Enabling Mobile/Wireless Broadband Technologies and Services for the Next Billion Users

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Abstract- **As wireless devices and the useful services they can deliver become more pervasive and affordable; the need for wireless broadband technologies meeting the demands of emerging market countries is growing. In this paper the technology choice in wireless broadband access and service architecture is discussed with reference to three important wireless broadband technologies and relevant parameters such as service activation, authentication and delivery, cost effectiveness and sustainability. The main focus of the article is towards wireless broadband technology deployment in developing countries and rural communities for providing innovative wireless broadband services.**

Keywords-Wireless broadband technology, rural, spectrum & energy efficiency

I. INTRODUCTION

It is becoming more and more apparent that the vast majority of subscribers in developing countries will be receiving information services through wireless terminals. Therefore secure and affordable wireless technology infrastructure and platforms for wireless broadband services are needed. To meet the large demand for various secure broadband wireless services and access technologies, research and development efforts are being exerted to achieve the goal by different stakeholders. The W3C workshop [1], on "The Role of Mobile Technology for social and economic development", indicated that a large number of innovative mobile broadband services are expected to appear in the near future. However, it was also said that innovative wireless broadband services such as M-Health, M-Banking/payment, M-Education, etc., require next generation wireless broadband technologies with authentication and security mechanisms for reliable service delivery. A number of important challenges require research solutions and intelligent choice of broadband technology platforms to make a successful and sustainable deployment of the technology. The next billion innovative mobile data service users reside in an environment where the customer base is sparsely populated, composed of greater than 95 % prepaid and with low income. Such a customer base require special consideration and promotion of partnerships by all stakeholders in the wirless value chain. Secondly, developing innovative and affordable mobile services with relevant content requires the inclusion of security mechanism in the broadband wireless infrastructure. Thirdly, promotion of sustainable energy resources is becoming crucial; therefore, power and spectrum efficient next generation radio network technologies and alternative energy usage to power the communications infrastructure are vital issues that should be addressed.

Hence based on the above discussion, a sustainable and cost effective choice of mobile broadband technologies, for developing regions is crucial. The sustainability factors are those including service relevance, inclusiveness and long term aspects of economic and social development in deploying the technology. The cost-effectiveness factors include the use of sustainable energy solutions, strategies for network sharing to reduce cost and improve affordability of services, and use of a combination of emerging wireless broadband technologies. The security and reliability factors include how one can reliably deliver mobile broadband services providing confidence for information stored in the mobile terminals, network servers and during transmission over the communications network. In the following sections the paper will deal with these issues, with respect to three existing and emerging wireless technologies.

II. WIRELESS BROADBAND TECHNOLOGIES

Although the choice of technology for mobile broadband services in general is multifaceted and new emerging technologies are being promoted, in this paper the discussion is restricted to the following wireless technologies for providing mobile broadband services: 1) 3-generation UMTS technology with high speed access (3G-HSPA promoted by 3rd generation partnership project 3GPP), 2) The multi-hop wireless technologies using a combination of WIFI (IEEE 802.11x) standards and Worldwide Interoperability for Microwave Access: WiMAX, promoted by the IEEE 802.16x standards. 3) Digital multimedia multicast/broadcasting technology, exemplified by the Mobile-TV technology standards.

All three technologies are discussed in terms of the following questions that will be addressed in the paper:

- Which technology is suitable for designing, activating and affordable delivery of relevant services such as mobile health, mobile learning and mobile payment in a developing country context?
- Which technology has support to alternative energy usage and provides low power network topologies relevant for developing countries? Is the technology suitable to provide access to sparsely populated rural communities?
- What is the contribution of such a technology deployment for the long term Wireless-ICT for development initiative and digital inclusion?

Figure 1, describes a conceptual diagram designed to support the choice and optimization of mobile broadband technologies and services based on the parameters listed above.

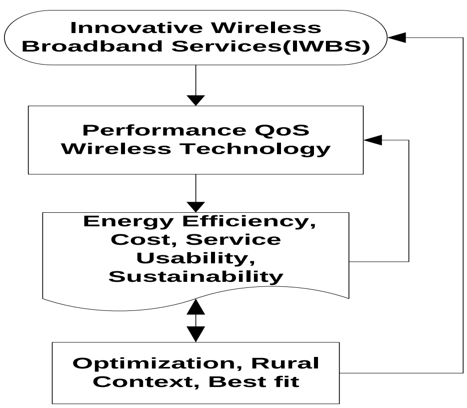

Figure 1,

A definition of an innovative wireless broadband service (IWBS) with respect to rural communities in developing regions is necessary before discussing the choice of technologies which will be used for delivering these services. The following definition of an IWMS is used in this paper:

Defn.: *An innovative wireless broadband service is a new wireless internet service which guarantees successful launch, and is motivated by real need of users. The service should be able to use low power and low cost network architecture and devices. With respect to customers, the service must fulfill a requirement, provide a benefit, and enrich the lifestyle of the subscribers.*

From the definition, we can deduct that the promotion of locally relevant IWBS services with the aim of improving the life of low income rural communities, add value to the daily business, and support to farming communities is envisaged. Service innovation and the building of an echo-system around the innovative mobile services for sustainable social and economic development are also targeted. It is assumed in this paper that services such as M-health, M-Education, M-Agriculture, e.t.c., fall under the category of IWBS.

III. THIRD GENERATION UMTS

With growing broadband internet and mobile data services demand, the 2.5 GSM generation GPRS (General Packet Radio System) was quickly introduced to fill the gap. However, even GPRS couldn't satisfy the demand for bandwidth hungry mobile broadband services, therefore 3GPP introduced the 3G-UMTS system. The system was updated again with high speed packet access (HSPA) mechanisms to support mobile broadband and internet services. The 3G-HSPA technologies, are the most common wireless broadband technology and facilitates a standards-based migration which allows the utilization of legacy infrastructure. 3G-HSPA systems can interoperate and share the core network with the legacy GSM 2G and 2.5G networks. Also a packet switching core-network can be designed to share and interoperate with WiFi and WiMAX broadband wireless technologies.

It is clear that standards-based migration lowers the cost of mobile broadband services. By utilizing communications infrastructure from the previous generation, initial investment is reduced, while service continuity and reliability is guaranteed [3]. Since mobile devices are always designed to be backward compatible and since people are used to mobile devices, service activation and delivery will also be seamless. 3GPP UMTS-4G technology with the HSPA and LTE (long term evolution) capabilities are the industry's favorite standard and choice for wireless broadband[1,2,14,15].

When it comes to power consumption, a full 3G system deployment would require a large amount of power outage from the power grid or the use of diesel generators (which is usually the case in developing countries) to produce the required energy to run each base station. Apart from this, since 3G uses higher frequencies (2100 MHz), it requires approximately twice the number of base stations, compared to GSM, therefore power efficient base station architectures and alternative energy sources such as solar power have been promoted. However, the cost and reliability problems associated with alternative energy use is still an issue. Wireless broadband internet services can nowadays be provided by a variety of devices and network technologies. Some of them are 3G-HSPA PC cards, USB modems or 3G-smartphones, or WiFi based tablets, smartphones and laptops . One of the advantages of the 3G-HSPA path is the diverse R&D activities by the industry to fulfill the requirements of enterprise wireless broadband solutions. IWBS services for rural communities can therefore benefit from the spin off of solutions that are produced for mobile enterprises. Although affordability of devices and services is still an issue, unless collaborative networking and next generation spectrum allocation techniques, described in the next sections can result in reduced service costs.

IV. WIMAX/WIFI WIRELESS BROADBAND

WIMAX, Worldwide Interoperability for Microwave Access, was designed first as a technology for extending broadband wireless services to areas without fixed line DSL (Digital subscriber line) services. It is an emerging wireless communications technology based on the IEEE 802.16x standard. In combination with multihop communications architecture, WiMAX can provide a cost effective broadband wireless access with large scale coverage [9]. A typical application scenario based on WiMAX and WiFi is shown in figure 3, where applications and services to rural, home and business environments is highlighted

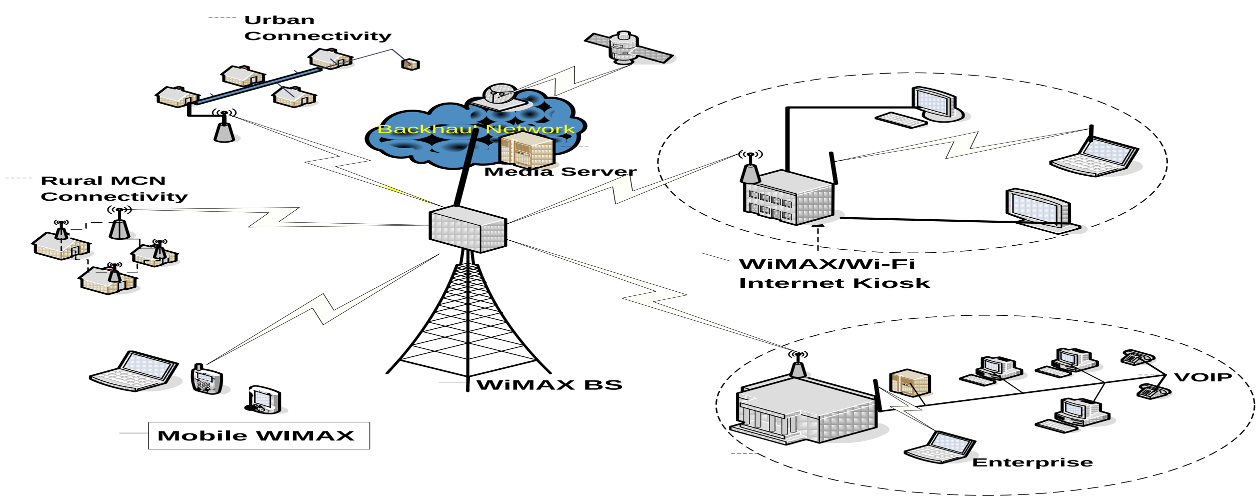

Figure 3, Technology and IMBS Services Possible with WIMAX/WIFI

As shown in figure 3, WIMAX/WiFi (IEEE 802.11x/16x) wireless broadband technology can be used to construct a multi-hop cellular network (MCN) topology, for energy and cost efficient provision of mobile broadband wireless services for rural communities. The multi-hop WIMAX scenario also helps to reduce the distance between wireless nodes, reduce the power requirement and meet the sparsely populated rural communities need for broadband wireless communications [8,9].One drawback of the initial WIMAX standard was its point to point topology and the absence of mobility. The combination of the WIMAX with WIFI as shown in figure 3 can give the possibility of nomadic mobility. The recently announced mobile WIMAX standard defined by the IEEE 802.16e extends mobility to WIMAX devices and services stations [8].

Although WIMAX presents a new and flexible technology for broadband wireless services, a number of issues have to be resolved before the technology can take up the dominant role in rural developing regions. The following are

- The competition from the popular GSM and 3G-HSA based network providers. Operators with lucrative voice and SMS service revenues see the new technology as a threat and new entrant WIMAX ISPs with suspicion.
- The initial deployment cost is high, availability of handsets and WIMAX PC cards is still limited.
- Spectrum licensing schemes are not clearly understood by regulatory authorities in developing regions. Intersystem interference is a contentious issue between competing WIMAX operators.
- Since WIMAX is a new technology, the system design is still affected by the lack of understanding of the services that will be carried by the WIMAX based broadband wireless network.

WIMAX and the Multihop cellular network topologies in combination with WiFi can provide mobile broadband services needed in sparsely populated rural communities. The CSIR - Meraka Wireless Mesh network deployment is one example [13]. The main advantage being enhanced coverage, low power consumption and running cost for providing mobile broadband services such as M-Education, M-health in rural setting [8,9].

V. DIGITAL TV BROADCASTING

The Digital TV Migration and IP TV exemplifies telecom and broadcasting convergence. The improved multimedia capability of mobile phones is one of the drivers for mobile TV services. Mobile/wireless IPTV presents a personalized indoor and outdoor multimedia platform that has distinct commercial and service appeal given its popularity, convenience and mobility. It spawns opportunities for content creation and enables service convergence. Mobile/wireless IPTV provides a platform where educational and health information content produced for traditional broadcasting platforms could be repackaged at relatively low marginal costs for additional distribution to the mass market mobile platform. If the content management issues and mobile device capabilities allow, it is possible to stream mobile content to Digital TV sets using short range wireless technologies such as Bluetoothh & UWB avoiding the display limitations. Such a move can enable mobile broadband services such as M-Education and M-health services for rural developing countries.

A. Digital Dividend Spectrum

The migration of analog TV broadcasting to digital technology such as the DVB-T2, proposed in South Africa frees a large chunk spectrum in the region 100-900 MHz, band, also called the digital dividend spectrum. This band of spectrum has excellent radio transmission characteristics, and is now being contested as the most useful broadband spectrum for improving wireless broadband connectivity in rural communities [4]. Both cellular giants and wireless internet service providers are looking for the spectrum allocation to be in their favor. At the same time communications regulatory authorities are looking for socio-economic advantageous allocation of the digital dividend spectrum for improving wireless broadband connectivity to the rest of the population who are not connected to the internet. This requires an open but managed spectrum licensing regime be applied in rural communities. The next sections will describe some of the models which can be applied to provide affordable broadband internet connectivity to rural communities.

VII. COLLABORATIVE NETWORKING

A. RAN Sharing

The simplest form of collaborative networking is radio access network (RAN) sharing by competing operators. It can be promoted as one of the effective tools to reduce both cost of infrastructure deployment and power consumption of 3G broadband mobile networks. A number of European mobile operators are opting to this scheme, to reduce the cost of mobile broadband services, made possible by the reduction in deployment, operational and power consumption costs. It is for example estimated that the deal by network operators T-Mobile and 3, could achieve a cost savings of 2 Billion UK Pounds. Further, an estimated 30% reduction of base station sites and a 70% reduction of the power consumption by the network nodes is expected [6]. This should also be followed perhaps by regulatory framework, at most to enable such collaborative moves by competing network operators, or put pressure or tax exemption to stimulate such moves by different stakeholders in the wireless value chain. Such a network sharing collaborative move in combination with other schemes to improve affordability, is crucial to reduce the cost of broadband mobile services to rural communities in developing countries [1,3].

B. Dynamic & Collaborative Spectrum Utilization

Universal broadband internet services for the next billion customers require dynamic and intelligent spectrum utilization techniques, to reduce the burden in utilizing the already scarce bandwidth availability. A number of next generation radio technologies are also being proposed to increase the bandwidth capacity of wireless networks [4,5,14,15]. Cognitive radio based networks using software defined radio technologies, in combination with white space sensing is a promising technology for broadband internet services in rural communities [4]. The concept of Cognitive radio and white space spectrum sensing is described in Figure 3.

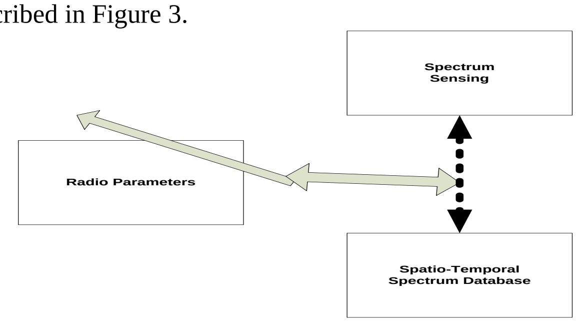

Figure 3. Conceptual Diagram of Cognitive Radio Technology

Spatio-temporal spectrum databases and spectrum sensing are used to find the available white spaces in a given area, with time information. This database is then used by wireless broadband access devices through paging information consisting of their current location. The information on available frequency at the device position is communicated to the device. The wireless device equipped with a software defined radio technology then re-calculates the radio parameters to communicate with the wireless infrastructure, and to send and receive required information. Spectrum sharing also means, incurring as little interference as possible to existing primary users, in the case of licensed primary users in that frequency band. A sample of a white space measurement in using a spectrum monitoring device is depicted in Figure 4.

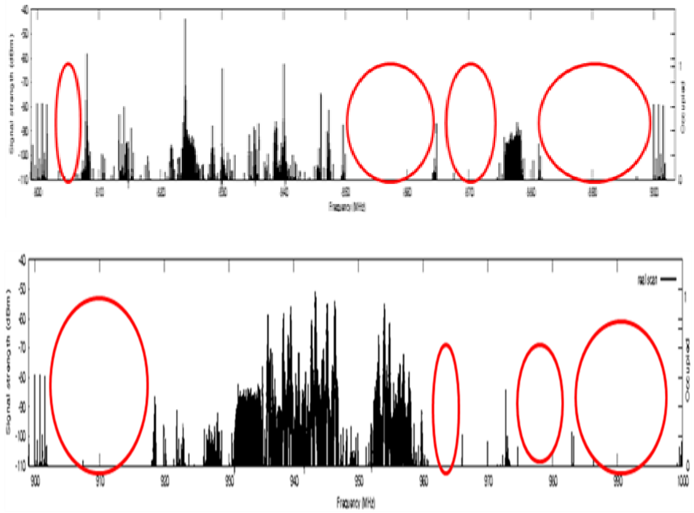

Figure 4., Spectrum Between 800-1000 MHz.

Possible white space spectrum in the Pretoria area is circled in red. According to several studies the white space spectrum, which is the spectrum that is not utilized by existing infrastructure, is even more pronounced in the rural areas, giving hope that one can build broadband wireless networks on unlicensed but managed spectrum to address the access gap in rural communities [1,4].

VI. SECURITY OF WIRELESS SERVICES

Nowadays wireless devices are able to access a large number of broadband services requiring some form of authentication. Making wireless internet services reliable is possible only by building security and authentication mechanisms, so that confidence and trust is built between service providers and customers. At the same time secure wireless internet services reduce fraudulent and unauthorized access to wireless broadband content and services, which is crucial to promote the continued growth of mobile broadband technology and services. Secure mobile services require the development of security aware mobile platforms and network protocols. Depending on the type of services on demand the dimensions and rigor of security mechanisms can vary. As shown in figure 4 below, mobile services such as financial transactions (M-Banking, M-Payment) and mobile enterprise services will require high security, while public information access such as an M-Government applications might need a low security level. Another important aspect that needs research is the interplay between strong/low security and less/better usability aspect of mobile services. The more secure a system of technology is the less unusable the service is by the low literacy and low income rural subscribers, which makes the next billion customers.

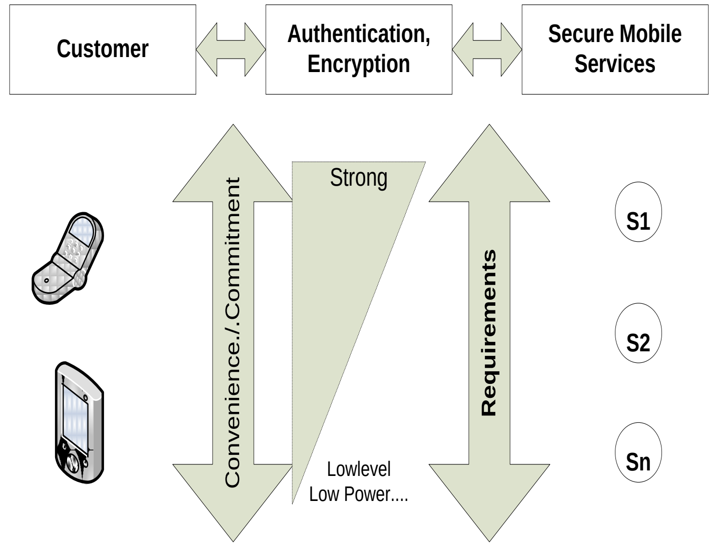

Figure 5, Security Dimensions of Mobile Broadband Services.

VIII. Usability of IWBS services

The need for wireless usability laboratory where mobile broadband services are localized and service usability studies are carried out have been highlighted in [1,7]. These requirements stem from the fact that the vast majority of the populations in developing regions, specifically rural communities have low literacy level and a limited exposure to technological gadgets. Therefore user interface design, usability testing, local language and cultural context adaptation of IWBS services is a must. Although setting up the network infrastructure is considered crucial for improved digital inclusion, usability, sustainability and service relevance are important issues to address in developing rural communities. A wireless usability lab or a Living Lab, in connection with higher educational institutes can be used for usability studies and capacity building in localization of services and wireless application development research [11,12].

CONCLUSION

As next generation wireless broadband technologies are being deployed in emerging market and developing nations, a number of important research challenges require solutions. The provision of innovative mobile broadband services in an environment where the customer base is composed of greater than 95 % prepaid customers and with low income is a challenge. The current state of wireless voice and SMS services are being challenged by the emergence of new wireless broadband technologies which can provide innovative wireless broadband services for low income rural communities. Sustainability and improved digital inclusion due to IWBS services can be promoted by improving affordability through collaborative networking and spectrum sharing schemes. Furthermore, promotion of a local village operators, local content and secure service provider sector can benefit developing countries to create employment opportunities leading towards sustainable economic development. Such models also need to integrate end-user focused studies such as security versus service usability studies and local language support. Research and studies towards next generation radio technologies and models of addressing the challenges of spectrum and energy scarcity are hence very important and necessary for the continued growth of the wireless broadband technology and services in developing regions.

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