Title: WiMAX network model performance testing using NS3 Simulation software

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ABSTRACT

The actual practical setup for WiMAX network testing is time consuming and costly for researcher so Solution for this problem is that to test WiMAX network using open source and free software is available for that. The paper reflects the WiMAX network model design and its performance. Many authors have worked on various QoS parameters using different service classes in WiMAX. The study is conducted on various quality parameters impacting the WiMAX service performance of a WiMAX network. The study suggests that these critical parameters of QoS are required to increase the performance of a WiMAX network. The WiMAX technology is considered for wireless network because WiMAX is becoming essential for electronic governance project in India. Most of the electronic governance projects are prepared by Indian government are based on WiMAX technology. The Indian citizen’s wants see the India into digital India so this dream could be completed by covering most of the rural and urban region by WiMAX technology in near future.

Key words: IEEE 802.16, Model and simulation, network simulation, open-source; QoS, WiMAX.

1 INTRODUCTION

In the network research area, establishing of network in a real time scenario is very difficult. A single test bed takes a large amount of time and cost. So implementation of a whole network in real world is not easily possible and very costly for researcher. The simulator helps the network developer to check whether the network is able to work in the real time. Simulation is one of the important technologies in research field. The simulation in computer can model hypothetical and real-life objects on a computer so that it can be study. The network is also simulated on the computer. A network simulator is a technique of implementing the network on the computer. Through this the behavior of the network is calculated either by network entities interconnection using mathematical formulas, or by capturing and playing back observations from a production network. Network simulator 3 (NS3) is discrete-event network simulator and it is free software for R&D purpose. The users of ns-3 [2] can construct models and simulates on computer using models of traffic generators, protocols such as TCP/IP, and devices and channels such as Wi-Fi, WiMAX and analyze or visualize the results. The simulators [8][9], has scheduler and several useful classes defining nodes on a network, packets, and other similarly near-universal concepts. Various models use portions of this core package to implement specific network types, such as WiMAX, or simple wired Ethernet networks. Scripts then define network topologies of nodes connected using the networks defined in these models, and Generate traffic between them. One of them most useful tools available for presenting the results of a simulation is animation. An animation package would be able to show both the network topology and data flow through that topology. This can either be displayed as the simulator is running or after the fact from a trace file generated by the simulator. The WiMAX provides high speed broadband service in most of the metro city and town from India. Today remote rural area is not getting proper coverage and connectivity of mobile service and WiMAX is such wireless technology which covers 50 Kilometer area from base station with high speed transmission is the only one solution for such remote area then only electronic governance is possible to transform India into digital India.

2 REASON FOR SELECTION OF NS3 [1]

The ns-3 simulator is selected because it is actively developed on multiple fronts, written entirely in C++.Ns-3 consists of a simulation core engine, a set of models, example programs, and tests. The ns-3 testing environment provides model validation and testing tools and encourages the publication of validation results. NS3 is free software for R&D purpose. Characteristics of the ns-3 development effort include

- Strict implementation of IEEE specifications
- Broad international use and contribution;
- Continuous academic, corporate, and public scrutiny of the source code
- Academic ‘‘validation’’ through published articles and conference presentations; and
- Extensive testing.
3 WIMAX APPLICATION SCENARIO

Worldwide Interoperability for Microwave Access (WiMAX) is currently one of the hottest technologies in wireless, it’s a standard-based on the IEEE 802.16 wireless technology that provides high throughput broadband connections over long distance, which supports Point to Multi-point (PMP) broadband wireless access. Fig 1 shows the application scenario based on WiMAX technology. The urban area and rural area covered with WiMAX connectivity. The WiMAX broadband connectivity good solution for urban and rural development. Digitization of metro cities, rural area and remote places are possible using WiMAX technology. The number of application is possible like telemedicine, teleeducation, teleagriculture, telemarketing, telefinancial service and government offices, private offices, NGO, state offices, community centers can form network based on WiMAX technology to build the efficiency in work, transparency, effectiveness in work. The WiMAX is a wireless digital communication system with range of 50km. This technology can be used to provide the “last mile” connectivity viz. providing broadband internet connectivity to the rural areas where installing GPRS is expensive [6][7]

4 WIMAX ARCHITECTURE AND SIMULATION ENVIRONMENT [4]

The 802.16 model provided in ns-3 attempts to provide an accurate MAC and PHY level implementation of the 802.16 specification with the Point-to-Multipoint (PMP) mode and the Wireless MAN-OFDM PHY layer. The model is mainly composed of three layers:

- The convergence sub layer (CS)
- The MAC CP Common Part Sub layer (MAC-CPS)
- and The Physical (PHY) layer

4.1 MAC Convergence Sub layer

The Convergence sub layer (CS) designed to work with the packet-based protocols at higher layers. The CS is responsible of receiving packet from the higher layer and from peer stations, classifying packets to appropriate connections and processing packets. It keeps a mapping of transport connections to service flows. This enables the MAC CPS identifying the Quality of Service (QoS) parameters associated to a transport connection and ensuring the QoS requirements. The CS currently employs an IP classifier.

IP Packet Classifier

An IP packet classifier is used to map incoming packets to appropriate connections based on a set of criteria. The classifier maintains a list of mapping rules which associate an IP to one of the service flows. By analyzing the IP and the TCP/UDP headers the classifier will append the incoming packet (from the upper layer) to the queue of the appropriate WiMAX connection. Classes IpcsClassifier and IpcsClassifierRecord implement the classifier module for both SS and BS.
4.2 MAC Common Part Sub layer

The MAC Common Part Sub layer (CPS) is the main sub layer of the IEEE 802.16 MAC and performs the fundamental functions of the MAC. The module implements the Point-Multi-Point (PMP) mode. In PMP mode BS is responsible of managing communication among multiple SSs. The key functionalities of the MAC CPS include framing and addressing, generation of MAC management messages, SS initialization and registration, service flow management, bandwidth management and scheduling services. Class WimaxNetDevice represents the MAC layer of a WiMAX network device. This class extends the NetDevice class of the ns-3 API that provides abstraction of a network device. WimaxNetDevice is further extended by BaseStationNetDevice and SubscriberStationNetDevice classes, defining MAC layers of BS and SS, respectively. Besides these main classes, the key functions of MAC are distributed to several other classes.

Framing and Management Messages

The module implements a frame as a fixed duration of time, i.e., frame boundaries are defined with respect to time. Each frame is further subdivided into downlink (DL) and uplink (UL) sub frames. The module implements the Time Division Duplex (TDD) mode where DL and UL operate on same frequency but are separated in time. A number of DL and UL bursts are then allocated in DL and UL sub frames, respectively. Since the standard allows sending and receiving bursts of packets in a given DL or UL burst, the unit of transmission at the MAC layer is a packet burst. The module implements a special Packet Burst data structure for this purpose. A packet burst is essentially a list of packets. The BS downlink and uplink schedulers implemented by the classes BS Scheduler and Uplink Scheduler are responsible of generating DL and UL sub frames, respectively. In the case of DL, the sub frame is simulated by transmitting consecutive bursts (instances Packet Burst). In case of UL, the sub frame is divided, with respect to time, into a number of slots. The bursts transmitted by the SSs in these slots are then aligned to slot boundaries. The frame is divided into integer number of symbols and Physical Slots (PS) which helps in managing bandwidth more effectively. The number of symbols per frame depends on the underlying implementation of the PHY layer. The size of a DL or UL burst is specified in units of symbols.

Network Entry and Initialization

The network entry and initialization phase is basically divided into two sub-phases,

(1) Scanning and synchronization

The entire phase is performed by the Link Manager component of SS and BS. Once an SS wants to join the network, it first scans the downlink frequencies to search for a suitable channel. The search is complete as soon as it detects a PHY frame. The next step is to establish synchronization with the BS. Once SS receives a Downlink-MAP (DL-MAP) message the synchronization phase is complete and it remains synchronized as long as it keeps receiving DL-MAP and Downlink Channel Descriptor (DCD) messages. After the synchronization is established, SS waits for a Uplink Channel Descriptor (UCD) message to acquire uplink channel parameters. Once acquired, the first sub-phase of the network entry and initialization is complete. Once synchronization is achieved, the SS waits for a UL-MAP message to locate a special grant, called initial ranging interval, in the UL subframe. This grant is allocated by the BS Uplink Scheduler at regular intervals. Currently this interval is set to 0.5 ms, however the user is enabled to modify its value from the simulation script.

Connections and Addressing

All communication at the MAC layer is carried in terms of connections. The standard defines a connection as a unidirectional mapping between the SS and BS's MAC entities for the transmission of traffic. The standard defines two types of connections: management connections for transmitting control messages and transport connections for data transmission. A connection is identified by a 16-bit Connection Identifier (CID). Classes Wimax Connection and Cid implement the connection and CID, respectively. Note that each connection maintains its own transmission queue where packets to transmit on that connection are queued. The Connection Manager component of BS is responsible of creating and managing connections for all SSs. The two key management connections defined by the standard, namely the Basic and Primary management connections, are created and allocated to the SS during the ranging process. Basic connection plays an important role throughout the operation of SS also because all (unicast) DL and UL grants are directed towards SS's Basic CID. In addition to management connections, an SS may have one or more transport connections to send data packets. The Connection Manager component of SS manages the connections associated to SS. As defined by the standard, a management connection is bidirectional, i.e., a pair of downlink and uplink connections is represented by the same CID. This feature is implemented in a way that one connection (in DL
direction) is created by the BS and upon receiving the CID the SS then creates an identical connection (in UL direction) with the same CID.

### Scheduling Services

The module supports the four scheduling services defined by the 802.16-2004 standard:

- Unsolicited Grant Service (UGS)
- Real-Time Polling Services (rtPS)
- Non Real-Time Polling Services (nrtPS)
- Best Effort (BE)

These scheduling services behave differently with respect to how they request bandwidth as well as how the it is granted. Each service flow is associated to exactly one scheduling service, and the QoS parameter set associated to a service flow actually defines the scheduling service it belongs to. When a service flow is created the Uplink Scheduler calculates necessary parameters such as grant size and grant interval based on QoS parameters associated to it.

### WiMAX Uplink Scheduler Model

Uplink Scheduler at the BS decides which of the SSs will be assigned uplink allocations based on the QoS parameters associated to a service flow and bandwidth requests from the SSs. Uplink scheduler together with Bandwidth Manager implements the complete scheduling service functionality. The standard defines up to four scheduling services (BE, UGS, rtPS, nrtPS) for applications with different types of QoS requirements. The service flows of these scheduling services behave differently with respect to how they request for bandwidth as well as how the bandwidth is granted. The module supports all four scheduling services. Each service flow is associated to exactly one transport connection and one scheduling service. The QoS parameters associated to a service flow actually define the scheduling service it belongs to. The current WiMAX module provides three different versions of schedulers.

- The first one is a simple priority-based First Come First Serve (FCFS). For the real-time services (UGS and rtPS) the BS then allocates grants/polls on regular basis based on the calculated interval. For the non real-time services (nrtPS and BE) only minimum reserved bandwidth is guaranteed if available after servicing real-time flows.

- The second one is similar to first scheduler except by rtPS service flow. All rtPS Connections are able to transmit all packet in the queue according to the available bandwidth. The bandwidth saturation control has been implemented to redistribute the effective available bandwidth to all rtPS that have at least one packet to transmit. The remaining bandwidth is allocated to nrtPS and BE Connections. This scheduler is implemented by classes BS SchedulerRtps and Uplink SchedulerRtps

- The third one is a Migration-based Quality of Service uplink scheduler. This uplink scheduler uses three queues, the low priority queue, the intermediate queue and the high priority queue. The scheduler serves the requests in strict priority order from the high priority queue to the low priority queue. The low priority queue stores the bandwidth requests of the BE service flow. The intermediate queue holds bandwidth requests sent by rtPS and by nrtPS connections. rtPS and nrtPS requests can migrate to the high priority queue to guarantee that their QoS requirements are met. Besides the requests migrated from the intermediate queue, the high priority queue stores periodic grants and unicast request opportunities that must be scheduled in the following frame. To guarantee the maximum delay requirement, the BS assigns a deadline to each rtPS bandwidth request in the intermediate queue. The minimum bandwidth requirement of both rtPS and nrtPS connections is guaranteed over a window of duration T. This scheduler is implemented by the class UplinkSchedulerMBQoS

### WiMAX Outbound Schedulers Model

Besides the uplink scheduler these are the outbound schedulers at BS and SS side (BSScheduler and SSScheduler). The outbound schedulers decide which of the packets from the outbound queues will be transmitted in a given allocation. The outbound scheduler at the BS schedules the downlink traffic, i.e., packets to be transmitted to the SSs in the downlink sub frame. Similarly the outbound scheduler at a SS schedules the packet to be transmitted in the uplink allocation assigned to that SS in the uplink sub frame. All three schedulers have been implemented to work as FCFS scheduler, as they allocate grants starting from highest priority scheduling service to the lower priority one.
4.3 WiMAX PHY Model

For the physical layer, we chose the Wireless MAN OFDM PHY specifications as the more relevant for implementation as it is chosen by the WiMAX Forum. This specification is designed for non-light-of-sight (NLOS) including fixed and mobile broadband wireless access.

Channel model

The channel model we propose is implemented by the class SimpleOFDMWimaxChannel which extends the wimaxchannel class. The channel class uses the method GetDistanceFrom() to calculate the distance between two physical entities according to their 3D coordinates. The delay is computed as delay = distance/C, where C is the speed of the light.

Physical model

The physical layer performs two main operations: (i) It receives a burst from a channel and forwards it to the MAC layer, (ii) it receives a burst from the MAC layer and transmits it on the channel.

![WIMAX module][4]

**Fig 2** WIMAX module [4]

![N/W scenario for 20 nodes and sub nodes][4]

**Fig 3** N/W scenario for 20 nodes and sub nodes
5 WIMAX NETWORK SCENARIO

The N/W scenario is designed using ns3 software. The WiMAX N/W scenario is shown in Fig 3. It is designed for total 20 number nodes and sub nodes with two base stations, base station 1 and base station 2. The across Base station 2 (BS2) there are total 10 number of nodes out of that 6 are subscriber (SN) and another 4 are subscriber sub nodes (SSN). All are fixed nodes. Across BS1 there are total 10 numbers of nodes out of that 6 are SN and another 4 are SSN and all nodes are mobile nodes. The simulation parameters and node parameter are set as per table 1

<table>
<thead>
<tr>
<th>Sr no</th>
<th>Efficiency mode</th>
<th>Mobility and ranging enabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AC Service Class Distribution (QOS)</td>
<td>UGS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(IP telephony)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) rtsp</td>
</tr>
<tr>
<td>2</td>
<td>Modulation Technique</td>
<td>Wireless OFDMA</td>
</tr>
<tr>
<td>3</td>
<td>Number of Subcarriers</td>
<td>2048</td>
</tr>
<tr>
<td>4</td>
<td>Band width</td>
<td>20 MHz</td>
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<tr>
<td>5</td>
<td>Duplexing Technique</td>
<td>TDD</td>
</tr>
<tr>
<td>6</td>
<td>Scheduling Type</td>
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</tr>
<tr>
<td>7</td>
<td>Maximum Sustained Traffic Rate (bps)</td>
<td>2Mbps</td>
</tr>
<tr>
<td>8</td>
<td>Maximum Reserved Traffic Rate (bps)</td>
<td>1Mbps</td>
</tr>
</tbody>
</table>

Table 1. Simulation parameters

6 PERFORMANCE ANALYSIS

The N/W scenario for 20 nodes and sub nodes is simulated and tested using NS3 software. The Fig 4 shows the overall transmission and reception response given by 20 nodes in 7 seconds. The total 80 packets are transmitted and received 80 packets therefore the packet delivery ratio is 100% which is shown in Fig 4 and Fig 7. The throughput is 93.9286 Kbps is shown in Fig 6 and delay time analysis is 0.0223871 seconds between two nodes communication is shown in Fig 5

7 CONCLUSIONS

High bandwidth and reliability of WiMAX helps the integration with bringing remote area ever closer to urban area. Furthermore, new advanced services are implemented every experience gained in this project could be useful in countries or areas where conditions are similar. The mobility and quick deployment offered by wireless communications will help change our former views of services for remotely and inexpensively. The application of integrated WiMAX and Wi-Fi broadband wireless access technologies for number of services to help the digitization. For testing the WiMAX network the NS3 software found suitable and maximum 80% response in case of transmission and reception is found. Without spending any cost the WiMAX n/w testing is done successfully. This could help to make India’s scenario in to digital form. The new design of the physical layer has improved the simulation time by several magnitude orders while still providing a realistic implementation of the standard. Furthermore, the IP classifier has enabled the simulation of an unlimited number of service flows per subscriber station, while the proposed schedulers improve the management of the QoS requirements for the different service flows.
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