A Study on Fourth Generation Wireless Network Using QualNet Simulator

Arthi Balasundaram, L. Rajesh, and K. Bhoopathy Bagan

***Abstract*—Fourth Generation (4G) systems, in addition to the usual voice and other services of Third Generation (3G), provides mobile ultra-broadband Internet access. Worldwide Interoperability for Microwave Access (WiMAX) forum promises to offer high data rate over large areas to a large number of users where broadband is unavailable. This paper focuses on routing in fourth generation wireless networks along with a brief study on layer three routing protocols. To this end, a wireless network scenario is simulated and their key features are exposed using QualNet Network Simulator.**

***Index Terms*—Quality of service, QualNet, routing protocols, WiMAX.**

I. Introduction

In developing countries and rural areas, the wire line infrastructures are considerably more expensive and time consuming to deploy than a wireless one. Wireless networks are generally less efficient and unpredictable compared to wired networks, which make Quality of Service (QoS) provisioning a bigger challenge for wireless communications. The wireless medium has limited bandwidth, higher packet error rate, and higher packet overheads that altogether limit the capacity of the network to offer guaranteed QoS [1]. In response to increasing QoS challenge, the IEEE 802.16 standard, also known as Worldwide Interoperability for Microwave Access (WiMAX), has emerged as the strongest contender for Broadband wireless technology with the promises to offer guaranteed QoS to wireless users. Broadband Wireless Access (BWA) has emerged as a promising solution for "last mile" access technology to provide high speed connections.

Wireless networking is expected to provide an extensive range of services with high transmission rate and enhanced QoS [2]. Small businesses can experience many benefits from a wireless network, including: Convenience, Mobility, Productivity, Easy setup, Expandable, Security, and Cost [3].

The main feature incorporated by IEEE 802.16 standard, which makes it a candidate to represent fourth-generation (4G) wireless communication systems, is the differentiated treatment of traffic generated by applications, essential to QoS provisioning [4].

The IEEE 802.16 standard can be deployed in two modes: the point to multipoint (PMP) and the multi-hop mesh mode (MSH). In PMP mode, all the subscriber stations (SS) are configured in direct single-hop neighborhood of the base station (BS). Also, the MSH mode allows inclusion of SSs in the network, which does not need a direct connection to the BS.

The rest of the paper is organized as follows. WiMAX network architecture is presented in Section II. In Section III, network layer protocols are described. Results and discussion are analyzed in Section IV. Conclusion is deferred in Section V.

II. WiMAX Network Architecture

The basic devices of WiMAX are of two types: WiMAX base-station and WiMAX receiver. The former is similar to a cellular tower, whereas, the latter could be a standalone tower or a Personal Computer Memory Card International Association (PCMCIA) card inserted into the laptop [5].

The WiMAX architecture developed by the WiMAX forum is unified network architecture to support fixed, nomadic and mobile operation. Fig. 1 represents the WiMAX Network Reference Model [6]. The major elements or areas of WiMAX network architecture are [7],

A. Remote or Mobile Stations

These are the user equipments that may be mobile or fixed and may be located in the premises of the user.

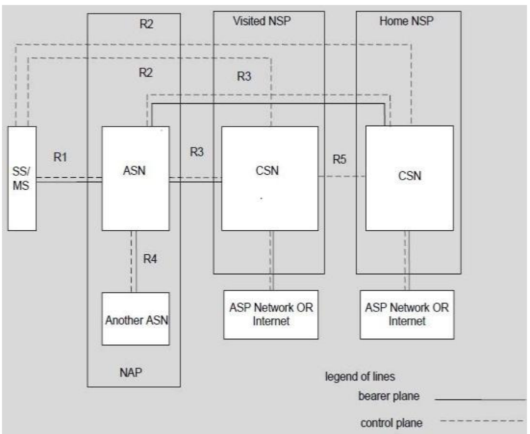

Fig. 1. WiMAX network reference model.

B. Access Service Network (ASN)

This is the area of the WiMAX network that forms the radio access network at the edge and it comprises one or more base stations and one or more ASN gateways.

C. Connectivity Service Network (CSN)

This part of the WiMAX network provides the IP

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connectivity and all the IP core network functions.

D. Subscriber Station (SS) / Mobile Station (MS)

The SS is also referred as the Customer Premises Equipment (CPE). These take a variety of forms and these may be termed either indoor CPE or outdoor CPE. The outdoor CPE has the advantage that it provides better performance as a result of the better position of the antenna, whereas the indoor CPE can be installed by the user. MS's are mostly used in the form of modem for a laptop.

E. Base Station (BS)

The base-station forms an essential element of the WiMAX network. It is responsible for providing the air interface to the subscriber and mobile stations. It provides additional functionality in terms of micro-mobility management functions, such as handoff triggering and tunnel establishment, radio resource management, QoS policy enforcement, traffic classification, Dynamic Host Control Protocol (DHCP) proxy, key management, session management, and multicast group management.

F. ASN Gateway (ASN-GW)

The ASN-GW in the WiMAX network architecture typically acts as a layer 2 traffic aggregation points within the overall ASN. The ASN-GW may also provide additional functions that include: intra-ASN location management and paging, radio resource management and admission control, caching of subscriber profiles and encryption keys. The ASN-GW may also include the Authentication, Authorization and Accounting (AAA) Server client functionality, establishment and management of mobility tunnel with base stations, foreign agent functionality for mobile IP, QoS and policy enforcement, and routing to the selected CSN.

G. Home Agent (HA)

The HA in the WiMAX network is located within the CSN. Mobile-IP forms a key element within WiMAX technology, the HA works in conjunction with a "Foreign Agent", such as the ASN Gateway, to provide an efficient end-to-end Mobile IP solution. The Home Agent serves as an anchor point for subscribers, providing secure roaming with QOS capabilities.

H. Authentication, Authorization and Accounting Server (AAA)

As with any communication or wireless system requiring subscription services, an Authentication, Authorization and Accounting server is used. This is included within the CSN.

III. Network Layer Protocols

Layer 3 provides the functional and procedural means of transferring variable-length data sequences from a source to a destination host via one or more networks, while maintaining the QoS functions. It is responsible for packet forwarding including routing through intermediate routers. The network layer responds to service requests from the transport layer and issues service requests to the data link layer [8].

The functions of this layer include Routing, Inter-networking, and Congestion control.

Fig. 2 depicts broad classification of different routing protocols. Based on the topology, the protocols can be either proactive, reactive or hybrid. Based on the position, the protocol can be either greedy forwarding or restricted flooding.

In the proactive approach, each node knows a route to each network node. The reactive seek to set up routes on-demand. A node initiates a route discovery when it must send a packet and it doesn't know any route to destination. Hybrid protocols combine the advantages of both proactive and reactive routing protocols. The characteristics of few of them are described in this section [9].

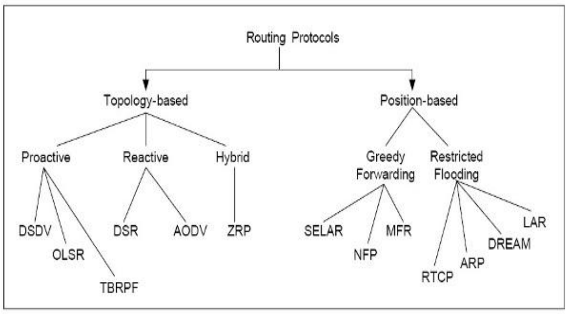

Fig. 2. Routing protocols.

A. Destination Sequence Distance Vector (DSDV)

DSDV is a table driven routing protocol that is an enhanced version of the distributed Bellman-Ford algorithm. Nodes in table driven protocols maintain a table that contains the next hop to reach all destinations [9]. To keep the tables up to date they are exchanged between neighboring nodes at regular intervals or when a significant topology changes are observed.

B. Ad-Hoc on-Demand Distance Vector Routing Protocol (AODV)

AODV is a reactive routing protocol designed for networks up to thousands of nodes. Traditional routing tables are maintained in nodes which specify the next hop to reach the destination. If there is no information in the routing table of the source then a route request is broadcasted. A node that receives the route request and has an up-to-date path to the destination will return it to the source and all nodes on the return path will update their routing tables. If no valid path is present in an intermediary node then the request is rebroadcasted. If a node receives multiple paths to the destination the one with the highest utility is chosen [9].

C. Zone Routing Protocol (ZRP)

ZRP is a hybrid protocol, which is a combination of the both proactive and reactive protocols. If a packet's destination is in the same zone as the origin, the proactive protocol using an already stored routing table is used to deliver the packet immediately. If the route extends outside the packet's originating zone, a reactive protocol takes over to check each successive zone in the route to see whether the destination is inside that zone. This reduces the processing overhead for those routes. Once a zone is confirmed as containing the destination node, the proactive protocol, or stored route-listing table, is used to deliver the packet [10].

In this way packets with destinations within the same zone as the originating zone are delivered immediately using a stored routing table. Packets delivered to nodes outside the sending zone avoid the overhead of checking routing tables along the way by using the reactive protocol to check whether each zone encountered contains the destination node.

Thus ZRP reduces the control overhead for longer routes that would be necessary if using proactive routing protocols throughout the entire route, while eliminating the delays for routing within a zone that would be caused by the route-discovery processes of reactive routing protocols.

D. Scalable Energy-Efficient Location Aided Routing (SELAR)

SELAR protocol is meant to be a fault-tolerant, scalable and energy-efficient protocol. This protocol is capable of handling large numbers of nodes as routing decisions are localized. So, the addition of more nodes does not degrade the performance of the network. SELAR has been influenced by the simplicity of flooding, the better efficiency of gossiping [11].

E. Location Aided Routing (LAR)

LAR scheme uses location information for the performance improvement of routing protocols. The location information is received through Global Positioning System (GPS). The route calculation is limited to a smaller request zone in the network. The expected zone is the region where source node S thinks that the destination node D at time T. The node S knows that the node was at location L at time T_0 and current time is T_1. If S knows that D travels at an average speed of V, then S assumes that the expected zone is the circular region of radius V (T_1-T_0) centered at location L. The scheme is very much similar to flooding, except the only nodes in request zone sends the route request. LAR reduces overhead of route discovery and shrinks the area of route request flood. The main shortcoming of LAR is the nodes need to know their exact physical locations [12].

IV. Results and Discussion

A. Software Used for Network Model

QualNet Simulator 5.0 is used for modeling wireless networks. It is a commercial program of GloMoSim, which is developed by Scalable Network Technologies. The core components of QualNet are as follows [13], [14],

QualNet Architect: QualNet Architect is a graphical tool that provides an intuitive model set up and execution capability. Architect has two modes: Design mode and Visualize mode.

In Design mode, Architect is used to create and design experiments. Architect enables a user to define the geographical distribution, physical connections and the functional parameters of the network nodes, all using intuitive click and drag tools, and to define network layer protocols and traffic characteristics for each node.

In Visualize mode, Architect is used to execute and animate experiments created in the Design mode. Using Architect, a user can watch traffic flow through the network and create dynamic graphs of critical performance metrics as a simulation is running.

QualNet Analyzer: QualNet Analyzer is statistical graphing tool that displays network statistics generated from a QualNet experiment. Using the Analyzer, a user can view statistics as they are being generated, as well as compare results from different experiments.

QualNet Packet Tracer: QualNet Packet Tracer is a packet-level visualization tool for viewing the contents of a packet as it goes up and down the network stack. This is a valuable debugging tool.

B. WiMAX Scenario

A simple model of WiMAX is deployed using seven mobile stations including three base stations. Fig. 3 represents the simulation of WiMAX network,

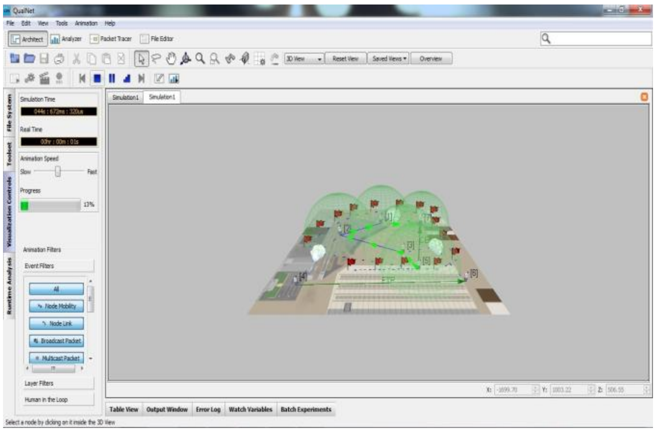

Fig. 3. WiMAX simulation.

Mobile station5 (MS5) sends data to MS7 under constant bit rate (CBR) application basis during its mobility. Table I is represented as follows:

TABLE I: Scenario Specifications

Parameter	Value
Simulation area	1500 m x 1500m
Simulation time	300 seconds
Channel frequency	2.4 GHz
Path loss model	Two Ray
MAC protocol	802.16
Physical layer - Radio type	802.16 Radio

The above table gives a brief view of the essential parameters and its value in the deployed scenario.

C. Performance Study

a) Application layer statistics

- *Bellman-ford algorithm*

The Bellman-Ford algorithm solves the single source shortest path problems even in the cases in which edge weights are negative. This algorithm returns a Boolean value indicating whether or not there is a negative weight cycle that is reachable from the source [15]. If there is such a cycle, the algorithm indicates that no solution exists and it there is no such cycle, it produces the shortest path and their weights.

Fig. 4 represents the number of triggered updates sent using Bellman-Ford algorithm.

The comparison is given for every node in the network. X-axis represents the node(s) and Y-axis represents metric value.

- *Constant bit rate (CBR)*

The CBR service category is used for connections that transport traffic at a constant bit rate, where there is an inherent reliance on time synchronization between the traffic source and destination. CBR is tailored for any type of data for which the end-systems require predictable response time and a static amount of bandwidth continuously available for the life-time of the connection. CBR include services such as video conferencing, telephony (voice services) or any type of on-demand service, such as interactive voice and audio. For telephony and native voice applications CBR provides low-latency traffic with predictable delivery characteristics, and is therefore typically used for circuit emulation [16].

Fig. 4. Triggered updates.

b) Transport layer statistics

Layer 4 provides end-to-end or host-to-host communication services for applications within a layered architecture of network components and protocols [14]. The transport layer provides services such as connection-oriented data stream support, reliability, flow control, and multiplexing. Fig. 5 represents the graph about the packets from the application layer in User Datagram Protocol (UDP) as follows,

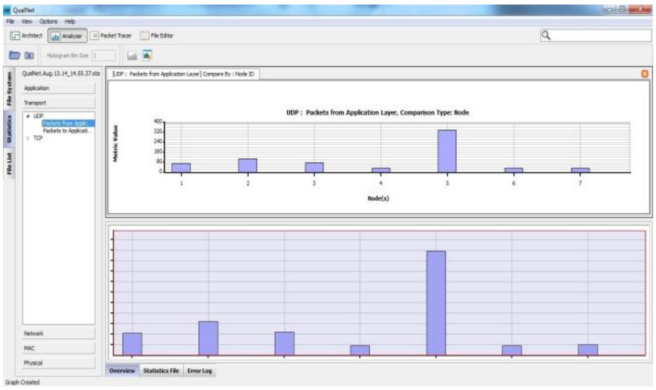

Fig. 5. Packets from application layer.

The best-known transport protocol is the Transmission Control Protocol (TCP). It is used for connection-oriented transmissions, whereas the connectionless UDP is used for simpler messaging transmissions. TCP is the more complex protocol, due to its stateful design incorporating reliable transmission and data stream services.

c) Network layer statistics

In this layer, Internet Protocol suite is suite is used in this scenario. Fig. 6 represents the queued packets as follows.

Fig. 6. Packets queued in FIFO.

The First-In-First-Out (FIFO) queuing mechanism is followed here for the routing of packets to the appropriate destination nodes.

d) MAC layer statistics

Media Access Control (MAC) data communication protocol is a sub layer of the data link layer, which itself is layer 2. The MAC sub layer provides addressing and channel access control mechanisms that make it possible for several terminals or network nodes to communicate within a multiple access network that incorporates a shared medium.

Some of the multiple access protocols that may be used in packet radio wireless networks are CSMA/CA (used in IEEE 802.11/Wi-Fi WLANs), Slotted ALOHA, Dynamic TDMA, Reservation ALOHA (R-ALOHA), Mobile Slotted Aloha (MS-ALOHA), CDMA, OFDMA [14].

Fig. 7 represents the frames sent in the link on every queue as follows,

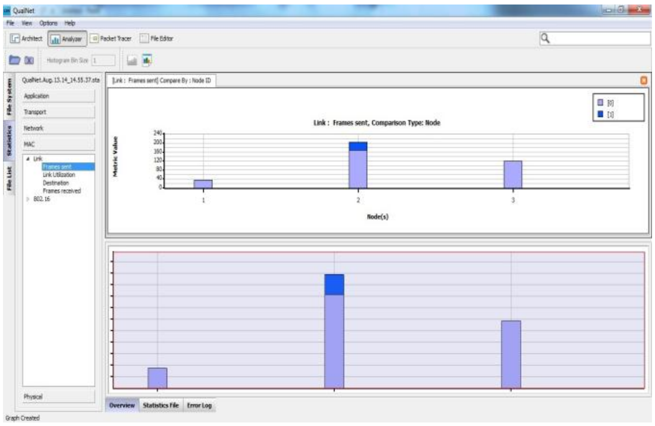

Fig. 7. Frame sent.

The primary functions performed by the MAC layer are Frame delimiting and recognition, Addressing of destination stations (both as individual stations and as groups of stations), Conveyance of source-station addressing information, Transparent data transfer of LLC PDUs, or of equivalent information in the Ethernet sub layer [14].

e) Physical layer statistics

The physical layer consists of the basic networking hardware transmission technologies of a network. Layer 1 defines the means of transmitting raw bits rather than logical data packets over a physical link connecting network nodes [14].

Fig. 8 represents the transmitted signals in PHY 802.16 radio as follows,

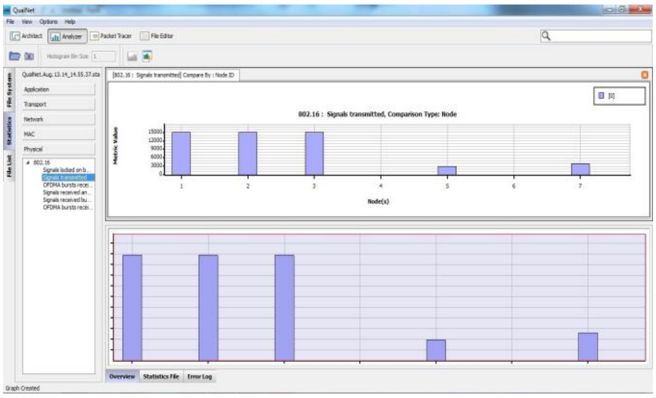

Fig. 8. Signals transmitted.

The major functions and services performed by the physical layer includes, Bit-by-bit or symbol-by-symbol delivery, providing a standardized interface to physical transmission media, Modulation, Line coding.

V. Conclusion and Future Work

A short introduction on the need for wireless networks is mentioned. The network architecture of WiMAX is discussed followed by a brief note on the routing protocols. A wireless network model is simulated in QualNet and its results are studied in the same.

The presented work will be extended to more number of nodes and deployed in a large wireless network.

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