Network Architecture and Routine Scrutiny of Multi-Olt Pon for FTTH and Wireless Sensor Networks

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Abstract

A unified fiber-to-the-homes (FTTHs) and wireless sensor network (WSN) provides a profitable solution to build up an immaculate ubiquitous-City (U-city). The key objects of actual convergence of FTTH and WSN are less computational intricacy for data packet processing, little installation cost, and good quality of services. In this paper, we familiarise an integrated network structure of multi-optical line terminal (multi-OLT) passive optical network (PON) which can lodge multiple service workers in a single PON. A modified version of interleaved polling algorithm is proposed for scheduling of control messages from multiple OLTs in a single network. We also provide thorough mathematical analysis of cycle time variation, succeeding grant scheduling time, and average packet interruption for both uniform and non-uniform traffic loads generated by each ONU, using fixed service bandwidth provision scheme and limited service bandwidth sharing scheme. We also compare the throughput of the anticipated scheme with existing single-OLT PON for non-uniform traffic load using limited provision bandwidth allocation scheme. The replication results show that the proposed multi-OLT PON system can ropes prevailing bandwidth allocation schemes with better routine than the single-OLT PON in terms of average packet delay, bandwidth consumption, and throughput.

Keywords - *Multi-OLT PON, Network Construction, WSN, FTTH, Limited Service Bandwidth Allocation Scheme, Interleaved Polling Algorithm, Non-uniform Traffic, Packet Delay.*

I. INTRODUCTION

Currently, the network construction of a u-City is very difficult due to convergence of several new service providers. WSN is also one of the most significant networks to build up a perfect u-City. Day-by-day the diameter of WSN becomes very large to provide the numerous new facilities and supports. Due to the large diameter as well as large number of wireless hops from the personal area network coordinator (PANC) to the surface nodes of a WSN, data packets from the surface nodes agonise from excess time delay. To resolve this problem, crowding of large WSN is a good approach to reduce the individual network diameter as well as quantity of hops while the whole network size is enlarged. In the clustered WSN, every cluster entails of a cluster head (CH), and data from all nodes in a cluster are transmitted to a CH over a short distance with a small number of hops. So the data diffusion delay in the clustered sensor network will be much lower than the case when each node unswervingly communicates with the PANC through a large number of wireless hops. Even though, the main attentions of this paper is only on latency issue and analysis of energy effectiveness is out of scope of this paper but theenergy efficiency is another momentous factor for an efficient WSN.

Since the capacity of cordless inside every sensor node and recurring replacement of them is idealistic that is why preservation of that energy is very important. Some clustering algorithms of WSN have been established to provide the energy effectiveness. In energy effectual homogeneous clustering algorithm is proposed to extend the lifetime of sensor nodes and to maintain a balance energy consumption of nodes of a sensor networks. Then in a u-city all the information systems are practically linked together, it is very important to make a linkup with optical network terminals and WSNs. In a cluster based WSN is projected where all sensor nodes of a cluster is coupled with a CH through a small number of wireless hops and all the CHs are connected to a PANC by Radio-over- Fiber (RoF) links. Presentation of optical network in clustered WSN is very useful in that the optical reduction is very small while wide bandwidth can be utilized.PON is an optical network it does not comprise active elements from source to terminus which effectively reduces the active power consumption of the networks.

PON provides numerous advantages over other access technologies. The main compensations of PON are high data rate, easy adaptability with new protocols and services, simple network structure, minimize the fiber distribution, less maintenance, and allow for long distance between the central office and customer places. PON also provides operative solutions to satisfy the increasing capacity demand in the access part of the communication arena. In, a clustered WSN is proposed where all the CHs are related with the PANC through a PON system. Though, conjunction of data networks and sensor networks in a single-OLT PON will increase the computational complexity for data packet dispensation in the OLT. To mitigate this problem some polling algorithms have been proposed to allow additional time in OLT for totalling and organisation in addition with the guard time between every two succeeding ONUs. Due to these increased computational involvedness and supplementary computation time, some delay sensitive traffic of WSN will suffer from unexpected delay.

To solve this problem, a solitary PON structure with multiple OLTs can be a good candidate. In this paper, we recommend a converged network building of multi-OLT PON for FTTH terminals and clustered-based WSN. Here, we undertake that a tree structured PON consists of two OLTs in the root side and *N* ONUs in the leave side sharing the same ocular fiber links. One OLT is associated with all the FTTH terminals, and the other is connected with all the CHs of WSN. The simulation results for following grant scheduling time, evolution of cycle time, and average packet delay for both uniform and non-uniform traffic conditions are inspected and compared with a single-OLT PON for fixed service (FS) bandwidth allocation scheme and limited service (LS) bandwidth allocation scheme. Quantity of multi-OLT PON is also analysed and compared with the single-OLT PON for non-uniform traffic load considering LS bandwidth allocation scheme. Since generated packet sizes of FTTH terminuses and CHs of WSN are not same, a comparative analysis is shown by changing the ratio of maximum bandwidth for FTTH and WSN because the maximum cycle time, *Tmax* , is endless for PON system.

In the clustered WSN, frequently all CHs are accountable to transmit data packet to the PANC finished radio frequency (RF) transmission which suffers from data accident and more active energy consumption. However, preservation of energy in WSN is one of the prime requirements. Here, whole sensor network is separated into several clusters and each cluster contains static CH. All static CHs of WSN are disseminated randomly in a wide area to collect the environment data such as temperature, dampness, the location of workers in the mine etc. Finally, all of the CHs are connected with the remote antenna units (RAUs) of RoF system to avoid data accident and RF transmission from CHs to PANC.

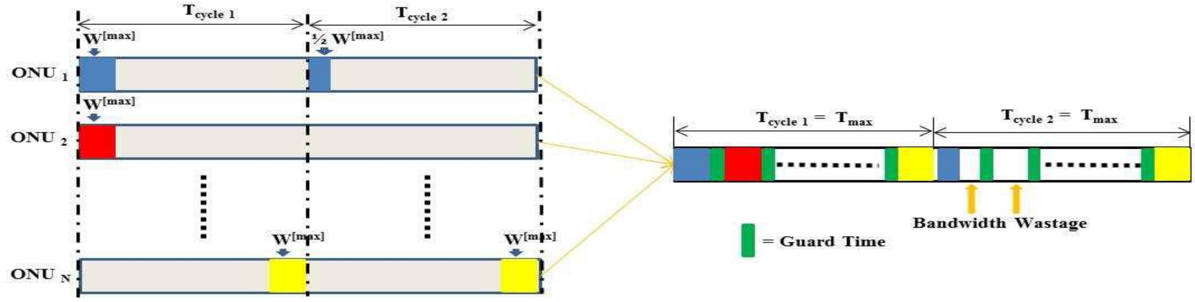

Figure1. Fixed Bandwidth Allocation Scheme

Figure 1 shows the main downside of this algorithm is light-loaded ONUs will under-utilize their assigned bandwidth important to increased delay to other ONUs and ultimately deteriorate the throughput and bandwidth operation of the system.

II. NETWORK ARCHITECTURE OF MULTI-OLT PON

In this paper, we deliberate an access optical network construction consisting of two OLTs and *N*ONUs connected using a single PON structure as shown in Figure 2. For effortlessness, only two OLTs, OLT1 and OLT2/PANC, and four ONUs with tree based network topology are shown in the figure to enlighten the network structure and data transmission sequences for both upstream and downstream. All transmissions in the proposed multi-OLT PON are completed among two OLTs in the root side and four ONUs in the leaf side of the tree topology. Here, OLT1 is connected with FTTH data terminals, ONU1 and ONU3. On the other needle, OLT2/PANC is connected with the static CHs of WSN, ONU2 and ONU4. All the influences among OLTs and ONUs are recognised through optical fibers and a passive splitter/combiner. In downstream transmission, both OLTs follow the same polling table to initiate a transmission of a Grant message to the ONUs.

Reliant on the RTT delay between OLTs and ONUs, the1st Grant message can be planned by any of both OLTs, because RTT be contingent on the physical distances between OLTs and ONUs and these distances are not fixed for all ONUs. Since, all downstream programmes are broadcasted from OLT to ONUs, both OLTs broadcast their Grant messages complete an optical splitter and each ONU filters the received packets according to its destination address.

In upstream transmission, all ONUs share a common channel volume and resources, and countless multiple access schemes are exist to share a common channel in a PON-based access network. In our model, we consider time-division multiple access (TDMA) scheme to ensure the use of a single upstream wavelength for all users and a single receiver in the bonce end to reduce the system cost. According to the principle of the proposed multi-OLT PON system,OLT1 receives data only from the ONUs of FTTH terminals (ONU1, ONU3) and OLT2 receives data only from the ONUs of WSN (ONU2, ONU4).

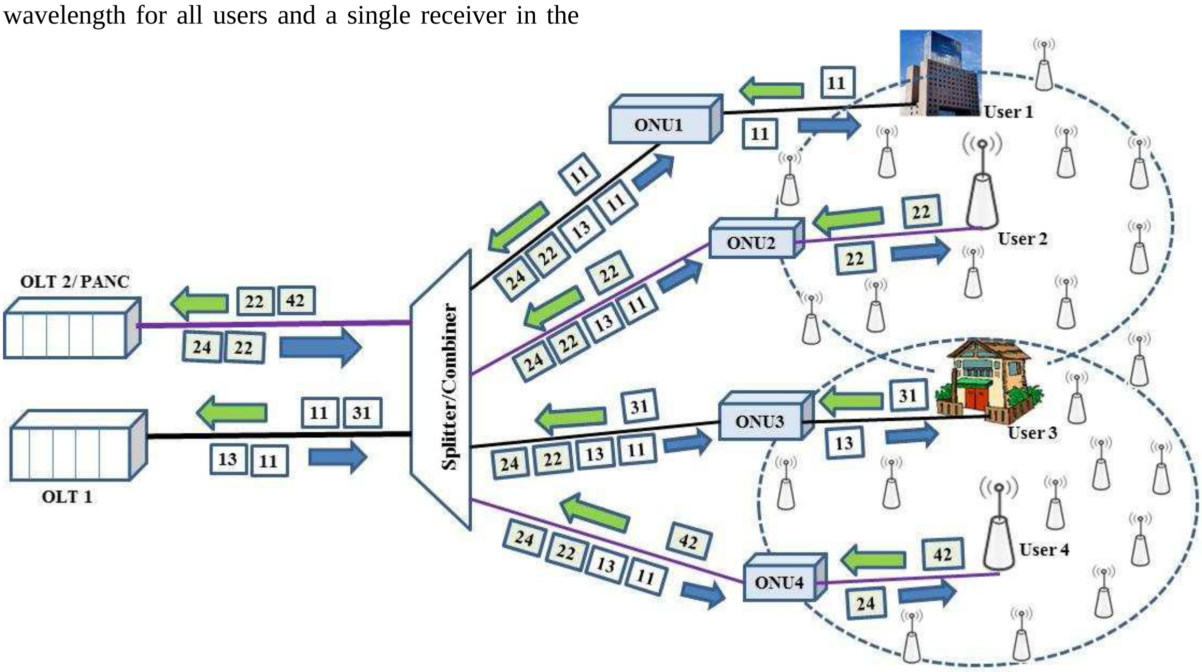

Figure 2. Network Architecture and Data Transmission in Proposed Multi-OLT PON

III. MODIFIED ALGORITHMS FOR MULTI-OLT PON

In this section, the altered version of interleaved polling algorithm and scheduling algorithm of a control message apposite for the multi-OLT PON system are described.

A. Interleaved Polling Algorithm

The central aspect of polling algorithm is the scheduling of data transmission of ONUs. Frequently, a polling protocol is cycle based, which used to circumvent high traffic load as well as data collision, and it limits the maximum transmission window for each ONU. A commonly used polling algorithm is round-robin, which orders the transmission of every ONU sporadically. To progress the network performance, interleaved polling with adaptive cycle time (IPACT) is used.

B. Scheduling Algorithm of a Control Message

Throughout upstream transmission in a single-OLT PON, all ONUs share a single uplink optical fiber trunk connected with an OLT. To avoid data collision due to multiple ONUs transmitting at the same time, a multi-point control protocol (MPCP) is being developed. Customarily, the MPCP operation in PON requires two control messages, Grant and Report. A Report message contains current queue length of each ONU to apprise the OLT. On the other hand, the OLT assigns a timeslot to an ONU by a Grant message. Scheduling of Grant messages from OLT depends on RTT and granted transmission window size of ONUs. This is since of the variation of RTT and granted window size for dissimilar ONUs.

IV. PERFORMANCE EVALUATIONS

In this section, the system presentations of the projected multi-OLT PON with the FS bandwidth allocation organization and the LS bandwidth allocation scheme are analysed and equated with the existing single-OLT PON in terms of following Grant scheduling time, cycle time evolution, and average packet delay for uniform and non-uniform traffic loads. Lastly, we have investigated the quantity of the multi-OLT PON and related with the single-OLT PON for non-uniform traffic load and LS bandwidth division scheme. For the variation of traffic model among FTTH terminuses and CHs of WSN, performances of the multi-OLT PON system are also analysed using dissimilar packet sizes for FTTH terminals and WSN by considering diverse maximum granted window sizes, *W[max]*.

The random packet-based reproduction model was used seeing tree topology based PON architecture with two OLTs and 16 ONUs, where eight ONUs (ONU1, ONU3 … ONU15) were measured for OLT1 and other eight ONUs (ONU2, ONU4 … ONU16) were for OLT2. The reserves from OLTs to ONUs were assumed as indiscriminate to range from 10 to 20 km [15]. The downstream transmission and upstream transmission speeds of both were 1 Gb/s. Highly burst random traffic patterns were generated for non-uniform traffic condition. For unvarying traffic condition every ONU was considered to generate an offered load while for non-uniform traffic condition every ONU was considered to produce any value from 0 to the accessible load. Our simulations took into account queuing delay, transmission delay, propagation delay, and processing delay. The simulation scenario is summarized in Table 1.

Table 1. Simulation Scenario

Symbol	Explanation	Value
N_{ONU}	Total Number of ONUs	16
N_{FTTH}	Number of ONUs for FTTH terminals	8
N_{WSN}	Number of ONUs for WSN	8
N_{OLT}	Number of OLTs	2
D	Distance between OLTs and ONUs (random)	10-20 km
T_{max}	Maximum cycle time	2 ms
T_g	Guard time for single OLT PON	5 μs
R_D	Transmission speed	1Gb/s
T_{proc}	Processing time	10μs
B	Packet size	1500 byte (FTTH) 1024 byte (WSN)
B_{eth}	Ethernet overhead	304 bits
B_{rep}	Report message size	576 bits
P_{max}	Maximum transmission window	20 packets
$W^{[max]}$	Maximum granted window	$(B_{eth}+ B)*P_{max}$

V. CONCLUSIONS

In this paper, we projected a multi-OLT PON structure for both FTTH terminuses and WSN. A modified interwove polling algorithm and scheduling algorithm of a controller message were also proposed. From the computer simulation results, evaluating average packet delay, it is found that the proposed structure can moderates the end-to-end latency about 0.1ms up to the offered load of 0.6 while 0.2ms at offered load of 1.0 for both uniform and non-uniform traffic loads. The analysis achieved in this study using the prevailing FS and LS bandwidth allocation schemes for both uniform and non-uniform traffic situations proves the validity of the proposed multi-OLT PON structure. Moreover, the proposed multi-OLT PON structure with modified interleaved polling algorithm also outperforms other existing single-OLT polling algorithms in term of quantity for no uniform traffic load with LS scheme. Additionally, it is found that the conjunction of FTTH and WSN in a multi-OLT PON is an efficient approach in that it provides cost operative solution than using two separate PONs, less packet delay, enhanced bandwidth utilization, and throughput under both uniform and non-uniform traffic conditions.

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