5G Network Slicing for Digital Inclusion

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***Abstract*—This paper focusses on the societal challenges related to Digital Inclusion. It revisits the 5G mobile communication objectives, and states the need for digital inclusion for all. Special focus is put on the entry into the digital society, including both discussion on key performance indicators (KPIs) as well as health information as the starting point for digital development. Main focus of this paper lies on the proof of the *Internet light* concept of free provision of information in developing economies. Both, the results from the first pilots in The Democratic Republik of Congo (DRC), and the ongoing installations of *Internet light* hot-spots in Tanzania support the objective of sustainable business operation with free access to information for all, thus fostering digital inclusion.**

Keywords–Internet; Internet light; Basic Internet; broadband; devices; network; information; developing economies; availability; affordability.

I. Introduction

The Internet now links several billion devices worldwide together and consists of a multitude of networks with local or global scope, privately or publicly connected to a broad array of networking technologies [1]. In the 1990s, the Internet had developed into a usable and efficient service that changed the economy. Around 46% of the world's households have access to Internet through either fixed or mobile subscriptions [2]. However, the gap between developed and developing countries is still wide. According to the International Telecom Union (ITU) [2], by the end of 2015, 34% of households in developing countries had Internet access, compared with more than 80% in developed countries. In the least developed countries, only 7% of households have Internet access. In this same set of countries, 12 of 100 inhabitants have active mobile broadband subscriptions, whereas less than 1 of 100 inhabitants have fixed broadband subscriptions.

Higher penetration of Internet access brings advantages for everyone in the society:

(i) for local governments, as digital inclusion is vital for six key sectors: health, education, financial services, retail, government and agriculture [3], [4].

(ii) for the inhabitants themselves to gain access to information related to education and healthcare, and thus offering a possibility to provide better care for themselves and their families.

(iii) for companies that realize the market potential behind this vast number of people currently not being online. This may not be in terms of the purchasing power of each inhabitant, but as a result of the mere number of people.

Access to mobile networks and feature phones have already increased drastically over the last 15 years, where the proportion of the worldwide population covered by a 2G mobile-cellular network grew from 58% in 2001 to 95% in 2015 [4]. A similar growth in access to mobile Internet is expected, but relies on overcoming the main challenges for adoption:

(i) pricing of phones. Many people in these regions cannot afford to buy smart phones and seldom use their mobile phones for more than the occasional voice call. Companies such as Micromax, Xiami and Google are however trying to meet the challenge of expensive phones by developing low cost handsets targeting these markets' needs [4].

(ii) availability and affordability of data traffic. The GSM Association (GSMA) has pointed out that by the end of 2014 around 77% of the developing world only had access to no (59%) or narrowband (18%) [5]. Though operators plan for cheaper networks with wider coverage, there will still be a substantial amount of people in the developing world not being able to connect (see section VII).

(iii) traffic speed. When connections with less than 2 Mbit/s are the normal situation, access to widely used websites and services, and downloading necessary information becomes cumbersome and sometimes even impossible due to time-outs.

(iv) lack of local content that is relevant for inhabitants in the region and exist in the local language.

The Basic Internet Foundation has been established to support *free access to information for all*, both on wireless and mobile networks. Free access to information, or the *Internet light*, is seen as a minor extra cost for the network operator, being either an Internet Service Provider (ISP) or a mobile operator. In this paper we address the Basic Internet solution and how it relates to other solutions with similar goals. Further we describe the experiences from previous installations and the ongoing work. The main contribution of the paper is on health information as starting point for digital inclusion.

The paper is organized as follows: Section II presents solutions from companies with similar goals. Section III focusses on the impact of free access to information for the Sustainable Development Goals (SDGs) [6]. Section IV addresses key performance indicators (KPIs) for digital literacy. Section V focusses on digital health as enabler for the digital society. Section VI indicates the ongoing developments for 5G network access, and discusses the technology of network layers as enabler for the *Internet light for all*. The remaining sections explain the traffic management needed for *Internet light*, and the ongoing activities in Africa.

II. Related initiatives

In this section, we provide an overview of existing solutions for Internet distribution in developing economies and discuss some of their limitations. We then give a brief introduction to our solution and its main technical challenges. Initiatives like ConnectTheWorld [7] and Digial Impact Alliance (DIAL [8]) form the political and societal platforms for digital inclusion by promoting *Internet for all*. This section concentrates on the technical approaches by Free Basics, Airtel Zero and Google.

Internet.org is a partnership between Facebook and several companies to bring affordable access to Internet services. The initiative targets both areas where access is non-existent and areas that have a mobile infrastructure. Internet access is also provided by Facebook in co-operation with local ISPs using Wifi Express. In areas with mobile coverage, zero-rated content is offered to mobile operators. Zero-rated content are web pages and apps, which are provided free-of-charge to the end customer. *Free Basics* is a Facebook service, and has been launched in 60 countries. Free Basics offers an open platform for providers of apps, websites or services. These services can be added to Free Basics as long as they abide by Facebook's participation guidelines. Free Basics has published technical guidelines for efficiency and size of pictures and other web elements [9], and has thus transferred the evaluation of apps and websites to objective measures. The idea is that the free access will help people understand what Internet is about and what it can be used for, and thus, that paying for further access to the broader Internet is worth the cost. Facebook estimates that 50% of people who use Free Basics will pay for data and access the full Internet within 30 days.

A similar platform, Airtel Zero by the Indian operator Airtel, offers free access to certain mobile applications and services [10]. Developers and service providers who pay Airtel a fixed fee for the cost of data transfer can offer their apps free to end customers.

Both Free Basics and Airtel Zero have been criticized for violating net neutrality [11], and the Telecom Regulatory Authority of India (TRAI) rulled against differential data pricing in 2015 and stopped these services.

Other actors like Google have dedicated resources for building and helping the development of wireless networks in emerging markets with the aim of connecting more people to the Internet [12].

III. Digital Literacy and Sustainable Development Goals

Our vision is encouraged by the Sustainable Development Goals (SDGs [6]), especially Goal 9. Target 9.C *Significantly increase access to information and communications technology, and strive to provide universal and affordable access to the Internet in least developed countries by 2020* is directly addressed through *Internet light*. Our hypothesis is that *Internet light for all* is viable and based on a sustainable business model.

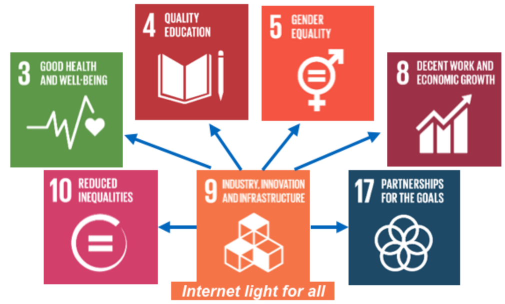

Figure 1. SDG9, target 9.C as catalyst for the SDGs

Furthermore, the free access to information is the catalyst for many other of the SDG goals (see figure 1), especially through digital health for SDG 3, digital information for education in SDG 4, empower women and girls through information (SDG 5), digital jobs and participating the in the digital economy (SDG 8), and strong contributions to SDG 10 on reduced inequalities within and amongst countries, as well as inviting everyone for the digital partnership in SDG 17.

The focus of many studies on inequalities is mainly on differences in socioeconomic backgrounds and in available resources, such as money or skills, or focused on developing inequalities such as access to basic human resources including equipment, knowledge, or education. It has clearly been recognised that digital divides influence digital literacy, engagement in social and educational life, and therefore overall participation and collaboration in an online society [13], [14]. Digital literacy skills are not "material", but the control of the material used to enact these skills is a hurdle in some poorer regions. Like other forms of human capital, digital literacy skills can be considered resources that are unequally valued and distributed.

The European Framework for Digital Literacy presents a set of tools for clarifying what constitutes digital literacy and how it can be mapped into European educational practice [15]. From this framework, we can distinguish the following types of digital skills: formal operational skills in order to navigate digital media, information retrieval and analytical skills, content creation skills, and digital communications skills. There is a need not only for updating the concept of digital literacy, but also for establishing the KPIs (Key Performance Indicators) in order to identify digital literacy and implement them into the sustainable infrastructures. Digital literacy is becoming a central empowering agent in education, business and everyday life, as work and personal lives become increasingly technologized. Computers in education are not the only way to gain access to digital content and the digital world, equally important are phones and tablets, as the Global Education Monitoring (GEM) Report indicates [16]. Information and communication technologies (ICTs) are raising the bar on the competencies needed to succeed in the 21st century.

The Global Education Monitoring Report indicates that in the European Union, in 2014, 65% of adults could send an email with an attachment and 44% could use basic arithmetic formulas in spreadsheets. While, in 2004 - 2011, only 6% of adults in 29 developing countries had ever participated in a specific digital literacy program outsides of schools. These are just examples that digital illiteracy is also present in developed countries, and make a strong case for the inclusion of digital literacy in the SDGs.

IV. Key Performance Indicators

Our research on digital inclusion using the *Internet light* builds the knowledge for people entering the digital society and will act as an important source for providing guidelines and business models for digital inclusion and foster development of emerging economies.

As many scholars have noted, the digital divide is also a divide of literacy and skills [14], [17]. Although the lack of access is still seen as the main barrier to digital literacy, in the case of education, business, and social development, many people could more practically engage with the technology if they had the basic skills. Thus digital literacy presents the relevant factor in bridging this digital divide by providing the social development. With regards to the social development and digital society, we are entering a critical period where emerging technologies and societal disruptive changes are happening around us.

There is a need for identifying and establishing the KPIs for identifying relevant social development criteria (such as literacies) and implementing them into the sustainable infrastructures. Regarding the KPIs, there are several issues, such as *(i)* how social development is defined for the certain project, and *(ii)* whether one is measuring the level of social development, or the consequent impact of the social development on aspects of society [18]. Also, there are challenges related to establishing KPIs and methods for digital literacy program assessment. There is no one size fits all digital skills assessment tool for measuring the success of the implemented programs. In the recent years the following organisations and academic institutions have developed a variety of concepts and methodological procedures for measuring digital skills (UNESCO, London School of Economics (LSE), Oxford Internet Institute (OII), University of Twente, etc.).

In our project we will create a framework and recommendations for developing KPIs of digital skills that can later on be deployed into developed societies as well. It will include guidelines in form of the methodological design protocol for research and assessment. The KPIs achieved from the DigI pilots (see section VIII-B) include to what extent digital inclusion fosters the uptake of digital society services, where digital inclusion is most successful and which content is most suitable to address the issue of digital inclusion.

V. Digital Health as enabler

Our research in the below described DigI project (see section VIII) started from the challenges on *(i)* how can we reach people that are not part of the digital society, *(ii)* where can we best approach them, and *(iii)* what is the type of content which will reach the people?

Our approach is to use digital health as entry to the digital society (see figure 2). In the global south around half of the population lives in rural areas [19]. Working with health and health education in such areas can be challenging due

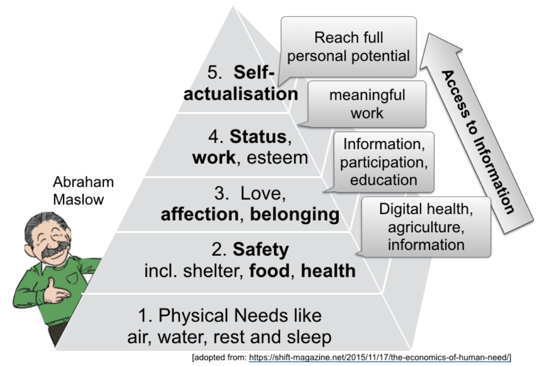

Figure 2. The role of digital health in development

to underdeveloped infrastructure and general resource poverty. Nevertheless, quality health education is needed in order to combat priority diseases referred to in national strategies and the SDG 3. The World Health Organization defines digital health as *"The use of digital, mobile and wireless technologies to support the achievement of health objectives. Digital health describes the general use of information and communications technologies (ICT) for health and is inclusive of both mHealth and eHealth"* [20]. Through the DigI project (see section VIII-B) we aim at digital health in general, and digital health education more specifically.

The objective of the digital health education intervention is to provide inhabitants in the intervention villages with free access to the InfoInternet, containing health messages in local language on HIV/AIDS, Tuberculosis (TB), *Taenia solium* (neuro)cysticercosis/taeniosis (TSCT) and Anthrax. This is mainly based on these diseases being highly prevalent or, in the case of Anthrax, a past history of outbreaks. The intervention is aimed at the inhabitants, although additional educational material will be targeting health workers through the video portfolio of the Global Health Media Project [21]. The format of the health messages will mainly be video, but facilitation of games and quizzes are also planned. The reason for choosing mainly video format is the thought of being non-discriminating when providing health education. Short videos with basic information, for example signs and symptoms of TB, can reach all — also the illiterate, and can contribute to less transmission and early detection of the disease.

The health information can be accessed at *Internet light* hot spots through own devices, like smart phones, or tablets provided by at the health facilities. Through this set-up, we achieve a non-discriminating access, especially in relation to SDG 5 on gender equality, and can contribute to balance power relations, as women are less likely to own a smart phone and therefore not able to access the Internet [22].

VI. 5G Network access

Mobile communications was classified through generations (see figure 3), with
1G introducing mobility into wireless communications,
2G addressing security through the SIM card, as well as capacity increase including the use of higher frequency bands,
3G introducing mobile Internet,
4G extending towards mobile broadband, and
5G introducing mobile networks for sensor communication, industrial networks and even higher capacity.

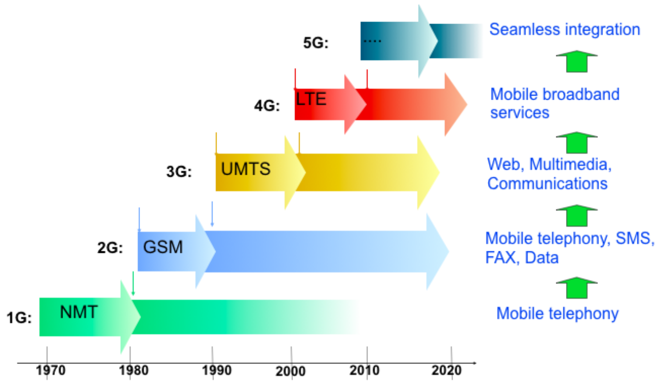

Figure 3. From 1G to 5G mobile network development

5G research introduces the concepts of software defined networks (SDN), network slicing and heterogeneous network integration to answer the diverging needs in the following three areas: *(i)* Massive mobile broadband, *(ii)* billions of devices and *(iii)* ultra-reliable and ultra-low latency networks. As argued earlier, digital inclusion is key for sustainable development and a catalyst of the SDGs. Already when 3G was developed, the slogan "always online, always connected" was one of the key arguments and seen as one of the most important features of any wireless system of the future [23]. However, even today the majority of people in developing economies *is not online, is not connected* and does not participate in the digital society.

This paper introduces a new and fourth aspect for 5G development: *(iv)* the free access to information for all. Software defined networks allows for a network slice being reserved for the provision of *Internet light*. Such an *Internet light* network layer, which needs as little as 2-3% of the available bandwidth, is a cost-effective instrument for digital inclusion, mobile onboarding and digital development.

VII. Network control for InfoInternet

In the same way as Web pages are responsive to the type of device you are using, Web pages and apps shold become network-aware. Though having Wifi networks indicating high capacity, the network is often the limiting factor, being low-capacity 2G, congested 3G or a satellite link limiting traffic (see Figure 4). This paper suggests solutions for both *(i)* optimised information provision and *(ii)* traffic shaping.

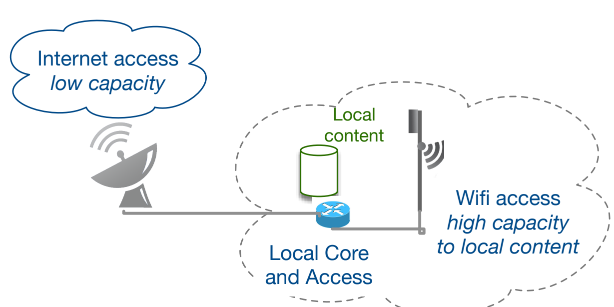

Figure 4. Bandwidth is limited by the low-capacity backhaul.

Instead of restricting content, and thus violate Net-Neutrality, we suggest to restrict content types, e.g., to allow text and pictures, but dismiss videos. However, both definition and technological implementations are not straight forward. As an example, filtering of apps with mixed content being text, pictures and videos is still an open issue.

The http archive provides various measures of content of web pages [24]. An average Web page has trippled in size from 2012 to 2017, being 1.09 MB in 2012, and 3.0 MB in 2017 (see Figure 5). The space used by scripts in web pages is between 15 and 19%, while images account to slightly more than 60%. The raise of video is documented first time in 2015, accounting for 10% of the web size, and has raised to 24% in 2017. Though the average size of Web pages has tripled within 5 years, there are remarkable differences in size. Google.com uses only 90 kB, while Wikipedia uses around 300 kB, both substantially lower than the 3.3 MB used by the NYTimes.com. On thin lines, e.g., a satellite link of 1 Mbps, a web page of 2.1 MB would load in 20 s, and block the satellite capacity for other users. The increase in size of web pages will *(i)* decrease the user experience due to longer load times, *(ii)* reduce the number of users who can be served and *(iii)* increase the cost of provision. Figure 6 is based on an analysis assuming that the average user consumes 100 Web pages per month, and compares the utilisation using uncompressed web pages, compressed web pages with 80% compression of text and pictures, and 20% compression of video, and the *Internet light* solution with compressed text and pictures, and

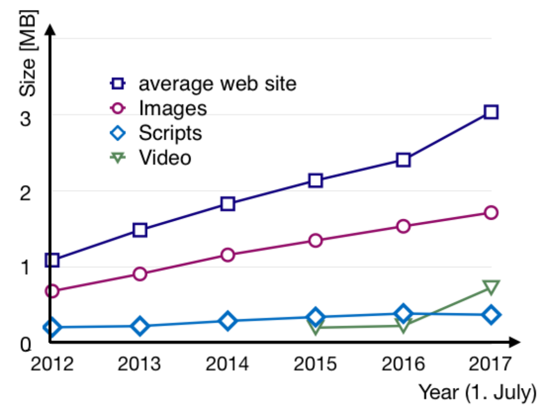

Figure 5. Increase of size in average web pages

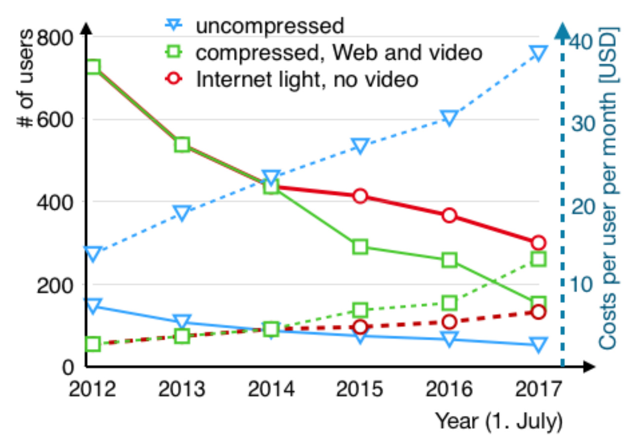

Figure 6. Number of users and costs per user (1 Mbps links)

video provision through paid channels. As figure 6 shows, a thin satellite link of 1 Mbit/s could provide more than 750 people with compressed web pages in 2012, while only about 180 people would be served without compression. Given the upcoming video services on web pages from 2015 onwards, the provision changes drastically. Using the figures from 2017, only 50 users can be served in uncompressed operation, 150 users can be served in compressed mode, while *Internet light* can serve up to 300 users over a 1 Mbit/s line.

Addressing the costs of provision makes the comparison even more significant. In 2012, the provision of 100 web pages to a user costed $13.6, while the compressed provision costed less than $3. In 2017, the provision for uncompressed web pages has raised to $38, while compressed web delivery costs $13. Using *Internet light*, information from 100 Web pages can be provided at the costs of $7 per month.

In conclusion, affordability requires reduction of information, which can be achieved through removing content, content elements, resizing images and compression of the whole web page. Opera Mini is one of the best examples of a browser designed primarily for mobile phones, smartphones and personal digital assistants that can provide a maximum of information, even though it has limited capacity in the network [25]. Statistics from Opera on using Opera Mini point to an average of 340 pages/user, resulting in an average of 4 MB per month for users in Nairobi (2011 numbers [26]).

Morgan Stanley Research describe in their 2015 report [27] that more than 50% of network traffic was initiated from web browsers. However, the report also show that users spend more than 80% of screen time in apps. These numbers indicate first of all that the browsers still constitute an important source of traffic, and that much network traffic can be reduced through adapting the browser. Secondly, there are large network traffic savings due to better guiding of apps or providing apps in *Internet light* mode.

A. *Traffic management and network centre*

The implementation of traffic management comprises two dimensions: *(i)* provide *Internet light* to many users as possible *(ii)* monitor and manage network infrastructure including a control centre and remote sites.

The Basic Internet Foundation has implemented a network architecture (see Figure 7) answering the need of a low-cost local infrastructure and rapid deployment. The infrastructure is divided into two segments, including the control centre in Norway and infrastructure in remote sites. The control centre is responsible for authentication and authorization of vouchers. In addition, the control centre operators monitor and manages network infrastructure in remote sites. The local network consists of a local control centre, a content server and the local distribution. The solution provides high capacity access to local content, payed access for Internet services, and *free access to Information*.

The Basic Internet control centre monitors local content usage trends in order to forecast and plan required network capacity and local content demand in remote sites. Thus, operators can predict which kind of contents should be localized in the remote site in order to manage expensive bandwidth efficiently. Monitoring the Basic Internet network infrastructure also improves the access network efficiency,

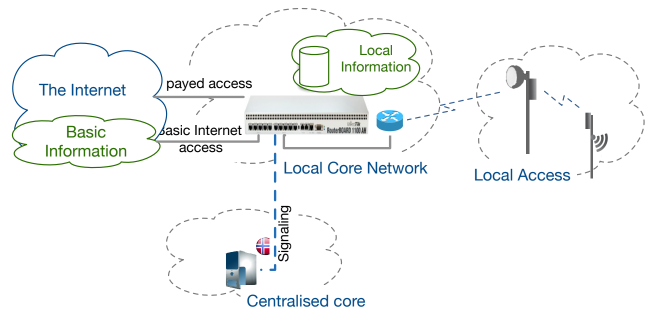

Figure 7. The cost-effective Basic Internet Architecture

while reducing operational and troubleshooting costs due to network insight. However, monitoring network infrastructure in a location with limited bandwidth imposes implementation challenges regarding monitoring intervals and volume of data collected from the network infrastructure.

The centralised control centre manages network infrastructure remotely so that it reduces the operational and maintenance cost of technical staff on remote premises. The remote management will simplify the network provisioning in remote sites so that new devices that are intended to expand the network can synchronize with the rest of the network smoothly.

VIII. Enabling the *Internet light*

The previous sections have provided the means for *Internet light* by addressing 5G network slicing, content type filtering to ensure net-neutrality, and the distributed infrastructure for affordable roll-out. This section will focus on how information provisioning and network-aware applications work together to achieve the digital society including everyone, rather than enhancing the digital gap.

A. *History and Results of Pilot Installation*

The Basic Internet Foundation started its activities back in 2010 for developing Internet access in Africa, following the idea that *information* should be accessible to everyone. A series of pilots were established in 2011, amongst others the Internet access for the region and the University of Lisala (DRC). Experiences from these pilots showed that the bandwidth limited and costly satellite link was the biggest hurdle for affordable Internet access.

The enhanced infrastructure (Figure 7), as piloted in Kinshasa (DRC), provides free access to Wikipedia and other educational sides from Cedesurk [28]. The customer infrastructure includes a local server, adding free-of-charge educational videos and content. The pilot had 5 phases (I-V), where phases I to III had the focus on integration of the centralised and the local core, the access to local information, and the provision of vouchers for the payed Internet access (see Figure 8) .

The major goal of the pilot was to bring the students up to Internet users, allowing them to use their own devices to search and use relevant content. The final goal was to leverage 90% of the students to be able to use the local content. In addition, the free access provided students with the opportunity to become creator of digital content and digital services providers. The first phases were concluded in March 2016, and the network control was handed over to a commercial actor.

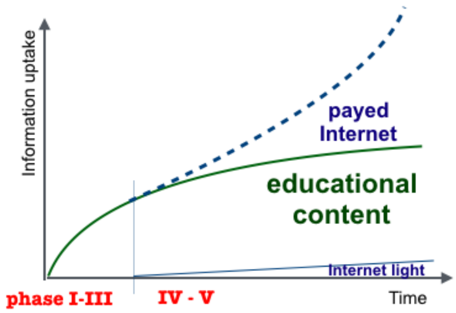

Figure 8. Uptake of Internet access (Kinshasa Pilot)

The results of the pilot implementations verify that

- A cost-effective Internet distribution is possible, providing a local core for roughly $400 and of-the-shelf access points.
- Digital access for students and faculty members enabling the use of own devices for free access to (local) educational content.
- Participation in the digital economy through creation of digital content and service provision.
- Complementarity to telecom services, providing services to people who cannot afford the access to mobile broadband.

The following section reports on ongoing activities.

B. Ongoing activities

In January 2017 the *Non-Discriminating Access for Digital Inclusion (DigI)* project started. This research and innovation activity spans over three years and is funded with 1.6 million by the Norwegian Research Council and the Norwegian Ministry of Foreign Affairs. DigI is truly multi-national and multi-disciplinary; 11 partners from 8 countries (Tanzania, Norway, Germany, Rwanda, Serbia, DR Congo, France and Spain) share knowledge in a variety of disciplines such natural sciences, mathematics, information technology, humanities, social sciences and medicine, including veterinary medicine. The sub-project, *Free access to digital health information in Tanzania*, of DigI in Tanzania focuses on digital health in general, and digital health education more specifically. This digital health education intervention is currently being prepared, and comprises the health related elements, from the development and the provision of health messages to the pre- and post-intervention study.

Focus of the DigI project is on African development, especially on the measurable means for uptake (KPIs), certainly when it comes to communications and the Internet of Things (IoT), aspects that are currently not addressed and not known. In the DigI project we will define the measurement framework and a set of KPIs to measure and evaluate the performance and impact of *Internet light* use on social development and digital society as a whole. We will identify and establish the KPIs for digital inclusion, both in terms of uptake of information, addressing: Equality through digital inclusion, growth through digital inclusion, sustainable business models, and roadmap for nation-wide roll-out.

In the first phase, the implementation will take place in three rural villages in Tanzania. Mtera and Izazi in the South, and Selela in the North. A technical team will establish hotspots in the villages with a powerful wireless network. This network gives the inhabitants free access to *Internet light* with locally stored health videos and health games. Related to the digital health education intervention, the DigI team will conduct a pre- and post-intervention study. The main aim of this study is to explore the knowledge and attitude level related to our chosen diseases before, shortly after and months after the intervention has taken place. By conducting such a study, the team will be able to indicate whether the intervention is successful concerning not only knowledge uptake, but also knowledge retention, that can contribute to change in health seeking behaviour, and ultimately reduce morbidity and mortality of the targeted diseases.

A pilot installation has been established at Kjeller, Norway, as shown in Figure 9. The pilot implementation consists of solar panel, integrated receiver and Wifi hot-spot, 19 Ah battery, LED light, mobile phone chargers and tablets providing users without a smartphone access to local videos and *Internet light*. The total costs of the health spot are below $300, and provide the users with free access to information, light and power to charge the mobile phones.


Figure 9. The Health Spot for Africa at Kjeller

The corresponding village infrastructure consists of the local network control centre (Mikrotik Hex PoE), a local content server (micro PC), and a 90° sector antenna to be mounted on the mobile network tower.

The novelty regarding business operation is the business proposition for mobile operators. Based on earlier finding, only 2-2.5% of the available bandwidth is used for free access to information for all, while more than 97% of the bandwidth are available for commercial services. These in-kind bandwith costs are rather small given the increase in digital literacy, on-boarding of customer, and the value added for the society, as well as local, regional and national authorities.

IX. Conclusion

This paper focusses on the societal challenges related to Digital Inclusion. It revisits the 5G mobile communication objectives, and adds the demand for 5G network slicing providing *free access to information for all*. In order to ensure net-neutrality, our approch of *Internet light* provides content type filtering, with free access to text, pictures and local video, and paid access to video, voice, games and other streaming content.

Results from the pilots both in DR Congo and Norway proved that *Internet light* is a cost-effective network deployment for information access, and provides people who cannot afford mobile broadband the access to digital content. Special focus is given on the entry towards the digital society, including both discussion on key performance indicators (KPIs) as well as health information as the starting point for digital development. A multi-disciplinary and multi-national team with 11 partners from 8 countries currently deploys health information pilots in Tanzania through the Digital Inclusion (DigI) project. The health spots for Africa have costs of less than $300, and provide people with free access to information, using either locally available tablets or their own smart-phones, and in addition light and power to charge their phones.

The paper suggests that *Internet light for all* supports sustainable business operation, as only only 2-2.5% of the available bandwidth is used for free access to information, while more than 97% of the bandwidth are available for commercial business operation. Given the societal advances in digital literacy, digital inclusion and the participation in the digital society, *Internet light* is seen as the enabler to connect the unconnected 3.5 billion people on the planet and to become the catalyst for the Sustainable Developmetn Goals (SDGs).

Acknowledgement

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References

[1] IETF - Internet Engineering Task Force. (1989, October) RFC 1122 - Requirements for Internet Hosts - Communication Layers, 1.1.2 Architectural Assumptions. Accessed 01Apr2016. [Online]. Available: https://tools.ietf.org/html/rfc1122

[2] International Telecommunication Union - ICT Data and Statistics Division, "ICT Facts & Figures," May 2015, accessed 03Apr2016. [Online]. Available: https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2015.pdf

[3] J. Manyika, A. Cabral, L. Moodley, S. Moraje, S. Yeboah-Amankwah, M. Chui, and J. Anthonyrajah, "Lions go digital: The Internets transformative potential in Africa," November 2013, accessed 01Apr2016. [Online]. Available: http://www.mckinsey.com/industries/high-tech/our-insights/lions-go-digital-the-internets-transformative-potential-in-africa

[4] GSMA, "The Mobile Economy report 2015 - Global," 2015, accessed 03Apr2016. [Online]. Available: http://www.gsmamobileeconomy.com/GSMA_Global_Mobile_Economy_Report_2015.pdf

[5] B. A. Lucini and D. Evans, "Mobile internet usage challenges in Asia — awareness, literacy and local content," July 2015, accessed 30Mar2016. [Online]. Available: https://gsmaintelligence.com/research/2015/07/mobile-internet-usage-challenges-in-asia-awareness-literacy-and-local-content/513/

[6] U. Nations. Sustainable development knowledge platform. [Online]. Available: https://sustainabledevelopment.un.org/sdgs

[7] "Connect the world," 2016, accessed 02Apr2016. [Online]. Available: http://connecttheworld.one.org/

[8] "Digital impact alliance," accessed 01Apr2016. [Online]. Available: http://digitalimpactalliance.org

[9] Internet.org, "Participation guidelines," accessed 01Apr2016. [Online]. Available: https://developers.facebook.com/docs/internet-org/participation-guidelines

[10] Airtel Media Centre, 02 2015, accessed 02Apr2016. [Online]. Available: http://www.airtel.in/about-bharti/media-centre/bharti-airtel-news/corporate/airtel+launches+-+airtel+zero-+a+win-win+platform+for+customers+and+marketers

[11] P. Doval, "Airtel Zero, Internet.org against net neutrality," *The Times of India*, May 23 2015, accessed 03Apr2016. [Online]. Available: http://timesofindia.indiatimes.com/tech/tech-news/Airtel-Zero-Internet-org-against-net-neutrality/articleshow/47391729.cms

[12] A. Efrati, "Google to Fund, Develop Wireless Networks in Emerging Markets," The Wall Street Journal, Tech. Rep., 05 2013, accessed 02Mar2016. [Online]. Available: http://www.wsj.com/articles/SB10001424127887323975004578503350402434918

[13] A. van Deursen and J. van Dijk, "Internet skills and the digital divide," *New Media & Society*, vol. 13, no. 6, pp. 893–911, 2011. [Online]. Available: https://doi.org/10.1177/1461444810386774

[14] D. Radovanović, B. Hogan, and D. Lalić, "Overcoming digital divides in higher education: Digital literacy beyond facebook," *New Media & Society*, vol. 17, no. 10, pp. 1733–1749, 2015. [Online]. Available: https://doi.org/10.1177/1461444815588323

[15] A. Martin, "Digeulit—a european framework for digital literacy: a progress report," *Journal of eLiteracy*, vol. 2, no. 2, pp. 130–136, 2005.

[16] UNESCO, "Education for people and planet: Creating sustainable futures for all," http://unesdoc.unesco.org/images/0024/002457/245752e.pdf#page=335, 2016.

[17] J. van Dijk, *The Deepening Divide: Inequality in the Information Society*, Thousand Oaks, California, 2005. [Online]. Available: http://sk.sagepub.com/books/the-deepening-divide

[18] D. Radovanović and J. Noll, "KPI for social development," 11 2017. [Online]. Available: http://BasicInternet.org/Publications

[19] The World Bank, "Rural population (% of total population)." [Online]. Available: https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS

[20] "Monitoring and evaluating digital health interventions: A practical guide to conducting research and assessment," World Health Organization, Tech. Rep., 2017.

[21] Global Health Media Project, "Video portfolio." [Online]. Available: https://globalhealthmedia.org/videos/

[22] GSMA, "The mobile economy sub-saharan africa 2017." [Online]. Available: https://www.gsma.com/mobileeconomy/sub-saharan-africa-2017/

[23] C. Andersson, *GPRS and 3G Wireless Applications: Professional Developer's Guide*. New York, NY, USA: John Wiley & Sons, Inc., 2001.

[24] "http archive," accessed 10Nov2017. [Online]. Available: http://httparchive.org/interesting.php?a=All&l=Jul%201%202016

[25] G. Duncan. (2006, 01) Opera mini officially brings web to mobiles. Accessed 03Apr2016. [Online]. Available: http://www.digitaltrends.com/mobile/opera-mini-officially-brings-web-to-mobiles/

[26] Opera Software, "State of the mobile web report," Online, 06 2011, accessed 03Apr2016. [Online]. Available: http://techloy.com/wp-content/uploads/2011/07/opera-state-of-the-mobile-web-report-june-2011.pdf

[27] Morgan Stanley Research, "Google: There's an app for that...the browser," Online, September 2015, accessed 02Apr2016.

[28] CEDESURK, "Centre de documentation de l'enseignement superieur, universitaire et recherche a Kinshasa," accessed 01Apr2016. [Online]. Available: http://cedesurk.cd/