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# ENERGY AWARE LOAD ADAPTATION TECHNIQUES FOR FI-WI AND OTHER NETWORKS

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***Abstract: As the number of telecommunication network users are growing day by day, efficient energy management has become today's need. Load adaption is one of the key techniques to save energy by putting low loaded equipments into low power state. In Fiber Wireless (Fi-Wi) access network, optical fiber communication and wireless communication has been combined for better quality of services (QoS) using passive optical network (PON) at back end and wireless network at front end. Although there is a tradeoff between energy saving and QoS.In this paper, we survey load adaption techniques for energy saving in telecommunication networks with an outlook to find applicability of any Energy Aware Load Adaptation Technique used in Non Fi-Wi network which can be adopted into Fi-Wi access network.***
***Keywords: Fi-Wi, Load Adaption, Energy Saving, ONU.***

## I. INTRODUCTION

In Fiber–Wireless (Fi-Wi) access networks advantages of both the optical and wireless access networks have been integrated to provide high bandwidth, transmission stability and ubiquity in a cost effective way. As the number of network users are growing rapidly and the whole world is suffering from global warming, we need to work on energy saving and green communication. Though optical access network is considered to be the most energy efficient technology as compared to other copper based wire line access and wireless access systems, further improvement in terms of energy reduction can be possible in Fi-Wi access network. A PON is used as a broadband access technology. It consists of Optical Line Terminal (OLT) in Central Office (CO) which is connected to multiple ONUs through optical fiber cable and passive splitter. As PON uses passive splitter at remote node to connect multiple ONUs, reduces the amount of fiber and central office equipment as compared to point-to-point architectures. ONUs communicates to user end via wireless routers in wireless front end network as shown in Fig. 1. As communication network technologies and number of users are growing rapidly, communication networks has become an important contributor to the carbon footprint and climate change. Energy saving is an important factor as we move towards green communication. Energy saving should be taken into consideration when planning telecommunication networks. As compared to other access network architectures, fiber–wireless access networks have more chances to save energy because wireless section of Fi-Wi consist multiple paths from ONUs to user ends via multiple router nodes, there for some selected ONUs can be either switched off or can go to low power state for a specific time and load can be rerouted through other router nodes.

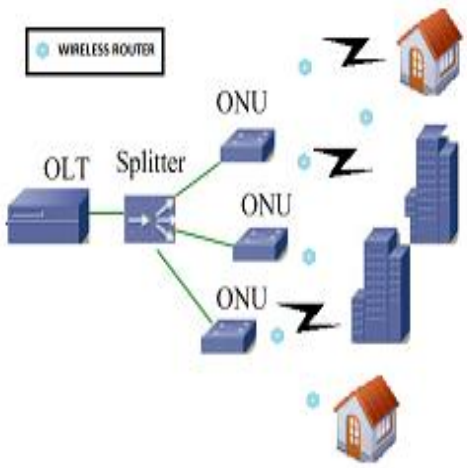


Fig. 1. Generic Architecture of Fi-Wi Access Network

Although there might be some router nodes which consist single path from ONU to user end [1].Energy Saving is also possible by proper ONU placement. As the no. of active ONUs reduces in the network, network requires less power. Survivability prone networks also helps in energy saving. In Fi-Wi network, traffic load varies during different hours. It is possible to selectively put some network components into low-power state i.e. either sleeping mode or switch off mode to save energy when the low-load hours and then they can be activated into awaken state when the load increases too much. In networks where traffic load significantly changes over time, load adaptive energy saving techniques can be adopted for network resources to be activated or deactivated according to network load conditions. Load adaption technique should save energy while maintaining stabilities in the IP routing, network fault tolerance, and quality of service (QoS) conditions provided to users [2].When ONUs are implemented with ONU sleep method, they are having two power consumption modes in a broad way. In active mode ONU can send or receive data but consumes more energy while in sleep mode ONU cannot receive downstream traffic coming from OLT but consumes less energy.OLT decides sleeping period of ONUs on the basis of energy saving technique adopted by Fi-Wi access network [3].

## II. LITERATURE REVIEW

### *A. Load Adaptation techniques used in Fi-Wi Access Network*

In [5] author proposed an energy saving algorithm for Fi-Wi

  

networks. Energy-saving Algorithm based on Sleeping Low-loaded OUNs (EASLO) is an heuristic algorithm where author predefined upper and lower limits of load coming to the ONU to decide whether ONU will put into sleep mode or in awaken mode. Load coming to the sleep ONU will be rerouted to active ONU. In [6] author proposed an algorithm named as Wireless Optical Energy Savings (WOES) for energy saving in Fi-Wi network. WOES applies energy saving technique at ONUs in optical back end as well as at wireless routers in wireless front end .Low loaded ONUs and wireless routers put into low power state to save energy with the help of Energy Efficient ONU Management (EEOM) and Energy Aware Topology Configuration (EATC) modules respectively. In[7] author proposed dynamic bandwidth allocation (DBA) mechanism in LREPON (Long Reach Ethernet PON). Author presented how DBA mechanism helps to save energy while Fi-Wi adopts Optical Burst Switching mode. As we cannot just apply energy saving methods in telecommunication network without considering its effect on QoS provided to the user. Author in [8] introduced Energy Efficient Ethernet (EEE) in Fi-Wi access networks for energy saving while maintaining expected QoS. In [9] an energy efficient segmentation (EES) scheme for energy saving in FiWi network has proposed by author. FiWi network divided into number of segments. Each segment consist number of ONUs and a Head ONU which is connected to maximum no. of wireless routers. Head ONUs always work in active mode and according to traffic load decide whether other ONUs should put into awaken state or into sleep state. Author in [10] proposed Load Balancing ONU Placement (LBOP) algorithm to minimize the numbers of ONUs and load balancing among ONUs. The LBOP algorithm consists of two stages ONU placement and load balancing. In first stage, firstly place the ONU in a network in greedy manner one-by-one, and then find best location for everyone such that the required number of ONU is minimized and the entire wireless router will connect to ONU under a wireless multi hop way. In second stage, the traffic load is given to each ONU according to their subordinate wireless router. Then implement the load transferring among different ONU until it satisfies the load balancing condition. From this algorithm the required number of ONU is minimized. In [11] Energy and Delay Aware Routing (EDAR) algorithm works on reducing the power consumption at both wireless and optical part. It switches maximum no. of nodes into the sleep mode while keeping the network performance to an acceptable limit. This algorithm first works in reducing the delay in the network so that if wireless switch or optical nodes are in the sleep mode the performance of network will not be affected. And the energy aware routing helps to reduce energy consumption of network. Author [2] presented a load adaptive and fault tolerant framework for energy saving in FiWi access networks. Under low traffic condition ONUs put into long standing sleep mode with the help of presented frame work. It helps to improve energy efficiency while maintaining QoS and fault tolerance significantly under low to medium traffic loads. [11],[19] Due to recognition of a necessity for power saving in a next generation optical network, the ITU-T achieved standardization with respect to two low power modes, a doze mode and a cyclic sleep mode, in G987.3 standards. The standardization relates to signaling between an ONU and an OLT, and state machine management. An optical transmitter and an optical receiver may be subject to power reduction. In the doze mode, an optical receiver of the ONU may be activated continually, and an optical transmitter of the ONU may be activated/ deactivated (on/off) periodically. In the cyclic sleep mode, both the optical transmitter and the optical receiver may be activated /deactivated (on/off) periodically. The performance of the fast/cyclic sleep scheme depends on the sleep mode scheduling and on the dynamic bandwidth allocation. It is necessary to observe overall effect of energy saving methods applied to the network. There are possibilities that different energy saving methods do not cooperate with each other and causes additional delay and energy loss to the network. The power saving issue should be carefully considered in FiWi networks. Author [3] presented two types of power saving techniques i.e. Power Saving Mode (PSM) and Adaptive Power Saving Mode (APSM) for WMN and ONU sleep method for PON. In both techniques energy is saved by turning off the transmitting devices. Author presented a cooperative ONU sleep method to reduce end to end delay and save energy. In [13] author proposed an energy-efficient scheme named as load adaptive sequence arrangement (LASA).This scheme can save up to 18% additional energy as compared to other fixed polling sequence schemes for ONUs in PON with the help of dynamic polling sequence scheme .LASA put ONUs into a long sleep time to save energy while maintaining average polling cycle time. For further improvements under low traffic conditions author proposed fixed minimal transmission time (FMT) scheme along with LASA named as LASA-FMT for minimal transmission time of an ONU in any traffic condition. The LASA scheme and the LASA-FMT scheme also supports delay sensitive services by maintaining packet delay.

*B. Load Adaptation techniques used in other Access Networks*

Author in [4] presented detailed analysis of three major domains of telecom optical network named as core, metro and access network for energy aware future work possibilities. Author presented huge possibilities in an access network for energy saving specially at ONUs. Author [12] presented load-balanced adaptive routing algorithm for torus networks, GOAL - Globally Oblivious Adaptive Locally Local load balance and compared its throughput, latency, stability and other performance factor to other routing algorithms. In [13] author compared a reference network having a constant power consumption to a network with a load adaption technique to calculate energy saving potential in load adaption technique. Energy efficiency improvements, strongly depends on traffic load variation with time. Author presented that energy saving potential increases rapidly if we concentrate on a service specific network rather than an aggregated network. In [15] author proposed the Switch-On

  

scheme in an IP-over-WDM network .In proposed scheme author concentrated on the IP link and circuits which are essential to put into switch on state in different traffic conditions. Author presented a comparative analysis of energy aware load adaptive schemes to discuss the trade-off between energy efficiency and routing stability. Author [16] presented detailed survey on two most common wireless access technologies, cellular and WLAN. Author proposed energy aware solutions while including cooperation between both wireless access technologies. Author in [17] presented an adaptive load distribution strategy using probing technique to obtain optimal load partitioning as compare to conventional divisible load scheduling algorithms to adopt unknown network parameters. In [18] author applied load adoption on top of OFDM/SDMA processors to lower the bit error rate (BER) of these processors and to exploit the frequency diversity of the multipath channels.

## III. CONCLUSION

Telecommunication networks have great potential for energy saving. Load adaption has been widely used in telecommunication networks to reduce power consumption. In this paper we discussed different approaches to cooperate dynamic load conditions with available network capacity to reduce power consumption while keeping QoS up to the mark. Energy aware Load-adaptation techniques for Fi-Wi as well as Non Fi-Wi networks were investigated .It is found that there is a limit for energy efficiency improvements as other network parameters e.g. latency, throughput, QoS, cost, cooperation between different energy aware approaches adopted in same network at different network sections, change in network operational practices, change in network hardware as well as software affects network performance. There is a long road map for energy aware load adaptation in Fi-Wi access network for further improvements.

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