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Statistical Performance Analysis Routing Algorithms for Wimax - Wi-Fi Integrated Heterogeneous Network

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Abstact: *To provide uninterrupted service to every subscribe in a wireless network, there is a 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. For data communication Wi-Fi/ Wi-MAX integrated network seems to be an ideal solution as it is able to provide easy deployment, high speed data rate and wide range coverage with high throughput, low end to end delay, flat and low jitter. As Wi-Fi (IEEE 802.11n) & WiMAX (IEEE 802.16m) network support mobility so from real time service providing to surveillance activities for mobile users can be supported by this integrated network. The selection of appropriate routing protocol for high speed uninterrupted applications is an important parameter while designing of scalable, flexible and efficient integrated network. The routing protocol should take into account the mobility factor in the network and the topology being used. So, in this paper we have first designed an integrated Wi-Fi/WiMAX network and then statistically analyze the performance of the network for various routing algorithms. This analysis will help to forecast the best suitable algorithm.*

Keywords: *Integrated network, Network performance, Routing algorithm, Wi-Fi (IEEE 802.11n), Wi-MAX (IEEE 802.16e)*

I. 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. Chronologically the high speed internet access from cable, Digital Subscriber Line (DSL), and other fixed broad-band connections are going to replace by wireless hotspots, Wi-Fi & WiMAX services. Due to advent of portable, low cost & user friendly devices users are attracted towards wireless services. As time & users demands for uninterrupted services so the last mile winner WiMAX can be able to cover large areas in metropolitan, suburban, rural or terrine with high speed mobile broadband internet access called wide area networks (WANs). Where Wi-Fi can provide high data rate in short range communication. Providing proper network services to every user, from time of registration to time to leave is the function of a network. As both networks support mobility so integration of both networks can be a best solution to maintain proper QoS. 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. These integrated networks have become more efficient with the introduction of mobility concept of nodes. One of the challenging aspects in these integrated networks is to find and develop routing protocols that can efficiently find routes between any two nodes (may be static or mobile). The routing protocol should take into account the mobility factor in these networks and the topology being used. For this reason, performance evaluation of various protocols has been carried out by different researchers. Routing is a function in the Network layer which determines the path from source to destination for the traffic flow. Router in the network needs to be able to look at a packet's destination address and then determines which of the output port is the best choice to get the packet to that address. In this paper, first we have designed Wi-Fi/ WiMAX integrated network and proposed a survey on routing algorithms used in this integrated networks for both uplink and downlink traffic using QualNet 5.0.2 simulator. Also this paper will enlighten best suitable routing algorithm for an integrated heterogeneous network to maintain proper QoS all applications.

II. Theoritical Overview of Wi-Fi (IEEE 802.11n) and Wimax (IEEE 802.16e) Technologies

2.1. Wi-Fi (IEEE 802.11n) 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. The new generation of IEEE 802.11n-based Wi-Fi technology is expected to pick up significant market momentum in 2008. The currently available draft 802.11n technology can comfortably cover a typical house with sufficient bandwidth to support video, gaming, data and voice applications. In the enterprise environment, 802.11n is expected to support mission-critical applications with the throughput, QoS and security capabilities comparable to Ethernet. The developing IEEE 802.11n standard is based on MIMO (multiple-input multiple-output) air interface technology. MIMO is a significant innovation and a technology that is being adapted for use by several non-802.11 wireless data communications standards, including 4G cellular. 802.11n is an amendment which improves upon the previous 802.11 standards by adding multiple-input multiple-output antennas (MIMO). 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. The IEEE has approved the amendment and it was published in October 2009

Table 1: Features of Advance Wi-Fi Protocols

	IEEE 802.11n	IEEE802.11ac
Frequency Band	2.4GHz & 5GHz	5GHz only
Channel Widths	20,40MHz	20, 40, 80MHz & optional 160MHz
Spatial Streams	1 to 4	1 to 8 total up to 4 per client
Multi User MIMO	No	Yes
Signal Stream [1x1] Multi Client Data Rate	150Mbps	450Mbps
Three Stream [3x3] Multi Client Data Rate	450Mbps	1.3Gbps

2.2. WiMAX (IEEE 802.16e) Technology:

The IEEE 802.16 Standard, first published in 2001, defines a means for wireless broadband access as a replacement for current cable and DSL "last mile" services to home and business. The adoption of this standard is currently in progress through the use of WiMAX Forum certified networking equipment and wide & spread adoption should appear over the next few years. This paper provides an overview of the 802.16 standard in regards to frequency bands, the physical layer specification, security sub-layer, MAC common part sub-layer, and service specific convergence sub-layer. The IEEE 802.16e air interface standard extends its fixed wireless access predecessor, IEEE 802.16–2004, to support mobile broadband wireless access systems [2, 3]. In addition to enhancing several advanced orthogonal frequency division multiple access (OFDMA) technology features, IEEE 802.16e incorporates the functionality needed to support user mobility. In particular, technologies such as hybrid automatic repeat request (HARQ), space time coding (STC), advanced antenna systems (AAS), multiple input multiple output (MIMO), and space division multiple access (SDMA) have been enhanced to support mobile environments and to improve the broadband access speed. some of these enhancements are similar in concept to those incorporated in third generation cellular standards such as CDMA2000 high rate packet data (HRPD) or the high speed downlink packet access (HSDPA) feature within the Universal Mobile Telecommunications System (UMTS) standard [4], they have been specifically tailored to an OFDMA air interface. Additional sub-channelization options have been added in IEEE 802.16e to improve recourse management flexibility and achieve better system performance under a wide range of operating conditions. IEEE 802.16e also adds new medium access control (MAC) procedures related to handover support. Multiple carrier bandwidths and associated fast Fourier transform (FFT) sizes are included to allow bandwidth scalability. Furthermore, time division duplexing (TDD) and frequency division duplexing (FDD) support are available in each of these cases to allow operation in unpaired or paired spectrum allocations respectively.

III. Routing Algoritms

Routing algorithms are required to build the routing tables and hence forwarding tables. The basic problem of routing is to find the lowest-cost path between any two nodes, where the cost of a path equals the sum of the costs of all the edges that make up the path. Routing is achieved in most practical networks by running routing protocols among the nodes. The protocols provide a distributed, dynamic way to solve the problem of finding the lowest-cost path in the presence of link and node failures and changing edge costs.

3.1. Bellman- Ford Routing Algorithm:

Bellman- Ford routing algorithm is the shortest path routing algorithm. In a network how a packet reached to destination using available shortest path is described by this algorithm. It is popular algorithm in networking. The algorithm is usually named after two of its developers, Richard Bellman and Lester Ford, Jr., who published it in 1958 and 1962.

3.2. AODV (Ad-hoc On Demand Distance Vector Routing Protocol):

This protocol is based on source-initiated on-demand routing. This type of routing creates routes only when desired by the source node. Route discovery process starts on demand by the source. This process is completed once a route is found or all possible routes have been explored. It provides unicast, broadcast, and multicast communication in ad hoc mobile networks [5]. Routes are maintained as long as they are needed by the source node. AODV nodes maintain a route table in which next hop routing information for destination nodes is stored. When a source node desires to send a data to a destination node and no route information is available, a path exploration process to find the destination node takes place. It broadcasts a route request (RREQ) packet to adjacent nodes, which in turn, forward the request to their adjacent nodes, and so on, until the destination node is found. Each node maintains a sequence number and a broadcast ID. The broadcast ID is incremented for each generated RREQ. The RREQ packet consists of the node sequence number, broadcast ID and the most recent sequence number it has for the destination node. Only those nodes reply to the RREQ which have their sequence numbers greater than or equal to that contained in the RREQ.

3.3. DYMO (DYnamic MANET On demand Routing Protocol)

It is one such protocol that is intended for the use by mobile nodes in wireless multihop networks. It can adapt to the changing network topology and determine unicast routes between nodes within the network. In On-demand protocols [6], nodes compute the routes and maintain routing information only when it is needed, thereby establishing routes as and when required by the source. This algorithm has two basic operations- route discovery and route management [7]. In route discovery operation, initiating node sends a route request to all the nodes in the network to find the target node then the target node sends the reply, in this way proper route is discovered. In order to respond to the changes in network topology, nodes maintain their routes and monitor the links over which the network traffic flows. DYMO can be typically utilized in a large mobile network consisting of large number of nodes where only a part of the nodes communicate with each other.

3.4. OLSRv2 NIIGATA (Optimized Link State Routing, version 2 Routing Protocol)

OLSRv2[8] retains the same basic algorithms as its predecessor (OLSR), however offers various improvements, e.g. a modular and flexible architecture allowing extensions, such as for security, to be developed as add-ons to the basic protocol. OLSRv2 contains three basic processes: Neighborhood Discovery, MPR Flooding and Link State Advertisements. In Neighborhood Discovery process, each router discovers the routers which are in direct communication range of itself (1-hop neighbors), and detects with which of these it can establish bi-directional communication. In MPR Flooding process each router is able to, efficiently, conduct network-wide broadcasts. Each router designates, from among its bi-directional neighbors, a subset (MPR set) such that a message transmitted by the router and relayed by the MPR set is received by all its 2-hop neighbors. In Link State Advertisement process routers are determining which link state information to advertise through the network. Each router must advertise links between itself and its MPR-selector-set, in order to allow all routers to calculate shortest paths.

3.5. RIP (Routing Information Protocol)

The Routing Information Protocol (RIP) is a distance-vector protocol that uses hop count as it's metric. RIP is widely used for routing traffic in the global Internet and is an *interior gateway protocol* (IGP), which means that it performs routing within a single autonomous system. RIP routers maintain only the best route (the route with the lowest metric value) to a destination. Routers running RIP send their advertisements regularly (e.g., every 30 seconds). A router also sends an update message whenever a triggered update from another router causes it to change its routing table.

3.6. OSPFv2

OSPFv2 is an IETF link-state protocol for IPv4 networks. An OSPFv2 router sends a special message, called a hello packet, out each OSPF-enabled interface to discover other OSPFv2 neighbor routers. Once a neighbor is discovered, the two routers compare information in the Hello packet to determine if the routers have compatible configurations. The neighbor routers try to establish adjacency, which means that the routers synchronize their link-state databases to ensure that they have identical OSPFv2 routing information. Adjacent routers share link-state advertisements (LSAs) that include information about the operational state of each link, the cost of the link, and any other neighbor information. The routers then flood these received LSAs out every OSPF-enabled interface so that all OSPFv2 routers eventually have identical link-state databases. When all OSPFv2 routers have identical link-state databases, the network is converged. Each router then uses Dijkstra's Shortest Path First (SPF) algorithm to build its route table.

IV. Statistical Analysis

Wi-Fi & WiMAX systems are using OFDM system of a block of N complex symbols are formed with each symbol modulation one of N subcarrier with frequency for the N chosen as orthogonal set. The complex envelope of the transmitted OFDM signal is represented by

$$x(t) = \frac{1}{N}\sum_{n=0}^{N-1} S_n e^{j2\pi f_n t} \quad \ldots\ldots (1)$$

S_n = Data Symbol, N= Number of Sub-Carrier, f_n =Represent frequency, n= bit subcarrier

Let $\Delta D_i \geq 0$ denote the expected decreases in distortion if the i^{th} packet decoded. The overall distortion can be written as follows,

$$D(I) = D_0 - \sum_{i=1}^{l} P_i \Delta D_i \quad \ldots\ldots (2)$$

Where D_0 is the expected distortion when the rate is zero P_i is the probability that the i^{th} packets are received correctly & l is the number of source packet that transmitted choose to send. The P_i can be written form,

$$P_i = \prod_{j=1}^{i} Q_j(r_j) \quad \text{……… (3)}$$

Where $Q_j(r_j)$ is the probability that the j^{th} of packet is received correctly when sending in a rate of r_f. If packets are transmitted in AWGN channel then packet loss probability will be $S(p) = 1 - \{1 - p\}^m$ where m is the number of bits in data a packet. This relation helps to calculate throughput of the network.

Average Throughput (τ_{t_1})**:** The amount of data selected for transmission by a user per unit time. The value is expressed in Kbps and calculated using an exponential moving average as follows

$$\tau_{t_1} = \alpha * (\tau_t) + (1 - \alpha)\tau_{t-1} \quad \text{…. (4)}$$

Packet Loss (ρ)**:** The percentage of packets dropped from the queue out of all the packets that arrived in the queue. The metric indicates the percentage of packets that missed their deadlines and is calculated as follows:

$$\rho = \frac{\sum_{i=1}^{m} \omega_i}{\sum_{j=1}^{n} Kj} \quad \text{…. (5)}$$

Where, $\sum_{i=1}^{m} \omega_i$ is the sum of packets dropped, $\sum_{j=1}^{n} Kj$ is the sum of packets arrived in the queue.

Both average delay and packet loss will allow us to determine how effectively a scheduling algorithm satisfies the QoS requirements of real-time SSs.

Frame Utilization: The number of symbols utilized for data out all the symbols in the uplink sub-frame. The metric reported as a percentage is calculated as follows

$$F_{util} = \frac{\sum_{i=1}^{n} \omega_i}{C} \times 100\% \quad \text{…. (6)}$$

Average Queuing delay (d)**:** The time between the arrival of a packet in the queue to the departure of the packet from the queue. The value is reported in milliseconds (ms) and is calculated for each SS as follows

$$d = \frac{\sum_{i=1}^{N} (f_i - a_i)}{N} \quad \text{…. (7)}$$

V. System Model

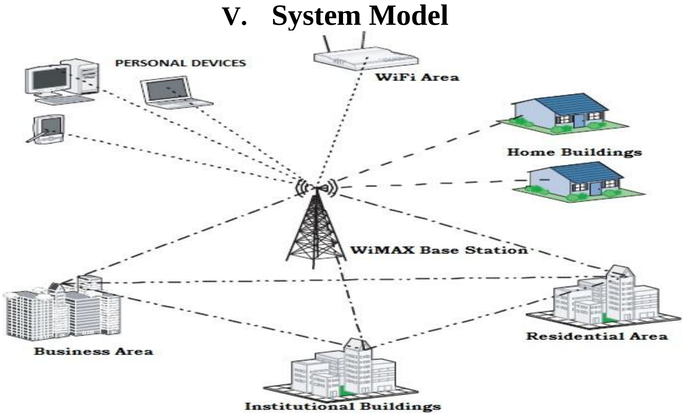

Figure 1: An Integrated WiMAX & Wi-Fi Network

As shown in above figure1, 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 [4].

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.

VI. Simulation Results

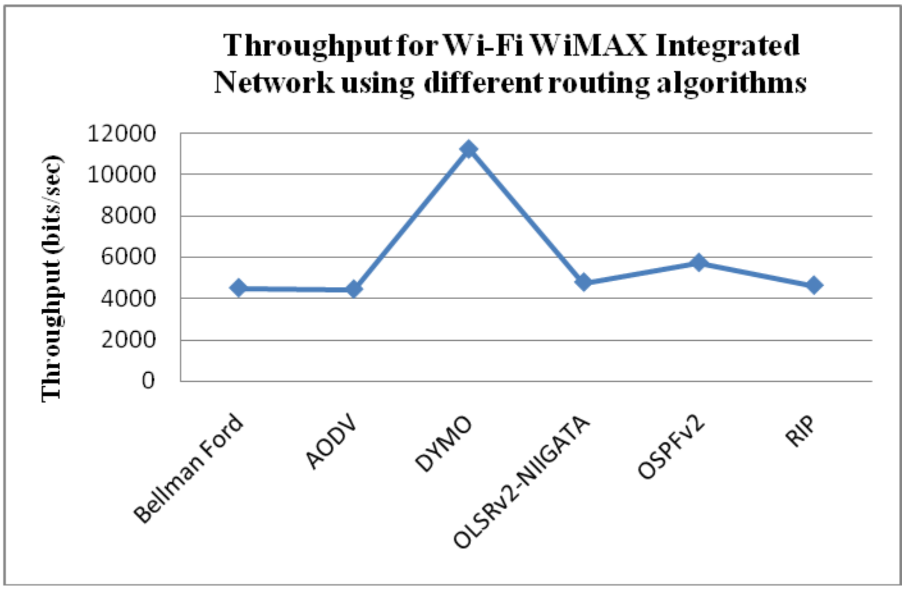

Figure 2: Throughput for Different Routing Algorithm for the network

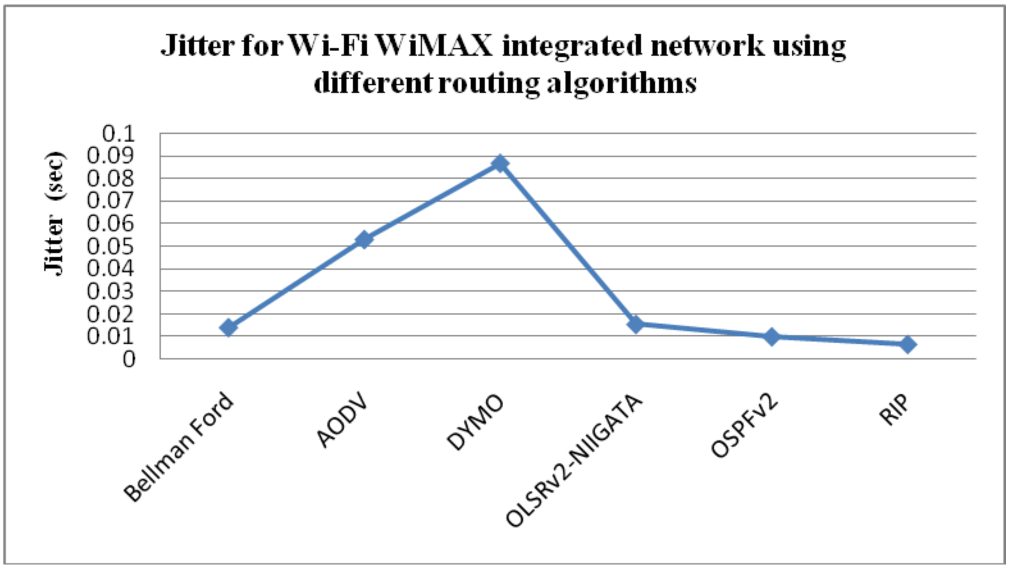

Figure 3: Average Jitter for for Different Routing Algorithm for the network

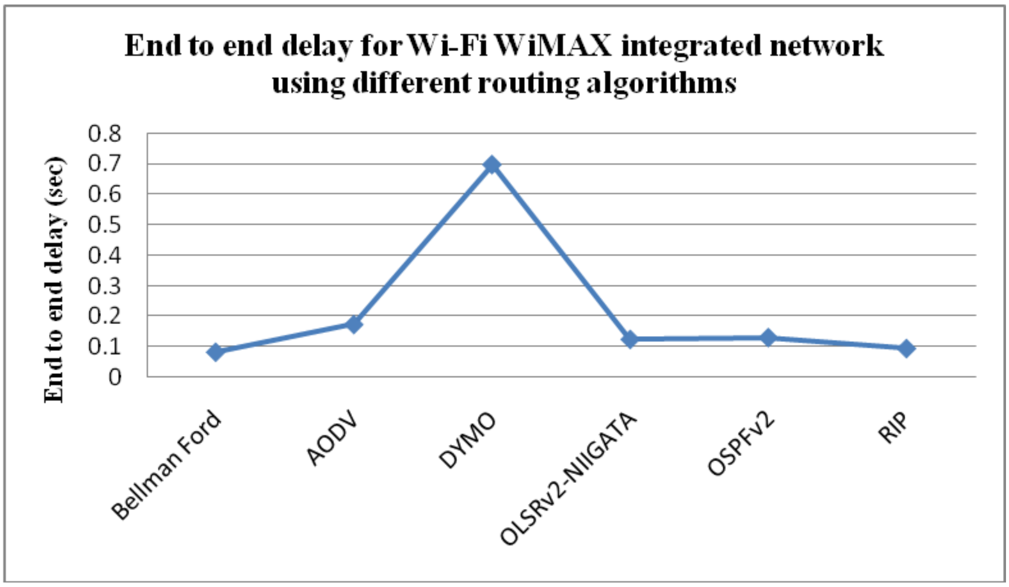

Figure 4: Average End to End Delay for Different Routing Algorithm for the network

VII. Conclusion

For this heterogeneous integrated network OSPF v2 shows better performance among all routing algorithms in terms of low jitter, End to End delay & High throughput. Such performance are helpful for implementing such networks for real time application & for better QoS for high speed mobile users.

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