ENERGY EFFICIENT TRANSMISSION USING OPTICAL ACCESS NETWORK: ISSUES AND CHALLENGES

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ABSTRACT

Everlasting increase of connected devices and users in communication networks carry out enormous traffic volumes. This reason places the network in a position to fine tune the energy consumption in proposal and attentive operations. Optical transmission technologies are a momentous paradigm which brings down the overall energy consumption in communication networks. This advantage increases an interest on research to improve the energy saving opportunities of optical networks. Regardless of this most vibrant research few unanswered questions direct the researchers to set effort on resolving the issues in energy efficient optical networks. Shannon limit and parallelism to support higher capacities is essential in approaching optical systems also without reducing the network performance parameters such as latency, reliability and survivability, energy consumption of optical networks must be laid out as it affects quality of services. New generation network services like optical cloud and fixed mobile convergence have necessity to meet out the end-to-end energy optimization. All these factors enlighten research area towards energy efficiency in optical network transmission. This special research work reconnoiters and consolidates the earlier research models related to energy efficient transmission in optical networks

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1. INTRODUCTION

Optical communication is pervasive in present internet data transport due to its magnificent increase in capacity since its first deployment in past. Being internet as backbone high performance applications are evolved for personal computers and other systems. Necessity towards optical transceivers on data center Dixit et al. (2015), Coimbra et al. (2014), Chen et al. (2016) networks reaches tens of millions every year. This rapid utilization of optical systems particularly places requirements on energy efficiency and scalability of optical systems. Increasing numbers and data rates focuses energy efficiency and power consumption as a primary consideration. In early-stage designs Mohamed and Ab-Rahman (2015) , Li et al. (2014) energy efficiency was secondary and now the scenario changes and it became a primary constrain in design and play an important role in future transmission systems. Classification of optical access networks includes.

- Fiber to the Business (FTTB)
- Fiber to the Curb (FTTC)
- Fiber to the Cabinet (Fttcab)
- Fiber to the Home (FTTH)

The FTTB is used for business users which has single business unit and multi-tenant unit based on the capacity. FTTC and FTTCabare used to access the curb or the cabinet over fiber for multi-unit which has large number of ports. FTTH is used in home for single unit includes less number of ports Bokhari & Saengudomlert (2013), Wang et al. (2017). Besides this fiber to the premises (FTTP) is used to provide service to user from internet service provider. It provides more bandwidth as there is no external devices in cables. The limitation of FTTP is in its architecture and cost. Table 1 summarizes the classification of OAN by end point.

Table 1

Table 1 Classification of Optical Access Networks by End-Point

S. No.	Types of Oans	Down/Up Data Rate	End User
1	Fiber to the Business (FTTB)	2.5Gbps/1.25Gbps	OFFICES
2	Fiber to the Curb (FTTC)	2.5Gbps/1.25Gbps	URBAN COVERAGE
3	Fiber to the Home (FTTH)	2.5Gbps/1.25Gbps	INDIVIDUAL HOME

Classification of optical access networks by infrastructure has two solutions as

- Point-to-Point (PtP)
- Point-to-Multipoint (PtM) systems

In PtP architecture each user unit is connected through an individual fiber line to the central office. Using separate line and end point inside the central office increases the cost in the PtP architecture. In order to minimize the fiber lines active star model is preferred in PtM architecture. It uses an active node to connect the central office, and this decreases the cost. The active node used in this model needs separate power to operate which increases power consumption. Even though it used less fiber lines the bandwidth capacity is reduced. The active node in star model is replaced by optical splitter or optical combiner in active star model PtM architecture Dourado et al. (2018). Using optical element in the delivery line this architecture is given as passive optical network and it is popular due to its cost-effective implementation. On the other hand, lots of research works are going on solitons propagations Senthilkumar et al. (2022), Selvaraj (2013).

2. SURVEY OF ENERGY EFFICIENT TRANSMISSION IN OAN

Passive optical network (PON) Shaddad et al. (2014). is most energy efficient than metallic access network systems. PON is used to implement multipoint architecture to serve abundant endpoints from single fiber using unpowered splitters. The net result of this system which briefs the architecture parts such as FTTH, FTTB or FTTC, so that it is not essential that each customer needs to be connected to the hub by separate fibers. In this FTTH is widely used to support increasing broadband services. Operators are interested in reducing the power consumption of FTTH systems. For 10Gigabit-capable passive optical network system ITU-T recently standardized by adding cyclic sleep to the optical network unit (ONU) Boiyo et al. (2017), Zhu et al. (2013). These added roles will turn out to be further imperative development in reducing the power consumption of next generation FTTH systems. Figure 1 gives an illustration about passive optical networks (PON).

Figure 1

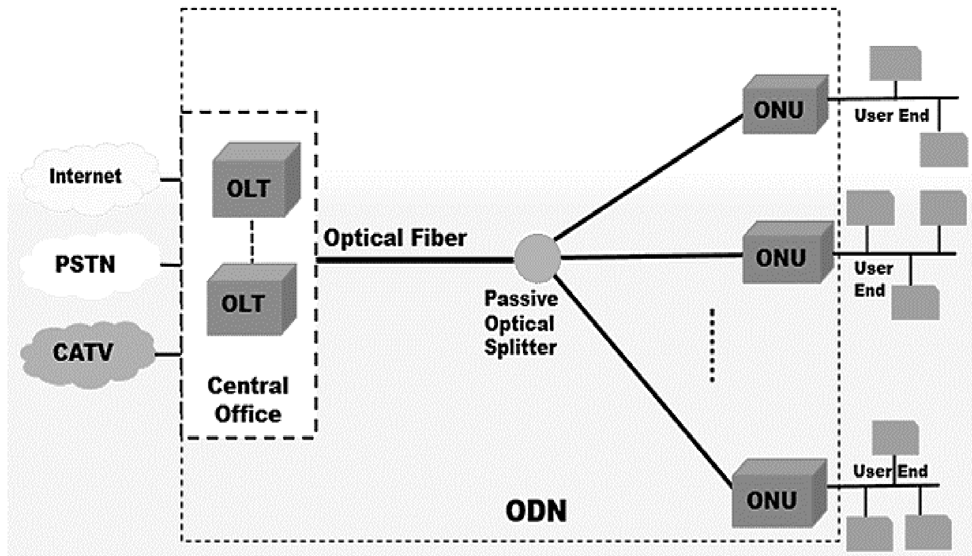

Figure 1 Passive Optical Networks

In traditional TDM PON optical line termination is used to connect the optical network units through an optical distribution network. Optical couplers and power splitters used in this architecture is transparent. IEEE 802.3ah and gigabit capable PON are widely used in FTTH as it uses broadcast and select in downstream and TDMA in upstream. Multiple ONUs uses OLT interface makes this traditional TDM PON as most energy efficient model. While WDM PON is another model which provides point to point access to individual ONU through dedicated wavelength. But it needs a thermo-electric cooling to stabilize its wavelength. As cooling unit consumes extra power which reduces the efficiency of the system. In hybrid TWDM PON time division multiplexing PON is combined with wavelength division multiplexing to increase the capacity of PON typically in wavelength pairs. It is used in full-service access network for NG PON2. The power consumption for a bandwidth used in TDM PON is lesser than the hybrid TWDM PON as it used multiple transceivers in OLT.

Recently OFDMA PON Zhao et al. (2012) is considered as an alternate solution for conventional PON as its services spectrum to large subcarriers by overlapping and this attains much spectral efficiency. Including intensity modulation and optical field modulation OFDMA PON uses two detection models such as direct detection and coherent detection. Coupling field modulation with coherent detection has better performance but it is much expensive and complex system design. While intensity modulation with direct detection simple and cost effective which is reliable for applications. Even though OFDMA PON performs better it requires extra power requirements for DSP operations. Using ADC and DAC consumes high power as it needs to be operated twice of the sampling rate because of intensity modulation only uses half of the transmitted subcarriers.

The design architecture of access networks must consider energy efficiency as the performance of the network depends on the cost and reduced power consumption. In transmission process ONU acquires more energy and various solutions are proposed by researchers to reduce the power consumption and to improve the energy efficiency. Instead of using ONU in its full potential and reducing the power consumption when it is not in active state has greatly reduces the power consumption. Techniques to reduce the power in PON conducted by ITU Wang et al. (2015), Han et al. (2018) which reduces the cost and size of the battery and overall power consumption average. It is essential to achieve the quality of services without affecting the quantity is available in earlier telephone services. Mentioning such power saving techniques Osman (2017), Lv et al. (2014) with further modification improves the optical access network energy efficiency. Modification in ONU hardware has higher complexity and cost effective and even if it reduces the feasibility of network services affects. Little popular power consumption in ONU is classified and this section provides a short summary about existing energy efficiency models with its facts in implementing in optical access networks. The improvement of QoS though sleeping in enhanced PON introduces improved Ethernet passive optical network. This QoS improves performance based on the ITU-I standards. It defines two sleep duration for ONUs.

- Fast sleep
- Deep sleep
- Dozing
- Power shedding

The fast sleep mode Lv et al. (2014) is used to save the ONU power by providing sequence of cycles to the system to enter the sleep mode. A simultaneous sleep and active periods are defined for the system which helps to reduce the power consumption. In sleep periods the activity of ONU goes into deep sleep state so that it stops all the activities for some time like a fully power offed system and only few activities detection function will run. In active period ONU behaves and performs all normal operations. The time period between the two states is common for the entire ONUs so that an OLT is used to control and synchronize the ONUs. OLT sends the alert message, and it defines the sleep period and wakeup time for the ONUs. A timer is used by OLT to generate signals to perform the time period action. OLT downstream the traffic and transfers to ONU when it came into active period so that the entire power of ONU is saved, and this allows better power saving option for optical networks.

The deep sleep mode Rauen et al. (2017) completely offs the ONU for the duration which is fixed by predefined program. Minimum basic operations like activity detection will run in the deep sleep model so most of the functions of ONU and transceivers are off which greatly reduces the power consumption. In this mode the ONU is controlled by user or the local timers. OLT is aware of ONUs transition period so that OLT decides the traffic streaming to ONUs if the traffic is high Newaz et al. (2013) it downstream the traffic and if ONUs is active, it upstream the traffic so that entire traffic is balanced to the ONUs. If OLT allocates upstream traffic to

ONU when it is in sleep model, there it should not get response from the ONU. This mode is useful in terminal equipment as it works like a switch to operate the ONU.

The dozing mode Abbas & Gregory (2016) has unique operation than earlier modes as it power offs the transmitter for certain period but at the same time its receiver is active on all the time. So that it can ignores the upstream allocation as it doesn't have traffic to send simultaneously its downstream is active which delivers the traffic to the users. Based on OLT request the ONUs comes into full active state. Without expecting response from ONU, the OLT sends the upstream so that is recovers when traffic occurs. The shedding sleep model the transceivers of the ONUs are always active ad only ONU functionalities are kept in sleep mode for some time period. Optical link Gong et al. (2013) always active so that it can be used in only in power supply failure. The shedding class is used to define the static time parameter and its intervals which supports also must be switched off when power failure occurs.

Based on the user requirements the services are stopped at certain time period so that the operator has opportunity to shut down the interfaces of user. This provides the user to define the ONU operating periods and consumptions. According to ITU-T power shedding YuanqiuLuo & Effenberger (2014) save 75% of active power and the battery backup has also been reduced into 60%. Many cellular applications, monitoring industries, communication devices are experimented this because of its power saving option. Table 2 shows the energy awareness through different modes.

Table 2

Table 2 Energy Awareness through Modes

S. No	Modes	Availability awareness	Energy awareness
1	Fast sleep	No	Moderate
2	Deep sleep	Yes	High
3	Dozing	Yes	Moderate
4	Power shedding	Yes	High

In the midterm upgrade of optical access networks the current generation includes Gigabit PON and Gigabit EA. The OLTs and EA are upgraded into 10 GB to accommodate the systems such as XG-PON and 10G-EPON. The power saving option in the new generation has

- Cyclic sleep
- Energy efficient Ethernet
- Adaptive link rate
- Advanced link aggregation

Implementing sleep modes in ONUs practiced in conventional model faces issues while encounter the important traffic from OLT. As ONUs enters into sleep model most of the services are stopped but the important tasks are missed sometimes so that a cyclic sleep Rouskas et al. (2016) is introduced in the new generation systems. This performs a cyclic sleep time and wakeup time for the ONUs and checks for traffic when it is sleeping mode. ITU-T G.987.3 is used to support this enhanced feature in sleep mode of conventional models. Energy efficient Ethernet used in ONU for network interface to reduce the power consumption. IEEE 802.3

group is used to define the electrical Ethernet interfaces, and this provides more power saving options to ONUs.

By providing adaptive link rate to ONUs along with cyclic sleep greatly improves the power consumption. Allowing 2 Gigabit and 10Gigabit to ONUs resides in same PON the high stream is reduced into 2 Gigabits so that it improves the power consumption for extra load. Literature demonstrated the ALR functions and parallel operations are performed by switching the link from one over the other. This gives extra time to ONUs to get into sleep model when the traffic is less.

Using advanced link aggregation in OLT for service node interface PON systems. IEEE 802.3ad helps to control the active links there by reducing the total power based on link aggregation. In this similar aim synchronous time-based switching in router operations on scheduling the traffic reduces the power consumption and increases the energy efficiency of the system. Pipeline concepts and time driven approaches are used to reduce the complexity of the network so that the accessing the bandwidth increases there by increases the efficiency. Comparison of few research works is highlighted in Table 3 as summary.

Table 3

Table 3 Comparative Analysis Energy Efficiency Models

Author	Parameter Used	Energy Cost	Degree of energy Saving
Chen et al. (2016)	Adaptive envelope modulation	Minimized	Low
Li et al. (2015)	Dynamic Bandwidth Allocation	Minimized	Medium
Dourado et al. (2018)	Bandwidth Allocation	Minimized	Medium
Coimbra et al. (2014)	routing algorithm	Minimized	Medium
Wang et al. (2015)	SDN enabled integrated control plane	Minimized	Medium
Li et al. (2014)	OFDM network coding	Minimized	Medium
Zhu et al. (2013)	CLS	Minimized	Medium
Bokhari et al. (2016)	Integrated sleep mode	Minimized	High
Bokhari & Saengudomlert (2013)	mean packet delay	Minimized	High
Wang et al. (2017)	Delay-aware adaptive sleep mechanism	Minimized	High
Abrate & Gaudino (2015)	OFDM and TDMA	Minimized	Medium

3. CONCLUSION

An elaborate survey of literature has been carried out to find out the research contributions and understanding the challenges and issues in energy efficient transmission in optical access network. Based on the findings of the survey the below inferences are summarized

- Most of existing works have been implementing sleep modes to improve the power efficiency with OLT.
- In analysing the modes, we have attempted to identify the issues in each model that can be traced from the literature, together with the challenges in network three base concepts are identified clearly emerge for next generation communication.

- Cyclic sleep mode, adaptive link rate and link aggregation modes improve the energy efficiency of the next generation optical network communication.
- Our conclusions indicate that future research should mainly address the aspects 1. Effective power minimization machine learning model 2. Optimization of energy efficiency in optical access networks.

CONFLICT OF INTERESTS

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