Performance Study of Interconnected Metro Ring Networks

Van T. Nguyen, Tülin Atmaca, Glenda Gonzalez,
Lab. CNRS/Samovar
Institut Telecom/Telecom SudParis
Evry – France
e-mail: nvt2302@gmail.com,{tulin.atmaca, Glenda.Gonzalez}@it-sudparis.eu

Joel Rodrigues
Instituto de Telecomunicações
University of Beira Interior
Covilhã - Portugal
e-mail: joelr@ieee.org

Abstract— **Metropolitan ring networks are usually used to connect the high speed backbone networks with the high speed access networks. Until now, metropolitan networks and access networks are gained much attention of researchers just as in separate direction. In this work, we study an interconnected Multi-Ring Network (MRN) architecture in which a Metropolitan Access (MA) Ring is interconnected by a Metropolitan Core (MC) Ring via a Hub Node who is in charge of the synchronization between them. The synchronization in this architecture is the major problem. To solve this problem, we propose a new mechanism called Common-Used Timer Mechanism (CUTM) inspired from CoS-Upgrade Mechanism (CUM) to create well filled optical packets in the hub. CUTM is developed and also integrated as a module to the software Network Simulator 2 (NS2), to simulate the behavior of the MRN considered. We compare the performance of this mechanism with the opportunistic one. The results have shown that, compared to existing solutions, the CUTM enhances the network throughput, optimizes the use of resources, and also offers a solution to the synchronization problem.**

Keywords-Interconnected Ring Networks; Synchronization; Performance; Simulation.

I. INTRODUCTION

Optical technology is being developed more and more in all levels of networks. It led the innovation of broadband networks. Passive Optical Networks (PON) have attracted much attention of researchers because it is an excellent solution for low cost broadband services. The next generation of Metropolitan Area Network (MAN) requires flexible, scalable and manageable architectures to provide different type of services to their customers at the access or backbone networks. With passive devices on the transmission line signal, it is easy to build and maintain the PON. So PON becomes the first choice for metropolitan area network.

Metropolitan ring networks are generally used to connect the high speed backbone networks with the high speed access networks. The metro rings can be interconnected transparently through a single access node (Hub node) or multiple access nodes. Current metro networks are typically SONET/SDH-over-WDM rings which carry the huge amount of bursty data traffic. The metro core and regional networks are normally both 2-fiber rings. A fiber failure in a metro access ring does not affect the traffic in the core and other access rings. The network thus becomes more reliable. Dual Bus Optical Ring Network (DBORN) has been proposed as one of the first passive architecture, known for the metropolitan networks. However, new transparent optical network providing packet-level granularity architectures have been proposed and studied called ECOFRAME. This architecture is studied and a prototype is developed as for next generation of MAN in the ANR/ECOFRAME (France) project. Its important characteristic is that it can be used as MA and/or MC Network. Until now, metropolitan networks and access networks are gained much attention of researchers in separate direction. Recently, the end-to-end metropolitan performance of a multi-ring architecture (in which MANs are interconnected by a metropolitan core network) has been investigated [1]. We consider a multi-ring architecture, in which MANs are interconnected by MC Network. The interconnection of MC and MA networks is made via Hub node that is in charge of the synchronization of the two ring networks. Other functions to be operated by the hub are similar to those of access node.

Some works have presented new architectures to integrate in a transparent way metro-access and metro-core ring networks [2]. Other works [3] have studied the design and the development of new devices to interconnect Metro Access and Metro Core Ring networks. However, the synchronization problem between the networks has been neglected and a major research opportunity exists in this sense. Several mechanisms to create optical packets that improve the performance of the multi-ring network have been proposed in the literature. In this paper, we present a new mechanism CUTM to create optical packets well filled and we compare the results obtained with the well known "opportunistic" mechanism in terms of waiting time, end to end delay, filling ratio, and jitter.

The rest of this paper is organized as follows. In Section II, selected Metro Access and Metro Core architectures have been summarized. In Section III the studied architecture is presented. In Section IV, our proposed mechanism CUTM is introduced. In Section V, our simulation scenario is described and in Section VI the simulation results are presented. Finally, we conclude our work.

 ISBN: 978-1-61208-174-8

II. METRO ACCESS AND METRO CORE ARCHITECTURES

According to the physical distribution of the network components, the bus, star and ring topologies can be implemented. Ring topologies have been widely adopted and studied for MAN because it is easy to construct and maintain with low cost, and bidirectional rings inherently provide fast restoration. Statistical multiplexing of data traffic flowing from different nodes over the shared medium provides efficient utilization of optical fibers. Some optical MANs in ring topologies are: Resilient Packet Ring (RPR), DBORN, ECOFRAME. DBORN [4][5] uses a double bus WDM rings topology with spectral separation and it functions in the asynchronous mode. This topology consists of two unidirectional buses: upstream and downstream. In the upstream bus, access nodes share a common transmission medium for carrying their traffic to a centralized node (hub) while the downstream bus carries traffic from Hub node to all access nodes. For the cost-effective solution, each ring node possesses passive components; lead in to the fact that they can not drop any transit packets in upstream line. Although of its simplicity, this architecture has several drawbacks as positional priority, fairness issues and bandwidth fragmentation. In our work we use synchronous DBORN version (slotted ring, fixed size packet) as a MA ring. Compared to the previously mentioned architecture, ECOFRAME [6] pays special attention to the deployment of optical technologies "low cost" to ensure good network performance while remaining competitive with electronic technology in terms of cost, service transparency and modularity. ECOFRAME ring uses fixed optical packet size, separate data and control channels and it can be used as MA and MC ring. In our work, ECOFRAME is used as a MC network.

III. STUDIED ARCHITECTURE

In this section, we present an architecture, which is composed of two segments: Access Network and Core Network (Fig. 1). For the access network synchronous DBORN architecture is considered and for core network ECOFRAME architecture. The interconnection is made via a hub node.

We distinguish two traffic flows: 1) the traffic flowing from the access network to the core network through the hub, and 2) the traffic flow circulating in the core network. In an access node of MA, the electronic packets are encapsulated in optical packets and transported through the hub. In the hub O/E/O converter is used to build new optical packets fill well coming from different nodes and going to same destination. These packets are stored in the queue in the hub. Hub architecture is presented in Fig; 2. It is composed of two parts: electronic part and optical part. In the electronic part, the packets are converted and stored in the buffer before processing. In optical part, it is used FDL.

One of the roles of Hub is to create new optical packets well filled. The creation of new optical packets can be made using three mechanisms: 1) mutual combination (electronic packets coming from different access nodes can be combined together), 2) local combination (combined with local electronic packets of the hub) and 3) total combination (two combinations mentioned), totally according to class of service. According to the access control mechanism used in the Hub, the optical packets coming from MA can be placed directly in the optical buffers (to be ready to be routed through the Hub) or they are converted in electronic packets by O/E converter and wait in the electronic buffer corresponding to their CoS until timer is expired and new timer is reset. New optical packets are created using a packet creation mechanism and are sent to the core network.

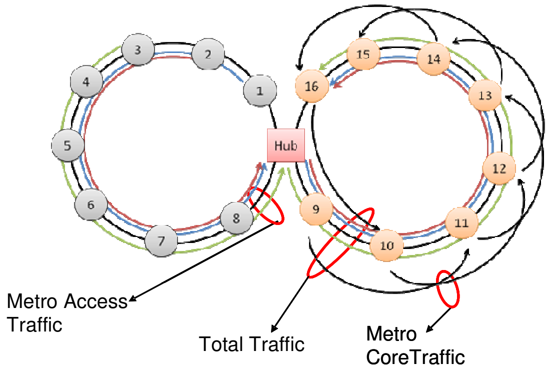

Figure 1. Networks Interconnection

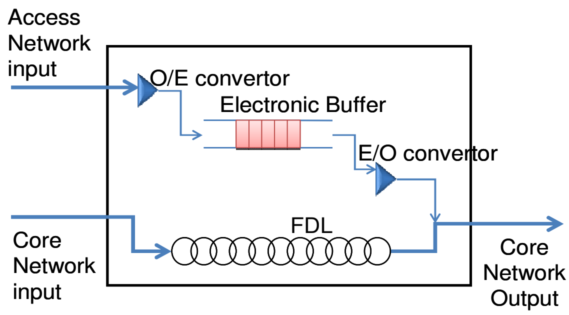

Figure 2. Architecture of Hub

We present a new packet creation mechanism in the Section IV. At the Hub node, the packets in transit in the core network have higher priority than traffic of access network; therefore, the E/O converter is performed if there is no packet in the optical FDL. The associated times to the creation process are specified in Fig. 3. One of the problems of interconnection between the rings is the synchronization of timer between them. Each ring is already synchronized but each one has different size of slot time and optical packet. Therefore, it is needed to synchronize data inputs and outputs at the Hub.

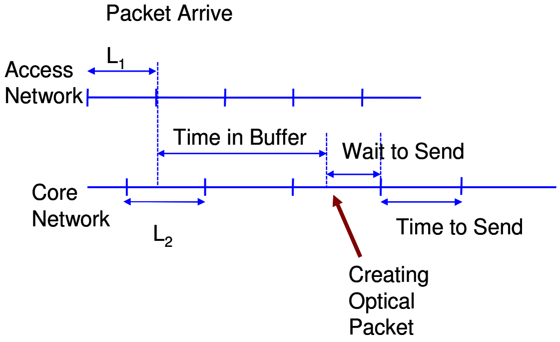

Figure 3. Times for the Optical Packet Creation Process

The synchronization problem is solved using electronic buffers in the hub. Packet creating process introduces the delay which helps to synchronize the two rings. Fig. 3 shows the transmission time slot of two rings with different sizes. L1 is the transmission time of a packet in the optical metro access and L2 corresponds to the transmission time of a packet in the core network. The correlation of the variables L1 and L2, and synchronization lag Δt affect the network performance.

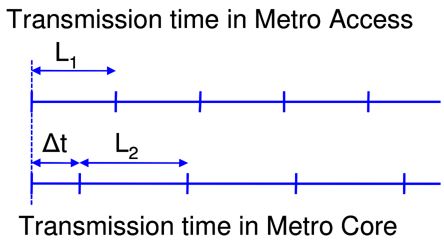

Figure 4. Transmission time in MA and MC

IV. CUTM MECHANISM

Some mechanisms have been proposed in literature to decide the time to create optical packets. A well known scheme is the opportunistic mechanism [6], this mechanism

is simple: if a slot in transit is free, the optical packet is built and transmitted on the ring. The purpose of this mechanism is to reduce the load of the hub and use fewer resources. However, other mechanisms have been developed to optimize the optical packet filling. We proposed a mechanism [1], called CoS-Upgrade mechanism (CUM), to synchronize the traffics in the access nodes. This mechanism can be used not only for the access nodes (in the access network and core network) but also for the Hub to solve the problem of creating fixed size optical packet, so it uses timers in deciding when the optical packet is constructed. CUM mechanism has many advantages but also some limitations: 1) it uses several timers and buffers, 2) the hub will be over loaded when all timers are running, and 3) when the order of packets is changed building the packet at the receiver side is complicated. To improve the limitations of CUM, we propose Common-Used Timer Mechanism (CUTM), which uses a single timer for all classes of service. The principal of CUTM is shown in Fig. 5. CUTM principal corresponds to the creation process descript before in this Section, according to the Hub function. To use CUTM, we need a single buffer to hold the optical packets.

V. STUDIED SCENARIOS

The traffic flow in network is shown in Fig. 1. All the access nodes in the first ring will send the data to the node 16 (the last node). In the second ring network, there are 2 types of traffic flow: one coming from the access network and one is the local traffic (core network). So in each link connect 2 core nodes, there are 8 traffic flow from access network and 2 local traffics from other core nodes. The traffic in second network is symmetric. We consider 8 classes of service for electronic packets and 4 CoS for optical packets with different traffic sources models and packet sizes (Table I).

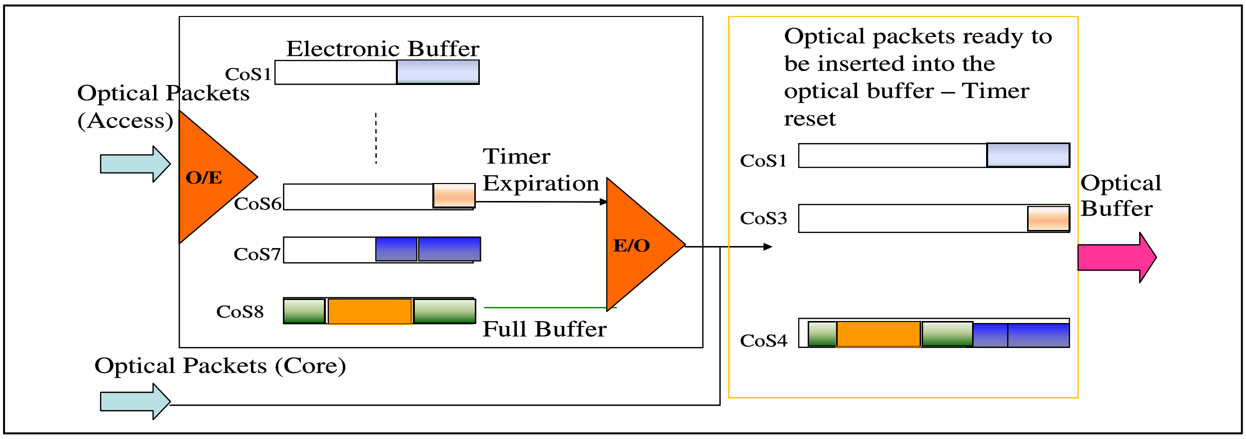

Figure 5. CUTM Principal

TABLE I. CLASSES OF SERVICE

	CoS 1 – CoS 2 Premium		CoS 3 – CoS 4 Silver		CoS 5 – CoS 6 Bronze		CoS 7 – CoS 8 Best Effort	
% CoS	10.4%	10.4%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%
Electronic Packet Size (Octet)	810	810	50 500 1500	50 500 1500	50 500 1500	50 500 1500	50 500 1500	50 500 1500
Source	CBR	CBR	MMPP	MMPP	MMPP	MMPP	MMPP	MMPP
Optical buffer size	1600 KOctets		4000 KOctets		4000 KOctets		8000 KOctets	

We simulate considered interconnected architecture with 3 scenarios (Table II). In the first scenario load of 2 rings are different and in the second scenario transmission rates, packets sizes and loads in two rings are differents for each ring. The scenario three uses same parameters of second one but only packet sizes are differents.

TABLE II. SIMULATION SCENARIOS

	Scenario 1		Scenario 2		Scenario 3	
	Metro Access	Metro core	Metro Access	Metro core	Metro Access	Metro core
Bit rate	10Gb/s	10Gb/s	10Gb/s	40Gb/s	10Gb/s	40Gb/s
Optical packet size	10µs – 12500 octets	10µs - 12500 octets	10µs – 12500 octets	5µs – 25000 octets	10µs – 12500 octets	10µs – 50000 octets
Load	35% - 3.5Gb	50% - 5Gb	60% - 6Gb	70% - 28Gb	60% - 6Gb	70% - 28Gb
Node traffic	437.5M b/s	2.5Gb/s	750Mb/s	14Gb/s	750Mb/s	14Gb/s

Qos requirements are specified in Table III according to the MEF recommendations.

TABLE III. QOS REQUIREMENTS

Class of service	Characteristic of service	Service Performance		
		Loss rate	Delay	Jitter
Premium	Telephone or real-time video application	< 0.001%	<5ms	< 1ms
Silver	Applications require less loss and delay	< 0.01%	<5ms	N/S
Bronze	Applications require guaranteed bandwidth	< 0.1%	<15ms	N/S
Standard	Best effort services	< 0.5%	<30ms	N/S

VI. NUMERICAL RESULTS

In this work, several performance criteria for the given architecture are evaluated by simulation using NS2 tool and the results are presented in terms of the waiting time in the hub, end to end delay, throughput, jitter and filling ratio, loss rate at node 16. Firstly, we fix the value of Δt = 1µs and study the interaction of L1 and L2 depending on the bandwidth and packet size in each network. CUTM uses a timer equal to 100µs. The results in Fig. 6 show the jitter for the 3 considered scenarios at node 16, both mechanisms ensure the jitter condition for data flow specified on Table III.

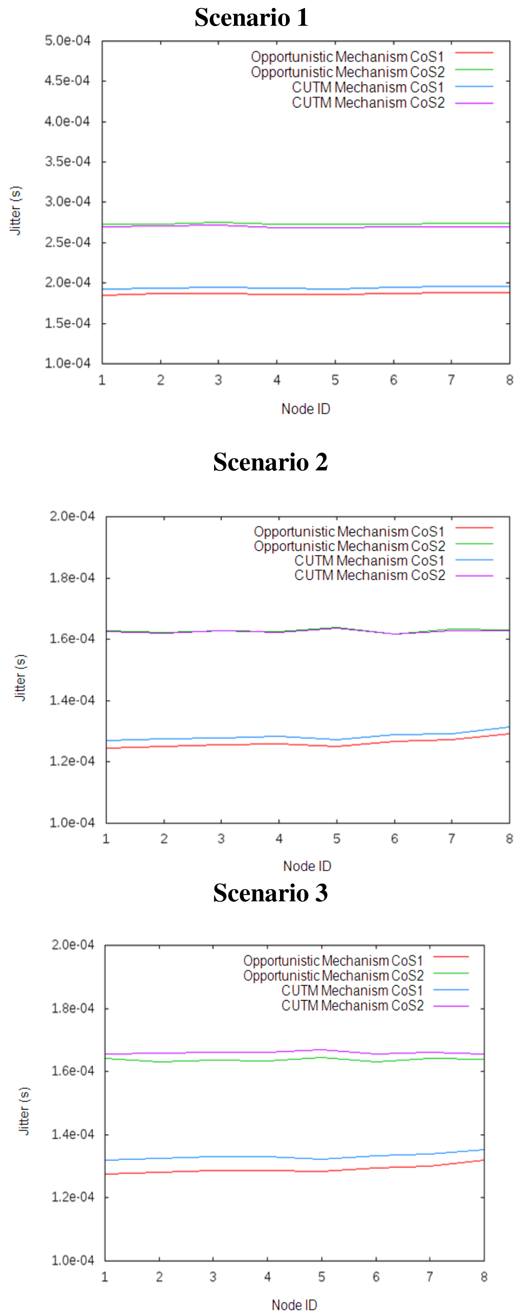

Figure 6. Jitter at Node 16

 ISBN: 978-1-61208-174-8

Fig. 7 shows the waiting time in hub, the average waiting time of packets in the electronic buffers with opportunistic mechanism is smaller than that of the CUTM. Based on these results we can say that CUTM is independent of L1&L2 correlation but depends on the capacity of the MC. By using opportunistic mechanism, the performance of hub does not depend on the capacity of MC; but it is sensitive to the correlation of L1 and L2.

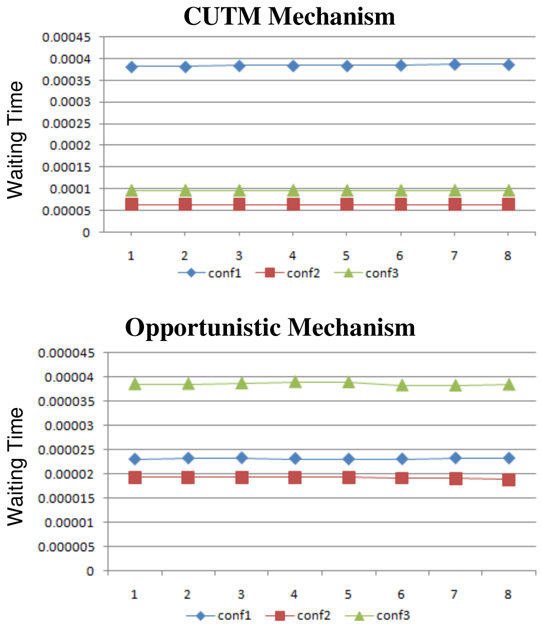

Figure 7. Waiting time in hub Δt = 1µs vs CoS

Fig. 8 shows the End to End delay for both mechanisms considered, the results are better with opportunistic mechanism, however it is important to remark that CUTM uses the timer 100µs.

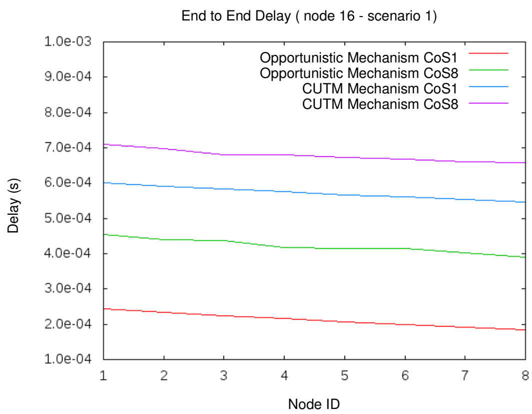

Figure 8. End to End delay (Node 16 – scenario 1)

Fig. 9 shows the throughput obtained for scenarios 2 and 3, here the opportunistic mechanism uses the network resources less effectively than CUTM.

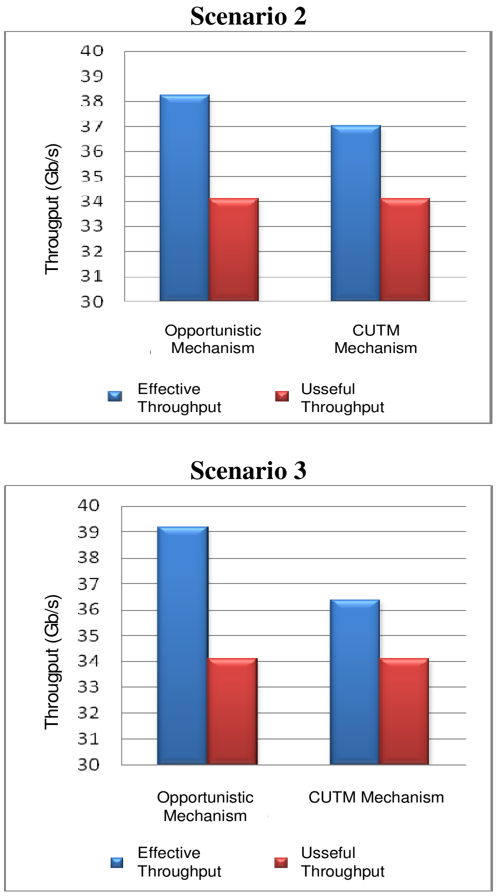

Figure 9. Throughput

Optical packet filling ratio is presented in Fig. 10; it shows that CUTM has a better result that opportunistic mechanism.

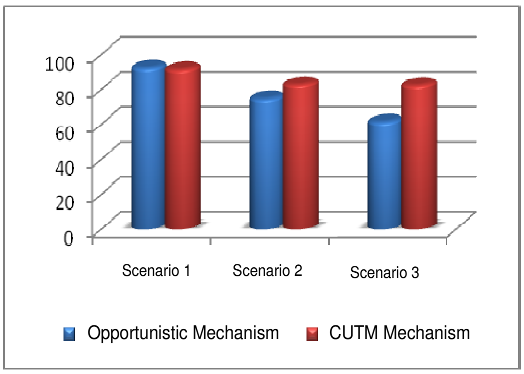

Figure 10. Filling ratio

 ISBN: 978-1-61208-174-8

The scenario 3 results show that the opportunistic mechanism uses more metro core bandwidth than CUTM, also that there is not loss at the hub and the nodes in the MC. To evaluate the loss rate we change the scenario 3 parameters. We increase the load of MA from 60% to 70%. With this change, we have the 3-1 scenario with MA load =70% ~ 8Gb/s, MC load = 70% ~ 28Gb/s, it means a total load = 35Gb/s ~ 87.5%@40Gb/s. The results in Fig. 11 show that for nodes 9 to 16 there is the loss of electronic packets. These nodes lack the bandwidth to send local traffic. The loss rate is zero at node 16 because node 16 is the destination of data flows from the Metro Access. So the loss rate at node 9 is higher than at node 10.

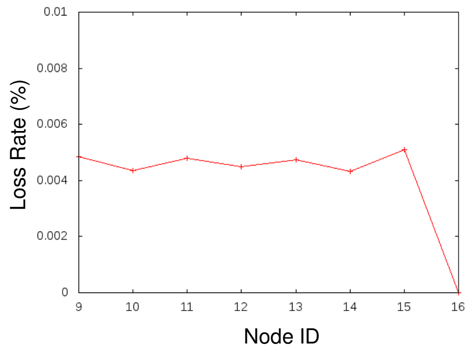

Figure 11. Loss rate for scenario 3-1.

The impact of Δt is analyzed in varying it from 1µs to 21µs (20µs = 2 x L2) on the performance of network and on hub. The Fig. 12 shows that the value of Δt does not significant impact on the network performance. The results are the same with the opportunistic mechanism.

Our results show that the opportunistic mechanism is better than CUTM. However, the filling ratio of CUTM is better than the opportunistic mechanism. Consequently CUTM mechanism saves more bandwidth than the opportunistic mechanism and provides good packet filling ratio.

VII. CONCLUSION AND FUTURE WORK

We have studied and analyzed the performance of interconnected MAN rings (MA and MC) and especially the synchronization problem between them. Performance comparison of two mechanisms: Opportunistic and CUTM has been presented. CUTM offers a solution to solve the problem of synchronization and provides good network utilization. CUTM is independent of the correlation between L1&L2, but depends on the core network capacity. Performance of opportunistic mechanism does not depend on core network capacity but it is sensitive to the correlation of L1 and L2. There is not a real impact of Δt on the network performance, variation in waiting time at hub is very small. We wish to study the impact Δt on the performance with other traffic models.

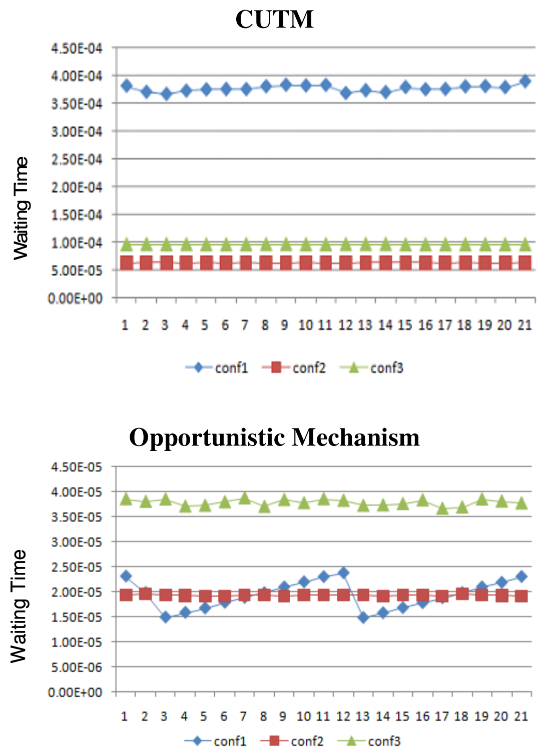

Figure 12. Waiting time in hub Δt = 1µs to 21 µs

REFERENCES

[1] T. Atmaca and T. D. Nguyen, "End-to-End Performance Evaluation of Interconnected Optical Multi-ring Metropolitan Networks", vol. 327, Springer 2010, ISBN: 978-3-642-15475-1, pp. 206-216.

[2] T. Orphanoudakis, H. Leligou, E. Kosmatos, and A. Stavdas, "Future Internet Infrastructure Based on The Transparent Integration of Access And Core Optical Transport Network". Journal of Optical Communications and Networking, vol. 1, Issue 2, july 2009, pp. A205-A218, doi:10.1364/JOCN.1.00A205

[3] R. Bonk, P. Vorreau, D. Hillerkuss, W. Freude, G. Zarris, D. Simeonidou, F. Parmigiani, P. Petropoulos, R. Weerasuriya, S. Ibrahim, A. D. Ellis, D. Klonidis, I. Tomkos, and J. Leuthold, "An All-Optical Grooming Switch for Interconnecting Access and Metro Ring Networks [Invited]". Journal of Optical Communications and Networking, Vol. 3, Issue 3, 2011, pp. 206-214, doi:10.1364/JOCN.3.000206.

[4] N. Le Sauze, E. Dotaro, and A. Dupas, "DBORN: A Shared WDM Ethernet Bus Architecture for Optical Packet Metropolitan Network", Photonic in Switching, July 2002.

[5] N. Le Sauze, E. Dotaro, and L. Ciavaglia, "DBORN (Dual Bus Optical Ring Network) An Optical Metropolitan Ethernet Solution", Research Report – Alcatel, 2004.

[6] T. Atmaca, T. Eido, T. Nguyen, P. Gravey, A. Gravey, M. Morvan, J. Roberts, S. Oueslati, T. Ronald, D. Barth, and D. Chiaroni, "Définition du Plan de Transport (MAC, Protocoles)", livrable D2.1, French ANR Project/ECOFRAME (Eléments de convergence pour les futures réseaux d'accès et métropolitain à haut débit), Conventions n°2006 TCOM 002, Project Report, January 2008.