Integrated WiMAX / Wi-Fi Network Coupler & Its Performance Analysis through QUALNET 5.0.1 Simulator

Poulomi Das*, Prof. Siladitya Sen, Arindam Banerjee***
*(Department of Electronics & Communication Engineering, Heritage Institute of Technology, Kolkata-107)
** (Department of Electronics & Communication Engineering, Heritage Institute of Technology, Kolkata-107)
*** (Department of Electronics & Communication Engineering, Heritage Institute of Technology, Kolkata-107)

ABSTRACT

To provide uninterrupted service to all subscribers, we need to incorporate a low cost, flexible Heterogeneous network which can able to couple any kind of network for efficient spectrum utilization, hence improve system capacity. Therefore we have designed an integrated Wi-Fi, WiMAX network which provides high throughput, low end to end delay, flat and low jitter.

Introduction

Wireless communication network will be 4G in near future. The 4G network will provide uninterrupted services for voice as well as data communication. So there is a huge scope of advancements in wireless networks' service quality. Technology growth lead users from high speed internet access from cable, Digital Subscriber Line (DSL), and other fixed broad-band connections to use wireless hotspots, Wi-Fi services. There is a huge development in Wi-Fi services in terms of quality of service and devices availability in market. At the same time the last mile winner WiMAX able to cover large areas in metropolitan, suburban, rural or terrine with high speed mobile broadband Internet access called wide area networks (WANs). As number of users and application are proportional to the requirement of radio spectrum. So spectrum management is an important factor in network designing. As population increased, the need for high rise buildings will also increase in residential or office areas. Therefore the designed network must provide seamless connectivity everywhere. Above 9th floor the subscriber cannot get network coverage properly, this may create a major challenge for wireless communication. To provide seamless connectivity for each level of subscriber we have to design an integrated Wi-Fi/ WiMAX network which can couple any kind of network for efficient utilization of spectrum, hence improve system capacity. It is important that the apparent similarity between Wi-Fi and WiMAX, But complementary natures between them are key designing aspects of this integrated network. While Wi-Fi has a short coverage range of about 100 meters, WiMAX offers a significantly greater coverage in a range of 500 meters and beyond; while Wi-Fi offers high raw data (up to 500 Mb/s is envisaged) capacity due to the use of unlicensed frequency bands with poor traffic control capabilities, WiMAX is capable of highly sophisticated traffic management and QoS control [1] with low data rates, due to the use of licensed frequency bands.

In this paper, we have designed an integrated network, which can able to couple any kind of networks using QUALNET 5.0.1 simulator, and also analyze the performance of this kind of integrated network.

II. Theoretical overview of Wi-Fi and WiMAX Technologies

a. Wi-Fi Technology

In 1997, the Institute of Electrical and Electronics Engineers (IEEE) created the first WLAN standard. They called it *802.11* after the name of the group formed to oversee its development. Unfortunately, 802.11 only supported a maximum network bandwidth of 2 Mbps - too slow for most applications. For this reason, ordinary 802.11 wireless products are no longer manufactured. While 802.11b was in development, IEEE created a second extension to the original 802.11 standard called 802.11a. Because 802.11b gained in popularity much faster than did 802.11a, some folks believe that 802.11a was created after 802.11b. In fact, 802.11a was created at the same time. Due to its higher cost, 802.11a is usually found on business networks whereas 802.11b better serves the home market. 802.11a supports bandwidth up to 54 Mbps and signals in a regulated frequency spectrum around 5 GHz. This higher frequency compared to 802.11b shortens the range of 802.11a networks. The higher frequency also means 802.11a signals have more difficulty penetrating walls and other obstructions. Because 802.11a and 802.11b utilize different frequencies, the two technologies are incompatible with each other.

IEEE 802.11g attempts to combine the best of both IEEE 802.11a and IEEE 802.11b. IEEE 802.11g supports bandwidth up to 54 Mbps, and it uses the 2.4 Ghz frequency for greater range. IEEE 802.11g is backwards compatible with IEEE

802.11b, meaning that IEEE 802.11g access points will work with IEEE 802.11b wireless network adapters and vice versa. IEEE 802.11n was designed to improve on IEEE 802.11g in the amount of bandwidth supported by utilizing multiple wireless signals and antennas (called MIMO technology) instead of one. 802.11n connections should support data rates of over 100 Mbps. IEEE 802.11n also offers somewhat better range over earlier Wi-Fi standards due to its increased signal intensity. IEEE 802.11n operates on both the 2.4 GHz and the lesser used 5 GHz bands. It operates at a maximum net data rate from 54 Mbits/s to 600 Mbits/s.

WiMAX Technology

IEEE 802.16 is the standard defining WiMAX i,e World Wide Interoperability for Microwave Access. As a standard based technology, it enables inter- vendor interoperability which brings lower cost, greater flexibility and faster innovation to operator. Interoperability can be established at different levels. The WiMAX forum certification program verifies the interoperability at PHY and MAC layers, which are responsible for essential over the air transmission, the management of connection, security and mobility management including handoff, power control and QoS. WiMAX supports two operational modes: Mesh and Point-to-point (PMP), this transmission can be done through two independent channels: the Downlink Channel (from BS to SS) which is used only by the BS, and the Uplink Channel (from SS to BS) which is shared between all SSs, in Mesh mode, SS can communicate by either the BS or other SSs, in this mechanism the traffic can be routed not only by the BS but also by other SSs in the network, this means that the uplink downlink channels are defined as traffic in both directions; to and from the BS. In the PMP mode SSs can only communicate through the BS, which makes the provider capable to monitor the network environment to guarantee the Quality of Service QoS to the customer. It offers very high data rates up to 70Mbps over large distances. Theoretically, a WiMAX base station can provide broadband wireless access in range up to 30 miles (50 kms) for fixed stations and 3 to 10 miles (5 to 15 kms) for mobile stations. Unlike wireless LANs, WiMAX networks incorporate several qualities of service (QoS) mechanisms at Media Access Control (MAC) level for guaranteed service of voice, data and video. There are some Design factors a designer must consider in order to provide guaranteed QoS. The initial implementation of WiMAX, IEEE802.16 was intended for the 10-66 GHz licensed band. Later modifications of the standards, IEEE802.16a and d made it possible to deploy WiMAX in the licensed and unlicensed frequency bands in the range of 2-11 GHz. To enable mobility the IEEE 802.16 working group came up with the IEEE802.16e standards to support mobility. With the introduction of mobility such as roaming, and power consumption had to be dealt with [4]. IEEE802.16e operates in the NLOS mode , operating 2-11 GHz. The Mobile WiMAX has been designed to provide Broadband Internet service to mobile users. It uses OFDM (Orthogonal Frequency Division Multiplexing) to enable non-line-of sight communication.

As an IP- based solution mobile WiMAX technology can provide converged video, voice and data services for the mobile user[2,3].

III. System Model

Here we have designed a complete wireless network. The main advantage of wireless network is to provide low cost architecture for mobile application. The Wi-Fi-WiMAX interworking module is shown in Fig.2. The purpose of this module is to convert the WiMAX signal received from the WiMAX network (*i.e.*, BS) to the Wi-Fi device (here we call it Laptop). As we have said earlier, each subscriber in a high rise building cannot get proper network coverage for communication; this problem can be overcome by using this kind of integrated devices.

This will placed on the top of the high rise buildings that can couple different kinds of network as well as provide seamless connectivity for each and every user present in that particular building. This interworking module (specially designed for small moving device) can be built into laptop/mobile to provide uninterrupted connectivity. The major application of this coupling network in a dual mode hand set service, where the subscriber can seamlessly handover connections among different kind of network topologies.

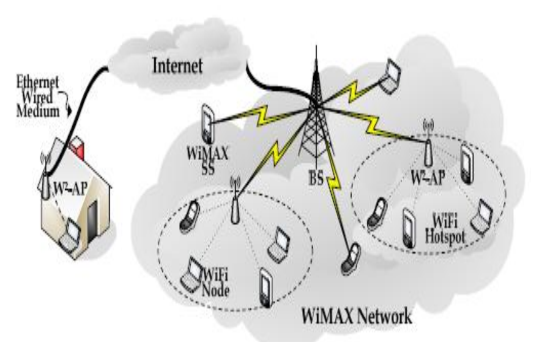

Fig1: Integrated WiMAX / Wi-Fi Network architecture

Briefly, the scheme works like this. There will be one WiMAX Base Transceiver Station (BTS), say, for a cluster of ten buildings and ten Wi-Fi/ WiMAX interworking module will cover the ten buildings. There are one or more Wi-Fi access point (RF unit) present in each floor (above 9th floor) at optimal position to provide uninterrupted data, voice and video services.

The MAC layer module plays a vital role in this integrated operation of the WiMAX/Wi-Fi network. As we know that Wi-Fi provides greater data speed compared to Wi-MAX.
Fig.2 and Fig.3, Fig 4 shows the block diagram of heterogeneous network.

Operation of Heterogeneous network

***1.* Receiving data stream and logical operation:**

In Fig.2, at first the heterogeneous network received a data stream wirelessly by the antenna. As the packet format is known, it segregate out logical bits, then these bits are put into comparator to identify the sender whether it is coming from a Wi-Fi or WiMAX network.

2. Conversion Process:

If the data packets are coming from a Wi-Fi network (from any hand held devices in a building), then the heterogeneous network identifies the sender information, receiver information, coupling information from the coming data stream and store it to Input Buffer. Then the scheduler schedules these packets according to the scheduling algorithm being used to maximize network utilization and achieve fairness among all users. Then the Output Buffer incorporates these information into WiMAX frame format. Then it is modulated properly and transmits from the end terminal.[4,5]

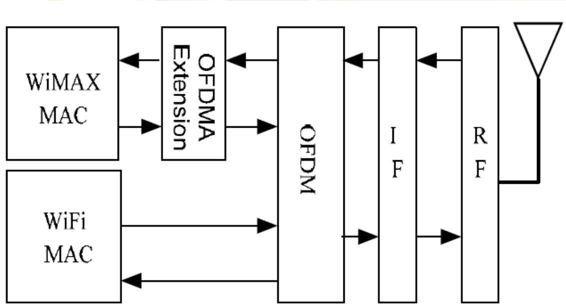

Fig2: Integration of Wi-Fi - WiMAX Network

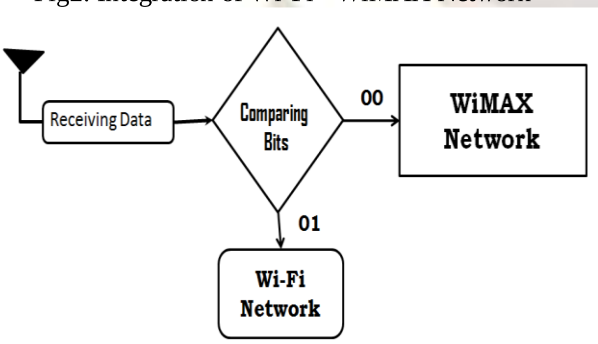

Fig.3: Receiver Section of Integration Network

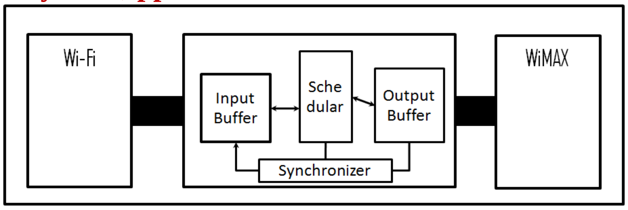

Fig.4: Wi-Fi/ WiMAX interworking Module

IV. Mathematical Analysis

Consider A is a Wi-Fi access point (AP), B is WiMAX base station C is also a WiMAX base station. Also consider that the AP, A can poll at most *M* wireless voice stations. The aim of the analysis is to evaluate the average reconnection failure ratio, average packet loss ratio, and average throughput when the aforementioned reconnection schemes are used. Suppose that there are *N* registered stations.

Let (l,c) denote the system state, where l is the number of active stations in the polling queue (i.e., connected stations) and c is the number of active stations attempting to send the reconnection message (i.e., connecting stations). The number of idle stations i then equals $N-l-c$. The set of system states is given by $S=\{(x,y)$: $0\le x\le N$ and $0\le y\le N-x\}$. We consider the bi-state on-off model for the traffic model of a voice station and assume that changes in state occur only at the beginning of the reconnection phase in each cycle. Specifically, an active station becomes idle with a probability α while an idle station becomes active with a probability β. To find the state transition probabilities, we use a two-step approach as shown in Fig. 1. We use $TA(l_B,C_B|l_A,C_A)$ to denote the transition probabilities that the state (l_A,C_A) at point A will change to (l_B,C_B) at point B. Similarly, the state transition probabilities for state changes from point B to point C are denoted as $TB(l_C,C_C|l_B,C_B)$. We derive $T_A(l_B,C_B|l_A,C_A)$ and $TB(l_C,C_C|l_B,C_B)$ for each of the schemes separately.
Suppose that the system state is (l_A,C_A) at point A. The number of idle stations i_A is therefore equal to $N-l_A-C_A$. With a probability

$$P(i_A,x,\beta)=\binom{i_A}{x}\beta^{x}(1-\beta)^{(i_A-x)}$$

stations are going to be active. On the other hand, y of l_A connected stations and z of C_A connecting stations are going to be idle with probabilities $B(lA,y,\alpha)$ and $B(C_A,z,\alpha)$, respectively. Hence, at point B, lB becomes l_A-y and C_B becomes C_A+x-z. In other words,
$y= l_A- l_B$ and $z= C_A+x-C_B$. $TA(lB,cB|\ l_A,\ C_A)$ can then be found as follows:

$$\sum_{x=\max(0,C_B-C_A)}^{\min(C_B,i_A)} P(i_A,x,\beta)P(l_A,l_A-l_B,\alpha)P(C_A,C_A+x-C_B,\beta)$$

….. (1)

In the polling phase of the *t*th cycle, up to l_A stations in the polling queue are polled. There are $r=N-lA$ remaining stations to be probed in the following reconnection phase, out of which C_B stations are connecting to the AP. To facilitate the analysis, we assume that there are *s* reconnection slots. We also assume that reconnection messages and null frames have the same length. *Tx* is the transmission time of the corresponding packet/frame *x* and *s* depends on the cycle length, l_A, and *M*. If $s \geq r$, all C_B stations will be replaced to the polling queue and may be polled in the polling, phase of the $(t+1)$th cycle. If there are fewer slots than *r*, some of the stations may not be probed by the AP. The probability that *n* of C_B connecting stations are probed can be calculated by the probability mass function the distribution is

$$P\{n\} = \binom{C_B}{n}\binom{r-C_B}{s-n} \Big/ \binom{r}{s} \quad ..(2)$$

Thus, as a function with arguments *r* and *s*, T_B $(l_C, C_C | l_B, C_B)$ is given by if $s > r$ or $s < r \wedge \max(0, s-r+C_B) \leq (l_C - l_B)$ Otherwise is given by

$$T_B(l_C, C_C | l_B, C_B) = \begin{cases} 1 \\ \binom{C_B}{l_C - l_b}\binom{r-C_B}{S-(l_C-l_B)} \Big/ \binom{r}{s} \\ 0 \end{cases}$$

… 3

By integrating (1) and (3), we have the transition probabilities from point *A* to point *C*, [6]

$$T(l_C, C_C | l_A, C_A) = \sum T_A(l_C, C_C | l_A, C_A) \times T_B(l_C, C_C | l_B, C_B)\{N - l_A\}$$

V. Simulation Results

Here we have simulated a Wi-Fi/ WiMAX integrated network using qualnet 5.0.1 simulator.

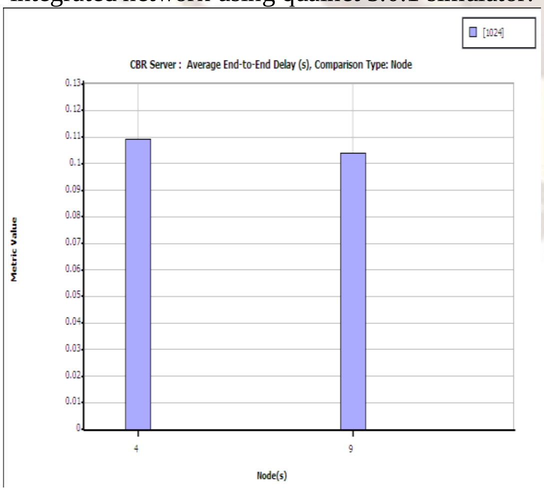

Fig.3 Average end to end delay for Wi-Fi/WiMAX integrated network

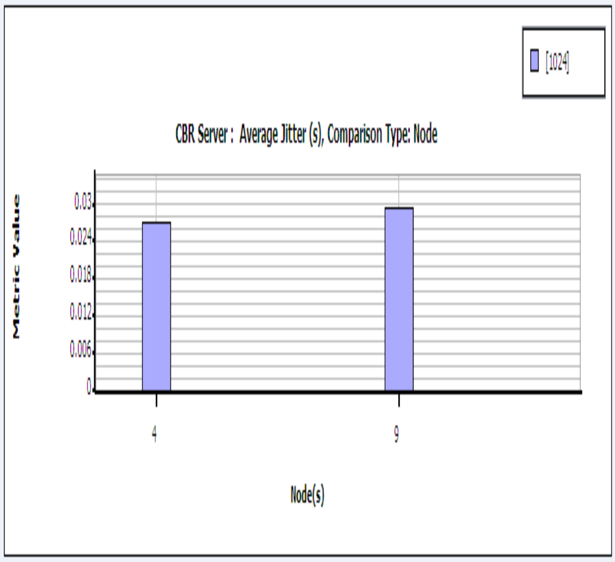

Fig.4 Average jitter for Wi-Fi/WiMAX integrated network

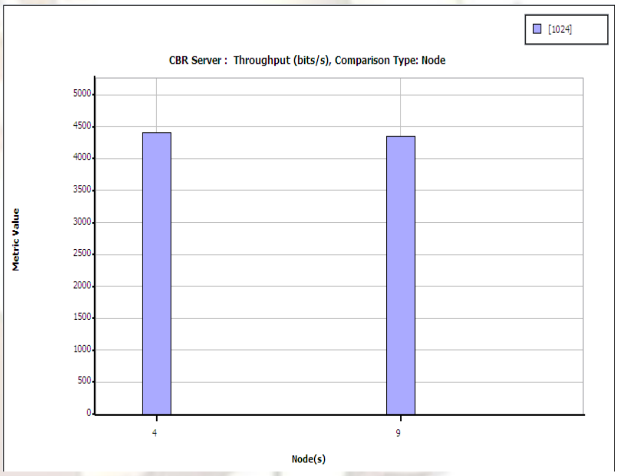

Fig.5 Throughput for Wi-Fi/WiMAX integrated network

VI. Conclusion and Future Work

As the designed model simultaneously using Wi-Fi & WiMAX systems, the operation of the network becomes faster. Wi-Fi network handles subscribers directly & WiMAX network provide back bone support to utilize radio spectrum utilized efficiently. This model have been verified in QUALNET 5.0.1 simulator & observed that results we can conclude that Wi-Fi/ WiMAX integrated network gives better performance in terms of low value of jitter, e 2 e delay and high value of throughput .

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[6] "What WiMAX Forum Certified products will bring to Wi-Fi," Business White Paper, WiMAX Forum, 2004.