Design of IEEE 802.16m and IEEE 802.11n Integrated Heterogeneous Network and Performance Analysis of the Network

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ABSTRACT

Advent of portable low cost smart & user friendly devices make the era of 21st century, the era of mobile communication & computing. So providing indoor, outdoor mobile facility has become a primary feature or condition [1]. At the same time for optimum performance of a network & improving the capacity of it the integrated heterogeneous network is also needed. If the integrated network provide flat Jitter, less delay & high throughput then it is reliable. In this paper we present a mathematical analysis of integrated IEEE 802.16m & IEEE 802.11n heterogeneous network & analysis the performance of it through QualNet Simulator. Mathematical model is also verified in MATLAB for conversion factor.

Keywords

Mobile communication, Mobile Computing, heterogeneous network, Integrated Network, Jitter, Throughput, End to End Delay, QualNet 5.0.2 Simulator.

1. INTRODUCTION

Recent surveys enlighten the fact that there will be an exponential growth for mobile data demand due to massive development in mobile devices like smart phones, laptop, tabs etc. It is also forecasted that demand of mobile data will be doubled from 2013 where the growth rate is 66 times in between 2008 to 2013. The Compound Annual Growth Rate (CAGR) of mobile data traffic is approximate 13%. It is expected that the data traffic will reach 2exabyte within this year [2]. Other cause for this huge load is all wireless service providers are collaboratively providing internet connectivity to the subscriber. WiMAX (IEEE 802.16m) & Wi-Fi (IEEE 802.11n) are the two most preferable technologies that have been implemented by service providers. Wi-Fi technology is mostly used in public places around the world. The Wi-Fi operators aggregate the wireless networks provided by micro carriers and provide a single access to the end users [3]. The coverage area of a Wi-Fi access point is low (in a room or in lobby) more over as it is working within public band so it broadcast weak signals to avoid interferences. Another emerging & last mile winning technology WiMAX offer data speeds higher than 3G wireless networks and cover much longer distances than Wi-Fi technology [4].

As per release from Sprint, 4G service provider using WiMAX, the download speeds are between 2 Mbps (Mega bits per second) and 4M bps. So it can be alternative for many DSL (Digital Subscriber Line) and cable modem services. Besides WiMAX coverage will be available to over 90 million potential customers by 2014. As time passes by, the rates and terms for WiMAX services are fairly attractive and could put pressure on competitors [5, 6, 7, 8].

Since each Wi-Fi hotspot needs a wired backhaul to offer Internet connectivity, so that increase the installation cost of Wi-Fi network which can be saved if Internet connectivity is offered by a wireless backhaul, such as a WiMAX base station. Such network will provide real time applications in moderate cost to the subscribers. The Convergence-Bridge is a smart modification in the Wi-Fi OFDM Physical layer to enable Wi-Fi devices to join the WiMAX-OFDM wireless network. In this paper the WiMAX (OFDM-256) and the WiFi-OFDM-64 have been selected to achieve the multi-carrier convergence. The convergence idea is initiated from the similarities between the WiMAX and the Wi-Fi, however the dissimilarities are still real obstacles to enable them to communicate with each other [9]. In this paper, we propose bridging solutions for mobile WiMAX & Wi-Fi network with traffic priority and implementation issues.

2. NETWORK DEPLOYMENT:

WLANs based on the IEEE 802.11 standard [10] emerged as the most widely deployed technology for the broadband wireless access; the key features of IEEE 802.11 WLANs are simplicity, scalability, and robustness against failure [11]. One of the main drawbacks of the IEEE 802.11 standard is the inability to provide priority support for those applications requiring QoS: The IEEE 802.11 MAC layer does not offer a specific treatment for each application running within the WLAN. To this extent, recently has been finalized the IEEE 802.11e-2005 standard [12], in order to enhance the original IEEE 802.11 MAC layer to support QoS, by improving the capabilities and efficiency of the basic 802.11 MAC protocol by defining a mechanism for QoS support to the different types of traffic, in order to satisfy their specific service level requirements. In figure 1 Wi-Fi Networks are shown.

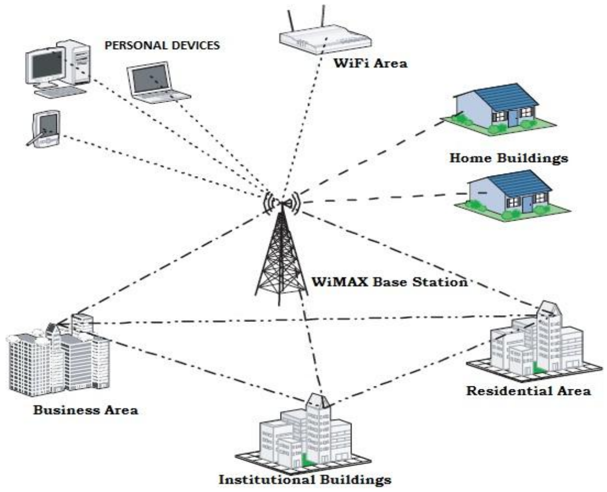

Fig 1: Schematic Diagram of an Integrated WiMAX & Wi-Fi Network

As shown in above fig 1, WiMAX service providers providing connectivity to Wi-Fi networks situated in office business area, residential area. The devices which are not in apartment can directly connect with WiMAX network [13].

The Wi-Fi network uses 802.11a physical layer. The auto rate fallback is turned off. The data rate is always 54Mbps. The number of APs is 16. We vary the number of original Wi-Fi users. The service area is a 1500x1500 m^2 square. APs are regularly placed in the service area. That is, they form a 4x4 grid. Since 802.11a has 12 orthogonal channels, we carefully assign the channels among neighboring APs such that any AP will have different channel from its neighbors. By doing this, we eliminate possible inter-cell interference among neighboring cells. In order to eliminate the interference from hidden-node collision, we use the following strategy. Each user randomly selects one AP to associate with. But once the association is determined, it will be placed very close to that AP. This ensures a random distribution of users, while at the same time guarantees that users belong to the same cell can hear each other.

WiMAX BS is placed at the center of the service area (i.e., (750, 750)). The adaptive modulation is on by default. But the transmission power is large enough so that each WiMAX user can obtain roughly the same QoS over a long period of time. The traffic source is CBR. Payload size is 1000 bytes. The rate is 16Mbps in the application layer. All traffic is uplink. That is, from users to APs or BS. Roughly speaking, 2 users can saturate a Wi-Fi network, and 6 users can saturate the WiMAX

3. ANALYSIS OF THE SYSTEM:

Single-hop Wi-Fi, the minimum throughput of the whole Wi-Fi network is defined as the minimum throughput among all APs in the service area. The throughput of any AP is defined as the throughput of each node in this AP. Under ideal channel assumption, the performance metric r is $r = \min\left(C_{WiFi} / x_i\right)$

(1)

Where C_{WiFi} is the total number of users of AP.

x_i is the capacity of a Wi-Fi AP.

Throughput of the WiMAX network is defined as the throughput of each user in the WiMAX network. Integrated Network: the minimum throughput of the integrated network is defined as the minimum throughput between Wi-Fi and WiMAX, whichever is smaller. Assume that the most congested AP is AP m. Xm $\in$ X, depending on the user distribution. Let us assume the simplest case, a linear relationship

where $0 \le \alpha \le 1$. Next step, we create a WiMAX only network in the same service area with another set of users with the number equals to

$$Y = \frac{C_{WiMAX}}{r} = \frac{C_{WiMAX}\alpha X}{C_{WiFi}} \quad (2)$$

Without loss of generality, we assume the distribution of the WiMAX users follows the same pattern of Wi-Fi users. That is, if all these WiMAX users decide to switch to the Wi-Fi network, AP m is still the most congested one among all APs. Its corresponding users from WiMAX only network is

$$y_m = \alpha Y = \frac{C_{WiMAX}\alpha^2 X}{C_{WiFi}} \quad (3)$$

We use y_i to denote the number of users associated with AP i if the WiMAX users are to switch to the Wi-Fi network. Here comes the integrated network. We imagine originally all users, from both Wi-Fi and WiMAX, associate with Wi-Fi network only. The most congested AP is still AP m. Its minimum throughput is

$$\frac{C_{WiFi}}{x_m + y_m} \quad (4)$$

After the WiMAX base station is added, the optimal strategy is to let WiMAX take away some users from AP m until both WiMAX and AP m have exactly the same minimum throughput, which is the minimum throughput r' of the integrated network.

$$r' = \frac{C_{WiFi} + C_{WiMAX}}{x_m + y_m} \quad (5)$$

The above idea ignores the possibilities that APs other than m may have number of users close to that of AP m. In this case, WiMAX may also want to help them, which leads to a lesser r′.

$$r' \le \frac{C_{WiFi} + C_{WiMAX}}{x_m + y_m} \quad (6)$$

The average throughput of Wi-Fi to WiMAX system is quite comparable.

There is a conversion between Wi-Fi to WiMAX signaling. Let the conversion factor (T).

$$T = \frac{r' - r}{r} \quad (7)$$

$$T = \frac{C_{WiMAX} - \alpha C_{WiFi}}{C_{WiFi} + \alpha C_{WiMAX}} \quad (8)$$

Assume each user is randomly and uniformly distributed in the service area, then xi follows a Binomial distribution.

$$P_r(xi = k) = \binom{N1}{K}\left(1 - \frac{1}{M}\right)^{N_1 - K}\left(\frac{1}{M}\right)^k \quad (9)$$

Let Y = max X_i thus r can be easily calculated from Y .

$$r = \frac{C_{WiFi}}{Y} \quad (10)$$

Based on r, we derive the number of WiMAX users for WiMAX only network as

$$N_2 = \frac{C_{WiMAX}}{r} \quad (11)$$

For the integrated network, we have N = N1 + N2 users. We imagine at the beginning, there are only Wi-Fi APs. We use x′ i to denote the number of users associated with AP i in the integrated network at the beginning. When WiMAX is added, we use T to denote how much WiMAX can help Wi-Fi. The strategy is, we inspect the Wi-Fi AP one by one.

$$\frac{C_{WiFi}}{T} = \frac{C_{WiMAX}}{\sum_{i=1}^{M}(\max\{0, x_i' - T\})} \quad (12)$$

Users choose the closest AP to associate with. For a given AP, all its associated users have the same data rate which equals to Cwifi regardless of their relative distance to the AP. Similarly, all WiMAX users have the same data rate of Cwimax. For the integrated network, we use the following formulation to obtain the optimal load balancing decision.

$$\frac{C_{WiFi}}{T_i - X_i} \geq r \quad (13)$$

For WiMAX Base Station,

$$\frac{C_{WiMAX}}{\sum_{i=1}^{K} X_i} \geq r \quad (14)$$

4. SIMULATION RESULT IN QUALNET 5.0.2 SIMULATOR:

4.1. Analysis of Throughput:

In communication network, throughput or network through-put is the average rate of successful message delivery over a communication channel. Data may be delivered over a physical or logical link, measured in bits per second. The system throughput or average throughput is the sum of the data rates that are delivered to all the terminals in a network [16].

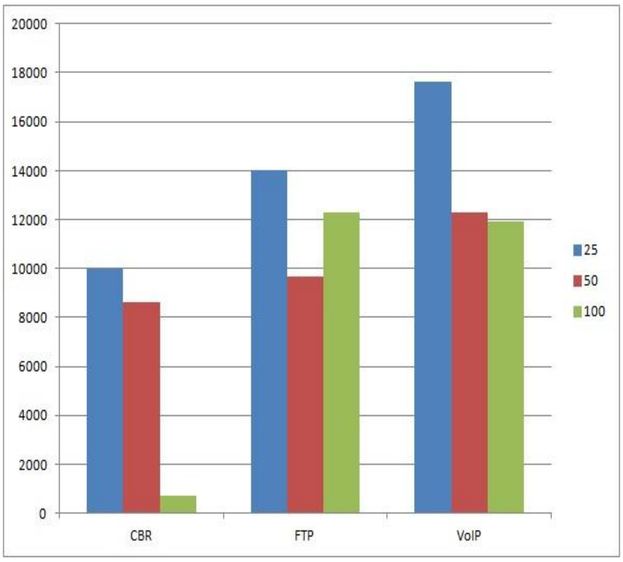

Fig 2: Throughput for various application & Variable Load

4.2. Analysis of End to End Delay:

Due to queuing and different routing paths, a data packet may take a longer time to reach its destination .The end-to-end delay experienced by the packets for each flow the individual packet delay are summed and the average is computed. [16]

dend-end = N[dtrans+dprop+dproc] [16]

Where $d_{end-end}$ is end-to-end delay, d_{trans} is transmission delay, d_{prop} is propagation delay, dproc is processing delay and N is number of links.

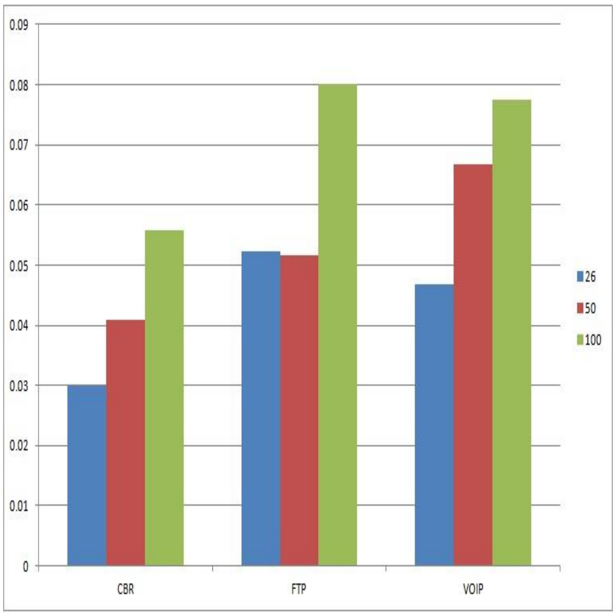

Fig 3: End to End Delay for various applications & Variable Load

4.3. Analysis of Jitter:

As the packets transmit from source to destination will reach the destination with different delays. A packet's delay varies with its position in the queues of the routers along the path between source and destination and this position can vary unpredictably. His variation in delay is known as Jitter. The jitter increases at switches along the path of a connection due to many factors, such as conflicts with other packets wishing to use the same links, and nondeterministic propagation delay in the data-link layer. Jitter can seriously affect the quality of streaming audio and/or video. A network could possibly average zero Jitter. Jitter for respective precedence bits are calculated and compared. [17]

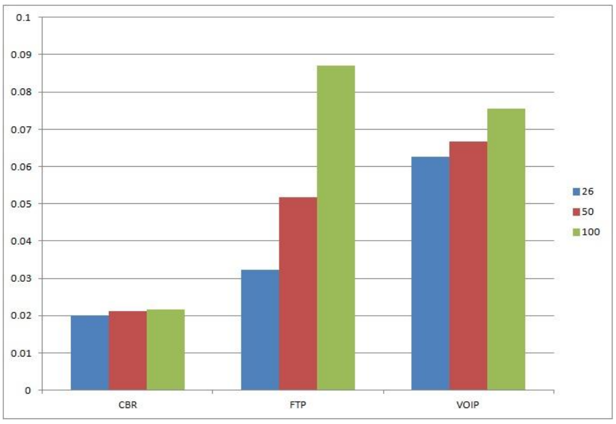

Fig 4: Jitter for various application & Variable Load

5. RESULT OF COUPLING FACTOR FOR VARIOUS NUMBER OF LOADS:

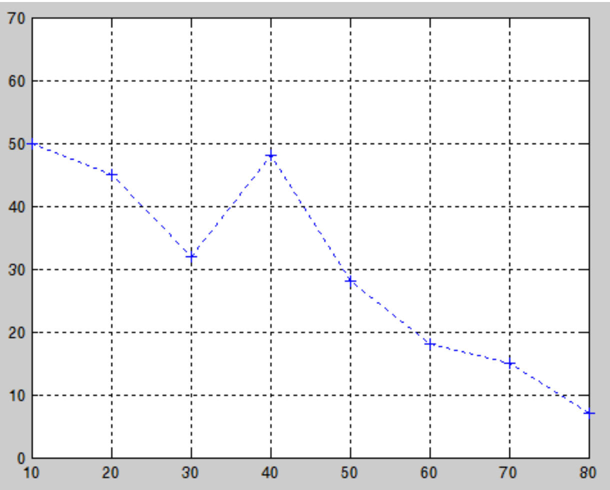

Fig 5: 'T' for Variable Load

6. CONCLUSION:

In this paper we designed a IEEE 802.16m & IEEE 802.11n Integrated heterogeneous network & analysis performance the same. By observing the system performance we can observe that Jitter remain flat though load is increased for CBR & VoIP application. There is a scope to introduce fuzzy logic to improve the performance of 'T' factor for this integration network.

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