Performance Analysis of Optical Networks and their Improvement using Power Saving Method

Shefali Goyal
Pursuing M.Tech (ECE)
UCoE, Punjabi University, Patiala
Punjab, India

Manjit Singh
Associate Professor (ECE)
UCoE, Punjabi University, Patiala
Punjab, India

ABSTRACT
In order to reduce power consumption among optical networks power saver method is used. The technique of reducing power consumption had been widely used in wireless networks. Previous studies have focused on improving performance of passive optical network only, since it had been proved to be most efficient network. But here, P2P and AON are also studied since, they are equally important. First various optical networks (P2P, PON, and AON) are analyzed through simulations without using power saving method. Results are compared for best network under varied conditions. In the next section, power saver method is used and networks are analyzed for power consumption. After that, the comparative analysis between power ignoring method and power saving method is done. Comparative analysis shows that PON consumes 9.435 W of power using optimization method and is less costly amongst these three networks.

General Terms
Downstream Traffic, Power Saver Method, P2P-Point to Point, PON- Passive Optical Network, AON- Active Optical Network

Keywords
Power Saver Method, Optical Networks

1. INTRODUCTION
There are two types of networks wired and wireless. Wireless includes Wi-MAX, Wi-Fi, GSM or UMTS and digital subscriber line or hybrid fiber coaxial (HFC), optical fiber networks are wired networks [1]. Voice, data and video can be delivered through different networks. Voice, data and video combine to form triple play service and can be delivered through single network but bandwidth requirement is greater than 75 Mbps and copper based networks are limited in bandwidth so optical networks are considered to overcome such problem [2], [5].

The optical networks consumes large amount of power while transmitting optical signal but it also consume power during idle modes i.e. when there is no signal to be transmitted. The sleep techniques reduce this power to large extent in passive optical network. Since, PON is already proved to be the efficient network but still there are situations where installing passive optical network is not possible. In those situations, point to point networks and active optical networks are used [3].

2. OPTICAL ACCESS NETWORK MODELS
The optical network as shown in (Fig 1) consists of transmitter at OLT i.e. optical line terminal and receiver at ONU i.e. optical network unit. The signal generated at core network is required to be sent towards requested ONU. The data is provided to OLT transmitter through service network interface (SNI).

At the ONU, the data is processed and provided to users through user network interface. There is remote node between OLT and ONU. In P2P network, all the ONU's are directly connected to OLT i.e. there is no remote node between them. There are N fiber lines and 2N transceivers for N subscribers, which is very costly.

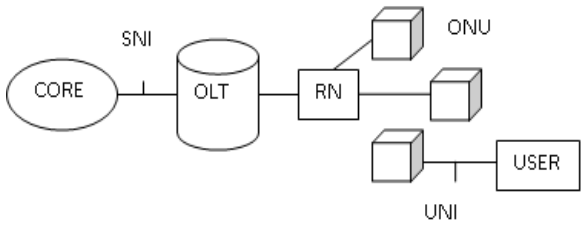

Fig 1: Block diagram of optical network.

AON requires only one fiber but it uses electrically powered equipment at the remote node such at switch or router which consumes energy.PON uses single fiber and there is no active component at the remote node since it consists of passive splitter. This network requires (N+1) transceivers only [4].

3. OPTICAL NETWORK
The power consumption in downstream direction is analyzed. The signal which is generated at core network is sent towards optical line terminal via service network interface and signal is converted from analog input to optical signal at transmitter side. The data is sent towards remote node which will direct this optical signal to optical network terminal. The photodiode (PD) and trans-impedance amplifier (TIA) located at ONU will receive the signal and convert optical signal into electrical current which is further converted into analog voltage by TIA. The limiting amplifier is used to amplify the electrical pulses and send them to users. The clock and data recovery help in retrieving synchronization with the network.

3.1 Simulation Flow of Network
The flow of signal in network during simulations is shown in (Fig 2).

1. First of all, the signal is generated and the UDP is used for faster delivery of data.
2. The UDP object is hired and the transmitter is activated for sending the signals towards OLT i.e. subscriber end.

3. The OLT-ONU connection is opened and the optical signal is sent to remote node situated between central office and the optical network units.
4. The ONU receiver reads data sent via OLT through service network interface. At receiver, the photodiode will convert magnitude of optical light pulses into analog current.
5. The current from photodiode is converted to analog voltage by trans-impedance amplifier.
6. The limiting amplifier is used as quantizer which will decide whether the signal is logical 1 or 0. The logical 1 proves proper reception of signal and if it's zero then signal level is not appropriate to be considered as logical 1 so it will be ignored.
7. After receiving signals, the UDP object which is hired to deliver signals will be released and connection is ended [6].

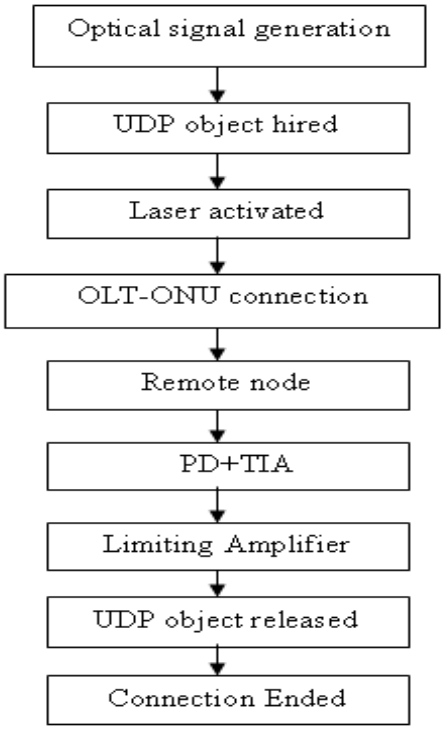

Fig 2: Operational Flow Graph

4. POWER CONSUMPTION ANALYSIS

The power consumption for three optical networks is analyzed. Here the network components are active all the time with or without data to be sent towards ONU. When the network is active without having data for transmission then that state is called idle state. During that state, the network consumes extra power [7].

4.1 Power Ignoring Method

The power consumption for optical networks (PON, AON and P2P) consists of two parts:

1. Power consumption when there is some data
2. Power consumption during idle state

When data is sent from OLT to ONU, the network wastes some power during cooling and due to some losses at splitters and switches [7]. The power consumed by network elements is shown in Table 1.

Table 1. Power Consumed by ONU components

ONU[9]				Conditions
Back end circuit	PD	TIA	LA	
3.015 W	0.10 W	0.20 W	0.20 W	Worst
1.015 W	0.10 W	0.10 W	0.10 W	Minimum
2 W	NIL	0.10 W	0.10 W	Optimized

The network works under varied conditions due to which the power consumption for optical networks varies. These conditions are:

1. Ideal Condition- All the components in network consume minimum power. All the components perform according to the specifications and free from losses and other external effects.

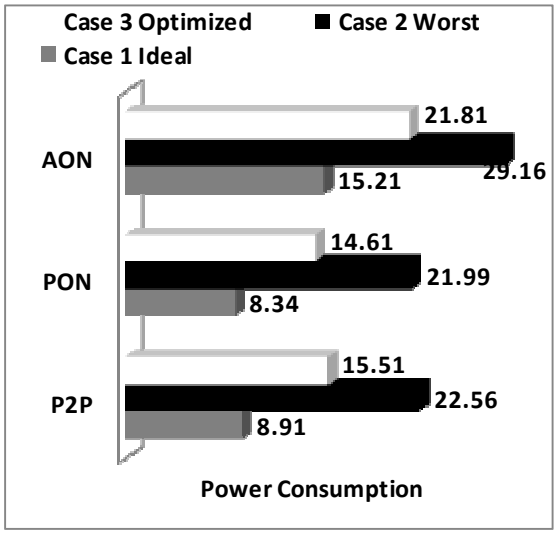

Fig 3:Power Consumption Comparison under various conditions For Power Ignoring Method

2. Worst Condition- All the components consume maximum power. The losses at splitters and at other

components are considered. Extra watts of power are consumed in cooling the network.

3. Optimized Condition- In this condition, network components are optimized for better performance and less power consumption.

From simulations in Matlab, the performance of optical networks (AON, PON and P2P) is analyzed for conditions (ideal, optimized and worst) and results are shown in (Fig 3).

5. POWER SAVER METHOD

The power is wasted in power ignoring scheme during idle period which need to be avoided by using some technique. In this project, the power saver technique as shown in (Fig 4) is used which switches off some of the circuitry in network [7].

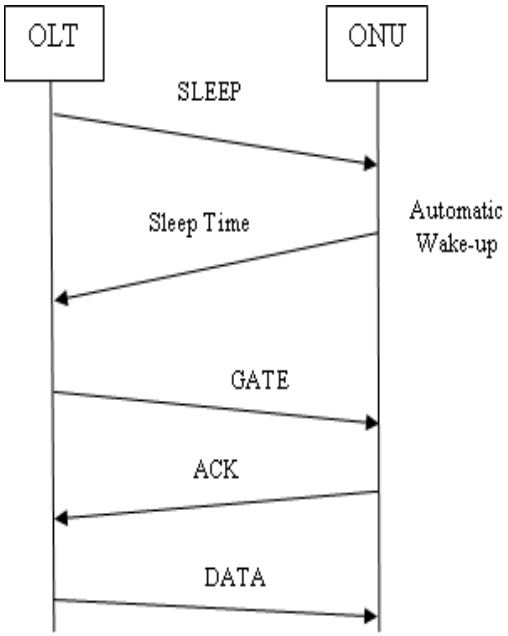

Fig 4:Power Saving Protocol

When there is no data to be sent then OLT requests ONU to go to sleep mode by sending sleep message to ONU. The ONU puts itself to sleep mode and switches off the Photodiode, Trans Impedance and Limiting Amplifier [8].

The user network interface goes to sleep mode as well. The user network interface is inactive in power ignoring scheme as well when network is idle. The sleep time for ONU is fixed at 2 msec.

The ONU wakes up automatically after this sleep time. The OLT back end circuitry will continuously monitor for signal arrival. Between this duration, if signal arrives, the OLT signals ONU to wake up by sending GATE message. The ONU will acknowledge this message by sending ACK signal and ONU become active and start receiving data from OLT.

During this transition process, from sleep to active or active to sleep some power is consumed as well but still less then power wastage during idle mode. The results for power saver method are shown in (Fig 5) for various conditions and networks [7].

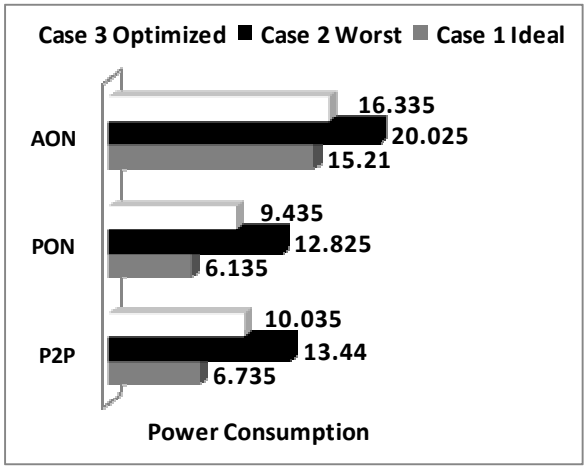

Fig 5: Performance comparison for power saving method

6. CONCLUSION

From power ignoring method simulations it has been concluded that passive optical consumes very less power as compared to other networks and declared as most efficient. So, optimization method is applied on this network for better performance. But, still applying power saving mechanism on point to point network and active optical network is equally important. There can be situations where passive optical network could not be used then at those places the optical network with power saving instead of power ignoring scheme could be used.

This will save large amount of power in larger size networks. PON consumes 9.435W of power as compared to power ignoring method which consumes 14.61 W of power.

7. FUTURE SCOPE

The power consumption can be further minimized by using reflective architectures of ONU such as reflective semiconductor optical amplifier (RSOA) at receiver unit [13].

Energy is consumed by network components at both IP and WDM layers. Routers consume maximum energy. Using adaptive link rate (ALR) mechanism in collaboration with sleep mechanism could help in reducing power consumption because hybrid mechanism overcomes drawbacks of both sleep mechanism and ALR. The dedicated path protection can be used to avoid link failure [10]-[12].

8. REFRENCES

[1] J. Moran, “Moving beyond the standard: Creating additional bandwidth through extending DOCSIS 2.0,” *Motorola Broadband Communication Sector*, white paper, September 2003.

[2] S.J.Park, C.H.Lee, K.T.Jeong, H.J.Park, J.G.Ahn, K.H.Song, “Fiber-to-the-Home Services Based on Wavelength-Division-Multiplexing Passive Optical

Network" *Journal of Light-wave Technology,* vol. 22, no. 11, pp. 2582-259, Nov, 2004.

[3] C. H. Lee, W. V. Sorin, and B. Y. Kim, "Fiber to the home using a PON infrastructure," *IEEE Journal of Light wave Technology*, vol. 24, no. 12, pp. 4568-4583, December 2006.

[4] C. Lange and A. Gladisch ''Energy consumption of FTTH access networks'', *OFC conference,* pp. 1, 22-26 March 2009.

[5] D. Larrabeiti, P. Reviriego, J.A. Hernandez, J.A. Maestro, M. Uruena " Towards an energy efficient 10 Gb/s optical ethernet: Performance analysis and viability ", *Journal of Optical Switching and Networking*, In Press, Vol. 8 Issue 3, pp. 131-138, July 2011.

[6] S.Aleksic, A.Lovric, "Power Efficiency of Extended Reach 10G-EPON and TDM/WDM PON" presented at the *optical fiber communication (OFC*), pp.1, 21-25 March 2010, San Diego.

[7] Ying-Yan S.W. Wong, L.Valcarenghi, S.H. Yen, D.R. Campelo, S. Yamashita, L. Kazovsky, L.Dittmann, ''Energy Management Mechanism for Ethernet Passive Optical Networks (EPONs)'', *IEEE International conference on communication (ICC)*, pp.1,23-27 May,2010 Denmark.

[8] J.Mandin, "EPON Power saving via Sleep Mode", IEEE 802.3az Meeting, September 2008.

[9] S.W. Wong L. Valcarenghi, S.H. Yen D.R. Campelo, S. Yamashita, Leonid Kazovsky ''Sleep Mode for Energy Saving PONs: Advantages and Drawbacks'', *Globecom Workshop*, pp. 1-6, 30 Nov - 4 Dec 2009, USA.

[10] Yi Zhang, Massimo Tornatore, P. Chowdhury, B. Mukherjee "Energy optimization in IP-over-WDM networks ", *Journal of Optical Switching and Networking*, In Press, Vol. 8 Issue 3, pp. 171-180, July 2011.

[11] A. Jirattigalachote, C.Cavdar, Paolo Monti, Lena Wosinska, Anna Tzanakaki "Dynamic provisioning strategies for energy efficient WDM networks with dedicated path protection", *Journal of Optical Switching and Networking*, In Press, Vol. 8 Issue 3, pp. 201-213, July 2011.

[12] R.Kubo, J.Kani, H.Ujikawa, T.Sakamoto, Y.Fujimoto, N.Yoshimoto ''Study and Demonstration of Sleep and Adaptive Link Rate Control Mechanisms for Energy Efficient 10G-EPON'', *OSA Journal of optical communication and networking IEEE*, vol 2, no. 9, pp. 716, Sep.2010.

[13] Y.Tukushima, K.Y.Cho, Y.C.Chung "Design Issues in RSOA based WDM-PON", *IEEE Photonics Global, IPGC 2008,* pp. 1-4, 8-11 Dec, 2008 Singapore.