Next Generation Communication Technologies: Wireless Mesh Network For Rural Connectivity

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Abstract— The opportunities and challenges of traditional communication technologies in the area of rural communication calls for a change in perspective and usual trends of wire line and wireless connectivity. In the quest to improve rural communication with the urban market, use of smart hand-held devices and easy-to-deploy wireless connectivity is catalytic according to our findings. To eradicate digital divide, we have presented a holistic approach to overcome the challenges of language barrier and information asymmetry. This paper provides an insight of $100 tablets, an interactive hand-held communication device, which allows low-literate farmers to share their information onto the network. These smart communication devices stay connected to the global network through the easy deployment of wireless mesh network (WMN) in a rural area. QoS constraints are imposed in the WMN setup and significant observation has been made regarding spectrum resource utilization at every hop by achieving certain level of cognition at the user end.

Keywords—Wireless Mesh Network; QoS Constraints; $100 Tablet; Bottom of Pyramid (BoP); Spectrum Resource Utilization

I. INTRODUCTION

With the use of communication technology, rural inhabitants can be given access to information. In rural areas, internet availability is low and in some regions inaccessible. It has been well documented that people choose media according to the content. Survey results indicate that there are 93% TV viewers, 90% mobile phone users, 60.9% radio listeners and 63.4% newspaper readers while only 6% Internet user [1]. The research findings indicate a prime example of the successful use of technology which is the ubiquitous presence of cellular communication. Even in the most remote areas, individual can be seen using a mobile phone. In pursuing commercial means, the telecom operators have successfully taught a large portion of the population the use of basic computerized device (i.e. 0-9 buttons, how to use the call/ answer/ end a call function as well as powering on and off the device). Many of the mobile phone users have gone beyond exploring the basic functions of the cellular handsets and started using complex applications like text messaging and playing games. It stands to reason therefore, that communication technology could be used as a vehicle for proper information circulation. However, cellular telephony is limited to 2G mobile handsets which only offer text messaging and voice communication services over the GSM/CDMA based network in rural Bangladesh. Moreover, telecomm operators cannot produce appropriate contents to meet diverse local needs in remote areas. In this paper, we present a holistic approach to achieve better rural connectivity by the use of smart hand-held devices ($100 tablets) over an intranet, supported by the deployment of wireless mesh network. Informational and interactive videos/audios can be sent over this intranet to users discussing issues such as government resources, natural disaster warnings, healthcare, environmental awareness, best farming practice and public notices. Wireless mesh network’s most promising application is to provide access to information where wired infrastructure is difficult or economically infeasible to deploy [2]. Network, as such, is characterized by static mesh routers connected by wireless links to each other, which in turn provides connectivity to the end user [3]. Wireless mesh network, in the context of rural areas, is suitable for its features such as high scalability, cheap-to-deploy and ease-of-maintenance.
Demonstration pilot for the $100 tablets as shown in Fig. 1 and the test bed for the rural wireless mesh connectivity are being tried out in the remote area of Nijmawna, Gazipur, Bangladesh to observe the impact of rural development through the use of next generation technologies. This paper suggests costs cut down at different hierarchies of the network model connecting the last mile users to the core network of broadband/Cloud computing/GSM/CDMA. We also clearly describe the pre-deployment and post-deployment observations and solution to different challenges faced during the pilot mesh.

The rest of the paper is organized as follows. In section II, we present traditional communication technologies for information circulation. Section III describes details of $100 tablets for rural communication. Then in section IV, we talk about wireless mesh network for rural connectivity. Finally, conclusion is drawn in section V.

II. TRADITIONAL COMMUNICATION TECHNOLOGIES FOR INFORMATION CIRCULATION

Hitherto progress in traditional communication technology for the rural communication has its drawback. However, it is not the communication technology that has to be blamed but the management schemes or approaches, to achieve efficient rural connectivity, can be considered faulty [2]. Before further explanation, the need for understanding the existing social information infrastructure [4] for the rural community is necessary. The existing social information infrastructure in rural Bangladesh comprises of-

1) Illiterate/poor users (farmers/villagers) – Before the arrival of mobile technology, face-to-face oral communication was the only means practiced to consume/produce information. After the acquaintance with mobile phones verbal communication is achieved even from a remote area. However generating/reading text messages are yet to see light when it comes to communication by texting from mobile phones.

2) Unavailability of affordable device and inefficient network connectivity- With 90% mobile and TV access this rural population scores a 6% internet penetration. Two types of devices that can provide connectivity to internet for this rural population are- smart phone and PC’s. Both of which are expensive and sophisticated to handle for the low-literate users of rural Bangladesh. Even the 2G mobile sets, which can offer internet connectivity, has a very small screen and amateurs lacking internet browsing skills makes the task tougher. Not to mention the average throughput of GPRS based data network to be less than 5 Kbps [4], which is too slow for rural users who can best communicate over voice or video.

3) Language barrier and overwhelming presentation of information- It is mandatory to transform and develop the basic infrastructure like local spoken and written languages into universally used set of computer codes and fonts breaking the language barrier that stands in the way of learning-by-understanding method. Besides language barriers information when presented at a large volume and too much hype using a sophisticated technological setup like- computer, might scare away rural users. Less intimidating intermediaries to better learning and access to information can be a suitable and appropriate approach in exploiting the opportunities in communication technology.

In this paper we explore an alternative way to get the most out of the opportunities in communication technologies for rural Bangladesh.

III. NEXT GENERATION COMMUNICATION TECHNOLOGIES: $100 TABLETS FOR RURAL COMMUNICATION

IT access for everyone (ITAFFE) [5] has defined a matrix of six elements required to enhance the use of information and communication technologies - 1) Power 2) Hardware 3) Connectivity 4) Software and applications 5) Training and support 6) Cost structure and financing.

With the above mentioned matrix in our calculation we present the demonstration pilot, a dynamic approach to efficiently utilize the resources offered by the next generation communication technologies. The components of the pilot project are -

• Affordable customized $100 tablets.
• Software application installed in the tablet, tailored to meet the local needs.
• Central Database/Cloud servers.
• An efficient wireless mesh network to keep the community updated and connected to Internet.

The $100 tablet provides simplified user access compared to computers and smart phones. In the 3 month pilot project $100 tablets were distributed among villagers for free. Sustainability of this project is achieved by exploring the market rural economy has to offer. E-commerce, agricultural products and fertilizers are integral elements of rural economy where banks, fertilizer industries and market census can provide financial support to keep such pilot projects alive. Simplicity and affordability of these tablets make it feasible and convenient for the rural population.
A. Next Generation Technologies: $100 Tablets for rural connectivity

The $100 tablet which is introduced in the pilot project launched in a remote area of Bangladesh points out the advantages of next generation communication technologies in many ways:

1) Agility- Introduces mobility and hence can be set-up in every household rather than 5-6 PC’s in ICT training centers or village Kiosks.
2) Resistive Touchscreen- See-and-Touch to Listen-and-Learn is enabled through the touchscreen functionality of the tablets.
3) Customized circuitry- Built with SOC (System on Chip) and runs on Android 2.2 operating system [6]. Android is an open source mobile/tablet operating system where hundreds of application can be developed to suit the local requirements.

B. Contents Developed for the $100 Tablet

The $100 tablets are designed to be used by the low-literate and bottom of the pyramid users [1]. So the contents were developed keeping in mind the local benefits and ease of access from the user's point of view. The diverse contents can be categorized broadly into 4 sections:

1) Agriculture- includes information on new farming practices, fertilizer usage, gardening etc.
2) Health - includes information on treatments for different diseases such as diarrhoea, eczima, food poisoning etc.
3) Education- contains e-books, fables, learning alphabets and numbers, interactive puzzles for children etc.
4) Administration- enables e-governance, government laws and provides information on local police station, healthcare facilities, voting rights, civil rights etc.

These applications are presented in the form of text, audio, video and interactive slides. Language barrier is addressed by developing contents in locally spoken language. New applications and further upgrades are delivered in a live, dynamic basis over an intranet, created by the deployment of wireless mesh network, to these tablets.

Two weeks after the distribution of the tablets to the rural inhabitants, the feedbacks and frequency of usage of different applications were collected from the server and relayed to core network for analysis and further improvement. Fig. 2 depicts the total number of clicks generated by the usage of applications in different sections. Statistics suggests that most users are interested in extracting information regarding agriculture and administration, while the response in health and education section is comparatively low. This analysis calls for the urge of attaining more interactive and informative applications in low response sections.

IV. Next Generation Wireless Mesh Networks for Rural Connectivity

Wireless mesh networks provide the opportunity for rural communities to deploy a dedicated wireless network which can be connected to a local server and the ownership can be shared to bring down the cost of such network deployment. Satellite link or the last coverage point of GSM/CDMA based network can be used to connect the local mesh to the global network. The pilot mesh project launched in Gazipur, Bangladesh demonstrates the feasibility of such network deployment where wired infrastructure is unsuitable and to some extent impractical.

A. Pre-Deployment Strategies:

The placement of wired gateways, connected to the local server, is a significant design criterion for the effective deployment of a wireless mesh network [7]. For minimizing the average communication cost, the gateways should be placed in the center of the network rather than the edge to ensure that they serve maximum number of wireless nodes. Similarly, their placement should allow contention free flow of intense backhaul traffic to satisfy the growing demand of the bandwidth hungry end user applications.

The optimal placement of wired access points (APs) and wireless nodes (AP/routers) is identified by site survey. All the households under the coverage area were bookmarked in Google map to get a bird’s eye view of the site. After intense studies of these locations, several QoS constrains were imposed to ensure maximum coverage area and feasible throughput for intended users. The network is divided in two clusters maintaining QoS constrains sharing a wired connection providing an extended backhaul as shown Fig. 3. The QoS constrains considered are:

- Hop Count: Theoretically it is observed that with the increasing number of hops, the throughput decreases significantly [8]. However, due to the presence of scattered dense foliage in the village, the throughput...
degraded drastically beyond second hop. Therefore the network diameter was restricted by assigning maximum hop count to 2.

- **Cluster Size:** Since all the APs in the mesh pilot are configured to operate on a single channel, we had to put a cap on the amount of resource shared by the wireless routers. Hence we restrict the cluster size by an upper bound of 3.

- **Signal Strength:** To maintain mesh connectivity with minimum achievable throughput, wireless routers are kept in such a way that they are approximately 100 m apart from each other and with a 20% overlapping transmission region.

Another important consideration, before the deployment, is to make a trade-off between costs of planning versus costs of maintenance. For example the wireless network setup might start with APs rather than routers which might cost less but on the other hand an AP will provide with bigger transmission range than a router thus reducing the number of wireless nodes needed to be maintained. Fig. 4 shows weather proofing by designing plastic box required to ensure the safety of AP from lightening and extreme climatic conditions. On that note, it must be pointed out that in the mesh pilot simple indoor APs are used instead of outdoor mesh routers which are comparatively expensive. While few outdoor mesh routers would have sufficed to cover the desired area, many APs together can cover the same amount of transmission range at a lesser expense.

For the mesh pilot, Cisco WAP 4410N access points [9] are used to set up mesh connectivity. As mentioned above, the pilot mesh is designed as a two hop mesh network to ensure good link quality and throughput. Six APs are deployed in a service area of size 1500m×1500m. All the nodes were configured to have the MAC addresses of at least two other nodes to avoid full fail-over in case any node goes out of operation. The APs operate on the same channel and share the same SSID (Service Set Identifier) to ensure uninterrupted connectivity. Mesh routing protocol like OLSR [10] routes IP traffic between the wireless nodes in the mesh. The knowledge of potential routes is gathered by listening to the routing information exchanged in the network where dynamic routing table is maintained. Dynamic update of the routing table increases fault tolerance by providing alternative routes in case of node failure.

**B. Post-Deployment Strategies:**

The two hop mesh network deployed reveals a vulnerability of WMN when observed carefully during our post deployment site survey. Whilst conducting post deployment site survey we estimated the data throughput. Our findings indicate that the spectrum resource at each hop is not being fully utilized. Gateway has assigned a band of frequencies to the user, but, at a particular time and specific location inside the overlapping transmission region of hop-1 and 2, the band is not being utilized by that user. Instead the end user occupies the band of frequencies assigned by hop-2 (AP-1) thus not fully utilizing the spectrum resource at every hop. A client in between gateway and access point (AP-1) is shown in the Fig. 5.

It is observed that the end user estimates RSSI (received signal strength indicator) received from both the AP’s and connects to the best signal transmission. From fig. 5 it can be seen that the client ($100 tablet) connects to the second hop (AP-1) when the user’s location is at \( r_s \) where \( r_s < r, r \) being the transmission radius of the gateway. As mentioned earlier, throughput in WMN decreases significantly when number of hop increases, it is apparent that the end user has just shifted to a hop (AP-1) which has lesser throughput than the previous hop (gateway). The signal strength (\( y \)) client receives at location \( r_s \) is measured and is found to be above threshold signal level required to maintain an efficient connectivity with the gateway.

Given the circumstances, at that signal strength client could have stayed connected to gateway and get a better throughput compared to AP-1 (second hop). Survey findings suggest that the end user receives a data throughput of approximately 190 kbps from gateway at location \( r \cdot r_s \) when at the same location it receives a data throughput of about 180 kbps from AP-1 (second hop). From the observation it has been studied that the spectrum resource at each hop is not being fully utilized and there is non-uniform node selectivity by the end user. However, next generation wireless communication demands intelligent use of spectrum resource where spectrum scarcity can be addressed and an optimal performance of WMN can be expected. Opportunistic node selection can be implemented by achieving certain level of cognition at the end user level where every user will be aware of their neighboring hops and intelligently connect to the best hop.

**Fig. 3:** QoS constraints imposed WMN setup.

**Fig. 4:** a) Cisco WAP 4410N Access points. b) Weather proof rooftop setup.
V. CONCLUSION

We conclude by pointing out a change in perspective regarding the use of communication technologies for rural connectivity. The rural population being the world’s poorest yet largest economy suffers the most from natural disasters and experiences a slow socio-economic growth because of inefficient circulation of information. Earlier works using traditional communication technologies needs an upgrade for rural communication. It is not the rural population who needs to be trained to have access to information but it is the next generation communication technologies that can be tailored to meet the local needs and be made easily accessible by rural communities.

REFERENCES: