Energy Efficient Femtocell based Architecture for Low Coverage Areas in WiMAX

H. H. R. SHERAZI †1, RAZI IQBAL[1], ASFANDYAR GILANI[1], M.H. CHAUDARY[2]

([1] Department of Computer Science & IT, Lahore Leads University, Lahore, Pakistan)

([2] Department of Computer Science, COMSATS Institute of Information Technology, Lahore, Pakistan)

†E-mail: sherazi@leads.edu.pk

Abstract -Femtocells are low power base stations operating in licensed spectrum with the intent to improve coverage and performance of voice and broadband services. The use of data hungry devices such as, tablets, smart phones and other wireless devices has rapidly been increasing in recent years and is driving the need to provide higher speed connections, more capacity and better quality of service. This article presents energy efficient femtocell based architecture for low coverage areas of wimax to improve indoor coverage of cellular mobile devices in the areas where coverage is weak or intermittent. It demonstrates the coverage is significantly improved introducing femtocells in low coverage areas and the total network capacity can be enhanced many folds as compared to macrocell networks. Simulation results show that the proposed architecture performs better in terms of different parameters like Throughput, End-to-End Delay, Voice Traffic Received and Mean Opinion Score (MOS).

Key words: *Femtocell, WiMAX, Femto Access Point, Wide Area Networks, Energy Efficient Networks*

1. INTRODUCTION

The insatiable desire for higher data rates and ubiquitous Internet access requires dense base stations deployment in networks. The traditional network infrastructure cannot meet customer demands with efficient manner and is not economical for the network operators as well. Femtocells are low power base stations that are installed in an office or a residential area for the sole purpose of cellular coverage improvement within a building. It is sold with various brand names like Airave (Sprint), Microcells (AT&T) and Network Extender (Verizon) in the market [1]. The connectivity of the different portable devices can be increased through femtocells deployment in cellular networks particularly in the areas where large macro cells offer weak coverage.

People use higher data rate services mostly at that time when they are at home or office. Eighty one percent (81%) of total data traffic originates from offices and homes according to Infroma Telecom & media statistics report [2]. This percentage is also increased due to the penetration of data hungry devices such as tablets, dongles, smartphones that generate large amount of data traffic on macro cellular networks. The user applications consist of voice, video calls, web surfing, receiving and sending emails, social networking and music downloads etc. In a related study [3] it was found that one indoor user uses the same capacity as ten outdoor users. But these macro cellular networks are not able to deal with high data rate traffic demands effectively. Moreover, dead zones can be there under the coverage area of macrocells e.g. at the edge of the cell, indoor environment, basements and thick walls etc. There is still a challengeable task for the network operators to find an effective solution dealing with this sort of increased traffic demand for customer satisfaction keeping in view the quality of service.

The femtocell architecture may look different to an ordinary user from macro base station architecture in a way that femto access point (FAP) is actually connected to the backhaul network by simple DSL or any other internet link. The difference is that a standard mobile device is connected to an outdoor high power base station but in femtocell it is connected through its own low power base station located at home. This localized base station provides efficient and stable connection for indoor users. Femtocells are very easy to deploy in plug and play manner with the existing DSL link.

There may be various benefits deploying femtocells for both users and network operator prospective. The use of these cells provides the better coverage in the area in addition to many other services to the users. More revenue can be earned by providing many services and better coverage to the users by the Network operators. There are many motivations for users to deploy femtocell at home or in an office. Femtocell fulfills consumer's demands for better coverage and improved quality of service in home environment. Hence, the demand of femtocell is increased since last couple of decades and various mobile operators are interested to exploit the advantage of technology via 3G and 4G/LTE.

Network operators deploy smaller cell sizes to offer better services to higher number of users due to increasing capacity and coverage demands. Femtocell base station is placed very close to the user which results in low Block Error Rate (BLER) and hence throughput is increased.

Coverage in a macrocell within a building is a big issue and Femtocell provides solution by providing better coverage within home, office and other buildings. The signal strength from the outdoor base station cannot meet the requirements of better performance due to high penetration loss from the walls inside buildings and larger distance from macro base station. Femtocell provides cost effective solution and better user experience through improved services [4].

Better coverage to customers allows access to wide variety of new applications from internet and mobile phone operators at homes or offices [5]. Users can achieve higher data rate, good quality of voice and multimedia applications due to better communication link.

Growth of energy consumption is directly related to the growth of greenhouse gas emission which is a threat for environmental protection. The amount of energy consumed by wireless networks is about 70 % of the total energy [6]. The exponential growth of energy consumption from mobile service requires an efficient energy solution. Femto base stations consume very low power as compared to macro base stations in cellular networks. Femtocell user can transmit signal with very low power because it is closer to the base station. This results in extended battery life [7].

This work analyses femtocell performance in WiMAX. The QoS parameters chosen for this purpose are Throughput, Packet End to End Delay, HTTP Page Response Time, MOS, upload and download response times and Packet Dropped. The different types of traffic like Web browsing, File Sharing and VoIP is evaluated using Opnet 14.5 network simulator [8] to validate the performance difference.

The remainder of this paper is organized as follows: Section 2 presents an overview of the related work. Section 3 discusses the proposed solution, identifying the problem scenario, the detailed design, implementation of the proposed work. While the evaluation parameters and discussions are elaborated in section 4 and finally concluding remarks are mentioned in section 5.

2. RELATED WORK

In [9,10] Kim and Mohjazi discussed indoor wireless network challenges and networks requirements encountered in femtocells during deployment in 2009 and 2011 respectively. These challenges include access methods, frequency planning, interference, mobility, synchronization and quality of service.

Kim et al. [9] have proposed some solutions for WiMAX femtocells in order to overcome these challenges. Femtocell base station must be synchronized with other femtocells and macrocells. The author proposed two types of synchronizations; network based synchronization using Network Time Protocol (NTP) and air interface based synchronization that uses Global Positioning System (GPS) and interface snooping.

The convergence of femtocells in WiMAX and UMTS was initially achieved by D. Sylvia [11]. Femtocells are deployed in these technologies in indoor environments and performance is compared with Wi-Fi. Different quality of service parameters are selected to evaluate the performance of femtocells with high data rate applications. The simulation results showed that WiMAX provided higher throughput as compared to Wi-Fi and UMTS.

Guillaume de la Roche [12] explored the access methods of femtocells and discussed the business model in this article. The main goal for network operators was to reduce the network cost and complexity of the system to compete with the existing indoor wireless technologies.

None of these articles compared the performance of conventional WiMAX with and without femtocell deployment. This paper presents a scheme with femtocell in WiMAX.

3. PROPOSED DESIGN

The design phase generically consists of two main scenarios in OPNET modeler 14.5 as given below.

- WiMAX without Femtocells
- WiMAX with Femtocells

Table 1 and 2 show the simulation parameters for WiMAX with and without femtocells respectively. In both the scenarios three different types of heavy application profiles are checked as Web browsing, File Sharing and VoIP.

In first scenario a cell of WiMAX is deployed with a coverage radius of 30 Km. There is one base station which is connected to the WiMAX backbone and four different types of servers are attached with the backbone. There are five subscriber nodes in this base station. These subscriber nodes are availing WiMAX services at the edge of the cell boundary in an indoor environment as shown in the figure 1. They are receiving very bad quality signal strength at this place due to very long distance from the base station and some other environmental conditions. The simulation is run for 500 simulation seconds.

Table 1: Parameters for Conventional WiMAX

Wireless Technology	WiMAX
Cell Radius	30 KM
Antenna height	40 Meters
Propagation model	Indoor
Antenna model	Omni Directional
Scenario	Conventional WiMAX
Maximum Power of Macrocell BS	15 W
Antenna gain of UE	2dBi
Maximum Power of UE	0.5 W
Number of Mobile nodes	5
Simulation Time	500 Sec

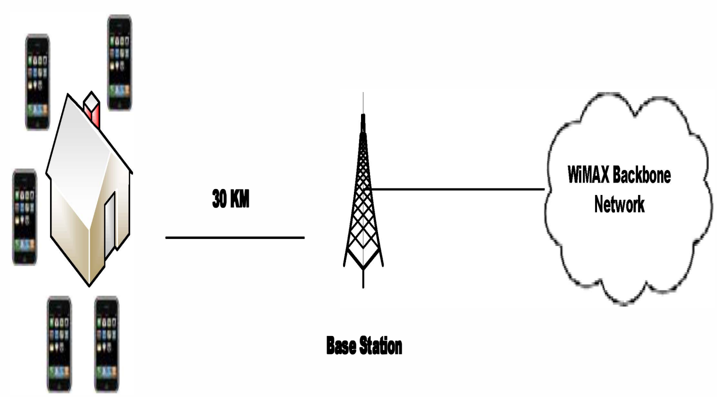

Figure 1: Problem Scenario

In second scenario, a small Femto base station is deployed to provide good quality of service to those subscribers suffering from degradation of performance in the indoor environment. This Femto Access Point (FAP) is connected to the Internet through a broadband router in the user premises using a simple

Ethernet cable. This is connected to WiMAX backbone through Femto Gateway. Again same 5 nodes are selected to measure the efficiency of femtocell using the same external environmental conditions. But here in this case femtocell is low power base station covering the radius of only 10 meters. These five nodes exist in the full coverage of femtocell as shown in the figure 2.

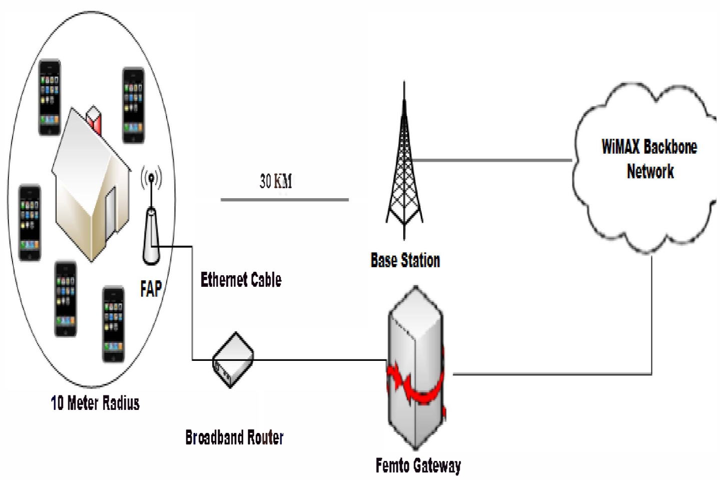

Figure 2: Solution Scenario using Femtocell

Table 2: Parameters for WiMAX using Femtocell

Wireless Technology	WiMAX
Cell Radius	10 Meter
Antenna height	1 Meter
Propagation model	Indoor
Antenna model	Omni Directional
Scenario	WiMAX using Femtocell
Maximum Power of Femtocell BS	0.1 W
Antenna gain of UE	-1 dBi
Maximum Power of UE	0.2 W
Number of Mobile nodes	5
Simulation Time	500 Sec

5. SIMULATIONS AND DISCUSSIONS

5.1. Throughput

Throughput is one of the most important parameter for measuring the system performance because it is an average rate of successful messages delivery over a communication link. Overall Throughput depicts the clear picture between the convention WiMAX systems and using Femtocell in the existing system. In conventional WiMAX scenario, it gives an average output of 50 Kbps for those five nodes which are lying in the service degradation region of the WiMAX macrocell. On the other hand, when a femtocell is deployed for those nodes then 170 Kbps average data rate is achieved due to best network coverage and improved QoS. It is easy to decide that femtocell is a best solution for indoor users to achieve high data rate than conventional WiMAX connection as shown in the figure 3.

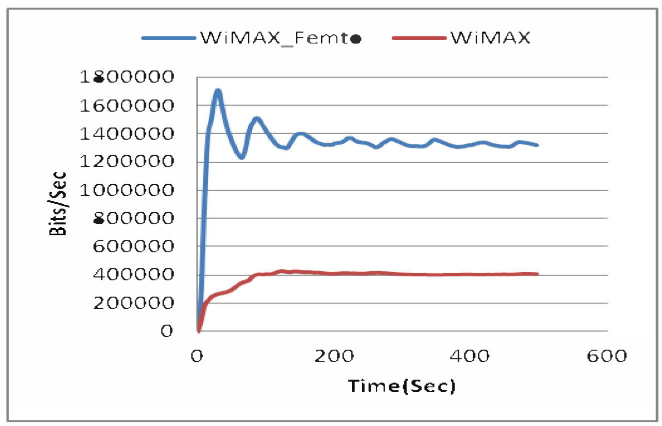

Figure 3: Throughput Comparison for WiMAX

5.2. Packet End to End Delay

The end-to-end delay is another parameter that favors the usage of femtocell for indoor environment for heavy applications. Initially at start of simulation there was very less difference because heavy load of applications running at the same time showing an end-to-end delay of 0.16 seconds. But after a few seconds femtocell performed well and its value declined to 0.14 seconds that is quite reasonable offering overall good performance. On the other hand, WiMAX without femto access point incurred higher delay of 0.16 sec on average throughout simulation causing degradation of service as shown in figure 4.

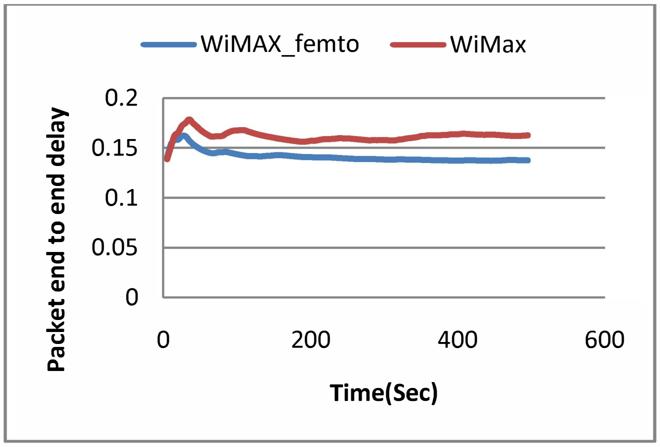

Figure 4: Packet End to End Delay Comparison for WiMAX

5.3. Voice Traffic Received

It is apparent from the results that Femto Access point (FAP) is capable of delivering far more voice traffic received to the subscribers than the conventional WiMAX system. Traffic received by the WiMAX femto users started off with 10000 bytes per second and continuously increased to 33000 bytes per second within a few simulation seconds. This range almost remains stable for the remaining time of simulation. While in conventional WiMAX system for indoor users which are located at the edge of the cell are not capable of giving more than 17000 bytes per second on average. Initially the performance has proved to be bottleneck for both systems due to less data rate but after some time it adjusted reasonably showing a clear difference between both systems as shown in the figure 5.

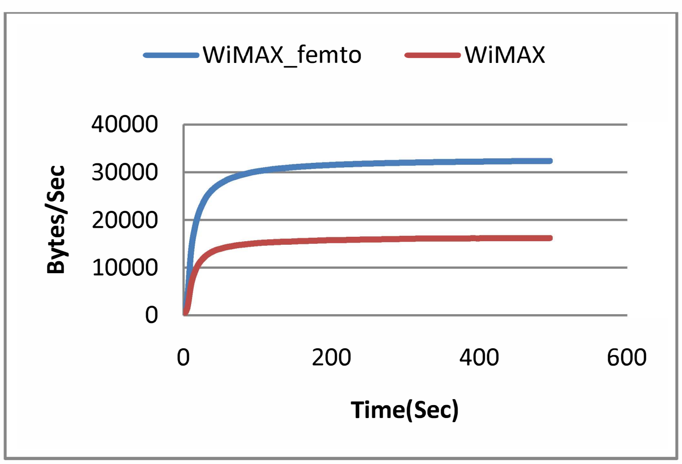

Figure 5: Traffic Received Comparison for WiMAX

5.4. MOS (Mean Opinion Score)

Mean Opinion Score is another parameter for calculating the quality of service in voice conversation between a caller and callee. Its value ranges from 1 to 5 where 1 is for the bad quality and 5 for the excellent quality of sound. There is an immense difference between WiMAX and femto users regarding quality of sound. In femto based WiMAX cell this score is 3.57 and almost remains constant throughout the simulation time. When same nodes are using the conventional Macro cell WiMAX connection this value is falls continuously for every second of simulation run time due to weak signal strength and poor service quality. For the first 100 seconds of simulation it was 3.50, after 200 seconds this value was 3.35 and after 500 seconds it declined to 3.29 results into degradation of voice quality as shown in figure 6.

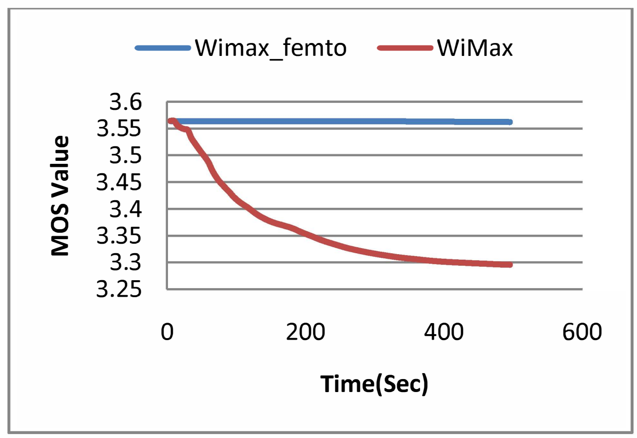

Figure 6: Mean Opinion Score Comparison for WiMAX

6. CONCLUSION

The main objective of this work was to propose, analyze and evaluate deployment of femtocell in WiMAX as compared to macrocell scenario. Throughput, End to End Delay, Traffic Received and Mean Opinion Score (MOS) were taken as the key evaluation parameters. The simulation results were encouraging depicting WiMAX with femtocells yielded better than that of simple conventional macrocell case hence it is the need of time to split up the macrocells of WiMAX, where the coverage is poorer, into small femtocells to achieve the enhanced quality of service for the real time applications.

REFERENCES

[1]. Bao, L., & Liao, S. (2010). Scheduling heterogeneous wireless systems for efficient spectrum access. *EURASIP Journal on Wireless Communications and Networking*, 45, *2010*.

[2]. Mohjazi, L., Al-Qutayri, M., Barada, H., Poon, K., and Shubair, R. (2011). Deployment challenges of femtocells in future indoor wireless networks. In *GCC Conference and Exhibition (GCC), 2011 IEEE* (pp. 405-408), 2011.

[3]. Huang, L., Zhu, G., & Du, X. (2013). Cognitive femtocell networks: an opportunistic spectrum access for future indoor wireless coverage. *Wireless Communications, IEEE*, *20*(2), 44-51, 2013.

[4]. Gago, A., & Cota, N. (2014). Performance Evaluation of Femtocells Usage on LTE. Procedia Technology, 17, 683–691, 2014.

[5]. Small Cell Forum available from *"http://www.smallcellforum.org/"* retrieved on *2nd April 2015.*

[6]. Chen, X., Zhang, H., Chen, T., Lasanen, M., & Palicot, J. (2013). On Improving Energy Efficiency within Green Femtocell Networks: A Hierarchical Reinforcement Learning Approach. *arXiv preprint arXiv:1303.4638*, 2013.

[7]. Dardouri, S., & Bouallegue, R. (2015). Performance Analysis Of Resource Scheduling In LTE Femtocells Networks. *arXiv preprint arXiv:1501.01868*, 2015.

[8]. Modeler, O. P. N. E. T. "OPNET Technologies Inc." (2009) available from "http://www.opnet.com" retrieved on *2nd April 2015.*

[9]. Kim, R. Y., Kwak, J. S., & Etemad, K. (2009). WiMAX femtocell: requirements, challenges, and solutions. *Communications Magazine, IEEE*, *47*(9), 84-91, 2009.

[10]. Mohjazi, L., Al-Qutayri, M., Barada, H., Poon, K., & Shubair, R. (2011). Deployment challenges of femtocells in future indoor wireless networks. In *IEEE GCC Conference and Exhibition (GCC)*, 405-408, 2011.

[11]. Sylvia, D., Jothi, M., and Srinivasa D. (2012) .Capacity Improvement in Wireless Networks using Femtocells. International Conference on Computing and Control Engineering (ICCCE-12), 2012.

[12]. De La Roche, G., Valcarce, A., López-Pérez, D., & Zhang, J. (2010). Access control mechanisms for femtocells. *Communications Magazine, IEEE*, *48*(1), 33-39, 2010.