Research Directions for low cost satellite communications: Building blocks for bridging the Digital Divide in Rural and Developing Countries

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Abstract. Bridging the digital divide in Africa is a key task in order to reach the Millennium Development Goals and allow the African Continent to take advantage of its potential for economic growth and prosperity. The absence of cheap and reliable communications means a lack of possibilities to develop a sustainable economy with local value creation. New and advanced satellite communication systems can bring fast and reliable communications even to remotest areas in rural and developing countries. New research in advanced algorithms could lead to bring the affordability of communication services further down.

Keywords: Digital Divide, Rural and Developing countries, Information technology, Broadband, Satellites, Education, Mathematical algorithms, Application Layer Forward Error Correction.

1. Introduction

The geographical morphology of the African continent, with vast and inaccessible terrains, combined with an insufficient energy infrastructure, makes it difficult and costly to roll out comprehensive wire line and fibre optic networks in African countries. Satellite services and especially low cost services, provide therefore an affordable and accessible opportunity for connectivity. There is however a need for developing new tools in order to bring the prices of satellite services and terminals further down. There are technological tools to be developed but also "legislative" tools. This paper addresses two "technological" tools, a new kind of "open source" Application layer Forward Error Correction (FEC) algorithms and subsequently a next generation Content Delivery Network (CDN) for low cost distribution of multimedia content and large files to proxy servers at or near the user terminal location. Indeed there is a lot of emphasis on the recent success of mobile networks in Africa and the undeniable push it had in penetrating ICT use in Africa. Nonetheless further action is imperative, if we want to stop the growing gap between Africa and the rest of the World to widen further. Research challenges for low cost networking in Developing countries, are present at every layer of the network, we have identified two so far for the scope of the present paper, relating to satellite services.

Of course there is also the need for "legislative" action, to further push the "Open Skies" policy of overcoming restrictions on access and further liberalization of satellite services. This is however outside of the scope of the present paper.

2. Context of satellite services

Indeed in order to bring about the conditions for economies of scale as a condition for lower prices and affordable subscriptions for community access points, SMEs, governments and households, a more open and development friendly policy framework for all of Africa has to be developed. At the present stage, although every square foot of Africa is covered by satellite signals, a still restrictive telecom policy framework hinders Africa's development (see Figure 1). Hefty license fees, monopoly operations, legislative heterogeneity from one country to another, all this stands as a barrier towards low cost 'consumer grade' satellite internet access in Africa. In this paper we address technological solutions for bringing the cost of internet services further down, based on state-of-the-art satellite communication services developed by Astra2Connect internet services, an already low-cost service for broadband two-way internet access over satellite. Augmenting current solutions with research actions along the lines proposed in this paper could lead to further price reduction on the service side and end user terminal side. It could also lead to increase the end-user access and download speed by providing a low cost CDN for intelligent caching of large files and content near to the end user site, either directly in the terminal device or at the nearest provider point of presence.

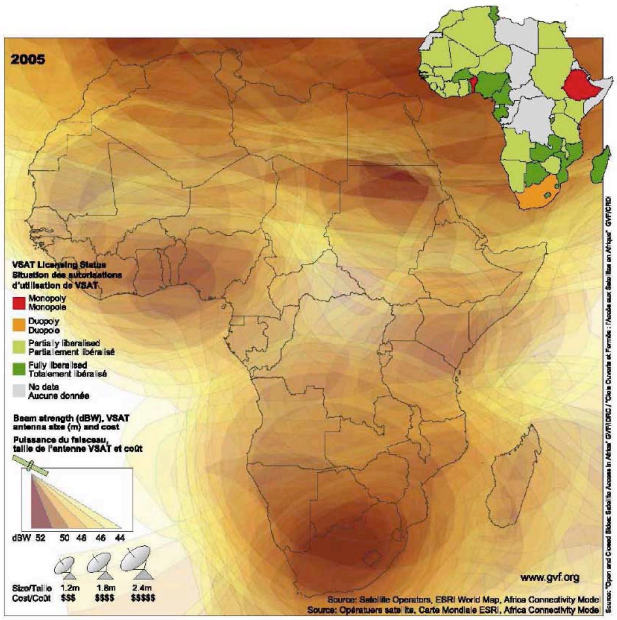

Figure 1. Satellite coverage over Africa (2005) –Source IDRC Report, 2005.

3. Satellite and Wifi links

A winning combination is the combined use of satellite backbone connectivity via low cost terminals such as Astra2Connect Sat3Play terminal and a wireless distribution system based on Wifi standard 802.11. This offers a great opportunity to deliver low cost broadband services to users in rural and developing countries.

Combined with a new kind of CDN these kind of setups can be powered by cheap solar panels and be delivering services to many users connected via WiFi. In a Rural and Developing context, the use of long-distance wireless links based on 802.11 is very promising, although research deficits exist concerning WiFi interference and loss. SES Astra has gained experience by furnishing connectivity to the OLPC XO project, in a field trial in Nigeria, at Galadima school. The connectivity was extended from the satellite terminal via a low cost Wireless mesh network. A mesh network offers an interesting approach for extending connectivity, especially in developing regions. Infact the more nodes in the network, the more resilient the network gets, as each nodes adds capacity to the network. Research directions needed are however on the standardization of Wireless mesh networking, in order to make it fully interoperable between different terminal manufacturers and wireless equipment. Indeed the high penetration of use of WiFi in Remote/Rural areas (see Figure 2), are a good starting point for further extending the combination of satellite and WiFi via innovative protocols such as Wireless Mesh Networking. Another major benefit of a wireless mesh topology is, that it enables and enhances further use of the wireless infrastructure beside connecting to the Internet backbone. Infact such a wireless infrastructure can be utilized on a local scale for VoIP telephony, health-care application, and other community related communications. While mesh networks perform well in denser populated areas, point-to-point Wireless links are a better solution for connecting groups of users for instance village-to-village. Cheap satellite links offer connectivity to the backbone and feed the proxy cache servers with updated content.

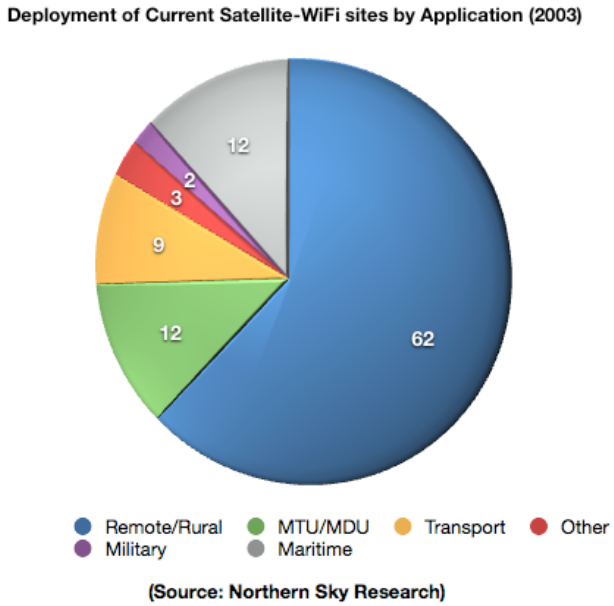

Figure 2. Satellite/Wifi deployment, by Application.

4. Forward Error Correction (FEC)

Digital communication systems, particularly satellite communication, need to perform accurately and reliably in the presence of noise and interference, caused by atmospheric events. Among many possible ways to achieve this goal, forward error-correction coding is the most effective and economical. Forward error-correction coding (also called channel coding) is a type of digital signal processing that improves data reliability by introducing a known structure into a data sequence prior to transmission or storage. This structure enables a receiving system to detect and possibly correct errors caused by corruption from the channel and the receiver. As the name implies, this coding technique enables the decoder to correct errors without requesting retransmission of the original information.

Research needed to determine and validate operating modes: Bringing together existing hardware and software in a real-world open-source test-bed would facilitate research needed to determine and validate operating modes and parameters of such systems. Researchers need to manipulate satellite link parameters (DVB-S2 modulation and coding), try out AL-FEC algorithms and parameters (LDPC choices and parameters), and CDN software configuration (RMT choices and carousel timing) on a real-world instrumented platform under varying environmental (rain), geographical, and operational conditions, in order to develop and validate a practical system design that can serve as a guide for deployment of such systems.

5. Satellite based Content Delivery Networks

Recent developments in satellite signal-coding and modulation (DVB-S2), application layer forward-error correction (AL-FEC), and reliable multicast transport-protocol (RMT) design suggests that it is now possible to build and operate satellite-based content-delivery networks (CDN) at a fraction of the normal cost (reduced satellite-power margin) for non-critical applications such as distance education in developing and developed regions.

Content Distribution Network (CDN) technology is essential in order to leverage the point-to-multipoint strength of satellites to build affordable satellite Internet services for education and development in remote areas of the world - these include Remote rural areas in Europe but also Developing Nations. CDN of this type depends on the use of Application Layer Forward Error Correction algorithms (AL-FEC), many of which have been patented. Developers of open software and hardware, such as the Ubuntu Linux distribution, are committed to the position that the use of patented or copyrighted technologies in fundamentally incompatible with their mission, and inhibits innovation. This is based in part on the certain knowledge that the Internet would not exist today without free and open, step-by-step, trial and error, on a broad scale, unencumbered by onerous licensing and paperwork obligations. In his paper “Digital Fountains: A Survey and Look Forward” Michael Mitzenmacher of Harvard University points out that “The development of new approximations to digital fountains [a type of AL-FEC], unencumbered by potential patent protection and accompanied by freely available reference implementations, could greatly speed adoption, and

provides a theoretical and technical challenge to the community. ” Vincent Roca a leader in the field from INRIA Grenoble has noted “Unfortunately we see more and more IPR claims on AL-FEC codes which has led to a dominant position of a very small number of private companies. The resulting unbalanced situation is, at the end, prejudicial to many European companies. It is therefore urgent to launch new research and development activities in this domain in order to develop codes and codecs that would be ideally free of any IPR.” Based on discussions with leaders in the field, such as Claude Berrou from École Nationale Supérieure des Télécommunications (ENST), recently elected to the French Académie des sciences for his work in this area, Vincent Roca, Brian Adamson of US Naval Research Laboratory, and many others, we believe that there are low-density parity-check (LDPC) Gallager type erasure code variants that can effect AL-FEC implementations as good or better than those already patented. It would be unconscionable to abdicate ownership of these yet unpatented AL-FEC codes to individuals or corporations for private gain, given their critical and essential importance for satellite and wireless technologies that are to play a key a role in bridging the digital divide, and the resulting enlightenment of under underprivileged individuals world wide.

6. Conclusions

We have found that low-cost satellite services such as Astra2Connect, based on low-cost terminals, are a fast and easy way to deploy broadband internet connections to remote areas in Developing Countries. The cost can be further reduced in the future by specific research actions that we have identified for the satellite part. We suggest the following research directions to be further studied in relation to allow the coming of a next generation of even more low cost satellite services for Developing countries:

- Identification and testing of AL-FEC algorithms (codes) useful for specific satellite channels (Ku band DVB-S2 satellite), and in particular open-source IPR free implementations enabling wide implementation, use, and on-going optimization.

- Low-margin link budget-study to identify optimal choices of AL-FEC type and parameters, file-delivery carousel parameters, and reliable multicast file-transfer protocol configuration, under rain fade conditions representative of developing areas (tropical).

- Reducing electrical power requirements through light-weight AL-FEC algorithms operable on slower low-power CPUs, new modes of operation such as occasional burst-in-route or receive-only, and dynamically leveraging DVB-S2 adaptive modulation and link level FEC parameters.

- Optimizing receiver design for mass-production and low-cost, such as minimizing antenna size and/or using flat panel antennas, developing a one-piece integrated and low-power design, and development of built-in installation pointing aids.

ICT offers a huge range of benefits and tools to Developing and Rural populations. Low Cost Technology hold a great promise to further democratize the use of advanced ICT tools to progress towards the MDGs and to offer sustainable means of bootstrapping economic activity in low-opportunity environments – and satellites can play an important role in offering a timely solution for Developing countries to bridge the digital gap quicky and effectively.

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