Optical Networks for Optimized and cost effective Performance

Ankur Singhal, Vinay Bhatia, Abhishek Sharma

Abstract: Recently there is rapid increase of multimedia applications in the access networks. The focus of this paper is to suggest a novel system architecture that can provide efficient and cost effective solutions for the access networks. To offer economical solutions with higher bandwidth optical networks are designed with passive components. In the presented system, 512 subscribers can access information for aggregated system line rate of 80Gbps. Proposed frameworks are subjected to intensive investigation in terms of Modulation Format, External Modulator, Photo Detector so that system architectures perform at an optimized level. Also, the access network is designed without the use of reach extender devices like optical amplifier or repeater so that installation and the recurring cost are minimized.

Index Terms: Access networks, Central office, Cost, Modulation formats, Optical networks,

1. INTRODUCTION

The rapid augmentation of broadband services offered on the Internet has resulted in increased bandwidth requirement from customers affecting both backbone networks as well as access networks. Access networks also termed as last mile systems because they comprise the last section of a communication network with the connection from service provider Central office (CO) to residential and commercial customers. Transmission capacity requirements of residential subscribers have increased sharply for accessing multimedia services. Access networks are more sensitive to operational and infrastructural expenditure because it connects few customers in comparison with the backbone network. Backbone network has shown tremendous growth in system capacity but access network have not scaled up commensurately due to revenue dynamics. It has created bandwidth bottleneck between end users and service provider central office over the access network. The major factor contributing to recent research initiatives in the access networks is to upgrade existing network infrastructure at decreased investment and operating expenses. Along with increasing requirements of customers for higher transmission bandwidth with communication at wider network spans so as to connect subscribers located at far off places without any major additional infrastructure [1]. Using passive components in the optical access networks minimizes the energy requirements and so operational expenditure is reduced [2]. Still, the capital expenditure of Passive Optical Access Networks (PONs) is a huge concern with vital facilities costing several thousand dollars. Infrastructural costs are a major challenge in meeting the huge end-user expectations for cheaper access to broadband multimedia streams [3]. It was observed that by distributing the system infrastructure among a large number of subscribers, the operative cost can be shared in a cost-effective fashion. By allocating the access system between more numbers of clients, it becomes easier and economical for service operators to repay the expenses incurred in installing the access systems. Most of the optical access architectures defined in the literature use optical amplifiers in diverse forms [4]. An optical amplifier alters the revenue dynamics of the access network by adding to the infrastructure and operational cost. Removing the use of reach extender devices without affecting the quality also helps in making the system cost-effective. For accomplishing the obligations of higher transmission capacity access networks hybrid WDM/TDM technology is believed as the best solution for cost-efficient subscriber shared infrastructure in optical passive access networks. Requirements of next generation access systems defined by various competent bodies worldwide include aggregated capacity of 128 Gbps to 500 Gbps with the support of up to 1024 ONUs, 40 Km or more extended reach using hybrid WDM/TDM technology [5]. With these considerations for access networks in mind, literature is surveyed.

In literature, hybrid WDM/TDM access network by utilizing cost-effective components like reflective semiconductor optical amplifier (RSOA) and an Optical add-drop multiplexer (OADM) to communicate over two channels with a line rate of 1.25 Gbps and length of 25 Km were investigated in [6]. In [4], an optical access system for diverse modulation formats like NRZ, RZ and Manchester encoding were evaluated and observed that NRZ mechanism gives
better results in comparison of other modulation formats. The
designed network gives optimum results up to a span of 20
Km. Researchers in [7] analyzed RZ and NRZ modulation
formats for next-generation passive optical systems with a
line rate of 10 Gbps. Performance of WDM-PON architecture
by employing Mach-Zehnder modulator (MZM) for
transmission of bit streams with a data rate of 10 Gbps over 16
channels was examined in [8]. In [9], Optical signal is
generated using Electro-Absorption Modulated (EAM) laser
with a power of 0 dBm. Performance of Hybrid TDM/WDM
40 Gbps optical access system to fulfill higher capacity
demands of next-generation subscribers was evaluated in
[10]. Optical receivers are an important component in an
access system, its performance was investigated in [11-12]
and a comparative analysis of the system performance when
PIN & APD photodiodes are employed at the optical receiver
was done.
Various system parameters impact the performance of optical
passive networks like the design of OLT and ONU along with
a choice of components used and their design parameters.
Most of the models were optimized in terms of any one of the
parameters but a comprehensive investigation on each and
every component and parameter is still not carried out. It is
also observed that presented system architectures are limited
in terms of users connected, aggregate transmission rate and
network length. In the proposed novel system architecture, the
work given in literature is pushed by testing the system in
diverse configurations so that it can support 512 users with
aggregated system rate of 120 Gbps and enhanced coverage
area of 80 Km without the help of any reach extender devices.

2. SYSTEM MODEL

The system model of hybrid WDM/TDM optical access
system in 08x512 configuration is depicted in figure 1.

![System Model of Hybrid WDM/TDM optical access network](image)

In the presented system architecture, sixteen WDM
transmitters are located at service provider Central Office
(CO) to communicate with 512 users at varying data rate.
Information generated is combined by WDM Multiplexer and
transferred to subscriber Optical Network Units (ONUs)
through optical fiber cable with a varying length of 50-130
Km. At receiver terminal, data signals are separated by WDM
(de)mux and sent to 512 ONUs using power splitters.
Information is transmitted in the frequency range of 192.4
THz to 193.9 THz which are separated by 100 GHz frequency
(0.8 nm). WDM Transmitter consists of an information
source, electrical signal generator, Continuous Wave (CW)
laser and the external modulator. At ONU, information signal
received from optical splitter is fed to the photo-detector
which is the primary component of receiver that converts the
incoming optical signal to an electrical output which is further
passed through a filter circuit before the signal being analyzed
by various test equipment’s. In the proposed framework,

The BER can be expressed in terms of Q factor as per
equation II by using the decision-circuit method introduced in
\[ BER = \frac{1}{2} \text{erfc} \left( \frac{Q_F}{2} \right) \] 

3. RESULTS AND DISCUSSION

The optical access networks, is comprehensively investigated
for various system configurations to find the optimum one that
can satisfy the needs of Next Generation Access Networks
(NGAN). The system architecture is tested with various
possible components and parameters for comparative analysis
and selecting an optimized configuration.

The system is analyzed for encoding form, NRZ and RZ
data format is used. MZM and EAM modulator are examined
to find the better external modulator. The system is evaluated
for a variable transfer rate of 05Gbps and 10Gbps and
network length from 50 Km to 120 Km. Hybrid access
architecture is examined to find the better photo-detector. In
the proposed system, a comparative evaluation is carried out
to figure out a suitable detector for the system. The results of
the analysis are presented so that an optimum configuration
can be used for the access networks. Encoding scheme has a
significant effect on the system performance. Initially, the
system is evaluated in terms of encoding format for a line rate
of 10 Gbps at a distance of 50 Km as tabulated in table 1.

<table>
<thead>
<tr>
<th>Modulation Technique</th>
<th>Q.F. (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRZ</td>
<td>5.7266</td>
</tr>
<tr>
<td>RZ</td>
<td>4.789</td>
</tr>
</tbody>
</table>

It is evident from the table NRZ data format gives better Q.F.
than RZ scheme. The results are verified by eye diagram
analysis as shown below in figure 2.
The observation is further verified using eye diagram analysis as shown below in figure 3. It is construed from the figure eye-opening is better for MZM modulator than EAM and validates our result.

Table 2: Comparison of various external modulators

<table>
<thead>
<tr>
<th>Modulator</th>
<th>Q.F. (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mach Zehnder Modulator</td>
<td>5.7266</td>
</tr>
<tr>
<td>Electro Absorption</td>
<td>3.984</td>
</tr>
</tbody>
</table>

The proposed system architecture performs well with NRZ encoding scheme when modulated through MZM modulator transmitted. Further, receiver terminal ONU designed with APD photo-detector gives optimum configuration. From the above analysis, it is clear that the system with a line rate of 10Gbps/channel and aggregate rate of 80Gbps can transmit for a maximum distance of around 50 Km with acceptable quality.

4. CONCLUSION

The presented system serves 512 users with full system rate of 80Gbps and transmits information signal over a distance of 50 Km without the use of the active device. By sharing the system infrastructure among 512 subscribers which may be remotely placed at a high rate without the use of additional resources, the installation and operational expenses are amortized in a cost-effective way. The system architecture performance is achieved without the use of reach extender devices like an amplifier and so the recurring cost is also reduced. The investigated hybrid system is an ideal choice for future access networks in comparison with the other system frameworks defined in the literature.

REFERENCES:

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Authors Profile

Prof.(Dr.) Ankur Singhal received his Ph.D in Electronics and Communication Engineering. Currently he is serving as Professor in Department of Electronics and Communication Engineering at CGC Landran. He has authored about 55 research papers in various national/international conferences/journals. Currently he is working on access networks and network security.

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