Architecture of WiFi Based Broadcast Network for Rural Community

JUMSHED AKHTAR*, NOOR MUHAMMAD SHEIKH**, AND SYED AUN ABBAS**

RECEIVED ON 08.04.2015 ACCEPTED ON 28.05.2015

ABSTRACT

Digital divide is a reality in developing nations. Most of the technological advancements are available only in urban areas and rural community is still deprived of communication technology even in 21st century. To ensure the availability of Internet, TV (Television) and other high data-rate services to the rural community; use of high power ISM (Industrial, Scientific and Medical) band broadcast should be of interest. The aim of this research work is to design a WiFi based broadcast network that provides broadband access to remote areas and to study the propagation characteristics of this network in a typical rural community in the plains of Pakistan. This paper uses extensive measurements in indoor and outdoor environments of village "Lower Kot Ratta" to develop a WiFi broadband broadcast propagation model for rural areas of Pakistan. The proposed model is simple, flexible and more suitable for rural areas as compared to existing models.

Key Words: Broadband, Broadcast, Rural Propagation, WiFi, Communication, Propagation Model.

1. INTRODUCTION

The information and communication technologies have revolutionized every field of life. They have great impact on education, business, e-commerce and information access. Information and communication technology play as pivotal role in the development of a country. These communication technologies are not available to the people living in rural and remote areas of developing countries. Most of the rural and remote areas have access to mobile services but Internet services are still out of their reach.

Many countries are trying to provide modern broadband connectivity to their remote communities and different projects have been initiated. ITU (International Telecommunication Union) has also started some projects to provide Internet access to the remote areas of different countries [1].

In Pakistan, this issue has been identified, and with the collaboration of USF (Universal Service Fund), remote villages and cities are being connected to the main telecom network via optical fibers and other transmission media. The USF experience shows that while a community has been provided with communication access, the sustainability has been a major challenge since there are not a lot of users who have the capacity to pay.

* Department of Electrical Engineering, University of Engineering & Technology, Lahore.
** Professor, Department of Electrical Engineering, University of Engineering & Technology, Lahore.
*** Sun-Volts Pvt. Ltd. Lahore.

Moreover, the services are limited to a small room equipped with the desired equipment.

In this research, we have proposed a solution to this problem – a local broadcast through a high powered WiFi network– which will benefit masses in rural areas. In this work, we have not considered the backhaul network. The backhaul network may be optical fiber, DSL (Digital Subscriber Line), WiMAX or 4G. Our work also includes the study of propagation characteristics of a channel based on practical measurements in outdoor and indoor environment for a typical rural community, design and optimization of WiFi based broadcast network. From measurements, we have developed propagation model for a selected area and calculated power required to provide broadcast services in that area. Proposed model has also been compared with well known existing propagation models.

2. BACKGROUND

2.1 Wi-Fi Broadcast Architecture

We propose two topologies:

In 1st topology, the main tower is connected to the backhaul network. Every node receives WiFi signals through antennas mounted on the roof top of houses. The received signal is then propagated to the WiFi device such as IPTV, placed inside the house using wired connection. This topology is depicted in Fig.1(a).

In 2nd topology, the main tower is connected to the backhaul network and every node receives WiFi signals using the apparatus placed inside the room as shown in Fig. 1(b).

In this research, we will use off-the-shelf existing WiFi router. The router is mounted on the top of long tower to take indoor and outdoor measurements in a real environment of a typical rural area, according to the above topologies.

2.1 Propagation Model

Here, we propose a simplest propagation model for WiFi broadcast model named as WiFi Propagation model.

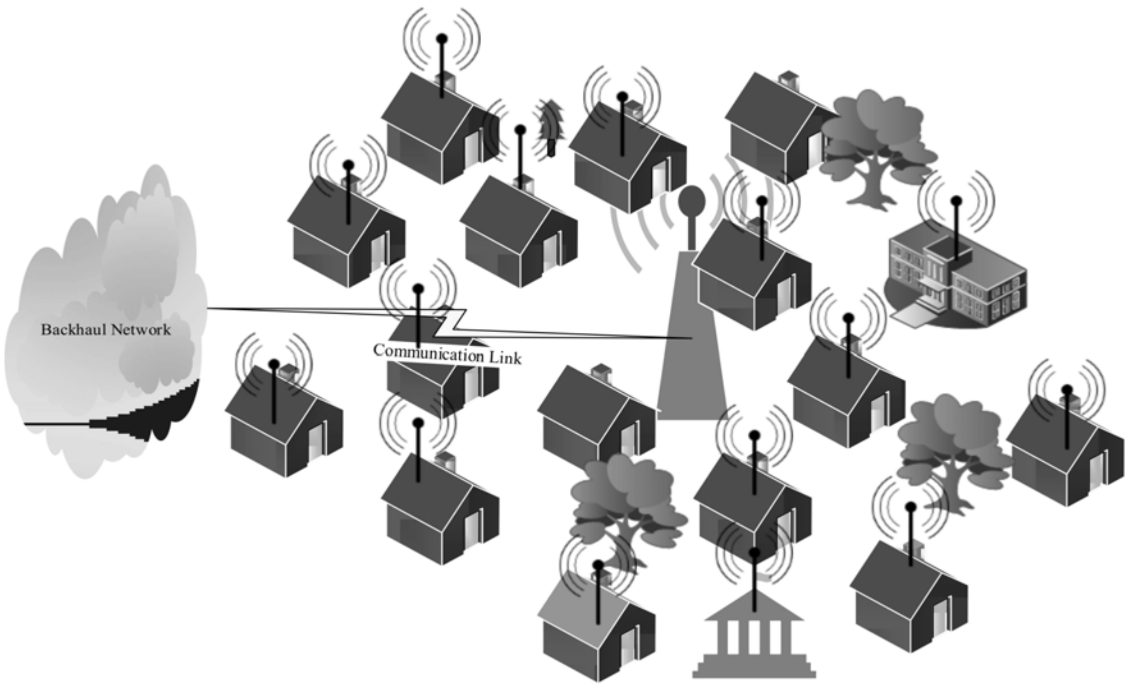
$$PL\ (dB) = \beta 0+\beta 1*\log d+\chi \tag{1}$$

Unknown parameters β0 and β1 depend on environmental factors. In this study, these parameters have been found for different environments. β0 and β1 are found by linear least square curve fitting method. χ is a Gaussian random variable with zero mean and σ standard deviation. It accounts for the shadowing effect.

2. LITERATURE REVIEW

WiFi technology uses ISM band, therefore, it is very popular in providing Internet access to cafes, airports and hotels, etc. In its current form, WiFi covers a very small area. Now, the trend is moving towards deploying long-range WiFi networks. This long range WiFi is also being used to provide modern network connectivity to remote and rural areas of the developing nations. As the people of rural areas cannot pay for other expensive network technologies like WiMAX and DSL etc., this long range WiFi solution is, cheap and easy from maintainability and sustainability point of view. There are many approaches suggested by different researchers to do this task efficiently, cheaply and optimally [2-8].

In [4], a case study for a village of Malaysia using QualNet simulation platform has been presented. There, a two-tier network model has been suggested. The 1st tier is from user to WiFi wireless routers, making Internet access, VOIP (Voice Over IP) and related services accessible, and 2nd tier is from backhaul network, i.e. from wireless routers to main gateway. In [4], the authors have considered a particular village wherein they have found that nine access points are needed to serve the entire village. Simulations have been performed, packet delay and packet loss have been found at each access point. The authors have not considered channel characteristics. The authors have further assumed that there are a fixed number of users.



(a)

(b)

FIG. 1. TOPOLOGIES FOR WIFI BROADCAST MODEL

Another interesting study proposes hybrid of WiMAX and WiFi [5-6]. Here, the users are provided with the Internet facility using WiFi, while backhaul network is based on WiMAX. The researcher has shown that no other technology can be combined with WiFi as easily as WiMAX. The performance metrics consist of jitter, packet delivery ratio, packet loss ratio and throughput.

There is a study of path loss and propagation characteristics in [9-24].

With reference to propagation characteristics of the channel, an interesting path loss model is suggested in [9]. Here, the researchers have studied the characteristics of an outdoor environment for a new wireless system. Their 50 MHz MIMO system operates at the center frequency of 781 MHz. The experimental setup consists of a transmitter and a receiver antenna mounted on two vehicles. Measurements are taken in different environments of Korea such as urban, suburban and rural. They have found that no existing path loss model can be used in this frequency range. Winner+ model is somewhat similar in urban environment. Therefore, a new path loss model based on Winner+ model has been suggested.

Another study of propagation characteristics includes the effect of carrier frequency on propagation channel [10]. Researchers have taken the measurements at different frequencies using MIMO based BECE2006 plus platform. Measurements have been conducted at 2.38, 3.705 and 5.25 GHz. A path loss model based on these measurements has been proposed.

There is a discussion of penetration losses in [15-16] and there is study of different modern wireless path loss and propagation models like SUI model, Okumura Hata model, and Cost 231 etc. [17-18].

Solution to a major issue of power failure at rural sites for rural WiFi networks is discussed in [25]. The authors have proposed the deployment of solar panels at different sites in rural WiFi network. This work provides a way of sustaining WiFi network against power failure or power unavailability in rural areas.

There is also a study related to long range WiFi in kilometers range using high powered point-to-point directional antennas via wireless mesh networks [2,7]. This study is related to point–to-point links. There, the main focus to increase the range seems dependent on antenna power and directivity. We are applying a new approach for WiFi broadband broadcast. For example, this broadcast may include all TV channels and Internet channels, etc. Moreover, to the best of our knowledge, there is no such study that includes all the environmental factors in designing a WiFi model for rural areas. There is, however, a study based on the effect of frequency on signal strength, and designing of WiFi networks using different networking topologies like mesh and multihop [2,4,7,8].

3. ENVIRONMENTAL AND MEASUREMENT CAMPAIGNS

In this research, we are considering Lower Kot Ratta as a rural village for designing WiFi broadcast model. In Table 1 some statistics of Lower Kot Ratta are presented.

TABLE 1. STATISTICS OF LOWER KOTRATTA

Characteristics	Value
Area of Lower Kot Ratta	64750 square meter
Radius of Lower Kot Ratta	144 meter
Population of Lower Kot Ratta	2100
Population of Lower Kot Ratta above 18 years	1030
No of Houses in Lower Kot Ratta	67

Terrain of Lower Kot Ratta is very helpful in our design. Population is concentrated and houses at the center of village are three feet higher than houses of the outer part of the village.

There are Brick and cement houses in LowerKotRatta. Mud houses are very rare in the village. Most of the houses are single storey, very few houses are double storey. In this paper, we are going to make a propagation model for the outdoor environment of the village, indoor environment of the village and then compare outdoor and indoor environments with the urban indoor environment. A congested street of Lahore city with tall buildings on both sides is considered as an indoor environment for urban area.

Kot Ratta is located at a distance of approximately 60km from Gujranwala city and at 2km distance from Chenab River. Google Earth view of Lower Kot Ratta is shown in Figs. 2-3.

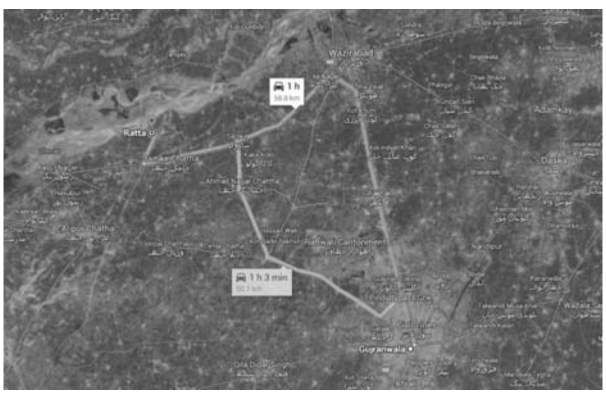


FIG. 2. KOT RATTA GOOGLE EARTH VIEW

FIG. 3. LOWER KOT RATTA GOOGLE EARTH VIEW

4.1 Testing Infrastructure

- TP-Link/MT-Link WiFi Access point
- Xirrus-WiFi Inspector and WirelessMon installed on Dell Laptop

In measurements, TP-Link access point and Dell Laptop are used. TP-Link access point is mounted at thirty feet long rod as shown in Fig. 4(a-b). Height of transmitting antenna is same for all three environments, so its effect is inherently included in the propagation model parameters.

4.2 Methodology

Here is the step by step approach to design a WiFi broadcast network for the rural community of Lower Kot Ratta and to find the propagation model:

(a)

(b)

FIG. 4. WIFI ROUTER/AP MOUNTED TO TAKE MEASUREMENTS

(1) Study the characterization of a particular rural community such as population size, area, and population per area.

(2) Take measurements in the range of WiFi 2.45 GHz using off the shelf WiFi devices in indoor and outdoor environments of that community to know the effect of mud houses and brick houses on signal strength.

(3) Take measurements in cellular band in outdoor and indoor environment to know the effect of mud houses and brick houses on signal strength.

(4) Consider different environmental factors affecting the wireless channel. These factors may include building heights, building material, trees, etc.

(5) Propagation and path loss characteristics of a WiFi wireless channel; LOS (Line of Sight), NLOS (Non Line of Sight) considerations in that community.

(6) Perform the simulations: design a WiFi broadcast network based on simulations to incorporate all the above-mentioned parameters.

(7) Optimize the link design for WiFi based broadcast network for that rural community.

(8) Compare the WiFi broadcast model with the existing propagation models.

(9) This work can also be used as a reference guide to deploy WiFi broadcast systems in rural communities by USF and other organizations.

4.3 Existing Propagation Models

In this study, we are considering Free Space Path Loss Model, Okumura Model, COST 231 Hata Model, SUI (Stanford University Interim) Model, Hata-Okumura extended model or ECC-33 Model, COST 231 W-I (Walfish-Ikegami) Model, and Ericsson Model [17-18,22-23,26] to compare with proposed model.

It has been shown that our simplest proposed model (Equation (1)) best fits for WiFi broadcast network for smaller rural areas and also has flexibility for other terrains such as urban environments for smaller coverage.

5. RESULTS AND DISCUSSION

This section discusses results of measurements taken in different environments. Measurements are taken in the outdoor environment of Lower Kot Ratta, Indoor environment of Lower Kot Ratta and indoor environment of urban area of Lahore, Pakistan.

Figs. 5-9 shows power received as function of distance and propagation loss as function of distance.

In Fig. 5 outdoor environment of a rural area is considered, Fig. 6 depicts indoor environment of rural area and in Fig.7, urban environment is considered. Following conclusions are conspicuous from Figs. 5-7:

(1) It can be seen that, at smaller height of antennas and smaller distance, none of the existing models best fits the WiFi 2.4 GHz broadcast.

(2) There are large power variations/small scale fading for rural indoor environments as shown in Fig. 6(a-b).

(3) GSM measurement results were not promising due to multiple sectors, electrical and mechanical tilt of antennas, so they have not been discussed here.

(4) Maximum coverage of Wi-Fi for rural indoor is 150 meter and for urban indoor is 110 meter as shown in Fig. 8 and in Table 2.

(5) If we increase the Tx power to 10dBm, then we can easily cover LowerKotRatta using only one WiFi broadcasting device.

(6) Propagation constants β0 and β0 for new proposed WiFi broadcast model for different environments are compared in Table 3.

6. CONCLUSION

The primary objectives of this research work are to provide broadcast services such as IPTV access to rural communities, to study the propagation characteristics of WiFi for a typical rural community and to optimize the WiFi network. Different WiFi broadcast network topologies have been proposed and finally a propagation model for indoor and outdoor environments has been presented. The proposed model is flexible and more suitable for rural areas as compared to existing models. Measurements have been performed to calculate Tx power required to provide broadband services in such areas. In future, the propagation model would be expanded to include other factors like temperature, humidity and seasonal effects etc.

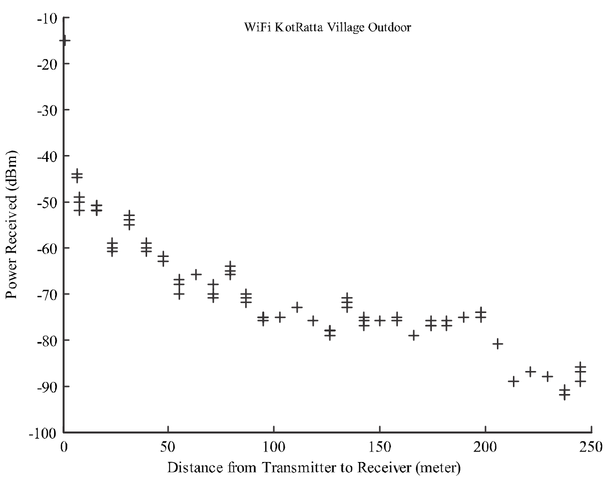


FIG. 5(a). POWER RECEIVED INRURAL OUTDOOR ENVIRONMENT, MEASURED VALUES ARE INDICATED BY '+'

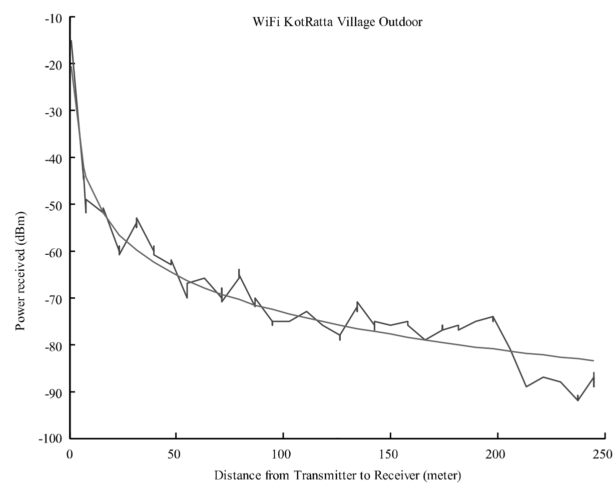


FIG. 5(b). ESTIMATED POWER RECEIVE MODEL

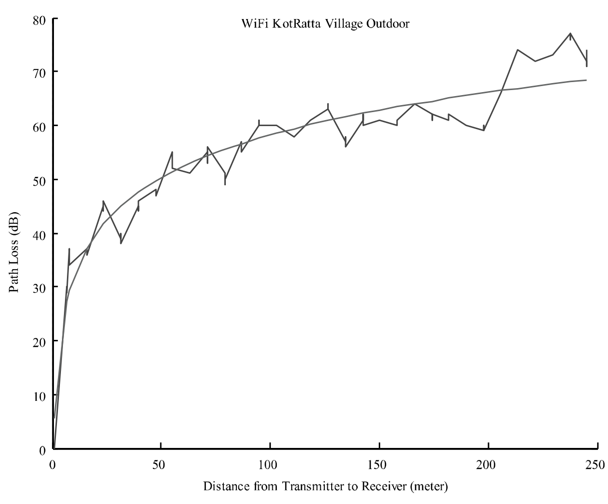


FIG. 5(c). ESTIMATED PROPAGATION MODEL INRURAL OUTDOOR ENVIRONMENT

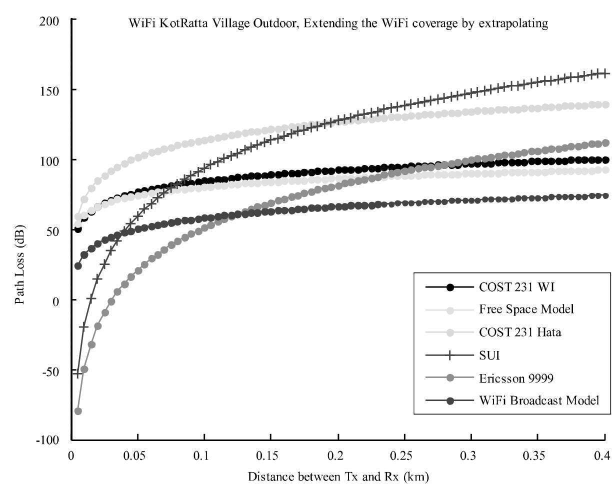


FIG. 5(d). COMPARISON OF ESTIMATED PROPAGATION MODEL OF RURAL OUTDOOR ENVIRONMENT WITH EXISTING WELL KNOWN MODELS FOR WIFI 2.4GHZ

FIG. 5(a-d). PROPAGATION MODEL INRURAL OUTDOOR ENVIRONMENT FOR WIFI 2.4GHZ KNOWN MODELS FOR WIFI 2.4GHZ

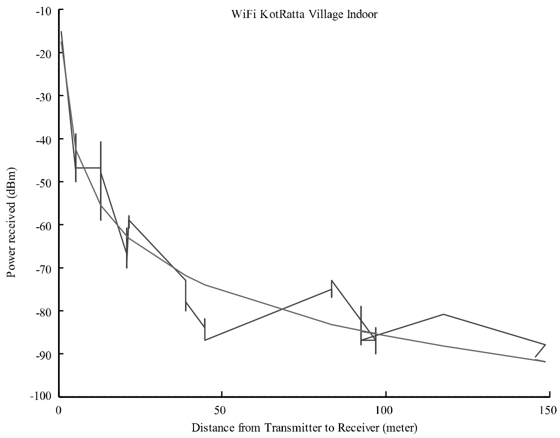


FIG. 6 *(a). POWER RECEIVED INRURAL INDOOR ENVIRONMENT AND ESTIMATED POWER RECEIVE MODEL*

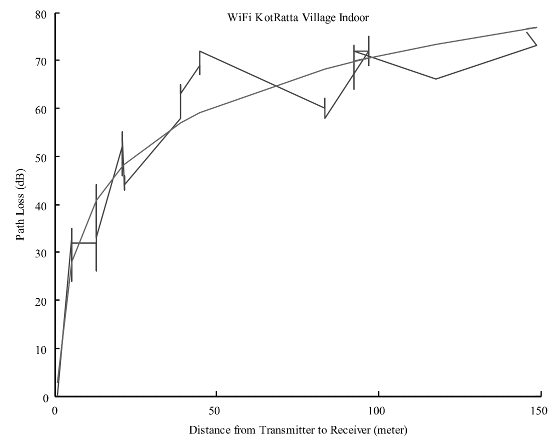


FIG. 6 *(b). ESTIMATED PROPAGATION MODEL IN RURAL INDOOR ENVIRONMENT*

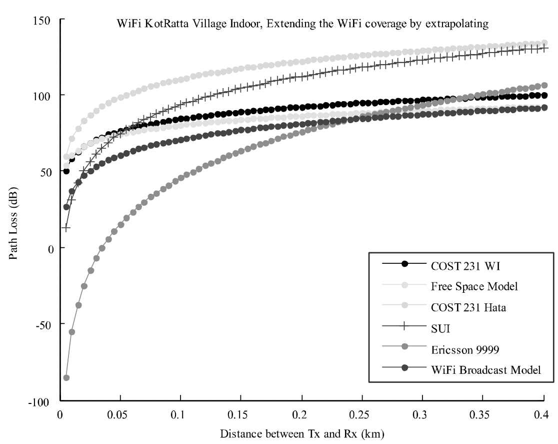


FIG. 6 *(c). COMPARISON OF ESTIMATED PROPAGATION MODEL OF RURAL OUTDOOR ENVIRONMENT WITH EXISTING WELL KNOWN MODELS FOR WIFI 2.4GHZ*

FIG. 6. (a-c) PROPAGATION MODEL IN RURAL INDOOR ENVIRONMENT FOR WIFI 2.4GHZ

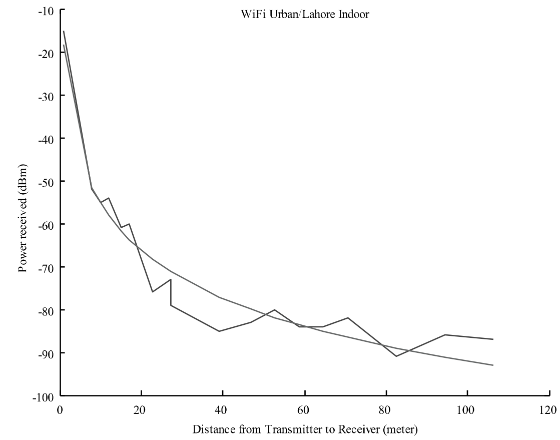


FIG. 7(a). POWER RECEIVED IN URBAN INDOOR ENVIRONMENT AND ESTIMATED POWER RECEIVE MODEL

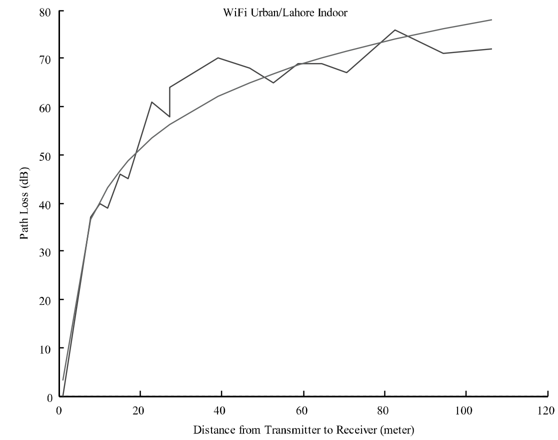


FIG. 7(b). ESTIMATED PROPAGATION MODEL IN URBAN INDOOR ENVIRONMENT

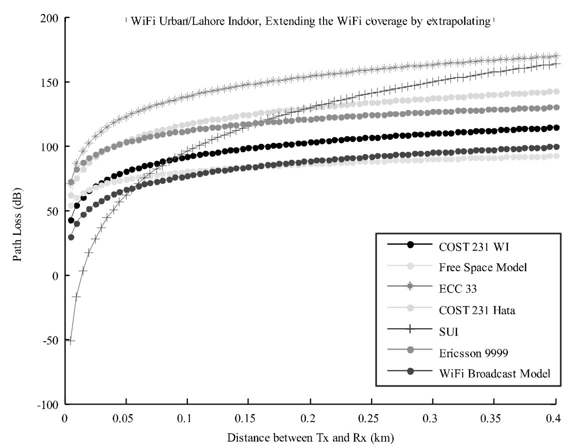


FIG. 7(c). COMPARISON OF ESTIMATED PROPAGATION MODEL OF URBAN INDOOR ENVIRONMENT WITH EXISTING WELL KNOWN MODELS FOR WIFI 2.4GHZ

FIG. 7(a-c). PROPAGATION MODEL OF URBAN INDOOR ENVIRONMENT FOR WIFI 2.4GHZ

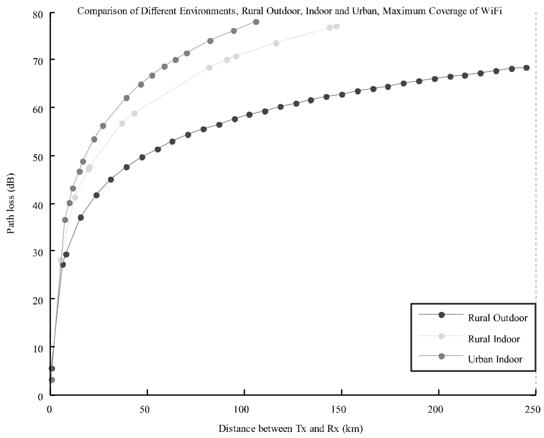


FIG. 8. MAXIMUM COVERAGE OF WIFI 2.4GHZ IN RURAL OUTDOOR,RURAL INDOOR AND URBAN INDOOR ENVIRONMENTS

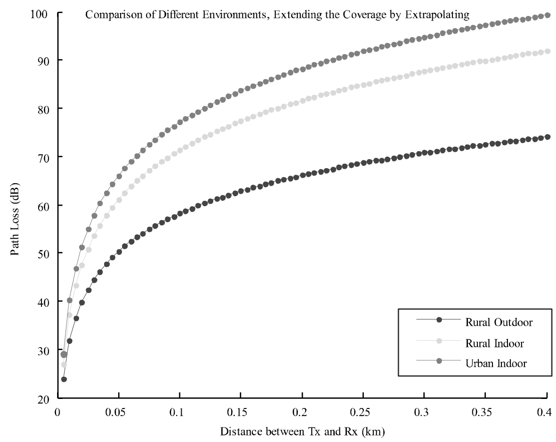


FIG. 9. COMPARISON OF ESTIMATED PROPAGATION MODELS OF RURAL OUTDOOR, RURAL INDOOR AND URBAN INDOOR FOR WIFI 2.4GHZ

ACKNOWLEDGMENTS

Authors would like to thank Mr. Bilal Ahmed, Mr. Muhammad Uzair Tanveer, for guidance in this research. Mr. Usman Abbas, Khuram Shehzad, Rafiq Yaqoob, Muhammad Khalid, Hassnain Mujtaba, and Muhammad Taha, for helping and participating at different phases of measurement campaigns.

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TABLE 2. MAXIMUM WIFI COVERAGE FOR OFF THE SHELF DEVICE FOR DIFFERENT ENVIRONMENTS

Environment	Tx Power	Rx Power	Coverage
Rural outdoor	-10dBm	-90dBm	>250 meter
Rural indoor	-10dBm	-90dBm	150 meter
Urban indoor	-10dBm	-90dBm	110 meter

TABLE 3. PROPAGATION CONSTANTS FOR DIFFERENT ENVIRONMENTS

Environment	$\beta 0$	$\beta 1$
Rural outdoor	5.5	26.33
Rural indoor	2.59	34.19
Urban indoor	3.19	36.97

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