Proposed System Design for Deployment of an e-Learning System in Rural Bangladesh

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Abstract—**Distance education in the form of internet based e-learning is gaining momentum in bringing basic and advanced education in remote locations. This paper proposes a model deployment of e-learning system in rural Bangladesh. The model includes all the important components spanning from communication infrastructure and link analysis to required facilities at the remote location along with the course contents. The analysis includes choice of communication technology and the available footprint from deployed systems and a 1st-order estimate of achievable average throughput. Additionally, currently available technology enablers are also studied to facilitate the proposed e-learning model deployment. Required IT facilities at the rural school premises along with suitable course contents are presented so as to the make the proposed a model a self-contained complete system that can be adopted for bringing quality education within the reach of rural population in Bangladesh.**

Keywords- e-Learning; 3G Communications; HSDPA; Femtocell

I. Introduction

E-learning is being widely used as an alternative method to bring education to remote locations by leveraging off the modern information and communication technology (ICT) facilities. Developing effective E-learning framework is one of the key research interests in the field of education [1]-[5]. E-learning and its practical issues and implementations are thoroughly studied in [6]. Specific focus areas such as universities are cited in [7]. The educational landscape of Bangladesh contains a major divide across urban and rural areas. The official literacy rate is claimed at 66%, however, the education system in the vast rural areas is well below satisfactory quality. E-learning is seen as a viable option for bringing education to remote rural areas in Bangladesh. With the wide deployment of cellular communication networks and proliferation of mobile phones in Bangladesh, pilot projects are being performed to evaluate the feasibility of e-learning systems [8].

Recently Bangladesh is experiencing an evolution of mobile communications networks to 3G and higher. Deploying wireless based e-learning system has been addressed in [9]. With the auction of 3G and LTE licenses and gradual deployment of 3G networks, it is not far that mobile broadband penetration in rural areas will be significant. The deployment of optical fiber based NTTN is aimed at bringing broadband connectivity at Upazilla levels that can be further distributed to deeper into rural areas. The govt. of Bangladesh is also working on to launch communication satellite that can provide complete communication footprint over Bangladesh. Thus, the existing and expanding communication infrastructure in Bangladesh presents itself as an excellent support system to provide various internet based services including e-learning.

To provide an effective e-learning system, a holistic approach needs to be taken that addresses the following relevant components: i) reliable broadband network, ii) enabling technology for deployment, iii) effective contents, and iv) detailed system requirements at the receiving end. Towards this goal, this paper presents an e-learning system focusing on each of these components to provide e-learning at rural school locations. Starting with a target area for implementation, the paper addresses the communication link analysis to estimate the average available throughput using HSDPA technology. Necessary IT components to implement the system inside school premises are also described. Resources that can act as a guide for preparing effective contents are also presented. The organization of the paper is as follows. Section II presents proposed system design while Section III link analysis and average throughput estimation. Section IV discusses available resources that can provide guidance to create effective e-learning contents for primary and secondary schools. Section V presents two enabling technology for e-learning system deployment while Section VI concludes the paper.

II. Proposed System Design

The proposed deployment for the system supporting e-learning includes: wireless wide area network (WWAN) for providing data connectivity, suitable broadband communication technology and wireless local area network (WLAN) for indoor coverage inside school premises. In the context of rural Bangladesh the candidate for WWAN is mobile cellular communication system. Due to high geographical coverage of cellular network, it is very likely that a base station will be available in vicinity of the target rural schools. The cellular communication needs to provide broadband service (e.g. 3G) to support effective e-learning system. This will be useful for real-time rich multimedia contents. In this paper we assume that HSDPA is available in the target coverage area and estimate the achievable data rate from an analysis of the link between the base station and the target school. The target schools need to install broadband modem and distribute the received signal through WLAN system inside the school for multiple accesses by different classrooms. Additionally future options of personalized learning can be introduced for students with different learning capabilities [10]. Fig 1 depicts the layout for the proposed system.

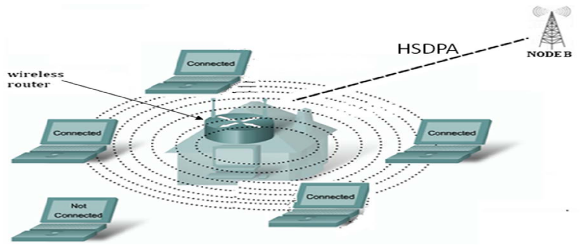

Figure 1. Proposed deployment layout supporting e-learning in rural areas.

A. Proposed deployment scenario

As a test case, the rural area of Haragach in Rangpur district is selected for e-learning system deployment. The Google map of that area including the locations of nearby schools is shown in Figure 2. The location of base station (Node B) is assumed to perform the required link calculations. The figure also annotates estimated distances from the Node B to the school locations.

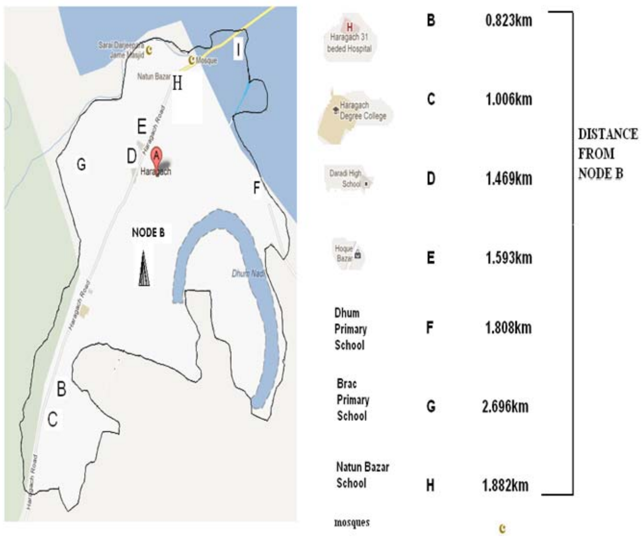

Figure 2. Map with school locations for the deployment scenario.

The names of the schools, their locations and distance from the Node B are presented in Table I.

TABLE I. SCHOOL LOCATIONS AND SEPARATION FROM NODE B

Location	Name	Distance (km)
D	Daradi High School	1.469
F	Dhum Primary School	1.808
G	BRAC Primary School	2.696
H	Natun Bazar School	1.882

As shown in Figure 1, a broadband modem will be deployed inside the school and a WiFi router will be connected to the modem so that the required data connectivity can be available in the classrooms.

B. Indoor equipments for hosting e-learning system

To fully implement the e-learning system, various IT equipments need to be deployed for effective utilization of the learning system. These will include:

i. Broadband modem
ii. Wi-Fi router
iii. PC systems with UPS,
iv. Web camera
v. Microphone and speaker
vi. Projectors
vii. Printers, Scanners
viii. Electrical accessories.

To provide power for the overall indoor system, solar power based system is proposed. There will be many schools where grid energy will not be available and solar energy-based power system will render the whole project as a green energy system.

III. LINK ANALYSIS AND DATA RATE CALCULATION

Based on the proposed setup, the communication link can be analyzed in terms of propagation characteristics and the resulting achievable average throughput.

A. Sample link design calculation

The link between the Node B and the modem inside school includes two different propagation channels, namely, the outdoor and the indoor channels.

Outdoor Propagation Model

Prediction of path-loss and resulting received signal power for outdoor environments are modeled by various existing path-loss models. Each model has its trade-off in terms of complexity and accuracy. In this paper, the HATA model is used for outdoor channel. By using the distance between the Node B and the respective school from Table 1, the path loss can be computed using parameters for rural environments.

Indoor Propagation Model

For indoor propagation loss a modified version of the Keenan-Motley model is used as shown below [11]:

$$PL(dB) = 38.46 + 20\log 10(d) + qW + Fn^{\left(\frac{n+2}{n+1} - 0.46\right)} \quad (1)$$

d is the separation between the transmitter and the receiver (in meters), W is the wall partition loss (assumed 5 dB), and F is the floor partition loss (assumed 18.3 dB). The number of walls between transmitter and receiver, represented by q. But the schools consist of single floor so F = 0 can be set in (1).

B. HSDPA

HSDPA was introduced in 3GPP standard to increase the packet data throughput with features that include a) Adaptive modulation and coding; b) Multi-Code operation and c) Node B scheduling. By using these features it can achieve up to 14Mbps downlink data rate [12]. The key idea of the HSDPA concept is to increase packet data throughput with methods known already from GSM/EDGE standards, including link adaptation and fast physical layer retransmission combining. The capacity is improved 3 to 4 times from a data perspective when having HSDPA network and the round trip delay is maintained below 100 ms (instead of around 150 ms). HSDPA can run on the same carrier or on a separate carrier and no new sites are needed when introducing HSDPA in the network.

The SNR at the receiver locations can be estimated by using outdoor and indoor path losses. The received SNR then needs to be converted to channel quality index (CQI) values that are reported to the network. Based on the reported CQI values, the network selects transport block sizes (TBS) or packet sizes to transmit data to the receiver. The SNR to CQI is expressed as follows [13]:

$$CQI = \begin{cases} 0; & SNR \le -16 \\ \dfrac{SNR}{1.02} + 16.12; & -16 < SNR < 14; \\ 30; & 14 \le SNR \end{cases} \quad (2)$$

The mapping between CQI and TBS can be found in [13]. Assuming that there is no packet loss in either direction (data in downlink and CQI or ACK/NAK values in uplink), one can monitor the received TBS and estimate the instantaneous and the average data rate for a given link.

C. Average data rate calculation

The average data rate estimation is summarized in Figure 3. The complete estimation process is divided into sub-processes and the final rate for a given user k can be obtained. The Node B to school distances are loaded as input database. Typical propagation parameters related to HATA model are stored in the code. The complete system has been implemented in Matlab.

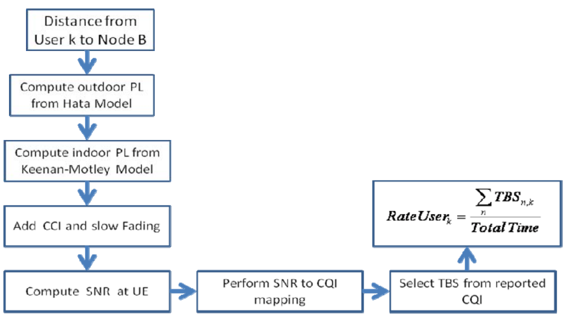

Figure 3. Simulation setup for estimating average data rate.

The SINR at the UE is calculated following the link budget for HSDPA in [14]. Important parameters and their values in this regard are: transmit power for DSCH= 1W; Tx antenna gain= 10 dBi; noise level= -108 dBm; downlink loading= 0.95; receive antenna gain= 0 dBi and 10 dB shadowing margin. Note that the downlink loading value represents a pessimistic value for resulting data rate, and thus, the data rate in practical scenario is expected to be higher than the computed values. For indoor propagation, the distances and the number of wall crossings are randomly chosen from 2-5m and 1-4, respectively. The estimated average throughput for different locations is as presented in Table II.

TABLE II. MEAN THROUGHPUT AT DIFFERENT SCHOOL LOCATIONS

Location	Mean Throughput (Mbps)
D	6.3043
F	4.8913
G	0.6982
H	0.6049

IV. TEACHING MATERIALS

Contents and delivery are important aspects in providing effective e-learning to rural areas. Contents need to be tailored to the level of the students and teacher training will be needed for the teachers adapt to this new form of learning method. While e-learning materials from developed world can be reviewed for quality contents, these need to be adjusted to address the educational need of the rural areas. Content delivery can include both realtime and offline approaches. Through offline method, contents can be downloaded from certified e-learning vendors and used in classroom teaching at latter times. Realtime methods can be used for studying educational materials that include animation, videos for children and live lectures from teachers/experts from good quality urban educational institutes. The following sites form a list of recommended web sites that host beneficial educational materials at different classes/grades. A group or panel of educationists need to review these contents and propose modified versions for rural schools and also the required teacher's training programs to harness the benefits from these vendors.

Class: Play and nursery

- http://thekidzpage.com/ : In this site kids can learn through games, coloring pages, puzzles like math puzzle, Sudoku etc.

Class: Play-I

- http://kidsknowit.com/ : Kids can learn about animals, astronomy, biology, math, history, geology, chemistry , spelling, and human bio.

Class: Play – II

- http://www.nickjr.com/games/index.jhtml : This site helps kids to learn art, math and different educational puzzles. Kids can learn through games here.

Class: Play - IV

- http://www.enchantedlearning.com/Home.html : This site helpful for students in math, geography, science/biology, drawing, illustrated dictionaries, general knowledge, and language arts and it also provides class room activities materials which is printable.

Class: III - X

- http://www.champs21.com/ : This site is for both english and bangla medium education system. It helps students to improve math and science through games.

V. Enabling Technology

The role of enabling technologies is important for the sustained growth of e-learning system. Small cell system formerly known as Femtocells and smart antenna systems can act as enabling technologies to improve coverage and performance for the proposed e-learning system. Mention Femtocell and antenna array.

A. Femtocell for network coverage

Femtocells are being widely considered for home deployments to provide more data throughput, better user experience and data offload. The Femtocell BTS are typically small form-factor devices that can be installed at homes to provide licensed indoor coverage within the home premises. The Femtocell BTSs with some modifications can be used for rural area deployment and provide broadband connectivity. Figure 4 shows the deployment architecture of a proposed system for rural areas.

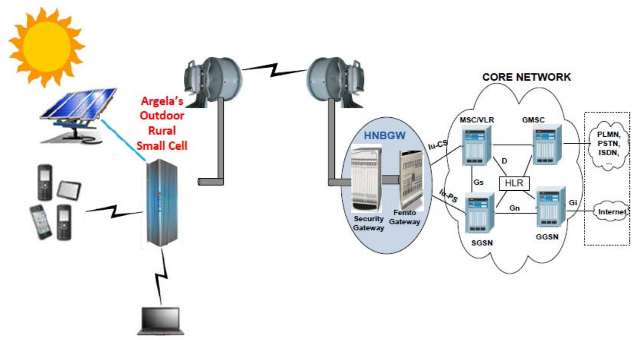

Figure 4. Network architecture of a proposed deployment of Femtocell in rural area [11].

The Femtocell site requires very small real estate to place small box-like devices at a moderate height. The power supply can be based on renewable energy (Solar and battery backup) to furnish around 100W load. While the backhaul is a major issue, however, current options are to rely on microwave links, broadband Satellite or fiber connectivity. Existing modified Femtocell BTS (or Node B) support a range of about 2 km at output power of 4W connecting 16 simultaneous users. Femtocells have been practically deployed in Rural Turkey to provide 3G coverage to remote village of C. Musellim [15].

B. Smart Antenna for better performance

Smart antenna systems have become an integral part of a communication system to improve coverage, mitigate interference in cellular networks and enhance data rate. Based on a system of antenna arrays, smart antenna systems can be operated in adaptive beamforming to enhance SNR or in space-time (ST) encoding to enhance high data rate system. Such a system can be incorporated at the receiver RF front end of the modem installed at the school premise to increase SNR and thus, higher download speed. Figure 5 shows the setup of a smart antenna system at the modem location.

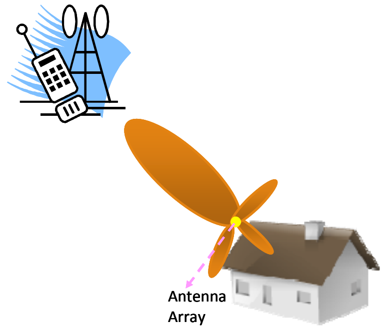

Figure 5. Proposed setup for using smart antenna at the receiver side.

Through customized smart antenna solution benefits of higher throughput can be achieved. Additionally since slow channel variations are expected in rural areas, convergence rate of adaptive beamforming will not be a problem.

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VI. Conclusions

The studies presented thus far in this thesis point to the feasibility of deploying an E-learning education system supported by HSDPA connectivity. HSDPA has the full technical capability to support such a system. Our propagation related calculations reveal that in the target area available data rate should be adequate to support smooth functioning of an E-learning system. The required peripheral accessories are readily available in our country. One key important factor for successful operation of such a system is the required training of the teachers in this area, and once that is conducted, children in the rural areas can benefit from the vast internet resources. This will definitely improve the quality of education in the rural areas.

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