the pyramid as still being offline.

The International Telecommunication Union (ITU), a United Nations (UN) agency, manages telecommunication operations and services throughout the world, and regularly publishes Information and Communication Technology (ICT) facts and figures, as shown in Figure 6.

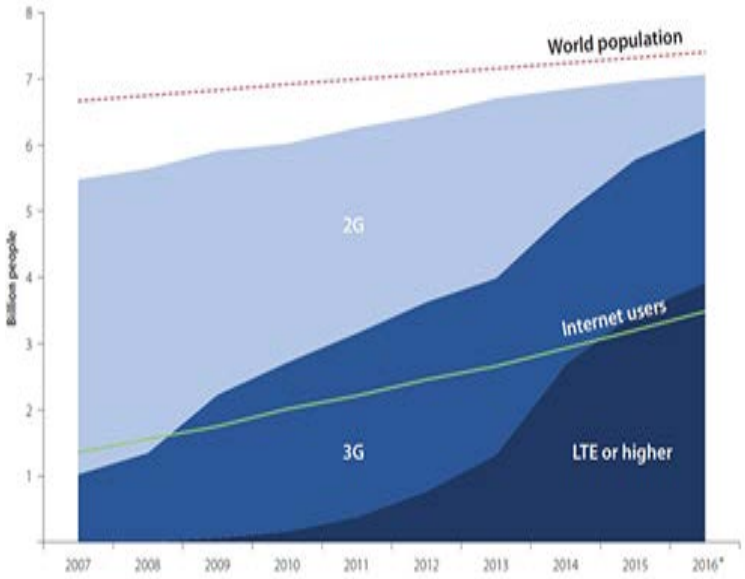

Figure 6: World Population using different technologies
Source: ITU

If we dig into the data, we find many countries where Internet prices are unbelievably higher or incredibly cheaper than the median cost. According to data released by ITU on July 22, 2016 (regardless of falling prices for ICT services), around 3.9 billion people (53% of the world's population are unable to access the vast resources available on the Internet. About one third of the population is offline in the Americas and the Commonwealth of Independent States (CIS) regions. Almost 75% of people in Africa are non-users, only 21% of Europeans are offline. In Asia, Pacific and the Arab States, the percentage of the population that is not using the Internet is very similar i.e. 58.1 and 58.4%, respectively [24].

Therefore, we need different business models to lower the cost of Internet access. Two option are outlined below:

***Community Internet or Crowdsource Approach*:** One of Interesting models proposed by Fon is based on a unique crowdsourcing approach. Wi-Fi signals have been divided into two signals: one dedicated for private use and other for shared purpose for Fon subscription holders. Fon users may share their home Wi-Fi in exchange for free Wi-Fi at other locations. Hotspots are free for users who contribute, offering the elimination of roaming charges.

***Internet Architecture*:** In certain parts of the world where it is expensive to provide end-to-end-always-on-connectivity, other methods like Information-Centric Networking or Delay Tolerant Networking may be explored. Information-Centric networking may help provide local services and content without being end-to-end connected. Internet-in-a-Box is a small and inexpensive device that provides essential Internet resources without any

Internet connection. It provides a local copy of half a terabyte of the world's free information.

BANDWIDTH

By early 2016, international Internet bandwidth reached 185,000 gigabits per second, up from 30,000 gigabits in 2008. But, bandwidth is unequally distributed globally. Absence of bandwidth remains a major impediment to improving Internet connectivity in developing and least developed countries. Fixed broadband prices across the world range from as low as $5 (per month) to an unbelievably high $1,700 (per month). However, most countries' range falls between $5 and $60 per month [25].

Low prices in Russia, Sri Lanka, and India can be at least partly attributed to a high level of competition between the suppliers and an obvious aim from the government to keep the cost low. A total of 12 nations offer broadband cost of $10 or lower per month. The least expensive broadband is just $5.5 per month in Sri Lanka. Cuba has by far the most expensive broadband services around $1,753 per month, but recent political and infrastructure changes in Cuba have allowed home internet access which was considered illegal a few years back. The second most expensive broadband is Swaziland, at $875 per month.

BROADBAND PRICES COMPARED TO INCOME

The cost of Internet seems to be falling in all parts of the world, which is a good news. Three years ago, the world's average price for fixed broadband was 115% of GNI per capita, which is now reduced to 40%. But in the majority of the world, the price of broadband is still very high, which hampers users from using the Internet with peace of mind. Prices also seem linked to the nation's income level, with the lowest comparative prices in countries that have the highest incomes.

The low income of individuals in the offline population is exacerbated by the often-high cost for Internet precisely in those same locations. Low income is because of the poor economic circumstances affecting the large segment of the offline population. Similarly, adjacent infrastructure such as electricity and roads is lacking, hence increasing the costs to network providers in extending Internet coverage. The Internet requires the presence of electricity; hence, without power, getting the Internet is difficult.

Moreover, developing countries face the challenge of the difficulty of doing business in specific regions, therefore impeding development of localized content and services. Poor infrastructure also ensures that Internet services to marginalized areas remain costly. Some of the barriers include lack of awareness of the Internet and lack of relevant content and service. While the individual in developed countries is often thinking of the Internet as a time killer, many in developing countries fail to see the relevance of getting online on a daily basis.

CHALLENGE AND SOLUTION: UNIVERSAL EDUCATION, DIGITAL LITERACY, AND CONTENT

The prerequisite of Internet literacy is general literacy. Previous literacy movements were aimed at assisting all with reading and writing the spoken language. With the beginning of the information age, the movement evolved to computer literacy that focused on efficient and effective use of traditional computers such as desktop PCs and laptops. This was sufficient until the technologies changed and became more mobile and powerful.

Moving further along on the technology spectrum, there is now the concept of digital literacy. "Digital Literacy is [defined as] the ability to use information and communication technologies to find, evaluate, create, and communicate information, requiring both cognitive and technical skills. [26]" One who is digitally literate can use a variety of diverse technologies such as laptops, notebooks, and smartphones, in his or her search for information. A person who possesses digital literacy can also search, retrieve, evaluate, and analyze information, its source, and its content. Communication and collaboration with colleagues and other peers is also a byproduct of digital literacy skills.

One of the main challenges of providing universal Internet access is digital literacy and multilingualism. Also, while some individuals are highly digitally literate, others fall at the other end of spectrum and possess only a few of these skills. Providing ways and means to increase digital literacy is a critical component to providing Internet access for all.

Fostering digital literacy will be applicable all across the world including undeveloped regions in Asia, Africa, and the Middle East. Digital literacy will assist in increasing usage of the Internet, empower citizens, improve productivity, and create social awareness. As per the fact sheet published by

UNESCO Institute for Statistics [27], the world adult literacy rate was 84.1%, and for youth it was 89.1%. Only sub-Saharan Africa and South and West Africa have adult literacy rates lower than 50%. South East Asia has slight higher adult literacy rate of 60%; however, the youth literacy is as high as 89%. Based on these rates, increasing digital literacy will clearly be a challenge in some regions of Africa and South East-Asia. However, having adult or youth literacy itself is not sufficient for increasing digital literacy, as this requires a different skill sets. With lower rates of digital literacy, there is a still a long way to go in providing universal access. Also without digital literacy, full social and economic benefits of universal access cannot be achieved.

Digital literacy and innovative policy are the two key elements that will control the growth of universal access in any country. As per [28], access to the Internet is not as simple as turning on the computer and clicking on "Google." A range of skills, some more complex than others, are required to access the range of online facilities. As per [28], the skills are variedly and unequally spread across the population with age, gender, and social-economic status all associated with different literacy levels of population. Younger people having home Internet access are likely to spend more time at home on Internet and thus have better Internet skills as compared to others [28]. Sufficient local expertise is required to create a local Internet ecosystem that can promote universal access. This expertise can be developed through training, which requires involvement from Government, NGOs, and the corporate sector.

A number of options exist for increasing Internet Literacy, especially through engagement of NGOs, NPOs, Government Authorities, Schools and Education Institutes. EU has more than 90% adult literacy rates; however, as per [29], 22% of the EU population has no digital skills, and 40% have insufficient digital skills. Article [27] states that "European campaigns such as e-Skills for Jobs 2015, and initiatives like the Grand Coalition for Digital Jobs, recognize that a digitally skilled workforce is a workforce that can meet the challenges of the not-too-distant future."

As per the statistics provided by National Digital Literacy Mission Program-India [30], only 10% of population can be considered digitally literate. The irony is that 62.6% of GDP comes from the service sector [31], and therefore insignificant efforts taken by India in promoting digital literacy can be economically damaging. In India, many non-profit organizations have developed dedicated programs for increasing Internet literacy among schools, rural women's groups, employed individuals, and retired groups. There is a big divide between rural users and urban users in India—only 36.6% of the total Internet users in India are from rural areas. Tata Trust

and Google-India have rolled out an Internet literacy program named "Internet Sathi" for rural woman in July 2015. However, the major problem in rural India is the low quality of bandwidth and Internet service, without which the actual benefit of Internet access may not be realized. Digital Empowerment Foundation has also taken initiatives to increase Internet literacy across rural masses and villages in India.

As per [32], only 28.6% of total Internet users in China live in rural areas. As in case of Africa, the Chinese rural masses do not have Internet connectivity due to lack of infrastructure and facilities. Only 28.1% [33] of Africans have Internet access, and the majority of users are located in South Africa, Nigeria, Kenya, Morocco and Egypt. In Africa, there are also a number of initiatives taken by NGOs, NPOs, Government, Educational Institutes and Business organization to increase digital literacy. SAP SE (German Software Firm) [33] has taken an initiative from October 2016 to educate 150,000 youth across 30 African countries to increase digital literacy. However, several African countries [34] are following the right path with heavy investment in Internet infrastructure and efforts to improve quality of access.

Another dimension to increase digital literacy is the use of regional languages for Internet content. The most common language used on Internet used to be English; however, today the English language is used only by 30% of the total users. A total of 10 languages are used by 82% [35] of the users besides English, and these languages are German, Spanish, Chinese, Russian, Arabic, Japanese, Portuguese, French, and Malaysian. There are total of 6000 languages in use today, and nearly 130 are available on Internet. However, in case of Africa, very few dialects are available on the Internet.

In summary, a number of emerging countries initiatives have been taken up by Government and non-profit organizations to increase digital literacy; however, more efforts are required in rural areas as compared to the urban areas.

CHALLENGE AND SOLUTION: DISINTEREST AND LACK OF MOTIVATION

Limited universal access will continue despite universal connectivity until and unless the factor of disinterest is satisfied. The IEEE ETAP Options and Challenges Working Group has classified disinterest at two levels—users and vendors.

At the user level, quite a few factors leading to disinterest need to be addressed. The first and foremost factor leading to disinterest is lack of skills or digital literacy, which was discussed above and is essential to embrace universal connectivity and universal access. Without the right skills, people's interest remains limited, and they are unable to explore the enormous potential of the Internet.

Digital awareness has an important role to play here. Without digital awareness, users remain ignorant of digital skills and their advantages and applicability. Thus, if anything goes wrong, they are likely to start blaming the change, hence gradually leading to disinterest. Lack of awareness can build a sense of fear among potential users.

Many other factors can cause disinterest. A fear of abusing or being abused by the technology (privacy concerns) can hamper embracing the change of Internet access, as well as a fear of the loss of personal online data. In addition, lack of digital skills can prevent users from finding relevant content of their choice, and the more irrelevant content appears to them, the more they tend to lose interest. Disinterest might also be caused by lack of time. If users do not have spare time to access the Internet, they might lack the motivation to do so. Age is yet another factor that contributes to disinterest. After a certain age, users do not want to embrace new things, develop new skills, or come out of their comfort zone. These factors, if they persist, will exclude a certain percentage of people from universal access.

Furthermore, people with poor economic conditions are skeptical of new technologies, since they can barely meet their daily needs with the technologies they currently have access to. Embracing universal access comes in a package—being digitally literate and buying devices to access connectivity. Therefore, until those in poor economic conditions can meet their daily needs, they cannot even consider what is needed for Internet access, so this percentage of population will remain offline until the initial hurdles are overcome. This problem should be handled by specific

governmental policies. Affordability becomes an issue here - but affordable connectivity won't lead to universal access.

In some countries, ethical and political limitations bar users from using the Internet to its optimum level. Individuals are restricted from finding the information they are looking for. Therefore, users tend to become disinterested after a certain period of time. In other countries, especially those prone to natural disasters, people lack interest, since they must worry a great deal about the safety of their families and belongings before they can worry about Internet infrastructure and continuous connectivity. Even if these areas have Internet infrastructure, natural calamities disrupt citizens' livelihood and infrastructure service. The natural result of repeated disruptions is disinterest. In yet other countries, unnecessary cost and taxation on Internet usage hinders affordability for most citizens.

Overall, the efficiency of any Internet connection affects both the availability and desirability of Internet service, including bandwidth, reliability, availability, and security. Slow bandwidth and/or interrupted Internet service, unreliable, insecure networks all contribute significantly to disinterest and can cause people to opt out of Internet access.

At the vendor level, the cost of business becomes an obstacle with the potential to deter when businesses have to digitalize every aspect and transaction. This obstacle dissuades many vendors from implementing digital connectivity in their organization. Security becomes the next most concerning factor, and information security comes with a cost. Compromise of important data about business transactions would lead to huge loss to the business. The cost of installation, operation, and maintenance of network infrastructure then becomes a deterrent to access.

CHALLENGE AND SOLUTION: LOCATION AND AVAILABILITY

Availability of Internet services is often a debatable topic, since highly reliable service may not be a necessity as is the case with the supply of electricity. Slightly lower availability of Internet services is considered acceptable to minimize degradation from user perception [36]. As per [37], availability of reliable, affordable and high speed broadband services is a key determent to Direct Foreign Investments. However, few services such as business Internet access may require greater availability of services. Normally, availability of Internet is greater in urban areas than in in rural areas. Additionally, Internet service providers have always targeted urban areas as a better return on investment than rural areas. Rural areas are not given priority for services mainly due to higher capital investments and poor returns on investments. Therefore, universal access is only increasing in rural areas mainly due to mobile Internet services. While this tendency is understandable, it works against the goal of universal access. Most proactive governments as well as the United Nations are pushing Universal Service Obligation (USO). This program requires a small percentage of their revenue to enable establishment of internet services in hard to access areas. This program has not completely solved the Universal Access problem as it will in addition require technologies that will control the cost of the infrastructure installations as well as the cost of running these installations.

As per the World Bank statistics in 2014, total of 47% of the world population is living in rural areas. In the United States, 39% the of rural population does not have universal access. However, the situation is more serious in South East Asia, where only 10% of the rural population has Internet access. Asia, Europe and Pacific countries are in similar situations.

The existing policies are not innovative enough to promote universal access to rural areas and much needs to be done. A mix of satellite and wireless broadband is recommended in rural areas in both Canada and the United States [38]. The same approach can be adopted for rest of the world, since building a fiberoptic network can be expensive and time consuming. In India, broadband connectivity to hilly rural areas in Himachal Pradesh was deployed by laying fiberoptic cables along the poles meant for electricity distribution lines.

However, in densely populated areas such China, India, or other South East Asian countries, one of two options can be achieved: Either provide Internet services to all with poor speed, or provide Internet services to limited citizens with high speed. In 2016, both China and India have witnessed a surge in

mobile Internet connections, and even with 4G services the reliability of connection is doubtful. Whether the location is rural or urban, customers are demanding high-speed Internet connections [39]. In Canada, only 32% of rural residents have faster Internet speeds. In conclusion, the Federal Communication Commission must re-evaluate the latest ICTs so as to provide high-speed connections to remote and rural areas [40].

Provision of universal access to remote and rural areas requires thorough analysis of demand and willingness to pay for services. However, considering the minimum speed required for universal access, the options of ICTs are limited. If services are too expensive, then local Governments may have to provide external source of funding or subsidies. Planning for universal access in remote and rural areas may not be the same for all countries [41]. For Europe, Middle East and North America, the density of population in rural areas is much lower compared the density in Asia, the Pacific, and South America [42][43]. As a result, providing universal access to people in rural areas of Europe, Middle East and North America will be more challenging.

As per [44], increasing awareness and digital literacy in rural areas will be a key for providing a sustainable universal service. China and India both have the slowest broadband speed in rural areas, although the Internet speed is not that strong in urban areas [45]. China has the largest number of Internet users in the world; however, the international Internet bandwidth is limited. South Korea has the highest Internet speed, with an average of 29Mbps and a peak of 103Mbps [46][43]. In the UK, only 18% of the population live in the rural areas, and average rural Internet speed is 9.9Mbps. The gap between speed in urban and rural services is about 16.5Mbps [47][48].

Overall, providing Internet services to rural and remote areas is going to be challenging, as demand and willingness to pay cannot be ascertained. Regulators and local Governments can only look towards use of better ICTs for reducing infrastructure costs and improving quality of services to rural areas. Several Universal Access Funds are established by local Governments to provide broadband services to rural and remote areas. However, universal access in rural areas may not be the same as for urban areas, and therefore a digital divide might persist.

Other factors affecting the availability in certain locations include areas such as hospitals, public transportation, and on airplanes and ships. Not all of these areas either allow or have Internet service available. In addition, natural disasters and other weather conditions may result in disrupted Internet access. This factor is important not only for telecommunication companies who own the networks and the businesses who use them, but for emergency crews and displaced citizens as well. The situation is worsened

when hospitals or other buildings necessary to disaster response lose their connections.

CHALLENGE AND SOLUTION: PUBLIC POLICY

NEED FOR PUBLIC POLICIES

Internet access can facilitate easier management of other public utilities and promote clean governance on a wider scale, of particular assistance in developing countries to eliminating corruption [49]. Only 43% of the total world population have Internet access, and the majority of the unreached population is in Asia and Africa [50]. Limited access to Internet due to legislative issues may block social developments with respect to global standards. The advantages of Internet access outweigh the disadvantages, and therefore public policy supporting quality Internet access at affordable rates would benefit a country.

Developing public policy requires involvement from governments, as well as private stakeholders. Internet is more than multi-media, and therefore the fundamental policy will be similar to that applicable for use of public space [51]. The Internet must not be considered by any government or private organizations as a tangible asset, since this will prevent universal access to citizens and prevent human development.

Additionally, the Internet cannot be controlled or restricted or taxed easily by the Government. Even today, many Governments fear that universal access will negatively impacts their society; however, this may not be true if the Internet is treated as a public space. It is a well-known fact that Internet access has increased productivity by 3% in the USA, and therefore other countries may have to re-examine the benefits of Internet [52]. The innovative policy for universal access can be common all across the globe, since the Internet can be considered as a necessary utility or even a fundamental right for citizens. The policy must cover both urban as well rural needs, and even low-income individuals of a country.

The main goal of public policy should be to provide universal access to all individuals from different communities, religions and age groups for human as well as economic development. As per [53][54][52], public policy should cover the following points:

- Provide choice and control to individuals over the access to Internet
- Allow an individual to originate and receive information considered as the right of expression
- Support application of Internet technology to education, culture, health, and employment
- Simulate interaction across geographical and social boundaries
- Increase community development through political debate and social engagement
- Increase transparency within government and private organizations
- Respect individual privacy, as well as protect data and intellectual rights
- Encourage usage of latest ICTs and infrastructure
- Provide quality services through proper allocation of radio spectrum
- Avoid burdensome taxes and prevent overregulation
- Treat Internet as a public space and not as a tangible asset for generating revenue
- Provide digital literacy for developing local Internet ecosystem

The regulator has to ensure that a competitive telecommunication market is available for successful roll-out of universal access to citizens [49]. A clear and stable regulatory framework will be required to ensure that the benefits of universal access reach all citizens, whether rich or underprivileged. As mentioned in [49], "universal access policy must take into account the new trends that are transforming the online world, and act with clear vision regarding the genuine - and unfulfilled – potentials of the new media." With regulator intervention, even the infrastructure cost can be reduced by passive or active sharing of assets [55]. Passive sharing involves non-electronics assets, and active sharing is usage of radio-access networks. The infrastructure sharing can reduce the deployment cost by 45% as per [55].

POLICIES SUPPORTING UNIVERSAL ACCESS

Full potential of universal access can only be realized when a government significantly develops multi-stakeholder policies. In the last few years, the United Kingdom (UK) and private agencies have initiated a series of policies to promote universal access through refurbishing PCs, providing public

kiosks, initiating literacy programs, and launching new funding sources and policies to reduce access cost.

A policy should not force a citizen towards necessary access. In the UK, universal access policies are not sufficient, although they are welcomed. More efforts are required from the government on the fronts of infrastructure, access from home, and open access to Internet contents [49]. The EU is planning to invest close to €155millions to boost network speed and increase universal access [56]. This investment is the outcome of promoting affordable broadband access a right to consumers all across the EU. The funding sources will be from the General Budget, and therefore telecom operators will not have to pay for building the new network infrastructure, especially in the rural areas. This intervention from the EU to promote universal access in rural areas is a supportive policy, as private players cannot afford to build infrastructures in rural areas. A few countries in the EU have policies that are promoting cheap broadband Internet access, and similar policies may be adopted by the UK. The EU is also working with various national governments for controlling lucrative auctions for selling radio spectrum. Further, the EU is seeking to improve quality of universal access by increasing the Internet speed through faster fiber optic network, instead of using old copper infrastructures [56]. The role played by the EU through development of uniform policies for all member countries can be considered as a positive step towards providing quality universal access to all citizens.

POLICIES DISCOURAGING UNIVERSAL ACCESS

The main reason for lower levels of universal access is absence of innovative policies and lack of commitment from the government and other stakeholders. A nation having a lower national wealth can also afford to provide universal access by promoting innovative policies. Article [57] clearly shows that universal access and national wealth are not directly correlated. Some emerging countries have shown slower growth, mainly due to restrictive policies, lack of transparency, and lack of commitment in spite of availability of huge copper or wireless infrastructure.

In fact, prevention of universal access can cause social and economic isolation [58]. A policy that is developed or dominated by the government or regulator will always focus narrowly on infrastructure and will not deal with developing and promoting content and services [50]. South Korea and Japan are ahead in terms of providing universal access. Policy makers may have to

depend on the expertise and commitment from a range of stakeholders to develop an innovative policy.

In February 2016, the Telecom Regulatory Authority of India (TRAI) passed a resolution after public consultation against differential data pricing of Internet services [59]. However, this step was led by TRAI, which is a semi-independent body, and more serious government involvement may be required to promote universal access to all citizens at an affordable price.

In summary, government must provide support to lower infrastructure costs, promote healthy competition, and encourage private investments [50]. Effective Public Private Partnerships must be developed so that high infrastructure cost can be borne by Public investments. This alone will not solve universal access problems, as the sustainable utilization, maintenance and growth of the network must be maintained by business models that will enable recovery of the running cost as well as growth of networks. Public enterprises have to support some of these investments to kick start development but then take a back seat once private enterprise finds sustainable business. This does however mean that public investments start recovering the investment cost at much longer investment cycles. It also requires Policymakers to think creatively in terms of Industry inputs as well as public inputs on how these policies have to be developed. As mentioned in [52], "the challenge to governments, is a rethinking of their role, their laws and regulations, and their national policies in the cyberspace era, so that they can maximize the driving forces propelling them to exploit to the fullest potential the positive benefits of this information technology, and minimize the constraining forces that act as barriers to frustrate this exploitation, while at the same time protecting the culture from harmful influences." Overall developing digital literacy and opening of Government structures is clearly needed to promote a multi-stakeholder approach for increasing universal access.

HOW UNIVERSAL ACCESS CAN AID CITIES

Universal Internet access for all is a critical human rights concern due to the evolution and implementation of ICTs in almost every facet of daily life. The growing need for cities around the world to provide more with less is a common theme that has emerged from many conferences in the past few years. City managers everywhere are looking for ways to turn their key assets into service delivery platforms that improve the lives of their citizens and help make their communities safer, more efficient, and cleaner in the process. In developing areas, the provision of basic services like healthcare,

food distribution, education, and other necessary services can all be aided by the architecture of the Internet of Things (IoT), IoT being defined as "a wired or wireless network of uniquely identifiable connected devices that are able to process data and communicate with each other with or without human involvement. [60]"

Industry is beginning to realize several point applications and solutions leveraging the power of IoT, such as connected streetlights, smart parking, smart waste management, smart transit, smart water systems, smartphones and connected cars. These are all great places for existing connected communities to thrive, providing immediate, tangible benefits that are gaining traction with city CIOs globally. For developing areas where there is little or no existing infrastructure, the IoT, properly configured to move information securely, can be utilized to provide critical services, addressing the provision of benefits to the citizens in each community.

For example, smart parking solutions are proven to reduce traffic congestion and CO2 emissions, and connected street lighting reduces city electric bills, saving money that cities can invest elsewhere. Smart water systems can predicatively pinpoint leaks within the water network and target repairs to prevent lead contamination. Electronic health care records, food subsistence programs, and social assistance programs can all be accelerated and made more efficient and effective. All of the technologies necessary to enable these programs are currently available, globally, for developed and emerging regions alike, to benefit from.

Often invisible, these technologies help our lives run more smoothly and remove inconveniences. Cities must work to ensure all these applications work together and interoperate on an integrated basis, enabling the future for Smart Cities and Smart Communities. To get there, city planners and technology providers must, at a minimum, follow three basic access concepts:

Openness

More than in any other IoT deployment, openness is key to the Smart City efficiencies of the future. Short-term, it enables a dramatic reduction in deployment and operation costs, by means of sharing and reusing a common infrastructure and field equipment (communication equipment, sensors, interfaces, etc.). Mid-term, it guarantees investment sustainability by avoiding vendor lock-in and encouraging competition. Longer term, third-party access to open data will enable new business models and use cases, spurring more innovation as well as reducing the digital economic divides and helping improve overall communications and literacy.

Standardization

Smart cities will need to rely on diverse connectivity technologies to support equally diverse use case scenarios found within each community. There is no one-size-fits-all solution. Cities will soon be required to house their complete environmental device in the cloud, an approach being adopted by industry standards, signified by the data flow layers of the IoT stack.

Furthermore, avoiding proprietary communication technologies and instead using global standards will leverage economies of scale and future proof deployments. Cities will be able to rely on standardized infrastructure for the long term, depending on accountable and transparent architectures. Comparable communication standards leading the way include cellular, 3GPP, Wi-Fi and 802.11. Necessarily, data security must be separated from a dependency on the IoT network to assure that the data control remains in the hands of the data owner, supporting the concept of net neutrality and making any delivery system quick, efficient and secure.

Finally, cities need to consider industry protocol standards that are adaptable and proven for distributed and constrained environments. MQTT, COAP or LWM2M are examples of such protocols that can be leveraged across the smart city fields and rely on IP communication. The breadth of choices will support the economic objectives and prevent hidden or inappropriate commercial business objectives from overshadowing the primary universal need for information.

Security & Privacy

Information security is widely defined as the "triad" of information confidentiality, integrity and availability. Therefore, Smart City planners should strongly reflect on how to ensure these three aspects become core values. Comprehensive end-to-end security and persistent data protection, at all levels of the IoT stack, is critical in the reduction of privacy and security vulnerabilities. Technologies that enable secure over-the-air data transmission and software upgrades will be important, particularly when paired with foundational components of policy, governance, and human rights issues. Confidentiality and integrity of data are often achieved through open standards such as TLS or DTLS at the transport layer and object-level encryption applied to the data itself, all of which are widely deployed in security-heavy industries such as banking and finance.

Availability of information, on the other hand, is often achieved through the redundancy of distributed systems that comprise the infrastructure. As mentioned before, a trigger for new business models is availability, because it provides the ability to share data among different stakeholders in a secure controlled manner. Availability is often seen as at odds with confidentiality;

however, these concepts can be reconciled by moving the protection process to the data itself under the control of the data owner. Supporting this approach, using widely adopted standards that allow for the establishment of an Identity of Merit and an easy delegation of credentials of access, such as those described in ANSIX9.69 and X9.73, providing attribute-based object oriented encryption, are key elements.

Privacy is ensured through combining the above mentioned technical solutions, as well as other legal tools, enabling stakeholders to make information about themselves selectively available. At a technical level, privacy is often associated, at first, with confidentiality (which is actually the process that ensures that information remains private). But beyond confidentiality, additional tools must be available to allow stakeholders to make information available in a controlled way. Delegated authorization and identification mechanisms, such as the OAuth and FIDO standards, have been developed to allow precisely this.

City CIOs around the world are looking into the Smart City model to enhance the lives of their citizens and find new revenue streams leveraging their assets. IEEE is a key enabler of this vision, working alongside city planners and global OEMs. Information security is a primary requirement, central to the broader concepts of a smart city and universal access to information for all.

CONCLUSION

The United Nations Sustainable Development Goals that are built on the three pillars of (1) economic development, (2) social inclusion, and (3) environmental protection, are also predicated on the assumption of Internet connectivity for all. Although the goal of providing universal Internet access appears achievable, the necessary conditions still do not exist that would support the worthwhile endeavor of global inclusion for all netizens.

First and foremost, a reliable source of electricity is needed to support the required ICT infrastructure. Solutions include using renewable energy sources to provide electricity if the traditional infrastructure is not yet in place. From that foundation, much work needs to be done to provide the network infrastructure that will support global Internet connectivity. Some solutions include DSL, BPL, cable modem, fiber optics, wireless technologies, and satellite. Parallel to the infrastructure issue is the location and availability of connectivity providers. Developed countries typically have more choices, whereas undeveloped and least developed countries have fewer options. Solutions include expanding the options available.

Underlying the choices of network infrastructure and connectivity providers are the challenges of cost. This includes both cost of the infrastructure and cost of connectivity service. Business models will need to expand or be created to address these challenges. Even if all of these prerequisites are in place, universal access will occur only if there are supporting public policies in place. With the appropriate public policies, additional challenges include universal education, digital literacy, and content. In other words, making the Internet content relevant for all possible netizens must be addressed. And lastly, there will always be part of the population that is not interested in connectivity. While they should not be ignored, getting this group to connect may be an issue that is beyond the realm of the task of the IEEE Internet Technology Policy working groups. The advantages of universal global Internet connectivity are many and varied, and providing universal access for all will most likely support the UN's Sustainability Development Goals.

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REFERENCES

[1] Maslow, A.H. (1943). A Theory of Human Motivation. *Psychological Review, 50,* 370-396.

[2] http://www.un.org/sustainabledevelopment/

[3] http://www.itu.int/en/sustainable-world/Pages/default.aspx

[4] http://www.broadbandcommission.org/Documents/reports/bb-annualreport2015.pdf

[5] Zeldin, Wendy. "UN Human Rights Council: First Resolution on Internet Free Speech." *The Library of Congress. Global Legal Monitor*. Vol. 12. 2012.

[6] http://time.com/facebook-world-plan/

[7] Goolsbee, Austan, and Jonathan Guryan. "The impact of Internet subsidies in public schools." *The Review of Economics and Statistics* 88.2 (2006): 336-347.

[8] http://www.egov4dev.org/success/definitions.shtml

[9] Goldsmith, Jeff. "How will the Internet change our health system." *EC Hein (Ed.), Nursing issues in the 21st century: Perspectives from the literature* (2001): 295-308.

[10] Ting-Toomey, Stella, and Leeva C. Chung. *Understanding intercultural communication*. New York: Oxford University Press, 2005.

[11] Crandall, Robert W., and Charles L. Jackson. *The $500 billion opportunity: The potential economic benefit of widespread diffusion of broadband Internet access*. Washington, DC: Criterion Economics, LLC, 2001.

[12] https://www.census.gov/geo/reference/urban-rural.html

[13] A.K. Bashir, Y. Ohsita, and M. Murata. A Distributed Virtual Data Center Network Architecture for the Future Internet. IEICE Tech. Rep., (IN2014-165), pp. 261-266, Mar. 2015.

[14] A.K. Bashir, Y. Ohsita, and M. Murata. Abstraction Layer Based Distributed Architecture for Virtualized Data Centers. Sixth International Conference on Cloud Computing, Grids, and Virtualization, pp. 46-51, Nice, France, 22-27, Mar. 2015.

[15] http://www.internetsociety.org/development

[16] www.oecd.org/sti/broadband/oecdbroadbandportal.htm

[17] Starr, Thomas, John M. Cioffi, and Peter J. Silverman. *Understanding digital subscriber line technology*. Prentice Hall PTR, 1999.

[18] Willie, Tom. "Broadband over power lines." 2006 IEEE International Symposium on Power Line Communications and Its Applications. IEEE, 2006.

[19] Hrastar, Scott E., Mark Scheil, and Tom Steipp. "Cable modem map display for network management of a cable data delivery system." U.S. Patent No. 6,272,150. 7 Aug. 2001.

[20] Ghatak, Ajoy, and K. Thyagarajan. An introduction to fiber optics. Cambridge university press, 1998.

[21] Crow, Brian P., et al. "IEEE 802.11 wireless local area networks." *IEEE Communications magazine* 35.9 (1997): 116-126.

[22] Spilker Jr, James J. "Digital communications by satellite." *Englewood Cliffs, NJ, Prentice-Hall, Inc., 1977. 685 p.* 1 (1977).

[23] Rappaport, Theodore S. *Wireless communications: principles and practice*. Vol. 2. New Jersey: Prentice Hall PTR, 1996

[24] http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2016.pdf

[25] http://royal.pingdom.com/2013/03/12/broadband-prices/

[26] Visser, M. (2012). Digital literacy definition. ALA Connect. Retrieved from connect.ala.org/node/181197

[27] Computing and digital literacy education needs a unified approach, By ECDL Foundation, www.euractiv.com, October 2015.

[28] Livingstone, Sonia, Magdalena Bober, and Ellen Helsper. "Internet literacy among children and young people: Findings from the UK Children Go Online Project." (2005).

[29] INFOGRAPHIC: Digital skills in Europe, www.euractiv.com, October 2015.

[30] www.defindia.net

[31] "India Getting Online Faster" A study by Boston Consulting Group

[32] Media Literacy Education in China by Chi-Kim Cheung, Springer Publication, 2016

[33] SAP initiative – with hundreds of partners – will offer job-relevant software coding skills to 150,000 youth across 30 African countries, http://www.africa.com/africa-code-week-2016-tackle-continents-digital-skills-gap/

[34] SAP initiative – with hundreds of partners – will offer job-relevant software coding skills to 150,000 youth across 30 African countries, http://www.africa.com/africa-code-week-2016-tackle-continents-digital-skills-gap/

[35] Broadband Internet Penetration in Nigeria: A Review Chinecherem Umezuruike, Awodele Oludele, Kuyoro S. O., Izang Aaron A. International Journal of Research Studies in Computer Science and Engineering (IJRSCSE), Volume 2, Issue 1, January 2015, PP 1-7, ISSN 2349-4840 & ISSN 2349-4859

[36] Is Five 9 s Availability Required for Internet Services?, Stephen Smaldone, Rutgers University, 2015

[37] World Development Indicators: Rural environment and land use, October 2016

[38] Broadband Networks in the Middle East and North Africa Accelerating High-Speed Internet Access, by Natalija Gelvanovska, Michel Rogy, and Carlo Maria Rossotto, The World Bank, January 2014

[39] Every Indian has a right to a high-speed dependable Internet connection – Tech2 by Nash David, June 2016, REUTERS

[40] Intervention – Telecom Notice of Hearing CRTC 2015-134-5, Review of basic telecommunications services, Federation of Canadian Municipalities, CRTC File No.: 8663-C12-201503186, May 25, 2016

[41] Universal Access and Rural Communication Development Funds: Success factors world-wide & practical insights from Uganda, Andrew Dymond & Sonja Oestmann, Intelecon Research & Consultancy Ltd. Rural Communication Funds: World-wide experience, Intelecon Research, 5 August 2002

[42] Rural Americans' Internet use has grown, but they continue to lag behind others, Peter Bell, Research Associate, Pavani Reddy, Research Associate, Lee Rainie, Director, February 17, 2004

[43] Akamai's [state of the Internet], Q1 2015 report

[44] Bringing Broadband Access To Rural Areas: A Step-By-Step Approach For Regulators, Policy Makers And Universal Access Program Administrators, The Experience Of The Dominican Republic, November 2009

[45] Internet Challenges and Solutions While Doing Business in China, Issue 159, From Dezan Shira and Associates, Special Edition October 2015

[46] Internet-Connection-Speed-Report-by-Fung-Global-Retail-Tech-July-11-2016

[47] The State of the Urban/Rural Digital Divide, August 10, 2016 by Edward Carlson, Policy Analyst, and Justin Goss, Intern, Office of Policy Analysis and Development

[48] Two-Speed Britain: Rural Internet Use , John Farrington, Lorna Philip, Caitlin Cottrill, Pamela Abbott, Grant Blank & William Dutton, University of Aberdeen, ISBN 978-1-85752-034-7, August 2015

[49] Universal Internet Access: A Realistic View, IPPR/Citizens Online Research Publication No.1, Damian Tambini, Institute for Public Policy Research, November 2000

[50] A policy framework for enabling Internet access by Internet Society-USA, September 2016

[51] The Internet as public space: concepts, issues, and implications in public policy, by L. Jean Camp, Y. T. Chien, John F. Kennedy School of Government, Harvard University Article in ACM SIGCAS Computers and Society 30(3):13-19 · September 2000

[52] Internet policy and diffusion in China, Malaysia and Singapore, Article in Journal of Information Science • June 2005, DOI: 10.1177/0165551505052472 • Susan Xue, University of California, Berkeley

[53] Public Policy Dimensions of Universal Access by the Lyndon B. Johnson School of Public Affairs, University of Texas, http://lbj.utexas.edu/research/Rhodes-PRP/universal_access/policy/

[54] The growth of the Broadband Internet access market in California: Deployment, Competition, Adoption, and Challenges for Policy (Research Brief), James E. Prieger, School of Public Policy, Pepperdine University, March 2016

[55] The Policy Tools Making Internet Access More Affordable Across The World, Internet Governance Forum 2015, by Dhanaraj Thakur (Research Manager), Kojo Boakye (Deputy Director), and Lauran Potter

(Communications Manager) of the Alliance for Affordable Internet. August 2015.

[56] Broadband Internet access will become a legal right under new EU telecom rules, By Catherine

[57] Smartphone Ownership and Internet Usage Continues to Climb in Emerging Economies But advanced economies still have higher rates of technology use, BY Jacob Poushter, Pew Research Centre-USA, February 22, 2016

[58] Internet Policy and Governance Europe's role in shaping the future of Internet Governance, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, Brussels, 12 February 2014

[59] India’s Universal Periodic Review: Third cycle, Stakeholder Report by the Internet Democracy Project, Internet Democracy Project by Anja Kovacs October 2016

[60] Corser, George. Internet of Things (IoT) Security and Privacy Best Practices. Internet Initiative, 2017.