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### A REAL-TIME MULTIMEDIA APPLICATION STUDY IN LMDS NETWORKS USING MPLS

#### ABSTRACT

Several wireless networking solutions have been developed to provide different types of services for various end user applications. Due to the success of ATM and IP technology in the information technology area. Local Multipoint Distribution Service (LMDS) is a broadband wireless access (BWA) networking solution.

In this paper, an LMDS (Local Multipoint Distribution System) over MPLS (Multi-Protocol Label Switching) network for real-time multimedia applications is introduced. LMDS-MPLS network model is realized and simulated by using OPNET 9.0 simulation package. The simulation results are obtained for sample voice, video, data and non-critical data traffics under varying network load conditions. Analysis of the end-to-end delay results is also presented.

**Keywords:** LMDS, MPLS, Broadband Communication, Multimedia Application, TDMA/FDD

### MPLS KULLANARAK LMDS AĞLARDA GERÇEK ZAMANLI ÇOKLU ORTAM UYGULAMASI

#### ÖZET

Son kullanıcılar için farklı hizmet sınıflarını sağlamak üzere farklı kablosuz ağ çözümleri geliştirilmiştir. Bu amaçla bu teknolojik alanda ATM ve IP teknolojileri başarılı olmuştur. Yerel Çok Noktalı Dağıtım Sistemi (LMDS) geniş bant kablosuz erişim (BWA) bir ağ çözümüdür.

Bu çalışmada çoklu ortam uygulamaları için MPLS üzerinden LMDS ağ uygulaması gerçekleştirilmiştir. LMDS-MPLS ağ modeli OPNET 9.0 benzetim paket kullanılarak simüle edilmiş ve gerçekleştirilmiştir. Çeşitli yük durumlarında örnek ses, video, veri ve kritik olmayan veri trafikleri için benzetim sonuçları elde edilmiştir. Uçtan uca gecikme sonuçları analiz edilmiş ve sunulmuştur.

**Anahtar Kelimeler:** LMDS, MPLS, Geniş bant iletişim, Çoklu ortam Uygulaması, TDMA/FDD

## 1. INTRODUCTION (GİRİŞ)

Multi-Protocol Label Switching (MPLS) is a new packet-forwarding scheme. Packets are assigned labels at the ingress label switched router (LSR) of an MPLS domain. The packets are based on the labels. In an MPLS network, a core LSR examines only the label when forwarding the packet and the IP packet header analysis is done only once at the edge router when the packet enters the network. MPLS enables end-to-end, high-performance implementation of the MPLS standard across backbone networks. It plays an important role in routing, switching, and forwarding of packets through the next-generation networks to meet the service demands of the users [1 and 2]. Using the advantages of MPLS in forwarding, it is possible to better handle congested networks, where in the MPLS domain both ingress and egress routing information is utilized.

Local Multipoint Distribution Service (LMDS) is a broadband wireless access (BWA) networking solution. Microwave Multipoint Distribution Systems (MMDS) and Local Multipoint Distribution Systems were originally developed for digital TV broadcasting and later extended to offer interactive services for homes and businesses. LMDS, standardization efforts for wireless systems are maintained by ATM forum, DAVIC (Digital Audio Video Council), ETSI (European Telecommunications Standards) and ITU (International Telecommunications Union). In March 1999 IEEE 802 LAN/MAN standards committee establish 802.16 working group on broadband wireless access systems. Most of the researches doing by this group are employed ATM cell as a basic transport unit [3, 4, 5 and 6].

The paper describes MPLS briefly in Section II and LMDS in Section III. Multiple Access and Duplexing Schemes is explained in Section IV. Sections V present the computer modeling of the LMDS-MPLS for transferring multimedia traffics followed by the simulation results, and comparative performance analysis, respectively.

## 2. RESEARCH SIGNIFICANCE (ÇALISMANIN ONEMI)

LMDS, for the location of the home and small business digital subscriber lines (xDSL) such as an alternative to wired solutions can be applied and xDSL, cable similar to coaxial cable and fiber technologies compete. This new technology service providers, Internet access, VPN and multimedia applications, and also to take into quickly integrated with the ATM infrastructure, Quality of Service (QoS) and Class of Service (CoS) for different types of services to provide recognizes the opportunity. Respond to needs of high bandwidth multimedia applications can be granted to the required capabilities and capacities of LMDS systems are increasing continuously. Models can be created with fiber and xDSL technology, especially with Internet access and corporate VPN applications may be economical and efficient communication technology.

## 3. MULTI-PROTOCOL LABEL SWITCHING-MPLS (ÇOK PROTOKOLLU ETİKET ANAHTARLAMA)

Recently, as Internet and its services grow rapidly, a new switching mechanism, Multi-protocol Label Switching (MPLS), has been introduced by IETF. MPLS by overlying IP and simplifying backbone of wide-area IP networks is a high speed technology. It substitutes conventional packet forwarding within a network, or a part of network, with a faster operation of label look-up and switching [7].

MPLS uses the control-driven model to initiate the assignment and distribution of label bindings for the establishment of Label Switched Paths (LSPs). An LSP is created by concatenating one or more label switched hops, allowing a packet to be forwarded from one label-

switching router (LSR) to another LSR across the MPLS domain. The MPLS network architecture consists of label switching routers (LSR) in the core of the network, and label-edge routers (LER) at the edge. The label-edge routers have the task of analyzing the IP header of each packet arrived, in order to find the corresponding forwarding equivalence class (FEC) and label-switched path, which facilitates the label swapping function in the LSR nodes [7].

MPLS is an accelerated data transmission technology that uses a method of label lookup. A short, fixed-length label is appended/swapped to the packets that traverse through an MPLS domain. Once that packet reaches the destination edge of the network, the label is stripped away.

Each MPLS packet has a header that contains a 20-bit label, a 3-bit Experimental field, a 1-bit label stack indicator and an 8-bit TTL field in a non-ATM environment, and holds only a label encoded in the VCI/VPI field in an ATM environment (Figure1) [8].

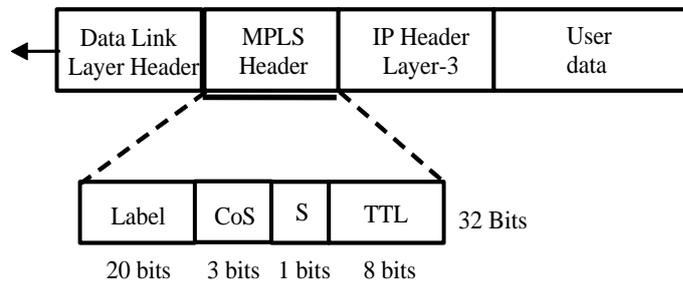


Figure 1. MPLS Header  
(Şekil 1. MPLS başlığı)

MPLS routing has several advantages over ordinary IP routing: [9, 10 ve 11].

- Packets of any type can be routed.
- Packets are routed very quickly by merely swapping their input label to the output label, the same mechanism used by ATM switching.
- More than one path can be established between an entrance and an exit router.
- Multiple paths can be used for traffic load balancing.
- Different paths can be used for different types of priority traffic.
- Different paths can be used for path diversity when avoiding rain fades.

#### 4. LOCAL MULTIPOINT DISTRIBUTION SYSTEM-LMDS (YEREL ÇOK NOKTALI DAĞITIM SİSTEMİ)

LMDS, operates at frequencies above 20 GHz (related to license in countries for example 28, 38 or 40 GHz) which provides 1,3 GHz bandwidth a broadband wireless point to multipoint communications system. Services providers using these frequencies to customer provide up to 38 Mb/sec continuous data transfer. These systems provide reliable digital two-way voice, data, Internet and video services. LMDS, setup has a central facility with a fiber-linked PSTN and internet connections relay signal via point to point microwave links which in turn pass the signal along to hubs, located on rooftops or as stand-alone towers, for point to multipoint transport to the end site. The customer premise equipment may attach to network using TDMA, FDMA

or CDMA [3, 12 and 13]. Basically, four parts in the LMDS architecture are;

Figure 2 shows a typical configuration of the LMDS system.

1. Network operations center (NOC).
2. Fiber based infrastructure.
3. Base station (BS).
4. Customer Premise Equipment and NOC designs.

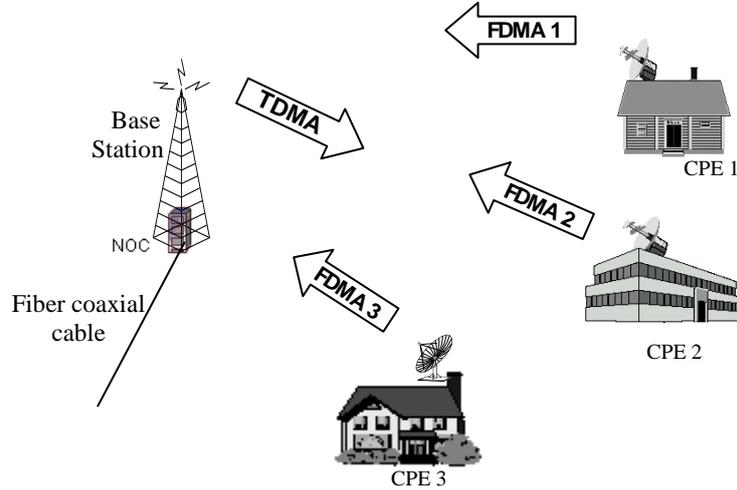


Figure 2. Typical LMDS architecture  
 (Şekil 2. LMDS ağ mimarisi)

LMDS cells are connected together by a core or backbone network. This is based on a mesh of logical ATM paths, VCs (Virtual Circuits) that provide interconnectivity and also provide some quick routes for priority traffic. The network also provides Quality of Service (QoS) guarantees based on the traffic class in the Type of Service (TOS) field of the IP header. All data traffic goes through the Base Station (BS), and because of that BS can control the allocation of bandwidth on the radio channel. The Fixed Broadband Wireless Access systems are Bandwidth on Demand (BoD) systems, which means that Subscriber Stations have to request the bandwidth, which is then scheduled and allocated according to the agreed traffic and QoS parameters by the BS [10 and 14].

Table 1. Capacity comparison of some available access technologies  
 (Tablo 1. Kullanılabilir bazı erişim teknolojileri kapasite karşılaştırmaları)

Type	Uplink data rate	Downlink data rate	Max. Range (km)
Analogue modem	14.4-33.6	14.4-33.6 kb/s	-
ISDN	128 kb/s	128 kb/s	-
ADSL	384 kb/s-640 kb/s	2 Mb/s-6-8 Mb/s	6-2-3
VDSL	640 kb/s-2Mb/s	13 Mb/s-25 Mb/s	1.4-0.6
Cable Modems	0-384 kb/s	30 Mb/s (shared)	-
Satellite; DVB-RCS	2 Mb/s	36 Mb/s (shared)	Not limited
LMDS	0-8 Mb/s typical 25.8 Mb/s possible	36 Mb/s (shared)	5

LMDS is favorable for operation in urban and suburban areas, and is definitely the preferred solution for operators without a copper network and as a supplement to the copper-based and interactive cable network. Table 1 lists the capacity of different access technologies [5].

## 5. MULTIPLE ACCESS MAC PROTOCOLS AND ACCESS METHODS (ÇOKLU ERİŞİM MAC PROTOKOLLERİ VE ERİŞİM YÖNTEMLERİ)

Multiple access schemes provide a technique for two or more data streams to access the same frequency channel. The multiple access schemes, Time Division Multiple Access (TDMA) scheme and the Frequency Division Multiple Access (FDMA) scheme. Duplexing schemes provide a technique whereby data flowing in both directions can be carried over the same frequency channel. The Duplexing schemes, Time Division Duplexing (TDD) scheme and the Frequency Division Duplexing (FDD) scheme. [15 and 16].

### 5.1. Time Division Multiple Access-Tdma (Zaman Bölmeli Çoklu Erişim)

In TDMA, transmitters share a common channel, but only one transmitter is allowed to transmit at a time. In particular, the uplink channel is divided into a number of time slots. Separation is achieved by allocating a separate time slot to each transmitter, as shown in Figure 3 [17 and 18].

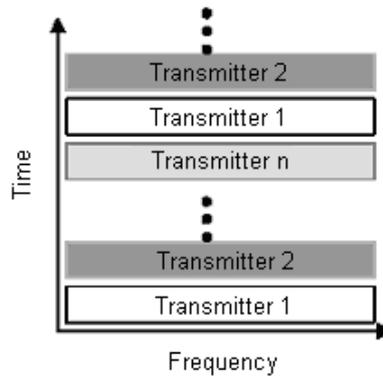


Figure 3. Time-frequency characteristic of TDMA  
(Şekil 3. TDMA için zaman-frekans karakteristiği)

### 5.2. Frequency Division Multiple Access-Fdma (Frekans Bölmeli Çoklu Erişim)

In FDMA, each transmitter is allocated a channel with a particular bandwidth and centre frequency, as illustrated in Figure 4. All transmitters are therefore able to transmit simultaneously. The only coordination required is the allocation of the individual channels. Separation is achieved by allocating an individual channel to each transmitter [17 and 19].

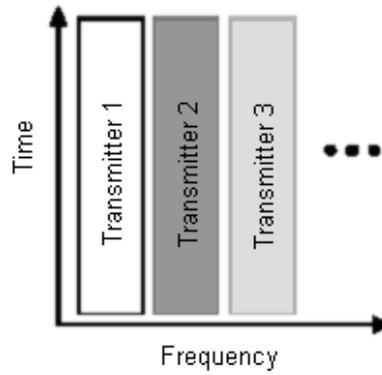


Figure 4 Time-frequency characteristic of FDMA  
(Şekil 4. FDMA için zaman-frekans karakteristiği)

### 5.3. Time Division Duplexing-Tdd (Zaman Bölmeli Çift Yönlü Kullanma)

In the case of TDD, the uplink and downlink transmissions occur at different times and usually share the same frequency. It is very suitable for asymmetric connection [15 and 20].

### 5.4. Frequency Division Duplexing-Fdd (Frekans Bölmeli Çift Yönlü Kullanma)

FDD system, the uplink and downlink channels are located on separate frequencies and each subscriber station can transmit and receive simultaneously. A fixed duration frame is used for both uplink and downlink transmissions [14 and 20].

## 6. MODELING AND SIMULATION (MODELLEME VE BENZETİM)

In the example scenario implemented using OPNET Modeler, there are 16 WTs (Wireless Terminals) on which four different applications operate to generate and receive data traffics. Models shown respectively in Figures 5 and 6 are independently obtained. There is only one type of application running at the same time on each WT. The data traffic introduced to the network by any WT is randomly destined to another WT. 1 of these applications are set to create voice transfer traffic, 1 for compressed video transfer, 1 of them for critical data application traffic and 1 for data transfer traffic. For instance, voice application traffic originated from the WT1 in LMDS1 subnet is transferred to the WT5 in LMDS2. Similarly the other types of traffics are transferred from the WTs in LMDS1 to the WTs in LMDS2 and LMDS sub-networks are connected to each other using MPLS network as seen from the Figure 5.

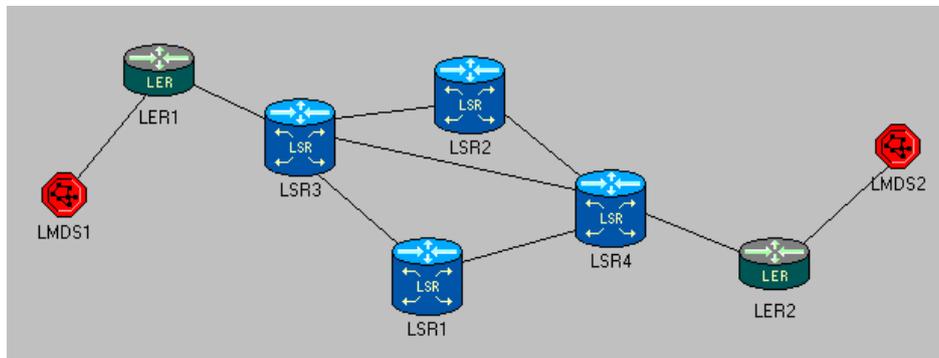
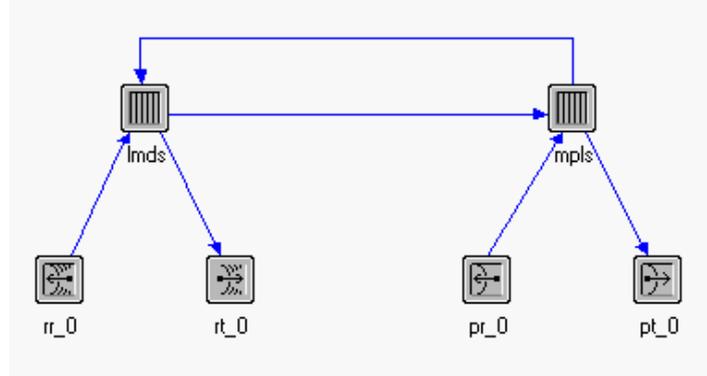
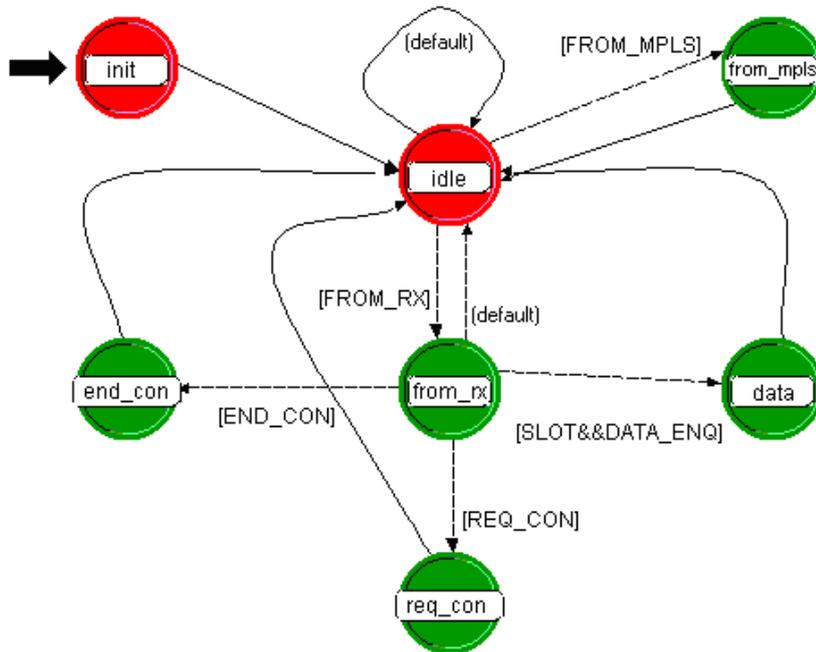


Figure 5. LMDS-MPLS network models  
(Şekil 5. LMDS-MPLS ağ modeli)

In LMDS sub-networks, to share the limited bandwidth among the WTs a demand assignment scheme is employed. As a multiplexing technique, TDMA is preferred due to its superiority and suitability for real-time multimedia traffics. In this technique, radio spectrum is divided into time slots which are assigned to different connections where a user application can send data only in its own dedicated slots. Due to the FDD Duplexing technique utilized, two distinct carrier frequencies are used for the uplink and downlink channels. When a WT needs to communicate with any other, initially it asks for a transmission channel from the BS. The BS then assigns adequate number of time slots for this connection considering bandwidth requirements of the application operating. A slot length of 200  $\mu$ seconds which has been determined considering 25 Mb/s data rate is chosen. With a total number of 1000 slots/frame, each time slot contains 7 ATM cells.



a



b

Figure 6. (a) BASE station node model,  
 (b) BASE station LMDS module process model.  
 (Şekil 6. (a)Baz istasyonu düğüm modeli,  
 (b)Baz istasyonu LMDS modülü işlem modeli)

Figure 6a shows the base node model realized using OPNET Modeler. "lmds" module functions in the base station node are used to

allocate the available bandwidth for wireless terminal applications and realize actual data packet transfer to routed wireless terminals. The "mpls" module is to prove connection between the base stations with mpls area. In Figure 6b, the process model of the LMDS module used in Base station node model is illustrated. The from\_rx state machine is responsible to coming packets according to formats related module by routing. The con\_req state machine provided received from WT according to connection request packets containing Class of Service parameters send to relate the module. The con\_end state machine create end of the connection to inform the request of connection termination taking of control packet. The data state machine is responsible to coming data packets from WT to send "mpls" module. The from\_mpls state machine send to coming data packets from MPLS area to send WT.

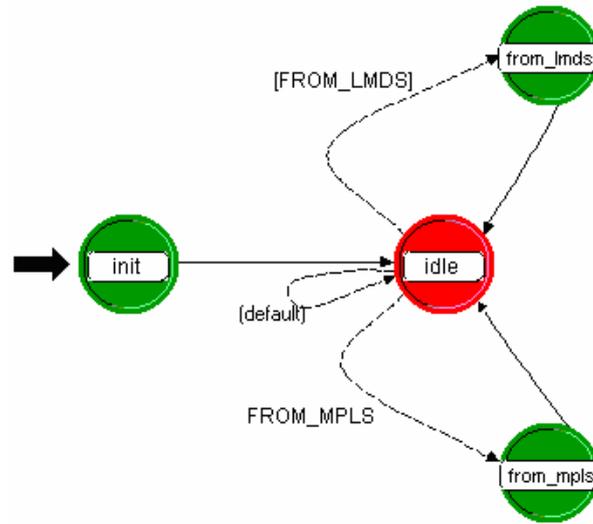


Figure 7. BASE station MPLS module process model.  
(Şekil 7. Baz istasyonu MPLS modülü işlem modeli)

MPLS module process model designed is also shown Figure 7. The from\_lmids state machine to make the process from lmids module coming to data packet to the MPLS area. The from\_mpls state machines are responsible for the coming packets to send LMDS module.

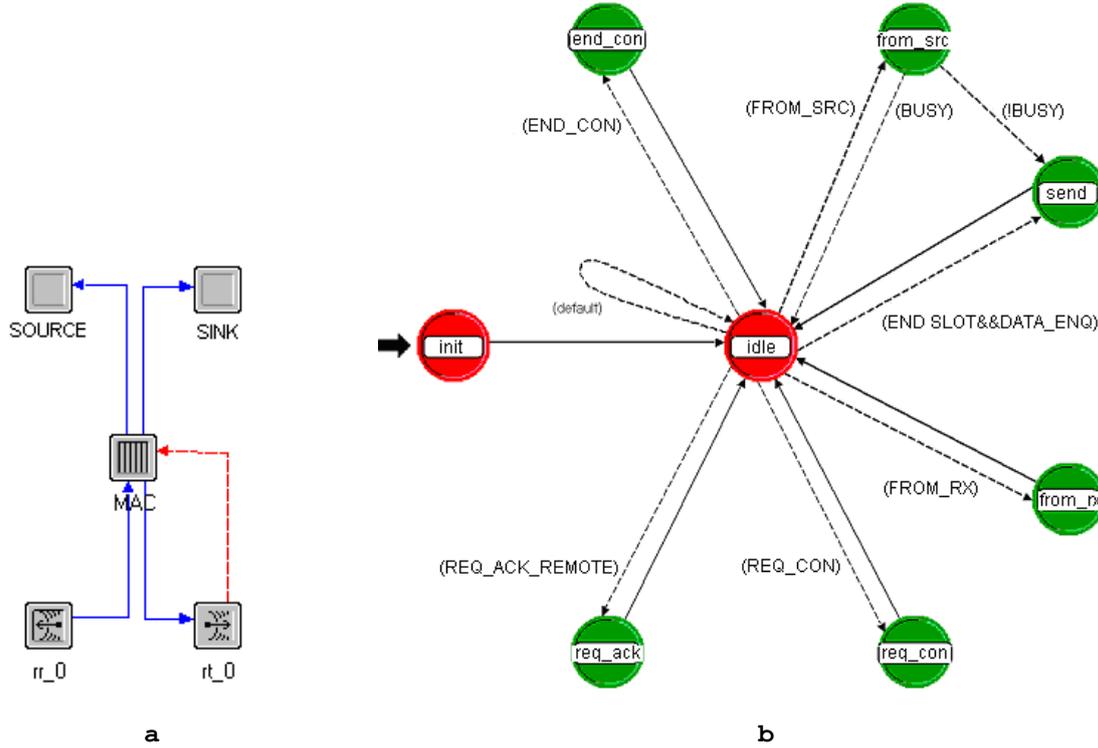


Figure 8. (a). WT node model,  
 (b). WT process model  
 (Şekil 8. (a) WT düğüm modeli,  
 (b) WT işlem modeli)

WT node model designed using OPNET Modeler is shown in Figure 8a. The SOURCE module used in the WT is responsible for packet generation according to the packet size and arrival time parameters defined. The SINK module collects statistics of the arrived packets and then destroys them. The physical layer (rr\_0 and rt\_0) is the interface between the node module and wireless environment.

In Figure 8b. the WT process model is illustrated. The con\_req state machine creates connection request packets containing. Using the from\_src and send state machines, data cells received from the SOURCE are sent to destination in the connection time slots allocated. The req\_ack state machine is responsible obtains connection time slots that are assigned the packet send by the Base station. The con\_end state machine creates connection termination packet and sends it to the Base station. The from\_rx state machine delivers any arrived packets destined to the SINK.

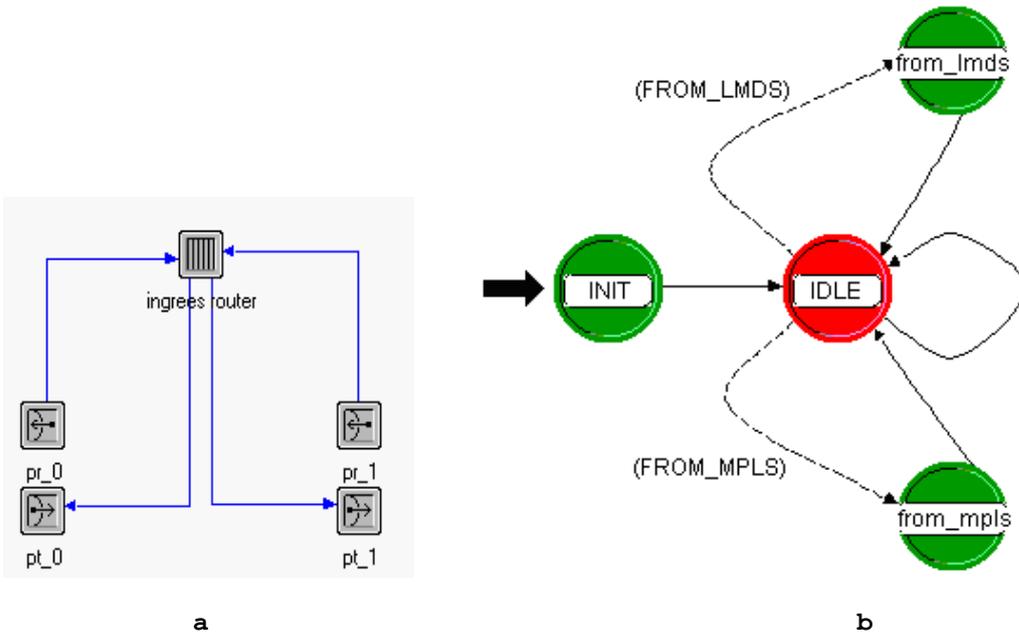


Figure 9 (a). MPLS/LER node model,  
(b). LER process model  
(Şekil 9. (a) MPLS/LER düğüm modeli,  
(b) LER işlem modeli)

Figure 9a shows the MPLS/LER node model realized using OPNET Modeler. LER ingress router module is responsible the MPLS label to add/to extract. The physical layer pr\_0 and pt\_0 is the interface between the base station and LER, pr\_1 and pt\_1 is the interface between the LER and ATM switch. In Figure 9b. the LER process model is illustrated. The from\_lmlds state machine is to do the LMDS packets send by the Base station adds 4-byte MPLS labels. The from\_mpls state machine is to realize MPLS labels are removed.

In the LMDS sub-networks of example scenarios, free space propagation model which is support to predict received signal strength when the transmitter and receiver have a clear, unobstructed line-of-sight path between them is utilized. Also in this system, Physical Layer consists of wireless connection. It is assumed that wireless channel bit ratio is small and that CRC bits which are added to the packages prevent the possible errors. In wireless networks especially in data communication, one service which is called "Best Effort" is provided. There is no guarantee relevant neither with the time delay nor with the given bandwidth. Thus performance results may be different. Additionally, the performance of the illustrating application is measured according to obtained simulation results under varying load conditions. In this study some parameters such as antenna model, antenna height, the power of transmit signal, data communication speed in radio frequency are ignored.

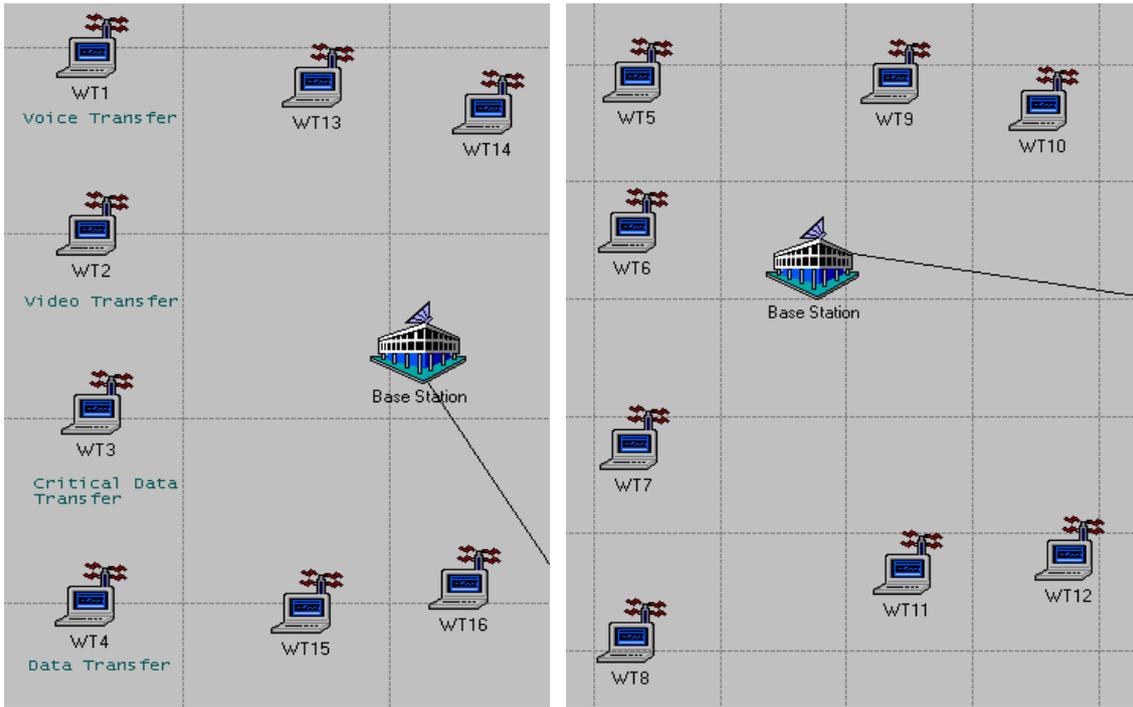


Figure 10. LMDS network models  
 (Şekil 10. LMDS ağ modeli)

The simulation parameters used for the example scenario are given in Table 2.

Table 2. Simulation parameters.  
 (Tablo 2. Benzetim parametreleri)

LMDS traffic sources	30.000-100.000* (Byte/sec)
Uplink/Downlink Bit Rate	25 Mbit/sec
Frequency Band	Uplink=38 GHz and Downlink=33 GHz
Channel Bandwidth	1,3 GHz
Modulation Schema	QPSK
MAC Protocol	TDMA/FDD
Voice application slot number	100 slot
Compressed application video slot number	95 slot
Critical application data slot number	40 slot
Data application slot number	20 slot
Wireless Channel Model	Free Space Propagation Model (Line of Sight)
*Generated using Exponential Distribution Function Exp(Mean).	

Varying the message size of all WT application traffics, average and maximum end-to-end delay (EED) and delay variation (jitter) results of the voice traffic transfer between WT1 and WT5, of the compressed video traffic transfer between WT2 and WT6, of the critical data traffic transfer between WT3 and WT7, and of the data traffic transfer between WT4 and WT8 have been collected during the simulation run time.

## 7. SIMULATION RESULTS (BENZETİM SONUÇLARI)

Voice (WT1-WT5), Video (WT2-WT6), Critical data (WT3-WT7) and Data (WT4-WT8) traffic sources at the Base Station 1 (LMDS 1) introduce 30000–100000 byte/sec. of information with an Exp (1.0) seconds inter arrival time to be transferred across the MPLS network to the Base Station 2 (LMDS 2), and vice versa. LER and LER2 ingress-egress edge routers add 4-byte MPLS labels to all Voice, Video, Critical data and Data packets before entering the MPLS cloud. MPLS labels are removed at the LER1, LER2 ingress-egress router, completing the Base Station 1 to Base Station 2 multimedia traffic transfer over MPLS cloud.

Varying the Voice, Video, Critical data and Data message source traffics between 30000–100000 byte/sec. at the Base Stations, end-to-end average message delay and delay variations for the end user applications are shown in Figure 11 and Figure 12. Average message delay and delay variation results for the Voice traffic reaches a maximum of 42 msec. when the offered network load is 100000 byte/sec and maximum of 8 msec. when the offered network load is 60000 byte/sec., respectively. These results are quite acceptable for real-time voice communication that is usually tolerable to less than 50 msec. end-to-end delay. The compressed Video application traffic (i.e. between WT2 and WT6) experiences 17 to 35 msec. end-to-end average delay and 3 to 15 msec. delay variation. The Critical data application traffic (i.e. between WT3 and WT7) end-to-end average delay varies between 35 msec. and 50 msec. while maximum delay variation obtained is 9 msec. On the other hand, the non critical Data application traffic (i.e. between WT4 and WT8) is subject to relatively higher end-to-end average delays of 44 to 58 msec. and delay variation of 4 to 11 msec.

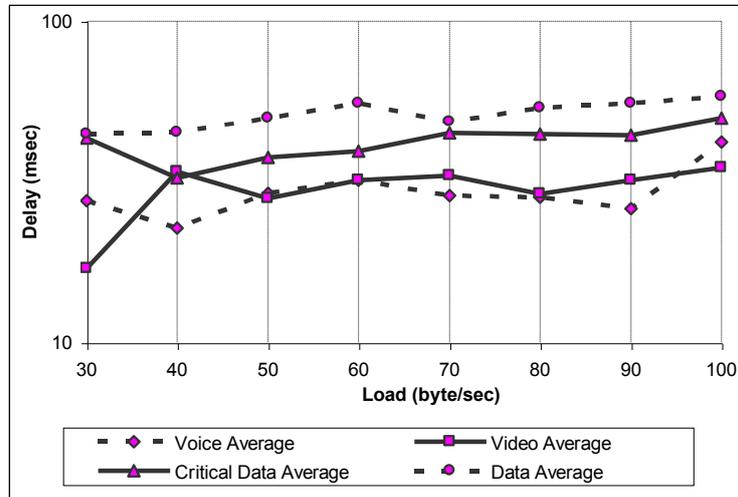


Figure 11. end-to-end average message delays  
(Şekil 11. Ortalama mesaj gecikme değerleri)

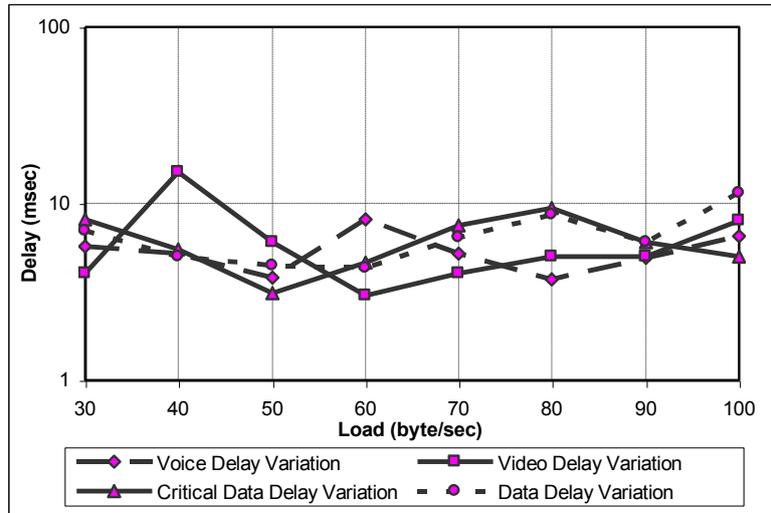


Figure 12. end-to-end delay variation  
(Şekil 12. Gecikme değişim değerleri)

## 8. CONCLUSIONS (SONUÇLAR)

An LMDS over MPLS networking environment for real-time multimedia applications is studied. Combining the advantages of both LMDS and MPLS in an integrated structure it is possible to obtain desirable end-to-end message delay results. Simulation results for four different application traffics showed that voice and video traffics were carried with 42 msec. and 35 msec. average end-to-end delays, respectively while data and non-critical data traffics are transferred with relatively higher end-to-end average delay under varying network load conditions. It can also be concluded that the networking environment provides reasonably low delay variation results for both voice and video traffics considering their real-time requirements.

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