Analysis of routing metrics for providing better link utilization in WiMAX using soft computing

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Abstract - Quality of service is a challenging problem in networks that offer multimedia services. WiMAX technology is able to offer multimedia services. Network quality of service for offering multimedia services depends on link utilization: better link utilization improves quality of service in a network. For satisfying QoS requirements in WiMAX technology we should take into consideration the most important metrics that affect directly to the QoS. In this paper we will consider four metrics: required recourses, buffer size packet queues, delay and losses. Those metrics affect directly in link utilization. It is very difficult job to consider three or more metrics simultaneously, but using soft computing this is possible. Fuzzy logic is the main branch of soft computing. We will use intelligent controlling techniques that are based on fuzzy logic for solving different problems in aspect of link utilization. The aim is to obtain better values of link utilization using different rules from Rule Editor and using appropriate defuzzification method. We will use MATLAB software for designing fuzzy logic controller. With MATLAB software we will see which rule (from Rule Editor) and which defuzzification method gives better results in aspect of link utilization.

Key words: quality of service, soft computing, fuzzy logic, defuzzifier, link utilization.

1 Introduction
In the past network applications have used a modest percentage of bandwidth and no one of those applications had QoS requirements. At this time, applications have been routed through network as best effort services. As we know, best effort services are not suitable for multimedia applications [1], [2] [3]. WiMAX networks are designed for supporting different classes of multimedia services that fulfills QoS requirements [4]. This technology (WiMAX) is able to transmit video, voice and real time data. For transmitting multimedia services in WiMAX network it is desired to design some controlling mechanisms for solving different problems in a network [5]. Because of complex nature of controlling mechanisms it is desired to design intelligent controlling techniques. One of the intelligent techniques that would be present in this paper is fuzzy logic controller which is the main branch of soft computing. One important part of fuzzy logic controller is defuzzifier. There are five methods for defuzzification. In this paper the aim is to obtain better link optimization in WiMAX network depending on rules selected in rule editor (Matlab software) and using appropriate defuzzification method. First we will explain WiMAX technology, including here main standards of this technology, MAC layer, security and quality of service. Also we will explain metrics in WiMAX network and their effect in quality of service.

After that, it is made a short description for soft computing. A special attention is paid for the main branch of soft computing – fuzzy logic and design of intelligent controllers based on fuzzy logic. Finally, it is made a simple analysis using rules from Rule Editor (Matlab software) for providing better link utilization in WiMAX technology using COG (Centre of Gravity) as defuzzification method [6].

2 WiMAX technology
IEEE 802.16 is a solution to broadband wireless access, commonly known as WiMAX. Today there are two main WiMAX standards:

1. **IEEE 802.16–2004** – for Fixed Broadband Wireless Access (sometimes referred as IEEE 802.16d), and

These two standards are evolved from the earlier versions of WiMAX standards. First standard IEEE 802.16 specified fixed broadband wireless systems operating in the frequency band 10 – 66GHz, and is only used for LOS transmissions. Another standard is IEEE 802.16a (published in April 2003, an improved version of 802.16) introduces NLOS transmission, adopts OFDM at the PHY layer, and can support lower
frequency band 2-11GHz. This standard also introduces mesh topology in addition to Point-to-Point and Point-to-Multipoint, and adaptive modulation which enable BS to dynamically assign modulation schemes to the subscribers [7]. IEEE 802.16-2004 (published in October 2004) is designed for fixed BWA systems, includes frequency bands 10-66 GHz and 2-11 GHz, and can support multiple broadband services. So far, the most likely spectrum is available at 2.3 GHz, 2.4 GHz, 2.5 GHz, 3.5 GHz, and 5.8 GHz [8]. The goal of this standard is to enable global deployment, and to support interoperability of multivendor BWA products. Some of the features of this standard are:

- The physical layer (PHY) is based on OFDM technique that allow WiMAX to operate in NLOS conditions,
- The peak data rate can be 75Mbps
- Adaptive modulation and coding
- Supports both TDD and FDD duplexing techniques
- Support QoS, due to MAC layer has a connection oriented architecture and can support different applications
- Security
- Is based on all IP network architecture

IEEE 802.16e (published in February 2006) standard add portability and mobility to wireless devices, and also enhance network performance by using OFDMA technique. Compared with IEEE 802.16-2004, this standard can support lower data rate (up to 15Mbps)

**MAC layer** – the WiMAX MAC Layer supports both PMP and mesh operation, and consists of three sublayers (see figure 2) [9][10]:

- **Service specific convergence sublayer (CS)** - Some of the main features of service specific CS are: packet classification, payload header suppression, and support of upper layer protocol.
- **MAC common part sublayer (CPS)** – allocation of bandwidth, connection establishment and maintenance
- **Security sublayer** – provides functionalities like authentication, secure key exchange, and encryption.

**Quality of service** – WiMAX support different applications, such as voice, data, video, and multimedia services. Each of these applications has different QoS requirements [8]. Packet switched technologies are designed only to support non real time traffic such as data, and when they are used to support real time applications (voice and multimedia) delay and jitter may become excessive if the flows of traffic are not controlled. In WiMAX QoS controlled by using connection oriented MAC architecture [11].

![IEEE 802.16 reference model](image)

In order to support different applications WiMAX defines five scheduling services: unsolicited grant services (UGS), real-time polling services (rtPS), non-real-time polling services (nttPS), best-effort service, and extended real-time variable rate (ERT-VR) service. **Security** – the key aspects supporting WiMAX security are: key management protocol PKMv2 (manages MAC security using PKM-REQ/RSP messages), device user authentication using EAP protocol, traffic encryption, and control message protection.

### 3 Routing metrics in WiMAX technology

Routign metrics have a significant role, not just in complexity of route calculation but also in WiMAX QoS. The use of multiple metrics is able to model the network in a more precise way, but the problem for finding appropriate path can become very complex [12][13]. There are 3 types of metrics: additive, multiplicative and concave. They are defined as below: If \( m(n_1, n_2) \) are metrics for link \((n_1, n_2)\). For one path \( P = (n_1, n_2, ..., n_i, n_j) \), metric \( m \) is \((n_1, n_2, ..., n_i, n_j)\):

Let \( d(i, j) \) be a metric for link \((i, j)\).

For any path \( P=(i, j, k, ..., l, m) \), we say that metric \( d \) is additive if:

\[
d(p) = d(i,j) + d(j,k) + ... + d(l,m)
\]

- We say that metric \( d \) is multiplicative if:

\[
d(p) = d(i,j) \times d(j,k) \times ... \times d(l,m)
\]

We say that metric \( d \) is concave if:

\[
d(p) = \min [d(i,j), d(j,k), ... d(l,m)]
\]
WiMAX is able to offer real time services. Thus, it is important to take into consideration some metrics that play a key role in offering those services.

In WiMAX network there are a lot of metrics that we can take into consideration, but in this paper, for sake of simplicity, we will consider four main metrics: required resources, buffer size, delay and losses. Those metrics play a direct role in quality of service in WiMAX network. In order to consider multiple metrics simultaneously, we will use the main component of soft computing, so called fuzzy logic. Controller based on fuzzy logic is called fuzzy logic controller (FLC). FLC is intelligent technique that can manipulate with two or more input parameters simultaneously without any problem.

4 Soft Computing

Soft Computing is more tolerable in uncertainty and partial truth than Hard Computing. The model in which soft computing is based in human mind. The main components of soft computing are: Fuzzy Logic, Neural Networks, Probabilistic reasoning and Genetic algorithms. The most important component of soft computing is Fuzzy logic, which will be part of this paper. Fuzzy logic will be used for a lot of applications. Applications of fuzzy logic in telecommunications networks are recent. Fuzzy Logic is organized into three main efforts: modeling and control, management and forecasting, and performance estimation.

4.1 Fuzzy Logic

Idea for fuzzy logic has born in 1965. Lotfi Zadeh has published one seminar for fuzzy which was the beginning for fuzzy logic [14].

Fuzzy logic is tolerant in imprecise data, nonlinear functions and can be mixed with other techniques for different problems solving. The main principle of fuzzy logic is using fuzzy groups which are without crisp boundaries.

5 Fuzzy Logic Controller

A Fuzzy Logic Controller [15] is a rule based system in which fuzzy rule represents a control mechanism. In this case, a fuzzy controller uses fuzzy logic to simulate human thinking.

In particular the FLC is useful in two special cases:

- When the control processes are too complex to analyze by conventional quantitative techniques
- When the available sources of information are interpreted qualitatively or uncertainly.

Fuzzy logic controller consists of: fuzzifier, rule base, fuzzy inference and defuzzifier.

**Fuzzifier**: A fuzzifier operator has the effect of transforming crisp value to fuzzy sets. Fuzzifier is presented with \( x = \text{fuzzifier}(x_0) \), where \( x_0 \) is input crisp value; \( x \) is a fuzzy set and fuzzifier represents a fuzzification operator.

**Rule-Base (Linguistic Rules)**: Contains IF-THEN rules that are determined through fuzzy logic.

**Example**: if \( x \) is \( A_i \) and \( Y \) is \( B_i \) the \( Z \) is \( C_i \)

Where \( x \) and \( y \) are inputs and \( z \) is controlled output; \( A_i, B_i \) and \( C_i \) are linguistic terms, like: low, medium, high etc.

**Fuzzy Inference**: Is a process of converting input values into output values using fuzzy logic. Converting is essential for decision making. Fuzzy Inference process includes: membership functions and logic operations

**Defuzzifier**: can be expressed by: \( y_{ou} = \text{defuzzifier}(y) \), where \( y \) identifies fuzzy controller action, \( y_{ou} \) identifies crisp value of control action and defuzzifier presents defuzzifier operator. Converting process of fuzzy terms in crisp values is called defuzzification. There are some defuzzification methods: COG (Centre of Gravity), COGS (Centre of Gravity for Singletons), COA (Centre of Area), LM (Left Most Maximum) and RM (Right Most Maximum).

In our case, we will use COG (Centre of Gravity), being one of the most important methods. This method determines the centre of zone that is gained from membership functions with AND and OR logic operators. With formula (1) we can calculate the surface of zone that is shown in figure below and also we can find one central point in this zone. Projecting this point in the abscissa axis determines the crisp value after defuzzification.

![Figure 2. COG method](image-url)
WiMAX metrics and their membership functions

In this case we will use metrics of WiMAX network as input parameters in FLC. Since the main metrics that affect quality of service in WiMAX networks are: required recourses, buffer size packet queues, delay and losses, then those metrics will be taken as input parameters in FLC. For each of those metrics we will use membership functions. Table below shows input parameters of FLC and their fuzzy sets.

<table>
<thead>
<tr>
<th>Inputs of FLC</th>
<th>Fuzzy Sets of these input parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required recourses</td>
<td>{Low, Medium, High} - Mbps</td>
</tr>
<tr>
<td>Delays</td>
<td>{acceptable, tolerable, intolerable} - ms</td>
</tr>
<tr>
<td>Losses</td>
<td>{acceptable, tolerable, intolerable} - %</td>
</tr>
<tr>
<td>Buffer size packet queues</td>
<td>{low, medium, high} - Mbps</td>
</tr>
</tbody>
</table>

Based in table above for fuzzy sets of those input parameters, using MATLAB software we can draw membership functions for those metrics in WiMAX network.

[Input1]
Name='Required_resources'
Range=[0 1000]
NumMFs=3
MF1='low': 'trimf',[-403 -2.65 170.6]
MF2='medium': 'trimf',[123 462 855.8]
MF3='high': 'trimf',[694.4 1000 1400]

[Input2]
Name='buffer_size'
Range=[0 100]
NumMFs=3
MF1='low': 'trimf',[-40 0 17.59]
MF2='medium': 'trimf',[12.6 43.78 71.6]
MF3='high': 'trimf',[62.3 100 140]

[Input3]
Name='Delay'
Range=[0 500]
NumMFs=3
MF1='acceptable': 'trimf',[-200 0 66.8]
MF2='tolerable': 'trimf',[39 244 438.5]
MF3='intolerable': 'trimf',[300 500 700]

[Input4]
Name='Losses'
Range=[0 10]
NumMFs=3
MF1='acceptable': 'trimf',[-4 0 3.108]
MF2='tolerable': 'trimf',[1.47 5 8.399]
MF3='intolerable': 'trimf',[5.78 10 14]

[Output1]
Name='Link optimization'
Range=[0 100]
NumMFs=3
MF1='Low': 'trimf',[-40 0 41.4]
MF2='Medium': 'trimf',[19.7 50 80.29]
MF3='High': 'trimf',[58.33 100 140]

[Rules]
1 1 1 1, 1 (1) : 1
2 -1 2 2, 2 (1) : 1

Using this simple software program, the membership functions as below:

a) Required resources

b) Buffer size
After defining the membership function and input parameters, we also have to define fuzzy rules for relevant parameters. Some of fuzzy rules derived from Rule Editor (MATLAB software) are:

**Rule 1**: IF (RS is Low) and (BS is Low) and (D is Acceptable) and (L is acceptable) THEN (Link optimization is Low=17.7 %)

**Rule 2**: IF (RS is High) and (BS is High) and (D is Acceptable) and (L is Acceptable) THEN (Link optimization is High=81.6 %)-see figure below

The value **81.6** is after defuzzification. Figure below shows in 3 D the surface viewer using COG method for this rule:
Figure 8. 3D view for Rule 2

For both rules, as defuzzification method we have used COG method.

7 Conclusion

In this paper we have analyzed the link optimization in WiMAX network. We have taken into consideration four metrics of WiMAX network in order to find better link optimization. For taking into consideration 3 or more metrics it is hard job, but using soft computing it is possible. In this paper we have used one intelligent controller that is based in fuzzy logic. As input parameters that act in this intelligent controller we took four metrics of WiMAX network. The main part of FLC is defuzzifier that plays a key role for obtaining crisp values in the output. As e defuzzification method we used COG (Centre of Gravity) method. Analysis of these metrics are made with MATLAB software and these analysis show that rule 2 from rule editor shows better results in aspect of link utilization (approximately 81.6%).

References