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A Proficient Setting up of BFWA with WiMAX For Linking Internet to Home Network

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Abstract: WiMAX was originally designed to provide a flexible, cost effective, standards-based last-mile broadband connectivity to fill in the broadband coverage gaps that are not served by wired solutions such as cables or DSL. This study presents an efficient and simple method for planning of Broadband Fixed Wireless Access (BFWA) with IEEE802. About 16 standard to support home connection to internet. The study formulates the framework for planning both coverage and capacity designs. The correlation between coverage area and access rate from subscriber in every environment area is presented. The study also presents the throughput and channel capacity of IEEE802.16 in different access rates. An extensive analysis is performed and the results are applied to the real case study to demonstrate the practicality of using IEEE 802.16 for connecting home to Internet. Using empirical data and original subscriber traffic from measurement, it is shown that the BFWA with IEEE802.16 standard is a capacity limited system. The capacity of IEEE802.16 is related to different factors including frequency bandwidth, spectrum allocation, estimation of traffic per subscriber and choice of adaptive modulation from subscriber terminal.

Key words: WiMAX, OFDMA, BFWA, DSL, capacity limited system, Iraq

INTRODUCTION

xDSL (Digital Subscriber Line) remains by far the most popular broadband access technology with the major market share. The basic problem with xDSL is a distance limitation due to signal attenuation. The maximum bandwidth of xDSL is limited by the distance of the user from the local the cable. The bandwidth limitation of xDSL causes the growth rate of wired broadband technologies to decrease in many countries due to the strong growth in Fiber to the Home (FTTH) and wireless access technologies. FTTH technology is the most innovative technology which can provide a limitless bandwidth per subscriber at a distance up to 20 km. This technology is very suitable but the fundamental problems are the installation cost of fiber and the CPE cost which is much higher than the cost of DSL modem.

As a consequence, broadband wireless technologies are gradually replacing wired technologies (Ritthisoonthorn *et al*., 2010) After the inclusion of Orthogonal Frequency Division Multiple Access (OFDMA) based technology, IEEE802.16 which also uses OFDMA technology, becomes more competitive with 3G cellular technologies. IEEE802.16, also known as WiMAX (Worldwide interoperability for Microwave Access) as defined by the WiMAX. Now-a-days, (WiMAX) technology becomes popular and receives growing acceptance as a Broadband Wireless Access (BWA) system due to low cost, rapid deployment where one base station can cover a small city (Al-Adwany, 2010; Patra *et al*., 2010; Bayan *et al*., 2010; Wang and Jia, 2009). Network planner devotes to optimize an efficient network planning with the target on lowering the system cost for broadband wireless access network. Lowering the cost of broadband wireless access derives from many alternatives for example, sharing network infrastructure, lowering the complexity of equipment and technologies. Only a few researches relating the planning issues of WiMAX are there. Wanichkorn and Sirbu (2003) and Wang (2004) discuss designing of broadband wireless access network without any specific details. In this study, an efficient network planning of BFWA system is proposed for lowering the cost of wireless access network. Researchers choose IEEE802.16 standard as a selected technology, since it has a high potential for BFWA system. In this study, researchers estimate path loss and throughput of IEEE802.16. And then find the number of Access Points (AP) form capacity and coverage planning. The model is validated by applying to Al Basra district.

MATERIALS AND METHODS

BFWA network planning: The efficient BFWA network depends on the system of network planning. A network

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can be either coverage or capacity limited so the dimensioning is carried out both from a coverage perspective and a capacity perspective, respectively. To ensure that both requirements are fulfilled, the number of access points needed for each area type is given by Wang and Jia (2009):

$$NAP = \max \{N_{AP\text{-}co}, N_{AP\text{-}ca}\} \quad (1)$$

Where:

$N_{AP\text{-}co}$ = The number of AP acquired from coverage planning

$N_{AP\text{-}ca}$ = The number of AP derived from capacity planning

Area coverage analysis: Coverage planning is estimating the needed number of APs to fulfill the coverage of all subscribers in a given service area. Coverage planning of BFWA network requires the knowledge of Radio Propagation Model for predicting the losses between transmitters and receivers path. The path loss represents the combined effects on signal attenuation due to the free space loss, reflection, diffraction and scattering and so forth.

The propagation of radio frequency depends on the physical environment, therefore researchers define the service area and select appropriate Radio Propagation Model to predict the path loss.

The accuracy of path loss prediction can greatly affect the estimated cell range which in turn determines the number of AP needed to achieve a coverage area in the network.

Link budget: The link budget is a tabulation of all gains and losses in the link that are added in order to deliver the mean signal level at the receiver. The term link budget is often used to indicate the allowance path loss which in turn is used to determine the cell range of AP. A simple Link Budget Calculation Model implemented in this study is shown in Table 1.

Cell range estimation: By using Propagation Loss Models in Table 2, there can estimate the cell range and then determined the number of access point for coverage planning by applying AP antenna height shown in Table 2, subscriber station antenna height of 6 m and carried frequency of 3.5 GHz, the closed form for prediction of the allowance path loss in urban, suburban and rural are given by Eq. 2, respectively:

$$\begin{aligned} L_{urban} &= 132.64 + (29.83 + 4.78 \log_{10}(d)) * \log_{10}(d) \\ L_{Suburban} &= 121.22 + 41.67 * \log_{10}(d) \\ L_{rural} &= 111.57 + 36.33 * \log_{10}(d) \end{aligned} \quad (2)$$

Table 1: Link budget

Transmitters	Units	Uplink (ST)	Downlink (AP)	Channels
Maximum Tx power	Watt	0.25	1.58	-----
Maximum Tx power	dBm	23.98	31.99	A
Cable loss and insertion loss	dB	0.00	3.30	B
Antenna Tx gain	dBi	2.00	18.00	C
EIRP*	dBm	25.98	46.69	D*
Receiver				
Thermal-noise density	dBm/Hz	-174.00	-174.00	E
Receiver-noise figure	dB	5.00	5.00	F
Receiver-noise density	dBm/Hz	-169.00	-169.00	G*
Receiver-noise power	dBm	-103.16	-103.16	H*
Interference margin	dB	3.00	3.00	I
Receiver-power interference	dBm	-103.18	-103.18	J*
Total effective noise +interference	dBm	-100.16	-100.16	K*
Processing gain	dB	5.74	5.74	L*
Eb/No	dB	9.30	9.30	M
Rx.sensitivity level	dB	-96.60	-96.60	N*
Antenna Rx gain	dBi	18.00	0.00	O
Cable loss	dB	2.00	0.00	P
Fading margin	dB	4.00	0.00	Q
Maximum path loss	dB	134.58	143.28	R*

Table 2: Propagation loss models parameter

Environment	Path loss models	AP antenna height (m)
Urban	Hata-Okumura Extended or (ECC-3) Model	30
Suburban	Stand University Interim (SUI-B) Model	40
Rural	Stand University (SUI-C)	60

where, d is the distance between transmitter and receiver in km. By assuming the cell shape as hexagonal, the area covered by a single cell is given by:

$$A_{cell} = 2.6 * d^2 \quad (3)$$

Number of AP acquired from coverage planning: The number of access point for coverage planning is given by:

$$N_{AP\text{-}co} = A_{service}/A_{cell} \quad (4)$$

where, $A_{service}$ is a given service area

Capacity planning: Capacity planning is estimating the needed number of APs to fulfill the traffic demands of subscribers in a given service area.

Channel throughput estimation: The channel Throughput (T) is defined as the aggregate cell payload that is the peak useful data rate. The aggregate cell payload for IEEE802.16 is given by:

$$T = 6/7 * [(k * 2^m * R_c * B_c)/(2^m + 1)] \quad (5)$$

Where:

k = The bits per symbol for the modulation being used
m = The cyclic prefix
m = {2, 3, 4, 5}
B_c = The channel width of IEEE802.16
R_c = The overall code rate for the modulation being used in subscriber station ST

Table 3 shows bit per symbol and overall code rate in different types of modulation.

Channel capacity estimation: Channel capacity is the active number of subscribers in a single channel. The maximum number of subscribers that can be supported by a channel is given by:

$$C = T/R_d \quad (6)$$

where, R_d is a peak traffic demand per user in kb sec^{-1}.

Number of AP acquired from capacity design: The number of AP is derived from the ratio of the expected number of subscribers in the service area to the maximum number of subscribers supported by single AP and given by:

$$N_{AP\text{-}ca} = N_{service}/c \quad (7)$$

where, $N_{service}$ is the number of users to be serviced. By the substitution of Eq. 6 into 7, the required number of AP for capacity design is obtained by:

$$N_{AP\text{-}ca} = [R_d/T]^* N_{service} \quad (8)$$

Where:
D = A - B+C
G = E+F
H = $G+10\log_{10}(3840000)$
J = $10\log_{10}(10^{\wedge}((H+I)/10) - 10^{\wedge}(H/10))$
K = $10\log_{10}(10^{\wedge}(H/10)+10^{\wedge}(J/10))$
L = $10\log_{10}(3840/\text{user data rate})$
User data rate = 1.024 kbps
N = M - L+K
R = D - N+O - P - Q
EIRP = Effective Isotropic Radiated Power

In this study, researchers look into the system planning of BFWA based on IEEE802.16 standard. The case study is within the area of Al Basra.

Table 3: Bit per symbol and overall code rate

Modulation types	Bit per symbol (k)	Overall code rate (R_c)
BPSK 1/2	1	1/2
QPSK 1/2	2	1/2
QPSK 3/4	2	3/4
16 QAM 1/2	4	1/2
16 QAM 3/4	4	3/4
64 QAM 2/3	6	2/3
64 QAM 3/4	6	3/4

RESULTS AND DISCUSSION

Key input for analysis

System design parameters: Table 4 shows the system parameters of IEEE802.16 as BFWA system.

Modulation distribution assumption: In the principle of adaptive modulation, the type of modulation being used by ST strongly depends on the signal-to-noise ratio at the receiver end when SNR is very good near the BS so higher order modulation scheme is used in this area to increase the throughput. However in areas close to the cell boundary, the SNR is normally poor. So, the system steps down to a lower order modulation scheme to maintain the connection quality and link stability. Normally, the main purpose of engineering design is to install the AP at the location where the number of subscribers is maximum. Practically not all subscribers are covered by single AP. Researchers therefore, need to assume the location of subscribers relating to AP. Researchers define the subscriber data access into three scenarios.

The 1st scenario is the low speed data rate where modulation scheme being used in ST is dominated by BPSK. This scenario describes the subscriber who is far from AP. The 2nd is the medium speed, where modulation scheme in ST is moderated. The last scenario is the high speed data rate where 64-QAM is a dominant modulation scheme in ST. This scenario describes the subscriber who is close to AP. Table 5 shows the assumption of modulation distribution in ST.

Traffic estimation per subscriber: The traffic demand of each subscriber shown in Table 6 (Vannan and Rajalakshmi, 2010).

Table 4: Design parameters

Parameters	Values
Frequency range (GHz)	3.5
Channel width (MHz)	1.75, 3.5, 7.0 and 14
Maximum transmit power (W)	3.2
Micro cell AP antenna height (m)	40
Macro cell AP antenna height (m)	60
Subscriber terminal antenna height (m)	6

Table 5: Assumption of modulation distribution in subscriber terminal

Access scenario	BPSK	QPSK	16-QAM	64-QAM
Low speed	0.80	0.10	0.05	0.05
Medium speed	0.01	0.48	0.50	0.01
High speed	0.01	0.05	0.10	0.84

Table 6: Traffic per subscriber

Access areas	Peak downlink (kb sec^{-1})
Urban	1000
Suburban	512
Rural	356

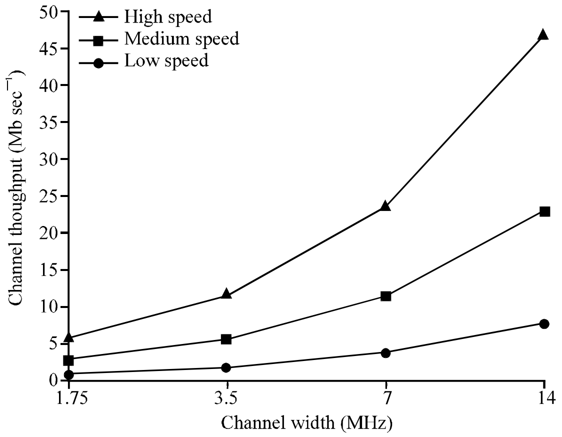

Fig. 1: Channel throughput and channel size for each access scenario

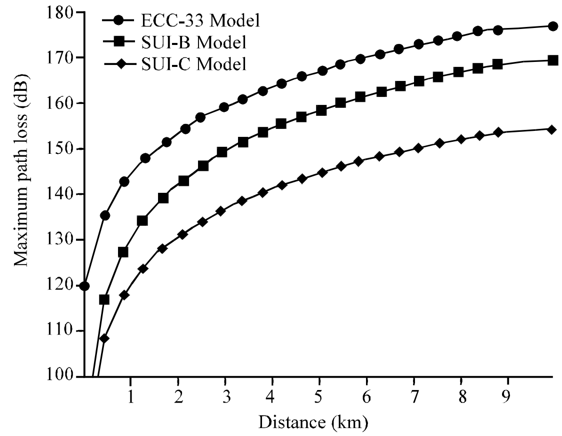

Fig. 2: Relation of path loss and cell range of each Path Loss Model

Table 7: Throughput and path loss for different channel sizes

Channel width (MHz)	Throughput (Mb sec^{-1})	Maximum path loss (dB)
1.75	2.75	133.39
3.50	5.51	130.98
7.00	11.01	127.97
14.0	22.02	124.88

Table 8: Cell range and path loss of medium access

Channel width (MHz)	Maximum path loss (dB)	ECC-31 (m)	SUI-B (m)	SUI-C (m)
1.75	133.93	600	1300	2400
3.5	130.98	500	1100	2000
7	127.97	350	900	1700
14	124.88	300	700	1400

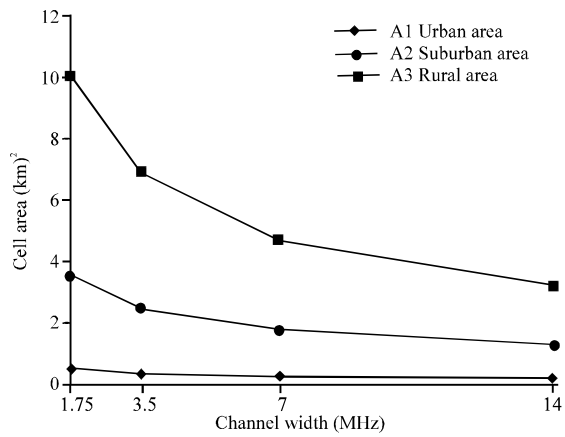

Fig. 3: Relation of coverage area of single cell to channel width for different type of environment areas

Key results from analysis

Channel throughput: Figure 1 demonstrates the results of channel throughput. The results shows that RF channels with higher channel width increase the channel throughput.

RF channel throughput also depends on the speed of data access from subscriber. The channel throughput that configures as high speed access has more channel throughput than a lower access.

Cell range: The cell range can be estimated by inserting the channel throughput into the Link Budget Calculation Model in Table 1. Researchers obtain the maximum allowance path loss between AP and ST. Table 7 shows the results of maximum allowance path loss in a variety of channel width.

Researchers select the empirical Radio Path Loss Models in Table 2 for prediction of the path loss between AP and ST. Equation 2 are used for converting the path loss into distance. Figure 2 shows the results of maximum path loss predicted by each model plotted against distance.

The results of cell range of particular channel width for medium access scenario estimated by Eq. 2 are shown in Table 8. The results indicate that cell size of remote open area is bigger than the cell size of urban dense area.

Cell coverage: Researchers assume the cell as hexagonal shape where coverage area of single cell is obtained by Eq. 3. Figure 3 shows the relationship of cell area and channel width in different of environment.

Channel capacity: The channel capacity is obtained from the ratio of RF channel throughput and subscriber traffic demand in Table 6. The results of channel capacity are shown in Fig. 4 and represent the relationship between channel capacities supported by RF channel in different environment and access scenario.

The channel capacity increases as expected when the channel width increases. The number of active subscriber per RF channel is very high in rural area compared to that in urban area.

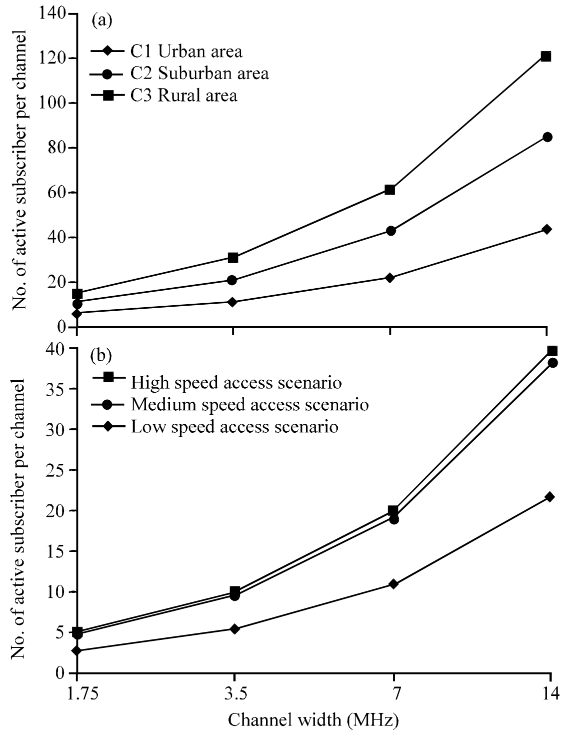

Fig. 4: Channel capacity of IEEE 802.16; a) channel capacity by environment and b) channel capacity by access scenario

Table 9: Demographic information of Al Basra

Environment	$A_{service}$ (km^2)	$N_{Service}$
Urban	7628.0	1,800,000
Suburban	6674.5	900,000
Rural	4767.5	300,000

This is due to that the traffic per subscriber in urban area is higher than traffic from rural area. The AP which is configured as low speed access has a lower capacity than high speed access.

Case study: Researchers address the benefits from IEEE802.16 standard to a large scale BFWA system by applying the results from analysis to the potential service area in Al Basra. The results of this research may be applicable to other similar cities in developing countries.

Service area information: Al Basra, the second largest of al Iraq governorates with total area of 19,070 km^2. The urbanized area is about 7628 km^2 or only 40% of total area.

The rest of 35 and 25% are suburban area and rural area, respectively. We define the area of Al Basra into three environment as shown in Table 9.

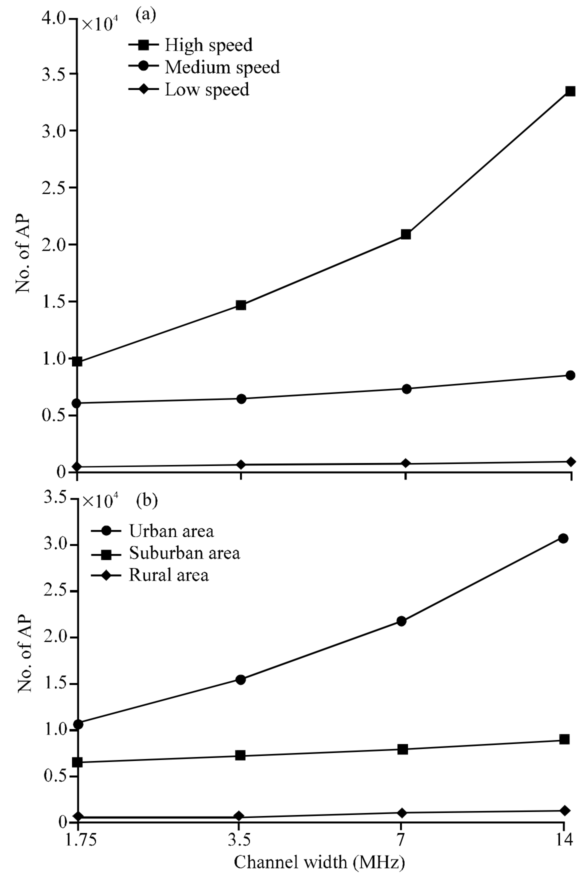

Fig. 5: No. of AP by coverage planning; a) coverage based number of AP access scenario and b) coverage based number of AP by environment area

Results of case study: Figure 5 shows that the total number of AP from coverage planning is increasing at the higher channel width. This is due to the fact that the cell range of a higher channel throughput of high channel width has a limit. On the other hand, results from capacity planning indicate that the required number of AP is opposite from that in coverage planning. The number of AP required for achieving traffic demand of capacity planning is decreasing at AP configured as a higher channel width. The number of AP increases in both area and access scenario as shown in Fig. 6. This is due to the fact that the higher throughput channel has the high capacity of AP.

The compared result of BFWA network planning for medium access scenario is shown in Fig. 7 by comparing between coverage design and capacity design, the results show that the number of AP is varying in opposite direction. According to Eq. 1, the number of AP required is dominated by cpacity planning.

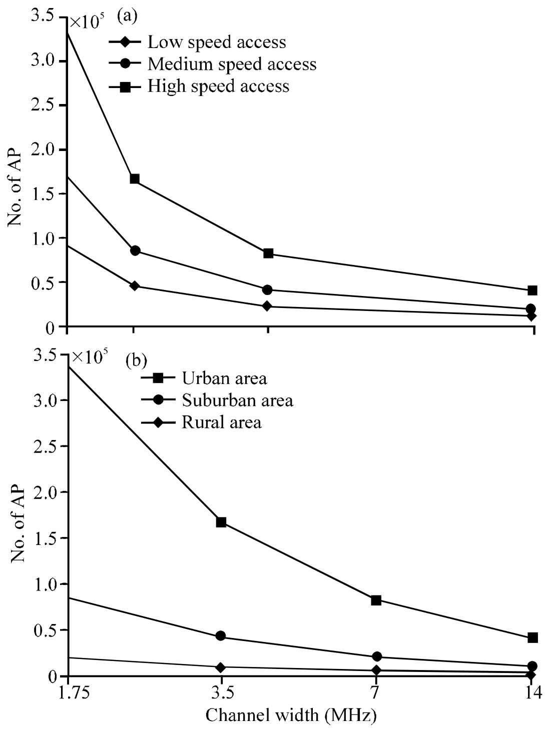

Fig. 6: No. of AP needed by capacity planning; a) no. of AP by access scenarios and b) no. of AP needed by area

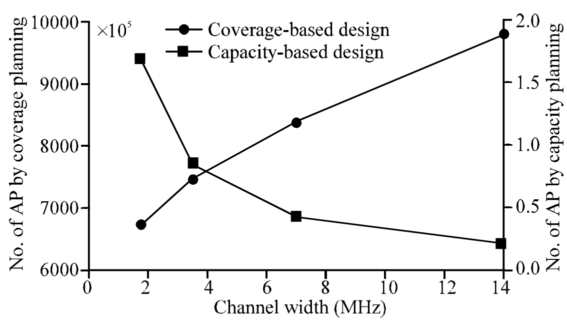

Fig. 7: Coverage design versus capacity design

CONCLUSION

In this study, researchers demonstrate the feasibility of designing BFWA system with IEEE802. About 16 standard for connecting a future smart home to the internet.

Through the case study, the results from study present the feasibility of having a large scale BFWA system in providing wireless Internet access. The results of planning indicated by the number of AP of BFWA system is dominated by capacity planning. It shows that BFWA with IEEE802. About 16 standard is a capacity-limited system.

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