Basic Internet Access: Capacity and Traffic Shaping

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***Abstract*—This paper analyzes economical and technological aspects for service provisioning on varying networks. Though mobile networks are continuously evolving, the use of mobile broadband is and will be limited. Availability and affordability are two aspects, which are addressed in this paper through the introduction of basic information and *low capacity (LC)* services. The paper addresses how information provisioning and network-aware applications work together to achieve a digital society including everyone, rather than enhancing the digital gap. Initiatives like Facebook's Free Basic and the Basic Internet Foundation and their approaches on LC-service and information provisioning are addressed. The second focus is on a pro-active approach for mobile applications (apps), adjusting to the network capacity and bandwidth limitations. The main results are recommendations towards a low-capacity Internet for everyone, supported by examples of LC-service provisioning, as well as network-aware apps.**

Keywords–Internet; 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, private or public 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. Today, 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 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 in these areas is important for three main stakeholders:

i) for local governments, as digital inclusion is vital for six key sectors: health, education, financial services, retail, government and agriculture [3]. In the latter Internet access is an important premise for harvesting benefits that lie in the use of IoT-technologies that can automate labor-intensive and health-hazardous industrial and agronomic work [4].

ii) for the inhabitants themselves to gain access to information related to education and healthcare, and thus providing 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 without access to Internet. This may not be in terms of the purchasing power of each inhabitant, but as a result of the mere number of people. Serving such a number of customers - often residing in rural areas - will only be possible through Internet instead of physical presence.

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 access is envisioned, but relies on overcoming the main challenges for adoption:

i) *pricing of phones*. Many 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, Google and Mozilla 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*. 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.

iii) *traffic speed*. When connections with less than 2Mbit/s are the normal situation, access to widely used web sites 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, in their local languages, and which also embraces the challenges of traffic speeds in the region.

The Basic Internet Foundation has been established to provide Basic Access to Information to inhabitants addressing these challenges. Free access to low-capacity information is seen as a minor extra cost for the network operator, being either an 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 main technological challenges of content delivery for capacity-limited networks, being traffic shaping on the server side and selected access on the mobile client side. The main contributions of this paper are solutions for traffic shaping and better matching of content to capacity. These solutions are vital in providing access to basic information, but will also be relevant and applicable for other implementations and usage scenarios.

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The paper is organized as follows: Section II presents solutions from companies with similar goals. Section III presents the technology challenges, and Section IV addresses first results from pilot implementations. Section V concludes the paper.

II. Related initiatives

In this section, we provide an overview of existing solutions for Internet distribution in areas with economic issues, and discuss some of their limitation. We then give a brief introduction to our solution and its main technical challenges. Initiatives like ConnectTheWorld [6] and Digial Impact Alliance (DIAL [7]) form the political and societal platforms for digital inclusion. From the technical point of view, this paper concentrates on the approaches by Free Basics, Mozilla, and the Basic Internet Foundation.

A. Free Basics from Facebook

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. Non-existent access is provided through local Internet Service Providers (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 by Facebook* is launched in 39 countries provides an open platform for providers of apps, websites or services an open platform. These can be added to Free Basics as long as they abide by Facebook's participation guidelines that shall ensure acceptable performance on older phones and slower network connections. The idea is that the free access will help people understand what Internet is and what it can be used for, and thus, that paying for further access to the broader internet is worth the cost. Internet.org estimates that 50% of people who use Free Basics will pay for data and access the broader internet within 30 days.

A similar platform, Airtel Zero, offers free access to certain mobile applications and services [8]. 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 has been criticized for violating net neutrality [9] as their approach creates a walled garden around information their users can access. Lately Free Basics has published technical guidelines for efficiency and size [10], and has thus transferred the evaluation of apps and web sites to objective measures.

B. Free access paid by ads

Mozilla has targeted the challenge of high prices on handsets by developing a low-cost handset with their own Firefox OS. In Bangladesh and several African countries they have teamed up with local mobile operators such as Grameenphone and Orange. In Bangladesh, Grameenphone offers the users 20MB of free data per day given that they visit the phones marketplace where users are exposed to advertisements that fund the access. Orange offers buyers of Mozilla's smart phone unlimited free Internet for a set period of time in several African countries.

C. Basic Internet Foundation

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.

Basic Internet thus introduced *compressed text and pictures* as the core elements for Basic Information. Information is seen as social, economic, political and cultural content depending on the background of the reader, and its importance will vary accordingly. Hence, non-discriminating access to Basic Information and net neutrality are fundamental for the Basic Internet solution. The solution allows any Internet provider, being it a mobile or an ISP operator, to set up a system where they can provide each user with free access to Basic Information. Voucher sales covers operating costs and allows end users to buy access to more data traffic. As opposed to the solutions described in Section II-B, the Basic Internet solution is not dependent on specific operating systems or apps on the users' phones.

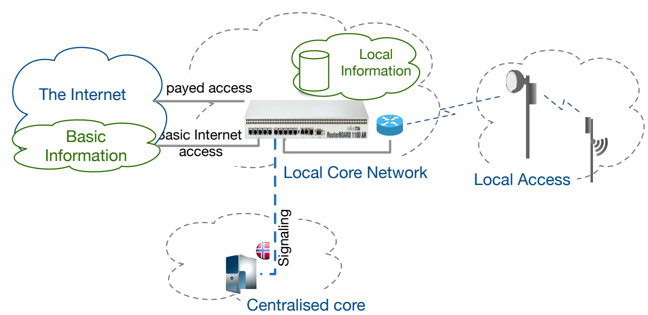

Figure 1. The cost-effective Basic Internet Architecture

As data costs constitute a barrier from accessing mobile data, the main focus of the Foundation is getting as much information as possible through a bandwidth-limited link. Some examples of such low-availability links are satellite links and congested mobile networks. The Foundation has implemented a network architecture (see Figure 1) answering the need of a low-cost local infrastructure and rapid deployment.

The Basic Internet network contains in its complete form: a local core network with local information, a local network, a centralised core, and the backhaul network/network termination. In areas where no Internet connection is available, the network termination can be achieved through either a radio link or a satellite connection. The solution provides high capacity access to local content, payed access for Internet services, and *free access* to Basic Information. Further elaborations on the business models are given in section IV.

The next section describes the major challenges related to information provisioning and traffic shaping that allows for Basic Internet access.

III. TECHNOLOGY CHALLENGES

Currently, the technological department of the Basic Internet Foundation is focused on solving two main challenges related to capacity optimization and traffic shaping: *(i)* the notification of information and *(ii)* traffic recommendation.

The *first challenge* is related to information provisioning and the way information is best presented in bandwidth-limited systems. Thus, we try to characterize information content related to the amount of bits being used in the communication. Instead of restricting content, 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. Taking the example of the resolution and the size of a picture. Depending on the content of a picture, a certain resolution and size is required to provide meaningful information. This part of capacity optimization takes place in the back-end of the Basic Internet system.

The http archive provides various measures of content of web pages [11]. An average Web page has doubled in size from 2012 to 2015, being 1.09 MB in 2012, and 2.1 MB in 2015. The space used by scripts on 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.

TABLE I. WEB SITE GROWTH AND CONTENT

	1Jul2012	1Jul2013	1Jul2014	1Jul2015
av. web site [kB]	1090	1485	1829	2135
Images [kB]	684	909	1159	1348
Scripts [kB]	210	225	293	344
Video [kB]				204

Though the total size has doubled, 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.

Thus 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 [12]. Statistics from Opera point to an average of 340 pages/user, resulting in an average of 4 MByte per month for users in Nairobi [13].

The *second challenge* is related to providing a better foundation for app developers to make their apps adhere to changing network conditions and the users' limited data plans by providing a *traffic recommender*. Basic Internet will be delivered to end users via WiFi hot spots or mobile broadband. Most smart phones allow the users to limit the apps from transferring large amounts of data when using mobile data. However, when WiFi is available, these apps usually do not consider the amount of data transferred, the end-to-end throughput, or allow for limited traffic profiles. This easily results in high bandwidth usage and poor user experience. The needs for better capacity usage in Basic Internet access networks is one application area. Addressing the bandwidth limitations is a second application area for the traffic recommender, as shown in these two scenarios:

A) The mobile unit perceives the WiFi as a high-capacity link when indeed the back end is a low-capacity 2G or satellite link limiting traffic (see Figure 2).

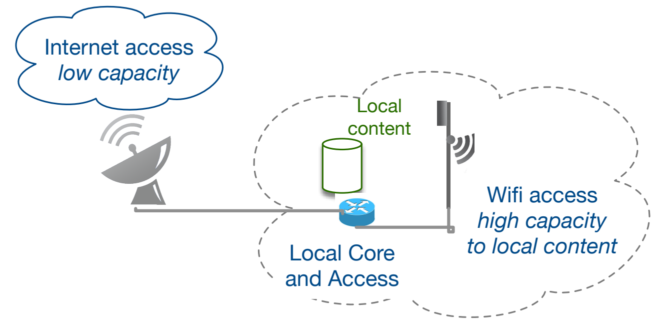

Figure 2. Bandwidth is limited by the low-capacity backhaul.

B) The WiFi AP and backhaul does indeed allow for high traffic, but the payment plan sets limitations. In the latter case, a misguided app can end up downloading unnecessary data worth a month's quota unless it is informed that access to WiFi is not the same as "send as much as you like". (see Figure 3).

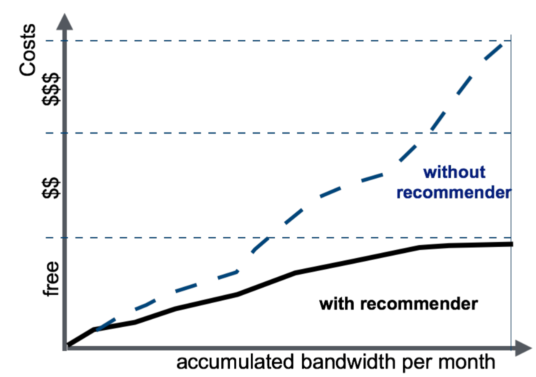

Figure 3. Free/low-cost use up to a certain data amount, and then experience full stop or high prices

A recent report by Morgan Stanley Research [14] describes 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.

In popular apps like Facebook and YouTube, further specification of bandwidth usage is available for defining whether videos should be started automatically or not, and in which quality. However, these settings require that users are aware that they *can* change these settings and also that they actually *use* that opportunity. With an average of 26 apps per mobile phone [15], we argue that the average users will not change these settings dynamically enough to a) limit their bandwidth usage as much as needed when on restricted networks nor b) get the full experience when connected to a higher-capacity access point without restrictions on bandwidth or cost. Table II shows typical bandwidth usage with different app types. Our proposal of a traffic recommender can pave the way for a more automated compliance with bandwidth restrictions.

TABLE II. NORMAL BANDWIDTH USAGE FOR TYPICAL APPILCATIONS

Service	Traffic
Web browsing	2.5 MB/min
Social Networks (1 Hour)	90MB
Video Streaming(i.e.YouTube) (1 Hour)	1125MB (720p)
Online Music, i.e. Spotify, 1 h	43.2MB (96kbps)
Mobile MMS with Video	100KB
Mobile SMS (1 message)	0.13KB

IV. Results and Impact

Section I summarised the main challenges for information provisioning to everyone. This section will focus on how information provisioning and network-aware applications work together to achieve the a digital society including everyone, rather than enhancing the digital gap.

Results of a simplified model for providing information over a satellite link are provided in Table III. For simplification, the costs per user are based only on the operational costs of the satellite link. The numbers are based on a 1 Mbit/s (Mbps) satellite link to Africa, with costs of 2000 US$/month, 12 h duty time, and a simplified linear distribution of the traffic. Table I in the previous section clearly shows the effect of basic information and compression, allowing to provide information at a satellite cost of half a dollar per month, given the average use of compressed 4 MByte per user and month. In comparison, a video transmission of 8 min, accounting to 50 MByte, would cost roughly 6 US$. Using a radio link or a mobile network termination will significantly reduce the cost, and can drop the Basic Internet provision to lower than 0.1 US$/month.

TABLE III. INFORMATION PROVISIONING COSTS

Usage [MB]	Users/1 Mbps	costs/user [US$/month]
4	3996	0.5
20	799	3
50	320	6

The Basic Internet Core Network (Figure 4) is the one responsible for the information optimization and supports traffic shaping, traffic balancing, free access to basic information and voucher-based access to full Internet including video and gaming.

The enhanced infrastructure, as piloted in Kinshasa (DRC), provides free access to Wikipedia and other educational sides from Cedesurk [16]. 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.

The major goal of the pilot was to bring the students up to Internet users (see Figure 5), allowing them to use their own devices to search and use relevant content. The final goal is to leverage 90% of the students to be able to use the local content. An additional goal is to get students become creator of digital content, and digital services providers.

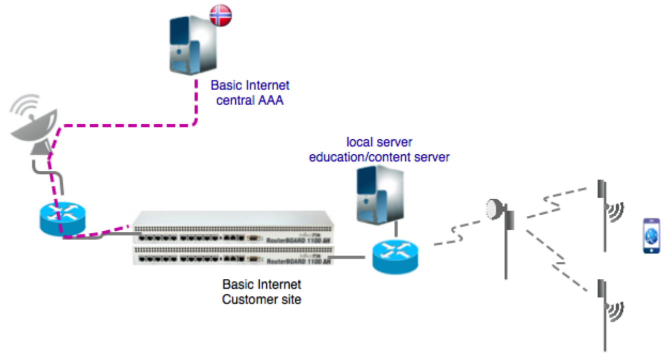

Figure 4. The Basic Internet central AAA and the Customer Equipment

At the time of writing (March 2016) the first phases were concluded, and the conversion into an operational and self-sustainable network operation is ongoing. This self-sustainable network operation consists of *(i)* voucher sales for access to Internet, and *(ii)* the provision of free access to Basic Information. This free access is financed by license fees, where a certain percentage of the sold Internet capacity is used for ordering bandwidth for Basic Internet.

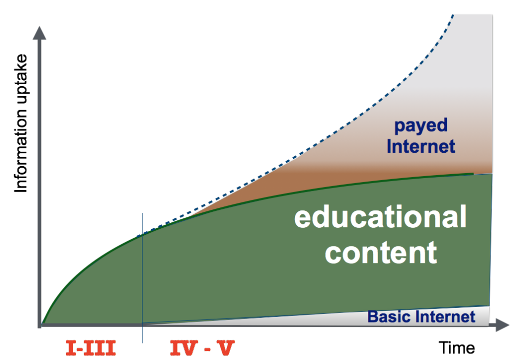

Figure 5. The expected update of Internet access

The results of the pilot implementations verify that

- A cost-effective Internet distribution is possible, providing a local core for roughly 400 US$, and of-the-shelf access points.
- The deployment leverage of students, using their own devices for free access to (local) educational content.
- Through the Basic Internet Infrastructure students can become creators of digital content, and digital service providers.
- The service offer is complementary to conventional telecom services, providing services to people who cannot afford the access to the basic information.

Other actors like Google have dedicated resources for building and helping the development of running wireless

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networks in emerging markets for connecting more people to the Internet [17]. The main concepts being provided by the Basic Internet Foundation and others are services reaching those who cannot access or cannot afford wireless Internet services. In that way, the access provision is complimentary to conventional Telecom services. Current activities include the marketing trial in Kinshasa to address potential scalability issues. Upcoming steps are pilots in selected African countries in order to address the ecosystem for digital education. Further steps include global alliances to reach out to countries seeing the need for digital inclusion.

V. Conclusion

In this paper, we addressed the needs for digital inclusion, both in developing and developed economies. Findings related to digital societies indicate that developing economies need to address digitisation as the driver of economical growth. What is common in both approaches is the need for an information infrastructure. Such an information infrastructure consists of *low capacity (LC)* services as a basic service for their inhabitants, as well as network-aware applications.

A LC-service offer can be provided as part of a public digital infrastructure, and through wireless as well as mobile networks. They will provide an always on-line experience, and thus reduce the digital gap. The LC-infrastructure is accompanied with a pro-active recommender, using the mobile device as decision maker. The recommender addresses technological aspects like actual bandwidth and economical aspects like individual capacity limits. Examples are provided how services can be adjusted to bandwith-limited systems like LC-networks, to individual data planes, and to combinations including network-availability forecast and personal information needs.

The paper further presents the results from the pilot implementation of LC-service provisioning in the Democratic Republic of Congo (DRC). The pilot proved the technical viability of LC-service provisioning, and is transferred into commercial operation following a novel business model.

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

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

[8] Airtel Media Centre, "Airtel launches airtel zero: A win-win platform for customers and marketers," 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

[9] 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

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

[11] "http archive," accessed 03Apr2016. [Online]. Available: http://httparchive.org/interesting.php?a=All&l=Jul\%201\%202015

[12] 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/

[13] 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

[14] Morgan Stanley Research, "Google: There's an App for that...the Browser," Online, September 2015, accessed 02Apr2016.

[15] Z. Fox, "The Average Smartphone User Downloads 25 Apps," *Mashable*, Sept 2013, accessed 29Mar2016. [Online]. Available: http://mashable.com/2013/09/05/most-apps-download-countries/\#9aqOLOcy6Zqo

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

[17] 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