Analysis of routing metrics for offering IPTV over WiMAX using fuzzy logic

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Abstract- The quality of delivering IPTV services depends on the network QoS and bandwidth of broadband service providers. The possibility to offer high bandwidth capacity of WiMAX technology is attractive to offer IPTV services. There is an increasing trend to deploy WiMAX technology for offering those services. Network QoS for offering IPTV services depends on network efficiency. To satisfy QoS requirements for offering IPTV over WiMAX technology we should take into consideration routing metrics that affect directly to the QoS. Here we will consider three metrics: bandwidth, losses and delays. For transmitting multimedia (in this case IPTV) services over WiMAX it is desired to design some controlling mechanisms for solving different problems in a network in case of packet delays, losses etc. 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. In this paper we will design FLC using Matlab software. As input parameters will be three routing metrics mentioned above, whereas as output parameter will be network efficiency. The aim is to obtain better values of network efficiency using different rules from Rule Editor and using appropriate defuzzification method.

Key-Words: -Routing Metrics, Quality of Service, WiMAX, IPTV, Fuzzy Logic, Defuzzification Method

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]. WiMAX technology is able to transmit video, voice and real time data. WiMAX can be considered as IP access network and is very transparent for packet based core networks. So, WiMAX network can be integrated into one network that is based in IP/MPLS such is NGN network. This integration provides the capabilities (infrastructure, protocols, etc.) for convergence of voice, video and data services into one common network infrastructure. This means that this infrastructure is ready to offer IPTV services. Transmitting IPTV (Internet protocol television) over WiMAX aims to make IPTV services available to users anywhere, anytime and on any device [5] , [6]. To achieve this aim it is needed an advance and very intelligent technology in order to be able to respond the needs of all customers that are located in different locations. Compared to wired access networks, transmitting IPTV services through WiMAX is very challenging because of the error-prone radio channels and limiting capacity. Additionally, there are some problems that can occur during this transmission, especially in aspect of delays, bandwidth and packet losses. Therefore it is desired to design some intelligent controlling mechanisms for solving different problems in a network. In order to design the above mention intelligent mechanisms in this converged network platform we have used fuzzy logic.

In this paper we describe the IPTV technology, including here the centralized architecture. Also we describe the transmission of IPTV services over WiMAX technology. WiMAX technology is explained, including here the main metrics in WiMAX network and their effect in quality of service. After that it is made a short description of WiMAX integration in NGN network in order to offer IPTV services. 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 network efficiency for delivering IPTV over WiMAX technology using COG (Centre of Gravity) as defuzzification method [7].

2 IPTV Technology

IPTV is used to transmit digital television via broadband connections using Internet Protocols. IPTV is designed to send streams of video programming to each costumer. These streams are continuous—each customer can select the stream they want to view. This process is functionally identical to the programming delivered by local broadcasters. [*8*]. IPTV service is transmitted through telephone lines and this is the reason why telephone companies are in the first position for offering IPTV to the customers. Preserving video quality in IPTV networks that rely in copper access lines is a big challenge for operators. Service providers need intelligent mechanisms in core and in distribution networks to offer IPTV services. IPTV service providers receive content in different formats and from different sources. Through IPTV technology all of these formats should be converted in IP format in order to be transmitted to customers as service with high quality in the same IP network.

For offering IPTV services the network should be prepared for supporting some specific protocols for signal stream processing. The main reason for using these protocols is that the bandwidth demands are increasing from day to day. Bandwidth limiting is critical in copper lines. So we need also to use some intelligent compressed techniques that are specified by some international standards for telecommunication. The main techniques for video compression are MPEG [9] (moving pictures expert groups) techniques. Usually, for video compression is used MPEG-2 TS (for transport stream) and MPEG-4 (for aggregated streams). Also it is needed to use audio compression protocols such as MPEG-1 audio, DOULBY digital etc. The equipment in access network must support IGMP snooping.

IPTV technology is based in 4 main layers (figure 1):

- Services (Video head end, internet, VoIP etc)
- Edge/core and aggregation
- Access network and
- Home network

Video head end receives content from different sources and transforms it into appropriate form for transmission through IP network. This content can be mix of national and local TV programs, advertisements, satellite content and interactive video services. Video head end encompass broad range of heterogeneous technologies. Internet and VoIP are not the scope of this paper.

The video head end is comprised from:

- satellite antenna farms which receives broadcast analog and digital TV content,
- terrestrial antennas for receiving national content from different TV providers,
- Cable TV receivers which receive content from CATV providers and live TV content in different formats from studio.

IPTV head end collects different formats of content from different sources and prepares it for transmitting in IP format. The equipments which convert different formats of content into IP format are:

- Video encoders- encode content in MPEG-2 and MPEG-4/H.264 and transmit it into IP network.
- Audio encoders-encode audio in multiple formats MPEG-1, Dolby Digital 2.0 Audio etc.

The edge/core and aggregation nodes are based on feature rich BSR (broadband service routers) and BSA (Broadband service aggregator) supporting all standardized protocols for IP/MPLS/Ethernet networks, guaranteeing QoS and respecting data traffic security for offering triple play services.

Access network: contain nodes which are broadband multiservice access nodes (BSAN). These nodes enable delivering of broadband services (IPTV, HIS, VoIP), with QoS guarantees through wireline (ADSL, FTTH) or wireless (WiMAX) connections.

Home network: contains home equipments (STB, residential Gateways, modems, TV set etc). These equipments enable conversation of IP packet format into analog or digital TV signals.

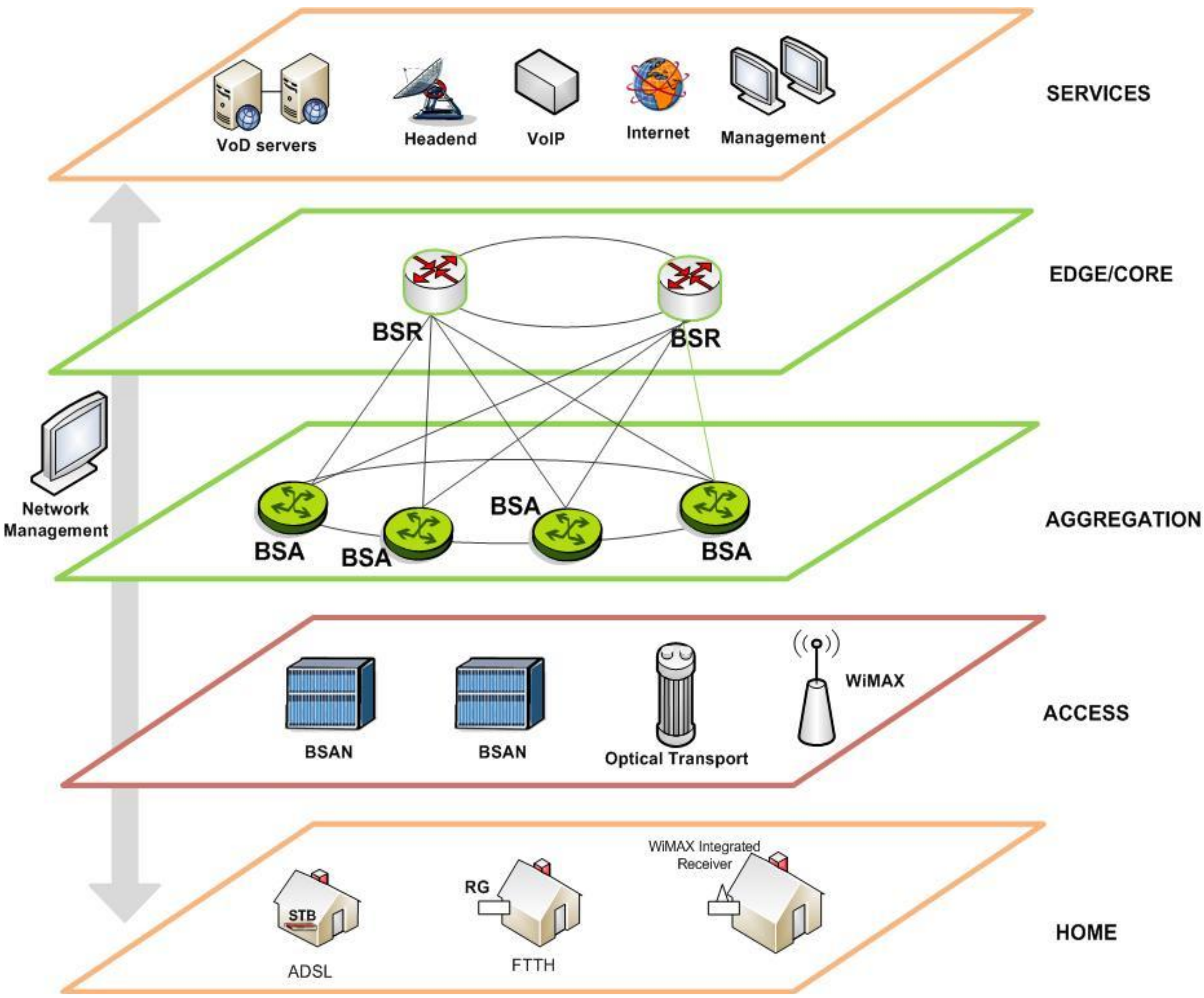


Fig.1- General architecture for offering triple play services

2.1 IPTV services

There are a lot of services that IPTV technology can offer:

- VoD content/movies: Video on demand allows users to select and view to video on demand. VoD content that can be transmitted through IPTV platform includes a library with movie titles, music on demand etc. [10]
- Pay per view or subscribe VoD: service which offers consumers access to one or more VOD movies for a subscription.
- PVR-personal video recorded: The personal video recorded (PVR) must allow the end-user to record broadcast content. The service mimics recording of broadcast TV channels in video cassette recorders (VCR).
- Network PVR- Network recording: NPVR is a PVR service where content is recorded on service provider equipment (VoD servers). Service must be activated per subscriber, and must support quota to limit amount of recorded content.
- Teletext for SD Live TV Channels: contain embedded teletext information (VTI) Picture-in-Picture. The Picture-in-Picture (PIP) service enables the end-user to bring up an additional broadcast channel in an overlay window to create a picture-in-picture.

2.2 IPTV service nodes
In service nodes are located servers which are the main components in technology for providing IPTV services. Video servers perform a lot of functions including here storage, processing and delivery of IPTV services. There are many types of video servers but the most commonly used are: live streaming servers, VOD (video on demand) servers and advertising servers.

- **Live streaming servers**: are characterized with low storage capacity and high processing possibilities. This server supports IPTV broadcast in IP network. This is achieved through one mechanism which has the possibilities to replicate unicast stream into more copy of streams delivering throughout multiple users. Live streaming servers also must have the processing power for channel changing information.

- **VOD servers**: are characterized with high storage and processing capacity. Three main parameters for defining VOD server performances are: content capacity in hours in server library, nominal bit rate of video content and the number of simultaneous streams which support this server. Content in VOD server commonly is stored in well known compressing formats also must support transrating. In the cases when content arrives in other formats, the server has the mechanism to convert in the adequate format. VOD servers must perform four main functions:
  - Storage of content
  - Network interface and Interface for offering multiple simultaneous streams
  - Interactive users support which enables a viewer to pause, rewind and fast-forward video content.
  - Catalog and ordering support

- **Advertising servers:** The advertising server's job is to insert advertisements into video streams at specially indicated times called avails. The result is a video stream delivered to a viewer with specialized advertising inserted **[8]**. Main characteristics of Advertising server are: handle multiple channels simultaneously, the storage capacity is low, the cost is low etc. They must be flexible in changing of advertises and in receiving of video content from different sources. Also they must support advertiser billing.

Digital right management-DRM
Digital rights management (DRM) is a set of software and hardware technologies designed to protect ownership rights of a content provider [8].
DRM System must support Content Protection. This means the protection of content stored in local devices of the user. Content protection must enforce viewing policy of content by defining expiry criteria such as number of plays and expiry date.

STB-Set up box
STB is user equipment which offers access in IPTV services and in network. From network side has Ethernet interface whereas from user side has a number of TV interfaces. STB must to decrypt incoming signals. It must have chipset in order to run decryption, also must have the opportunity to receive IP packets which contain MPEG-4 TS encapsulation and to convert them in video signal which can be displayed in the TV set. STB supports middleware functions. Middleware supports user interface and possibility for navigation of EPG, searching new channels, VoD etc.

3 General IPTV architecture and functional components
There are a lot of architectures for offering IPTV services. Two most common architectures are centralized and distributed. Each of them has the advantages and disadvantages.

Centralized architecture is used from little and middle service providers in small geographical area. The advantages of using this architecture are: less number of equipments for operation and maintenance, network management, user management, low cost for implementing. It is more appropriate for offering multicast IPTV. In this architecture is just one Head end so called Super Head-end (see figure 2). Distributed architecture will not be the scope of this paper.

The disadvantage of centralized architecture is in the case of offering VoD service-unicast, which overload core network

In figure 2 we will present in detail access part of network architecture which is critical in aspect of bandwidth for offering IPTV services.

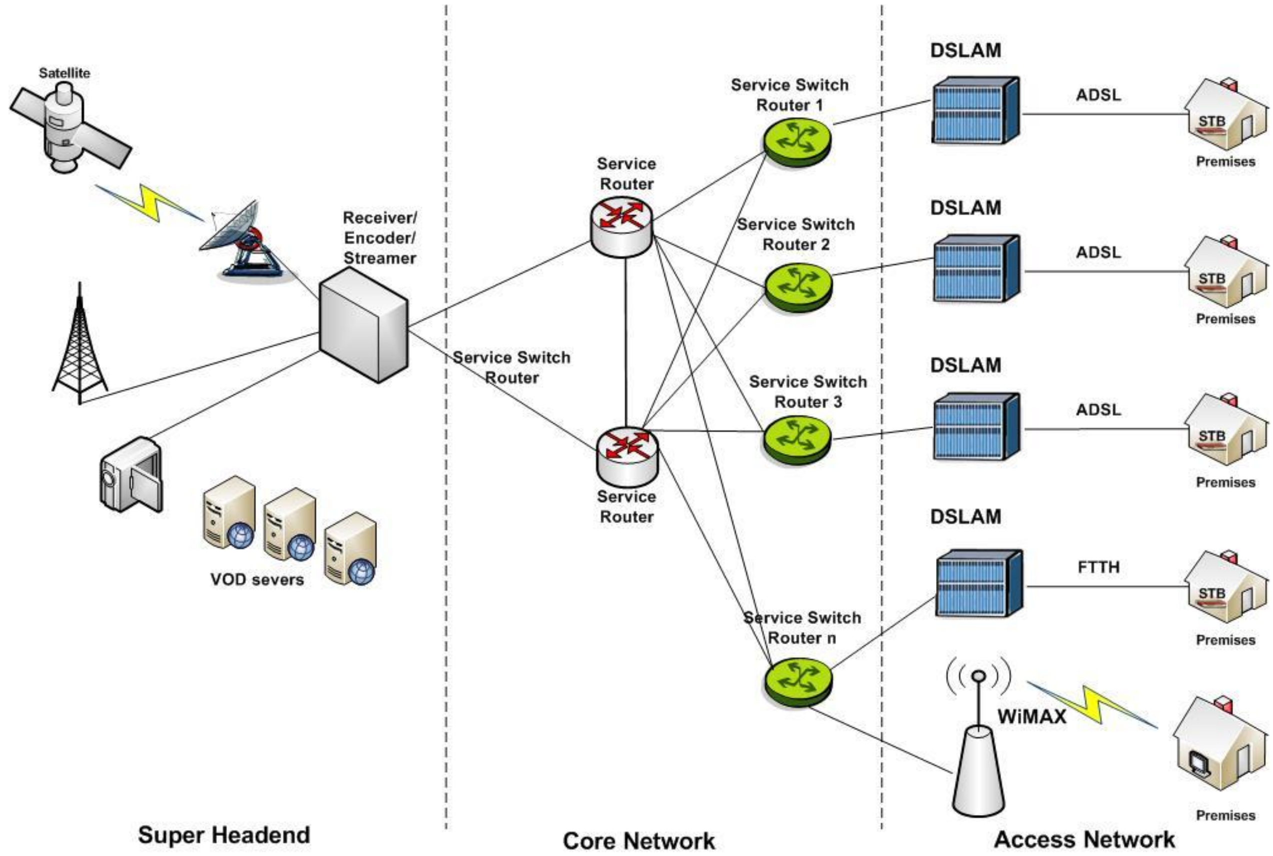


Fig.2- General centralized architecture for offering IPTV services

4 Access networks and bandwidth requirements for offering IPTV services

Operators must deliver broadband services (IPTV, VoIP, HIS-High speed Internet) to any user at any time in the most efficient and cost effective way. To achieve this, operators must use a variety of access technologies including [11]:

- FTTx technology
- DSL technology
- Carrier ethernet
- WiMAX technology

In this paper we will explain in detail the delivery of IPTV over WiMAX access technology.

Bandwidth requirements for offering one TV channel with MPEG-2 compression method are:

MPEG-2 SD 4 Mbps
MPEG-2 HD 18-24 Mbps

Whereas, bandwidth requirements for offering one TV channel with MPEG-4 compression methods are:

MPEG-4 SD 2 Mbps
MPEG-4 HD 8 Mbps

Those requirements for broadband dictate the needs for using broadband access technology. The best case is using FTTH (or FTTU-Fiber to the User). In rural areas this wireline technology is very expensive, so in these areas it is more appropriate to use wireless access broadband technology such as WiMAX.

5 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
2. **IEEE 802.16e–2005** – for Mobile Broadband Wireless Access.

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 [12].

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 [13]. 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 operations, and consists of three sublayers (see figure 3) [14] [15]:

- **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 [13. 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 [16].

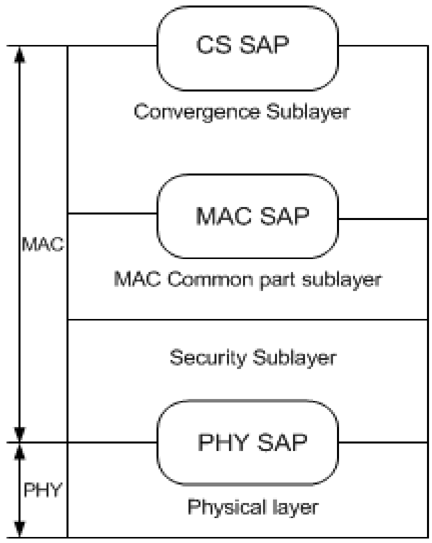


Figure 3 – IEEE 802.16 reference model

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 (nrtPS), 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.

6 WiMAX integration to NGN network and possibility to offer IPTV services

WiMAX is based on IP network. As a result, today many operators around the world are interested to integrate WiMAX in existing networks to facilitate the move to an all IP. Integrating WiMAX in NGN network makes easier to deliver IPTV services over WiMAX. Core network will be based in IP/MPLS and thus will have enough capacity to carry IPTV services. In figure 4 is shown PMP WiMAX scenario supporting different applications such are broadband for residential, small office/home office (SOHO), and small- to medium-enterprise (SME) markets; E1 or fractional E1-like services to businesses, and; wireless backhaul for Wi-Fi hotspots [17].

For an incumbent fixed operator trying to extend their existing network with BWA (Broadband wireless access); most, if not all, of the edge, core and central office equipment would already be in place. The exception would be the possible need to add capacity to support the additional anticipated customers that would be covered by the WiMAX portion of the access network. The wireless portion of the network begins at a fiber node with a WiMAX base station or a wireless point-to-point link to a remotely located WiMAX base station. This wireless backhaul connection must have sufficient capacity to match the WiMAX base station capacity. The backhaul link can be a WiMAX-compliant point-to-point solution or another commercial off-the-shelf point-to-point radio in any frequency band licensed for fixed microwave applications.

To integrate WiMAX into NGN core network we need new hardware and software solution in order to provide QoS control for subscriber services, especially VoIP telephony. Point of Integration to NGN's Edge/Core Network will be BSA (Broadband service aggregator).

BSA should providing 10/100/1000Base-T Ethernet ports, Layer 2 VPN, VLL, VPLS and service-aware Ethernet aggregation as well as IP and MPLS tunneling. They also handle routing with IS-IS, OSPF, RIP, GRE and IGMP protocols.

For MPLS, static and dynamic LSPs are used and LDP and RSVP-TE as signaling protocols.

Each WiMAX base station will have to have a dedicated backhaul transmission with capacity up to 155 Mbps.

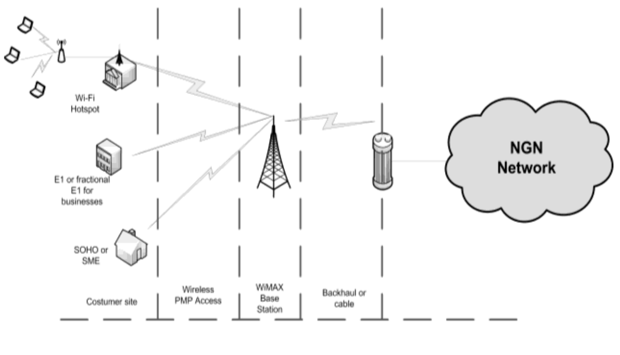


Fig. 4 – WiMAX integration in NGN network for offering IPTV services

7 Routing metrics in WiMAX technology

Routing metrics have a significant role, not just in complexity of route calculation but also in WiMAX QoS, especially when we have to deliver triple play services. 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 [18] [19]. In general 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 d is additive if:

  $$d(p)=d(i,j)+d(j,k)+...+d(l,m) \quad (1)$$

- We say that metric d is multiplicative if:

  $$d(p)=d(i,j)xd(j,k)x...xd(l,m) \quad (2)$$

- We say that metric d is concave if:

  $$d(p)=\min[d(i,j),d(j,k)...d(l,m)] \quad (3)$$

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 three main metrics: bandwidth, delay and losses. Those metrics play a direct role in for delivering triple play services over 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.

8 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 [21].

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.

8.1 Fuzzy Logic Controller

A Fuzzy Logic Controller [21] 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 AND
- 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 $x=fuzzifier(x_0)$, 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; Ai, Bi and Ci 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: $y_{ou} = defuzzifier(y)$, 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.

Fuzzy Logic Controller with all of its components is shown in figure 5.

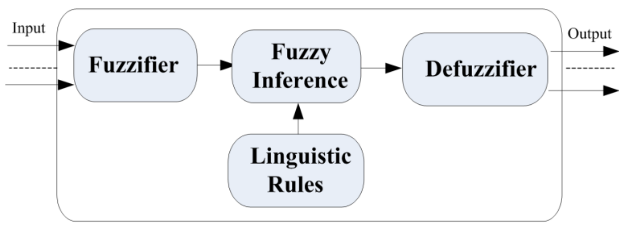


Fig.5- Fuzzy Logic Controller (FLC)

In order to gain better results at the output of the FLC, one important role plays selection of defuzzification method. 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).

Three most important methods are: COG, MOM and LOM. It is important to find which method gives better results in aspect of link efficiency for offering IPTV services over WiMAX network.

8.2 Centre of Gravity

This method determines the centre of zone that is gained from membership functions with AND and OR logic operators. Formula with which we can calculate the defuzzified crisp output U is given:

$$U = \frac{\int_{Min}^{Max} u \;\mu(u)du}{\int_{Min}^{Max} \mu(u)du} \tag{4}$$

Where U is defuzzification result, u = *output variable*, $\mu = membership\ \ function$, *Min=minimum limit for defuzzification*, *Max=maximum limit for defuzzification*

With formula (4) 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 defizzification (figure 6).

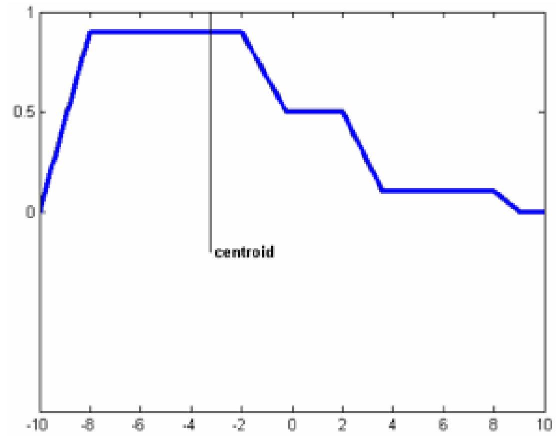


Fig. 6- Centre of gravity (COG) method

8.3 LOM (largest of maximum), MOM (middle of maximum) method

LOM method determines the largest of maximum value in the zone that is obtained from membership functions with AND and OR logic operators whereas MOM method determines Middle of maximum value in that zone.

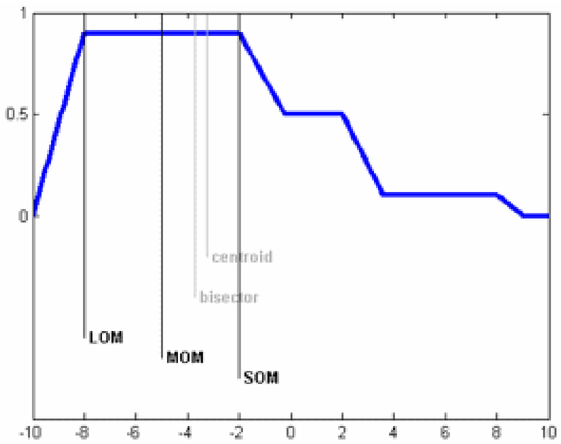


Fig. 7- LOM, and MOM methods

In some cases MOM and LOM (figure 7) methods are better than COG method, but in general, for the most of cases, no matter what zone we will have, COG method shows better results.

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.

9 Analysis of WiMAX routing metrics for offering IPTV and their membership functions

In this case we will use most important routing metrics of WiMAX network as input parameters in FLC. Since the main metrics that affect quality of service in WiMAX networks are: bandwidth, delays and percentage of packet losses, then those metrics will be taken as input parameters in FLC. For each of those metrics we will use membership functions. Table 1 shows input parameters of FLC and their fuzzy sets.

Table 1: Input parameters and fuzzy sets

Inputs of FLC	Fuzzy Sets of these input parameters
Bandwidth	{Low, Medium, High}-Mbps
Delays	{acceptable, tolerable, intolerable}-ms
Losses	{acceptable, intolerable}-%

As output from FLC we will have efficient link utilization in percentage.

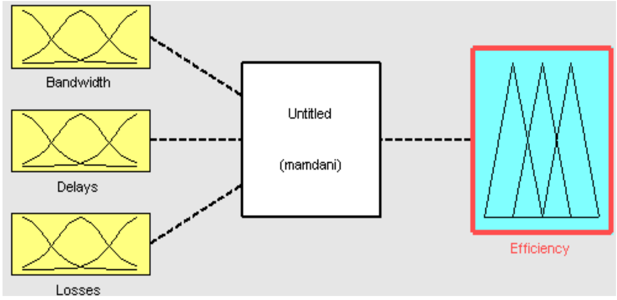


Fig. 8- Mamdani type Fuzzy logic controller

For delivering IPTV services over WiMAX, we need to do a deep analysis of these three metrics that affect directly in the network efficiency. Using membership functions for three abovementioned Metrics allows us to define threshold values for each metric. Also we will define here a set of rules, one rule per each metric, defining thus an acceptable range or a minimum/maximum acceptable value for bandwidth, delays and losses.

Bandwidth: Bandwidth is one the main metrics in WiMAX network. In this case we will define 3 membership functions that show the scale of bandwidth: low, medium and high. Bandwidth is expressed with triangular membership functions.

Delay: is the most important parameter for the most of applications, especially for triple play applications (IPTV). For transmitting one service between two points, delays are one of the most important parameters for QoS guarantee that indicate directly in better link efficiency. For delay we also have defined 3 triangular membership functions to show the scale of delays that can be: acceptable, tolerable and intolerable.

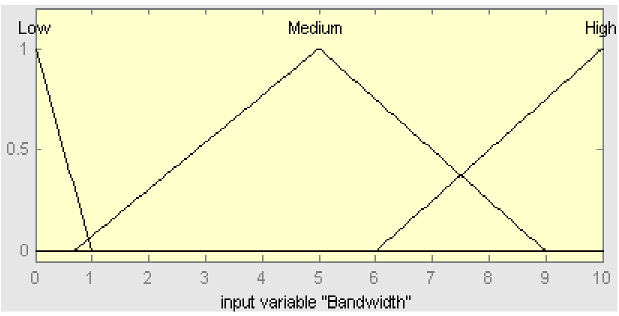
Losses: for delivering IPTV services over WiMAX network, the most critical parameter that we should take into consideration is loss. For losses we have defined 2 membership functions: acceptable and intolerable. When the percentage of packet losses is above 0.1 % then we will have serious problems with quality of figure in IPTV.

Based in table 1 for fuzzy sets of these input parameters, using MATLAB software we can draw membership functions for these metrics in WiMAX network.

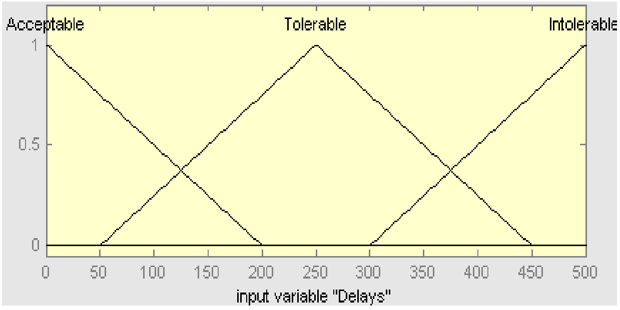
```
[System]
Name='WIMAX link optimization for delivering IPTV'
Type='MAMDANI'
Version=2.0
NumInputs=3
NumOutputs=1
NumRules=9
```

AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='max'
DefuzzMethod='COG'
[Input1]
Name='Bandwidth'
Range=[0 10]Gbps
NumMFs=3
MF1='low':'trimf',[-1 0 1]
MF2='medium':'trimf',[0.6746 5 9]
MF3='high':'trimf',[6 10 14]
[Input2]
Name='Delay'
Range=[0 500]
NumMFs=3
MF1='acceptable':'trimf' [-200 0 200]
MF2='tolerable':'trimf', [50 250 450]
MF3='intolerable':'trimf', [300 500 700]
[Input3]
Name='Loss'
Range=[0 100]
NumMFs=2
MF1='acceptable:'trimf' ,[-0.2 0 0.2]
MF2='intolerble':'sigmf', [18 0.3]
[Output1]
Name='Network efficiency'
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

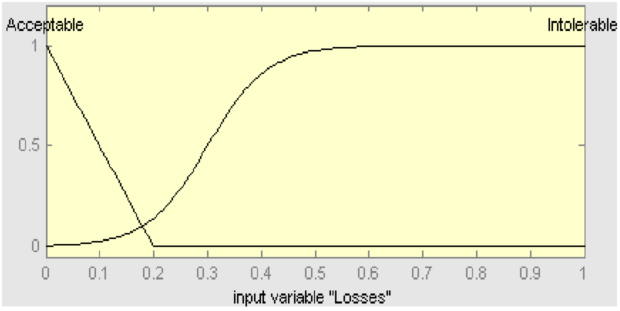
Using this simple software program, the membership functions are shown in figure 9.



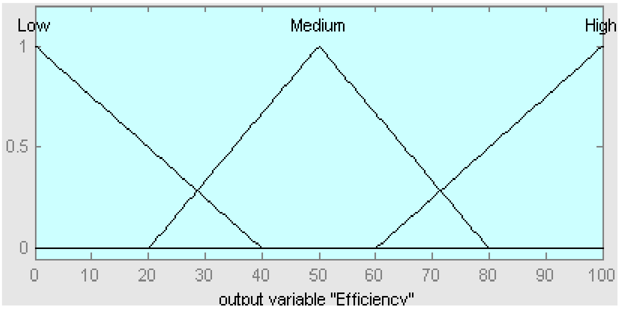
a) Bandwidth (Gbps)



b) Delays (ms)



c) Losses (%)



d) Network Efficiency (%)

Fig. 9- Membership functions for: a) bandwidth, b) delays, c) losses and d) network efficiency

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 (Bandwidth is Low) and (Delays is Acceptable) and (Losses is Acceptable) then (Efficiency is Low)
Rule 2: If (Bandwidth is Medium) and (Delays is Acceptable) and (Losses is Acceptable) then (Efficiency is Medium)
Rule 3: If (Bandwidth is High) and (Delays is Acceptable) and (Losses is Acceptable) then (Efficiency is High)

Rule 4: If (Bandwidth is High) and (Delays is Tolerable) and (Losses is Acceptable) then (Efficiency is High)
Rule 5: If (Bandwidth is High) and (Delays is Tolerable) and (Losses is Intolerable) then (Efficiency is Medium)
Rule 6: If (Bandwidth is High) and (Delays is Intolerable) and (Losses is Intolerable) then (Efficiency is Low)
Rule 7: If (Bandwidth is Low) and (Delays is Intolerable) and (Losses is Intolerable) then (Efficiency is Low)
Rule 8: If (Bandwidth is Medium) and (Delays is Intolerable) and (Losses is Intolerable) then (Efficiency is Low)
Rule 9: If (Bandwidth is High) and (Delays is Intolerable) and (Losses is Acceptable) then (Efficiency is Medium)

We will take into consideration just some of those rules.

Rule 1: If (Bandwidth is Low) and (Delays is Acceptable) and (Losses is Acceptable) then (Efficiency is Low)

If we take fuzzy values for bandwidth –Low (542 Mbps), delays-acceptable (33.1 ms), losses-acceptable (0.0542 %), then we will see that network efficiency is 15.6 % (Low). These values are after defizzification. We can see this graphically with rule viewer in MATLAB in figure 10.

Fig. 10 – Rule viewer in Matlab for rule 1

Rule 4: If (Bandwidth is High) and (Delays is Tolerable) and (Losses is Acceptable) then (Efficiency is High)

If we take fuzzy values for bandwidth –High (8.98 Gbps), delays-Tolerable (286 ms), losses-acceptable (0.114 %), then we will see that network efficiency is 84.1 % (High). These values are after defizzification. We can see this graphically in figure 11.

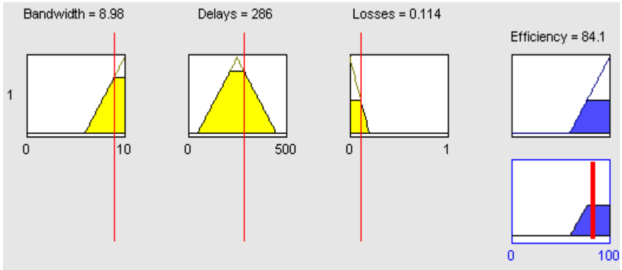


Fig. 11- Rule viewer in Matlab for rule 4

Rule 5: If (Bandwidth is High) and (Delays is Tolerable) and (Losses is Intolerable) then (Efficiency is Medium)

If we take fuzzy values for bandwidth –High (8.98 Gbps), delays-acceptable (298 ms), losses-acceptable (0.382 %), then we will see that network efficiency is 50 % (Medium). We can clearly see that for delivering IPTV services over WiMAX network, the most critical parameter that we should consider is “losses”. From the figure we can see that even bandwidth is high and delays are acceptable, when losses are above the acceptable limit we will not have high network efficiency. These values are after defizzification. We can see this graphically in figure 12.

Fig. 12 – Rule viewer in Matlab for rule 5

For those rules we have used COG method as defuzzification method, because this method is proved that is more effective than the other methods for all the forms of membership functions.

10 Conclusion

In this paper we have presented a platform deployment model for delivering IPTV services over WiMAX technology. In particular, we have discussed the challenges for delivering IPTV over WiMAX. These include the challenges in routing metrics that affect directly in the QoS. Quality of service is considered the most important criteria for delivering real time sensitive applications; such are IPTV services, over an IP/MPLS network. In this

paper we have analyzed the network efficiency in WiMAX network for offering IPTV services. We have taken into consideration three metrics of WiMAX network in order to find better network efficiency. For taking into consideration 3 or more metrics it is hard job, but using fuzzy logic it is possible. In this paper we have used one intelligent controller that is based in fuzzy logic, so called fuzzy logic controller (FLC). As input parameters that act in this intelligent controller we took bandwidth, delays and losses. 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. We have consider 3 of 9 rules from Matlab editor. By choosing rule 1 we have seen that when bandwidth is low, delays are tolerable and losses are acceptable then the network efficiency will be Low. In rule 4 we have seen that when bandwidth is high, delays are tolerable and losses are acceptable then network efficiency is High. Also, the rule 5 shows that if bandwidth is High, delays are tolerable and losses are intolerable the network efficiency is Medium.
Analysis of these metrics are made with MATLAB software and these analysis show that if the losses are bigger that 0.1% we will have problems in QoS. So we can see that this parameter is very critical for QoS. But, also the two other parameters are very critical for QoS.

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