THE INVESTIGATION OF OPTICAL – WIMAX HYBRID ACCESS NETWORK

Lina Narbutaitė

Rasa Brūzgienė

Tomas Adomkus

Mindaugas Ruočkus

Stasys Kaseta

Kaunas University of Technology
Department of Telecommunications
Studentų str. 50-452, Kaunas, Lithuania, LT- 51368
E-mail: rasa.bruzgiene@ktu.lt

Abstract

Optical – WiMAX network provides the transfer rate in a different level, which shows an appropriate hierarchy of the capacity. The integration of Optical network with WiMAX is regarded as a promising solution for the access in realizing the convergence over fixed and mobile networks. The integration of Optical – WiMAX hybrid access network allows the allocation of the connecting bandwidth and a packet transfer scheduler, that better supports quality of service and improves the bandwidth of the network. The complementary features of such network can bring the economic efficiency to the network providers also. Therefore, the task of this paper is to investigate the traffic of services in the hybrid ONU/BS unit of the access network, evaluating the effect to the services of different type flows, which are provided over the Optical – WiMAX hybrid access network. Due to this, the mathematical model was created and the hybrid ONU/BS unit was divided into two parts: the unit of the optical network and the base station. The service's time in ONU/BS was estimated using the formation and description system of M/M/n/n/n for the queues of non-preemptive and preemptive priorities. The QoS parameters of uplink and downlink traffic of services in the hybrid ONU/BS unit was analysed using the created model in the environment of Java Modelling tool. The method of selection the queuing behaviour in the QoS scheduling, when the incoming traffic is dependent on the different distribution of the various classes of the services are as the result of this investigation.

1. INTRODUCTION

The hybrid optical – WiMAX network is a broadband network with a wide bandwidth and network coverage, the high reliability of the quality of service (QoS), the more cost effective network deployment and the lower prices of the network operating [1]. The integrated architectures of the hybrid optical – WiMAX network are based on the broadband antennas. Their base stations are sending the same wireless signals to mobile stations at the same time within the coverage areas [2]. Optical and WiMAX networks provide the transfer rate in different levels. The integration of these networks allows to combine the allocation of the transmission bandwidth and the planning of the packets transmission. This affects the higher QoS and improves the network throughput [3]. However, such processes as the control, data transmission or management [3,4] increase the impact of the hybrid network's parameters to the provision of the services of different types. The search of solutions for the effective management of these processes is a subject to a various investigations for the dependence of the network parameters, such as: the probability for the packets loss versus load [5]; the power use versus data bandwidth [6]; the packets' delay versus the transmission bandwidth [7] and traffic load, when the duration of the cycle (CT) is different [8]. Nevertheless, the main problem is the gateway ONU/BS node, which affects the processes of the control, data transmission or management. The hybrid ONU/BS node influences the processing time of the services at the user's side.

Due to this, the investigation of the traffic of services in the hybrid ONU/BS node, evaluating it impact to the processing time of the services of different type flows in the optical – WiMAX hybrid access network are presented in this paper.

2. THE PROPOSED ALGORITHM FOR THE INVESTIGATED ONU/BS OPERATION IN THE HYBRID OPTICAL – WIMAX ACCESS NETWORK

The integration of the hybrid optical – WiMAX access network nodes can be in different variants

(Fig. 1). The variant, when the optical network unit (ONU), WiMAX base station (BS) and the connection controller (CC) is in one place, was selected for the investigation. The optical network was the Ethernet passive optical network (EPON). The network management is centralized, because the optical line terminal (OLT) manages the flows from the subscribers' stations (SS) and the data transmission of WiMAX network. The quality parameters of the different services strongly depend on the processes of such management.

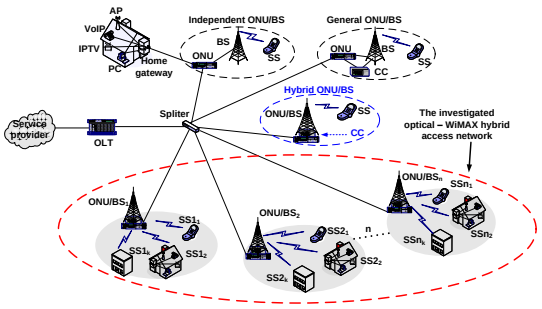

Figure 1. The structure of ONU/BS nodes in the investigated hybrid EPON – WiMAX access network

The relation between the centralized management of the data flows in the hybrid EPON – WiMAX network and QoS classification is presented in Fig. 2.

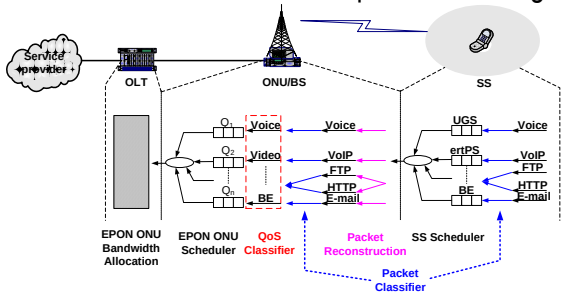

Figure 2. The relation between the centralized management of the data flows in the hybrid network and QoS classification

According to the centralized management of the data flows in the hybrid EPON – WiMAX network the authors proposed the algorithm for the effective ONU/BS operation (Fig. 3). First, the subscribers' stations (SS) create a log queries over WiMAX generator. The WiMAX requests' aggregator collects all these queries using the messages of the bandwidth requests. Then the queries are sent to the ONU/BS and classified according to the five classes of QoS: the unsolicited grant service (UGS), the extended real time polling service (ertPS), the real time polling service (rtPS), the non-real time polling service (nrtPS), the class of best effort (BE). The classification depends on the bandwidth management table (BMT).

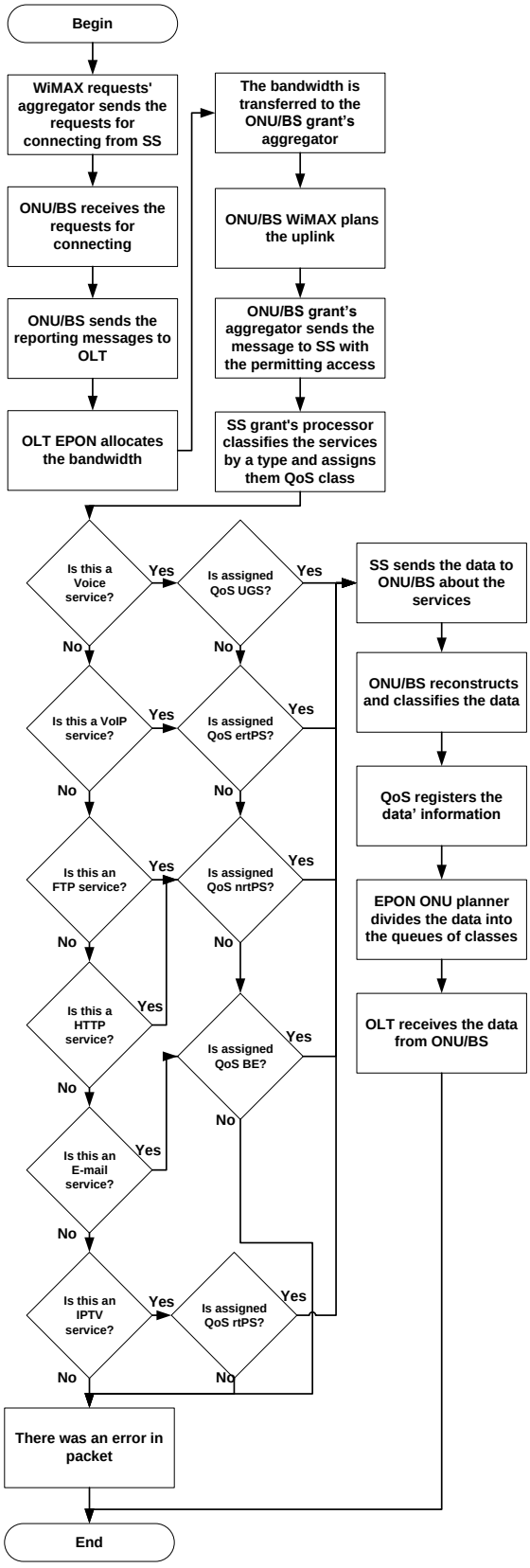

Figure 3. The proposed algorithm of ONU/BS operation in the hybrid EPON – WiMAX access network

The EPON services' classes have given bandwidth, which is transmitted using the GATE messages into the EPON grant processor. When the bandwidth is assigned to the ONU/BS, the scheduling of WiMAX uplink provides the bandwidth to the subscribers'

stations according to the BMT instructions. The uplink data transmission and the classification of the different types of services are executed in the subscribers' stations (SS). The planned data traffic from UGS to BE reaches only the ONU/BS node. The data is multiplexed into the queues' priorities after the quality classification. EPON ONU planner transmits the data traffic with the QoS records to the OLT. At the end of the transmission, the data traffic is transmitted from the SS directly to the OLT, thus reducing the delay of the data packets transmission.

3. THE MATHEMATICAL MODEL FOR THE HYBRID ONU/BS NODE

The mathematical model of the hybrid ONU/BS was created in order to evaluate the processing delay of the data packets in this node. The proposed algorithm for the delay evaluation of the packets transmission is presented in Fig. 4. The model is applied for the hybrid ONU/BS of the centralized planning. The mechanism of the centralized planning starts later than the packets leave the ONU/BS node. In this case, the instantaneous transfer of the data is approaching during the cycle or a frame. All reservation of the bandwidth is performed through the SS and the ONU/BS. The duration of the cycle (CT) or the frame (FT) varies from 2 ms to 5 ms [8]. The packets' delay T of the hybrid optical – WiMAX access network can be calculated [8]:

$$T = T_{poll} + T_{grant} + T_{queue}; \qquad (1)$$

here T_{poll} – the time between the packet arrival and the next request from ONU; T_{grant} – the time between the request from ONU and the permission from OLT; T_{queue} – the queuing delay after the permissions from OLT.

The time between the packet arrival and the next request from ONU is evaluated using

$$T_{poll} = \frac{T_{\max}}{2}; \qquad (2)$$

here T_{max} is the maximum polling during the cycle (3).

$$T_{\max} = N^{\frac{ONU}{BS}} \cdot \left(G + \frac{W_{\max}}{R} \right); \qquad (3)$$

here $N^{\frac{ONU}{BS}}$ marks the number of ONU and BS; G is the guard time between the transmission windows; W_{max} is the maximum size of the transmission window; R is the uplink transmission rate of EPON.

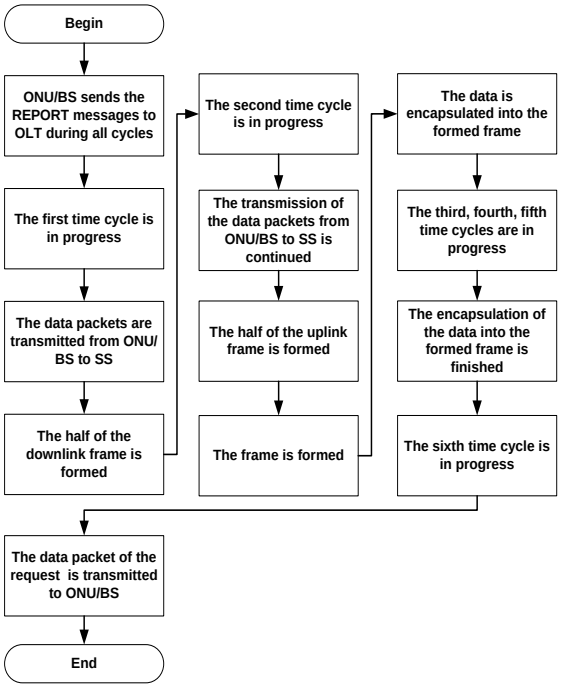

Figure 4. The proposed algorithm for the delay evaluation of the packets transmission

4. THE INVESTIGATIONS OF THE PROCESSING TIME OF UPLINK AND DOWNLINK DATA TRAFFIC OF THE DIFFERENT SERVICES

The simulation tests of the processing time evaluation of uplink and downlink data traffic of the different services were carried out using the software of Java Modelling Tools v.0.8.0. The structure of the simulated uplink hybrid ONU/BS node is presented in Figure 5 and the structure of the simulated downlink hybrid ONU/BS node - in Fig. 6. The characteristic, that was analyzed, is the delay analyzed as the dependence of the services' processing time on the load of the ONU/BS.

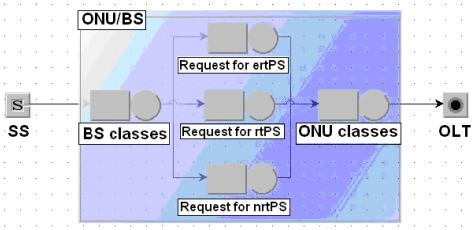

Figure 5. The structure of the simulated uplink ONU/BS

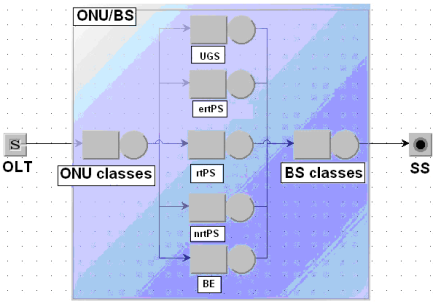

Figure 6. The structure of the simulated downlink ONU/BS

The uplink ONU/BS is when the users send the requests for the service to the OLT. The downlink ONU/BS is when the OLT transmits the services to the users. The investigation of the hybrid optical – WiMAX access network was carried out in two ways: a) when there is one hybrid ONU/BS node in the network; and b) when there are N hybrid ONU/BS nodes in the network. The initial data, used in simulation, are presented in Table 1. The investigation of one hybrid ONU/BS node in the network was carried out when the intensity of the data packets' flow λ was described in the different laws of the different types of services: the exponential distribution – for the UGS and ertPS; the Pareto distribution – for the rtPS and nrtPS; the burst normal distribution – for the BE services.

Table 1. *Parameters used in simulation*

Parameter	Value
The number of ONU/BS nodes *N*	16
The guard time *G*	5 μs
The maximum size of the transmission window W_{max}	750 B
The uplink transmission rate of EPON *R*	10 Mbps
The duration *CT*	5 ms
The length of the queue *Q*	600 packets
The length of the waiting permission W_P	250 B
The intensity of the data packets' flow λ, packets/s	UGS – 10 ertPS – 15 rtPS – 25 nrtPS – 15 BE – 35
The intensity of the processing of data packets' flow μ, packets/s	UGS – 550 ertPS – 550 rtPS – 550 nrtPS – 750 BE – 750

The intensity of the processing of data packets' flow μ was described in the exponential distribution with the limited capacity of the buffer.

The results of this investigation are presented in Figures 7 and 8.

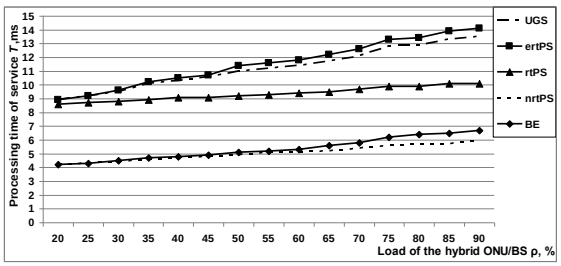

Figure 7. The service's processing time versus the load of ONU/BS in the uplink

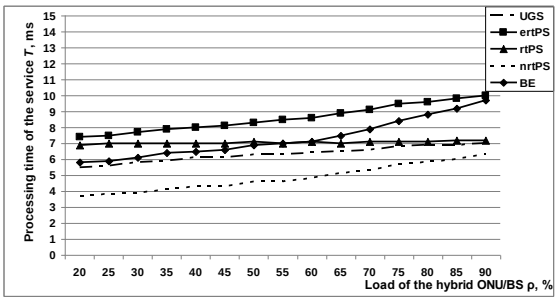

Figure 8. The service's processing time versus the load of ONU/BS in the downlink

According to the results from Fig. 7 and Fig. 8, it can be seen, that the uplink delay is longer than the downlink delay, except the BE service. The average processing time of the uplink services is longer in 1.9 times for UGS service, 1.4 times for ertPS and rtPS services, 1.1 time for nrtPS service in comparison with the downlink. The average processing time of the uplink service is shorter in 0.7 times only for BE. The processing time of BE service in the downlink ONU/BS varies from 5.8 ms to 9.7 ms, according to the load of the ONU/BS.

The results of the investigation, when there were N hybrid ONU/BS nodes in the network, are presented in Figures 9 and 10.

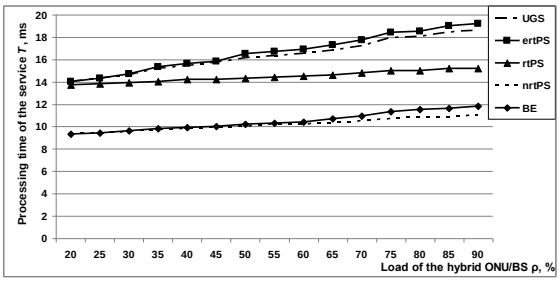

Figure 9. The service's processing time versus the load of ONU/BS in the uplink

According to the results in Fig. 9 – 10, when there are 16 hybrid ONU/BS nodes, it can be stated, that the uplink delay is longer than the downlink delay, except the BE service. The average processing time of the uplink is longer in 1.5 times for UGS service, 1.3 times for ertPS, and rtPS services; 1 time for nrtPS service in comparison with the downlink. It is shorter in 0.8 times for BE service.

The processing time of BE service in the downlink ONU/BS varies from 10.9 ms to 14.8 ms.

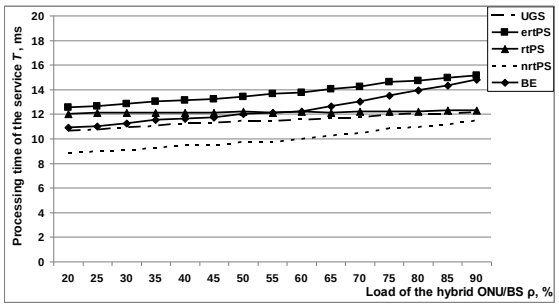

Figure 10. The service's processing time versus the load of ONU/BS in the downlink

5. CONCLUSIONS

In this paper, the authors investigated the optical – WiMAX hybrid access network and proposed the algorithm of the effective ONU/BS operation in this network. According to the obtained results, it can be stated, that using the proposed algorithm for the ONU/BS operation:

- the processing time in ONU/BS of rtPS and ertPS services are 29% shorter in the downlink than uplink, when was investigated one hybrid access node in the network;
- the processing time in ONU/BS of rtPS service is 19% shorter and the processing time of ertPS service – 21% shorter in the downlink compared with the uplink, when was investigated 16 hybrid access nodes in the network.

The obtained results of the investigation allow to state, that the proposed algorithm for the operation of the hybrid ONU/BS node enables to process more effectively the users' requests for the real – time services, such as VoIP or video, even with the increasing load of the access node in the hybrid optical – WiMAX network.

References

[1] Shumao Ou, et al. "A control bridge to automate the convergence of passive optical network and IEEE 802.16 (WiMAX) wireless network", Proceedings of the 5 International Conference on Broadband Communications, Networks and Systems, September, 2008.

[2] Kim, Min-Gon., et al. "Distributed antenna-based EPON-WiMAX integration and its cost-efficient cell planning", IEEE Journal on Selected Areas in Communications, vol. 28, no. 6, South Korea, 2010, pp. 808 – 817.

[3] Gangxiang Shen, Rodney S. Tucker, Chang-Joon Cha. "Fixed Mobile Convergence Architectures for Broadband Access: Integration of EPON and WiMAX", IEEE Communications Magazine, vol. 45, no. 8, Melbourne, 2007, pp. 44 – 50.

[4] Chowdhury, P., *et al*. "Hybrid wireless-optical broadband access network (WOBAN): prototype development and research challenges", IEEE Network, vol. 23, no. 3, California, 2009, pp. 41 – 48.

[5] I-Shyan Hwang, Jhong-Yue Lee. "Performance Study of Homogeneous Uplink Scheduling in Hybrid ONU-BS Architecture", Proceedings of the International MultiConference of Engineers and Computer Scientists, March, 2011.

[6] Ghazisaidi, N., Maier, M. "Fiber-Wireless (FiWi) Networks: A Comparative Techno-Economic Analysis of EPON and WiMAX", Proceedings of IEEE GLOBECOM, November and December, 2009.

[7] Ranaweera, C. "Quality of service assurance in EPON-WiMAX converged network", Proceedings of the International Topical Meeting on Microwave Photonics, October, 2011.

[8] Bokrae Jung, et al. "Centralized Scheduling Mechanism for Enhanced End-to-End Delay and QoS Support in Integrated Architecture of EPON and WiMAX", Journal of Lightwave Technology, vol. 28, no. 16, South Korea, 2010, pp. 2277 – 2288.