Simulation model for multihop relay network based on mobile WiMAX standard

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Abstract: - Paper deals with simulation model of multihop relay network consisting of pico WiMAX base stations which act as a relay nodes. The new concept of the WiMAX pico base station is introduced to support the relay functionality. The proposed WiMAX pico base station consists of the components already available on the market.

Key-Words: - WiMAX, 802.16j, Pico base station, Simulation model, OPNET

1 Introduction

The IEEE 802.16 standard provides technical specifications for the PHY and MAC layers for fixed or mobile wireless access and addresses the first or last-mile connection. Wide variety of specifications for channel coding and modulation schemes, duplexing methods, variations in the bandwidth and carrier frequency allow several profiles and PHY layers [1, 2].

However, the IEEE 802.16e standard does not specify multihop approach, in spite of its advantages, mainly in a last-mile connectivity where wired infrastructure is insufficient or absent. For that reason the IEEE 802.16 task force has formed a task group to extend mobile WiMAX specifications to allow also multihop communication, in order to extend fix infrastructure and provide better signal to noise ratio (SNR) in particular inside buildings [3, 4].

Its aim is to enhance the coverage per user, throughput, and system capacity of IEEE 802.16e. Compared with base station (BS), multihop relay system (RS) does not need a wire-line backhaul and has much lower hardware complexity. Using RS can significantly reduce the deployment cost of the system [5].

1.1 The 802.16j standard

Mobile WiMAX has not been foreseen to work in the mesh networks, which today it turns out to be an important drawback for future wireless communication systems. The basic contribution of the IEEE 802.16j standard is the ability to enable relay communications by splitting the WiMAX time frame in sub-frames [6].

The first difference as compared to the 'old' standard 802.16e is renewed terminology. Multihop-relay base-station (MR-BS) is a base station, which enables multihop access and its definition is in consensus with the 'old' definition.

Relay station, as suggested by the name, allows communication between the two stations; either between the two base stations or base station and user(s).

At the moment there are no components supporting...
802.16j standard on the market, so in this paper a new concept for the pico WiMAX base station is proposed, which could act as an access point and it is also able to connect to the neighbouring pico WiMAX base stations and form a mesh network. The concept is presented in Figure 1. The aforementioned pico base-stations are used to build the simulation model of a multihop WiMAX network. The network is loaded using the simulated traffic of real applications. The simulation model is built using OPNET Modeler 15.0 PL3 [7] and is based on the standard OPNET elements. This allows the complete 7 OSI layers analysis.

2 Multihop network

An example of a multihop cellular network is presented in Figure 2. The network consists of pico base-stations that are interconnected with WiMAX point-to-point links, WiMAX last-mile network and internet network. The following case studies are of over interest in a communication network limited by three hops:

- End user inside the multihop network accesses the content in the remote server.
- Multiple end-users access simultaneously the same application in the remote server.
- End users communicate with each other inside the multihop network.

The communication links for three interested study cases are also stressed in Figure 2. Since the IEEE 802.16j standard in most cases does not limit the number of hops in the multihop relay communications towards mobile station [8] it places greater responsibility in the hands of the network operator. Number of hops from end user to the remote server is in the case of "end user - end user" communication doubled. This places constraints in the provision of the QoS demanding applications. The problem has already been noticed and proposals to decrease delay due to network hopping have already been proposed [9].

Looking deeper into the proposed communication study cases reveals that quasistatic tree shaped topology is sufficient for simulation model that allows analysis of the proposed interesting study cases. Temporal changes in the network, link breakdowns, traffic increase or decrease, adding new users to the network, starting new service, etc. can be modelled as a series of static scenarios that differ in the selection of input parameters. Generally, the settings for the new scenario are based on the current scenario settings.

2.1 Pico base station

The network model has been based on the pico base station which has been built using standard elements that roam the market for a while and have been well tested. The WiMAX pico base station has following features:

- four point to point connections based on the mobile WiMAX standard,
- the wireless access part based on mobile WiMAX standard,
- Several Ethernet ports enabling wired connection and the router enabling routing traffic to and from all wired and wireless connections.

Figure 3 shows the basic element of the simulation model: the pico base station composed of the Ethernet switch or alternatively a router, WiMAX base station for the last-mile access for the end users, and four pairs of base stations and mobile WiMAX subscriber stations. Base station-mobile station pairs are placed there to simulate the radio relay point to point links. At these pairs we set the appropriate WiMAX relay parameters (e.g. the wireless links attributes such as capacity, stability, SNR, etc). Ethernet switch allows users to connect to the Internet via the Ethernet cable.
### 3 Simulation model

OPNET 15.0 PL3 [] version supports the IEEE 802.16-2004 and IEEE 802.16e-2005 standards while simulation modelling of the 802.16j is at the moment not supported. Even though the solution proposed in this paper can be modelled using standard WiMAX OPNET models, allowing evaluation of custom scheduling algorithms for WiMAX base and subscriber stations, optimization of application performance by leveraging WiMAX QoS policies, predicting network performances for different MAC and PHY layer profiles, and visualizing live application performance over a simulated WiMAX network infrastructure.

#### 3.1 Pico base station simulation model

Similarly as a theoretical model presented in section 2.1 the simulation model of the pico base station has all the basic elements from Figure 3. The radio relay links are modelled as a pair of subscriber and mobile WiMAX base station, which guarantee the duplex connection of the radio relay links. The wireless access part is a standard mobile WiMAX base station, while the router is a standard IP router. The proposed OPNET model of the WiMAX pico base station allows us to form a mesh network consisting broadband wireless and wired access part, duplex relay links based on mobile WiMAX connection and wired connection to the internet.

The interference between base stations is controlled by using different carrier frequencies at individual WiMAX rely stations. Four pairs of base – mobile station model for point-to-point connections between neighbouring WiMAX pico base stations. The proposed model allows analysis of:

- point-to-point duplex connection where download channel and upload channel are separated by using two different radio link carrier frequencies
- point-to-point half duplex connection where in one WiMAX connection part of the frame is used for the downlink and part of the frame is used for upload connection.

Four WiMAX connections allow pico base stations to form a plain multihop ad-hoc network. By increasing the number of WiMAX connections we get only redundant elements. For instance an element with six connections is a cornerstone for forming a network in 3D space. Since terrestrial radio based networks are formed round the earth surface the four WiMAX connections are sufficient.

By using proposed approach we are able to set up parameters in the WiMAX MAC and PHY layer to:

- Model capacity of the downlink and uplink channel, we can set up the appropriate ratio between the download and upload link capacity by modifying the coding and
modulation schemas, changing the downlink upload ratio in one frame, and extending and narrowing the band of the channel.

- When we have a line of sight between the two parties quality of the active connection can be modelled by receiver's and transmitter's antenna gain, receiver's sensitivity, and setting up the transmission power.
- Radio channel modelling is enabled by choosing environment (Vehicular, Pedestrian…) and the altitude of the pico base station.
- By setting up the carrier frequencies and zero sub-carriers in the OFDM schema one can model the size of the co-channel and adjacent channel interference.
- Individual applications can be scheduled differently through the WiMAX network. The simulator supports all the WiMAX defined QoS service algorithms (UGS, rtps, ertps, etc.)

3.2. Network model

We have already concluded that for modelling interesting scenarios the static topology suits our needs. Thus, in order to simulate various scenarios in WiMAX mesh network we propose to use a tree topology of the mesh network, which is depicted in Figure 4. It consists of seven WiMAX pico base stations, from which only one is connected (through wired links) to the application server(s).

The traffic arriving from the other relay links and access network is modelled as an aggregated traffic entering each base station through Ethernet connection. One must keep in mind that this aggregated traffic loads the network but the QoS parameters (such as delay in VoIP application) should be interpreted correctly.

To make this discussion complete we have to point out the router element in the pico base station. Naturally its main function is to direct traffic correctly from end-users to routers.

3.3. Network traffic load

OPNET enables loading the network with application simulations. Generally, applications belong to different types of services and have different demands for quality of service (QoS). Applications vary in their properties. Moreover, analyzing traffic in today’s network operator reveals a large bucket of applications, thus, picking the representative applications is an important task. We considered three types of traffic to be denoted as potentially the most interesting ones. In addition to that these three types of traffic cover the majority traffic diversity:

- Video Conference (VC) has high QoS demands. In addition, it is highly bandwidth consuming. It represents constant traffic flow.
- VoIP application represents majority of the traffic load in the network. Moreover, it represents the basic network functionality. It represents constant traffic flow.
- FTP traffic comes in bursts and represents all other traffic in the network. Due to low QoS demands it has the lowest priority of all the observed traffic types.

When possible, we propose loading the network symmetrically. This means that we have the same throughputs in the download and upload direction. Though, real networks normally have their load in the download direction few times larger as compared to the upload load. Loading the simulation network in such a way will not affect the simulation results, but it will allow better control of the network occurrences.
The exposed applications differ in their demand to keep the delay or jitter below the certain number. The quality of the FTP application is evaluated by determining the response times in the download and upload direction. By loading the network with the selected applications and the measurements collected we can get enough information to evaluate the network performance.

4 Test case

The simulation model allows setting up the complete seven layers OSI stack (i.e. from physical to application layer). To collect meaningful results from such a simulator one should have at least approximate knowledge on how the real deployed network will look alike. The complexity of setting up correctly the network can already be evaluated from the next example. The main parameters from the WiMAX MAC and PHY layer are presented in Tables 1 and 2. PHY layer parameters presented in Table 1 consider relatively poor propagation conditions for setting up the WiMAX point-to-point connection. QPSK 1/2 coding-modulation scheme has been foreseen. This scheme allows communication even with relatively low SNR. In the uplink that has been implemented for the relay-relay, relay-end user and base station – relay communication we have approximately 1.9 Mbps band available. This is even theoretically almost the worst case scenario from the throughput point of view and can only be improved. One can do so by increasing the transmission power at the transceiver, changing the UL/DL ratio and modifying the coding-modulation schemes. MAC scheme, specifying the QoS service type, may be adapted only after the PHY parameters have been set. For the three applications from the section 3.3 three s QoS service types have been foreseen. The exact settings can be seen in Table 2.

Using more than one QoS service type is appropriate solutions when network operators already have some knowledge on the end user behaviour. Generally the cost for using more than one s QoS service type is loosing some of the available bandwidth, since we have to arrange traffic in more than one queue. While the main benefit in using this approach is providing better QoS for different applications since the applications themselves generally do not interact with each other from the throughput perspective.

For Video conference calls we have reserved the UGS traffic QoS service. The Maximum sustained traffic rate parameter is set at the value to allow one Video conference call per branch. Regardless of the other applications load the network.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP length</td>
<td>1/8</td>
</tr>
<tr>
<td>BW (MHz)</td>
<td>10 MHz</td>
</tr>
<tr>
<td>Modulation</td>
<td>QPSK 1/2</td>
</tr>
<tr>
<td>Permutation</td>
<td>PUSC</td>
</tr>
<tr>
<td>Frame length (ms)</td>
<td>5</td>
</tr>
<tr>
<td>FFT size</td>
<td>1024</td>
</tr>
<tr>
<td>TTG (us)</td>
<td>105.7</td>
</tr>
<tr>
<td>RTG (us)</td>
<td>60</td>
</tr>
<tr>
<td>DL/UL ratio</td>
<td>29/18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>QoS service type &amp; application</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>UGS - Video conference</td>
<td>Maximum sustained traffic rate [kbit/s]</td>
<td>720</td>
</tr>
<tr>
<td></td>
<td>Minimum reserved traffic rate [kbit/s]</td>
<td>720</td>
</tr>
<tr>
<td></td>
<td>Maximum latency [ms]</td>
<td>10</td>
</tr>
<tr>
<td>ertpS - VoIP</td>
<td>Maximum sustained traffic rate [kbit/s]</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>Minimum reserved traffic rate [kbit/s]</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Maximum latency [ms]</td>
<td>30</td>
</tr>
<tr>
<td>rtpS - FTP</td>
<td>Maximum sustained traffic rate [kbit/s]</td>
<td>256</td>
</tr>
<tr>
<td></td>
<td>Minimum reserved traffic rate [kbit/s]</td>
<td>128</td>
</tr>
<tr>
<td></td>
<td>Maximum latency [ms]</td>
<td>30</td>
</tr>
</tbody>
</table>

Second group of traffic is the VoIP traffic. We have allowed the VoIP traffic to make good use of almost all of the remaining bandwidth (the one not dedicated for the Video conference). The rtpS QoS service has been chosen to set the upper bandwidth limit for the VoIP application. Furthermore, when the VoIP traffic throughput is between the minimum reserved traffic rate and the maximum sustained traffic rate the FTP application has the ability (using the best effort QoS service) can take advantage over the freed up capacity and increase its throughput, even if the maximum sustained traffic rate has been exceeded. When the VoIP application is using its dedicated bandwidth up to its limits the FTP application still has some bandwidth available to continuing its activities in the network.
5 Conclusions and further work

The presented approach for building pico WiMAX base station can be used for the first real deployments. Its main benefit comes from using standard elements that have been roaming the market for a while. Though to build a pico base station, the base station elements and also subscriber station elements are needed.

The proposed approach has been tested by developing a simulation model also presented in this paper. Similarly, also in the simulation only already developed models have been used. The simulation model has been verified and evaluated and is in idle state while waiting to resolve the real network problems.

References:


