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Next Generation Optical Access Network Using CWDM Technology

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ABSTRACT

We are developing a novel technology for the next generation optical access network. The proposed architecture provides FTTX high bandwidth which enables to give out 10Gbit/s per end-user. Increasing the subscribers in the future will cause massive congestion in the data transferred along the optical network. Our solution is using the wavelength division multiplexing PON (CWDM-PON) technology to achieve high bandwidth and enormous data transmission at the network access. Physical layer modifications are used in our model to provide satisfactory solution for the bandwidth needs. Thus high data rates can be achieved throughout the network using low cost technologies. Framework estimations are evaluated to prove the intended model success and reliability. Our argument that: this modification will submit a wide bandwidth suitable for the future Internet.

1. Introduction

Optical access network has attractive much attention [1], this is because of the low loss and enormous bandwidth of optical fibre, the increasing demand for capacity, coverage, and the benefits it offers in terms of low cost optical system ,all of which make it an ideal candidate for future access network.

The network and service providers are seeking to reduce their operational costs. The concept of using a passive optical network (PON) is an attractive option. In a PON there are no active components between the central office and customer's premises, which can eliminate the need to power and manage active components in the cable system of the access network, and usually the PON has a tree topology in order to maximize their coverage with minimum network splits, thus reducing optical power loss [2].

Each PON terminates on an Optical Line Termination (OLT) in the head-end, or hub facility. The OLT connects through a Wave Division Multiplexing (WDM) coupler with a single fibre strand to the optical distribution network (ODN), and broadcasts an optical signal at 1490 nm that reaches each subscriber connected to that fibre through passive optical splitters. The OLT also re-

ceives signals at 1310 nm from each customer optical network user (ONU). OLTs are housed in a shelf that typically supports multiple OLTs, common control cards, and interfaces to voice and data services equipment [3]. Basically, fibre can deliver the information such as data, voice, and video from central office CO to the end of subscribers Figure 1. According to Heron [4], both FSAN-ITU and the IEEE have initiated projects to standardize a next generation of PON with 10Gbps bandwidth. Numerous options are under consideration. In anticipation of some of the potential options, FSAN-ITU is proposing a wavelength blocking filter for Gigabit PON (GPON ONT)s in order to allow for the potential coexistence of GPON ONTs with other wavelengths on the PON.

Dinan [5] argued that there are two alternatives for WDM metro networks dense WDM (DWDM) and CWDM. In high capacity environments, DWDM is used. In DWDM, the channel separation can be as small as 0.8 or 0.4 nm, for up to 80 optical channels at line rates up to 10Gbps. DWDM technologies is very expensive, so its application to access networks is difficult. Instead, CWDM is emerging as a robust and economical solution. The advantage of CWDM technology lies in its low-cost optical components. CWDM offers solutions for 850,
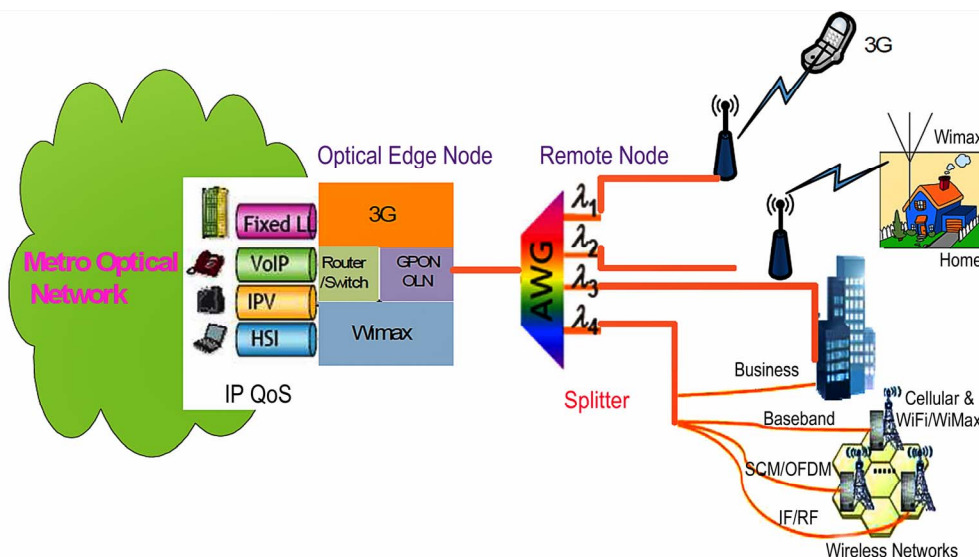
Figure1. Optical access network architecture.

1,300, and 1,500 nm applications at 10 and 40Gbps on up to 15 optical channels spaced 20 nm a part. Furthermore, the wavelength multiplexer with low channel crosstalk can be implemented easily for CWDM. It has been argued that the total system cost is 40% cheaper for the CWDM-PON [6].

2. WDM-Based Optical Access

2.1. Requirements of Next-Generation FTTH Architectures

A set of performance objectives was established by the members of Full Service Access Network (FSAN) for next-generation PONs that increase bandwidth and cost-effectively while safeguarding previous investments. These performance requirements can be summarized as follows [5]:

- Increase bandwidth by 4x.
- Respect similar optical distribution network parameters.
- Respect wavelength allocations of GPON.
- Keep changes of the media access control (MAC) layer to a minimum.
- Enable coexistence with GPON.

In addition, the IEEE has set like targets, but its focus is centred on the 10G time division multiplexing (TDM) Ethernet (EPON) solution. Any coexistence issues with EPON are addressed by using a different wavelength for the 10G EPON.

Hybrid four-wavelength PON is an approach that places four logical PONs on a single fibre using four discrete wavelengths. At 10 G bps, this increases the downstream bandwidth of GPON four fold. The existing downstream waveband of 1480-1500nm could be easily sub-divided into four bands permitting the cost effective use of four inexpensive medium-density lasers.

In the case of GPON and FSAN, the use of hybrid splitters is proposed. This would allow only one of the four GPON signals to pass to any particular ONT. Opportunely, the overall loss of a hybrid splitter would stay put similar or improved to that of a power splitter. A special dual-use splitter is being proposed that could be used firstly as a power splitter and later as a hybrid splitter, thus avoiding its replacement cost. In the upstream route, ONTs would contribute to the existing 1310nm wavelength and the upstream bandwidth would remain unaffected, resulting in an 8:1 ratio between downstream and upstream bandwidth.

2.2. Wavelength Options

Coarse (WDM) one of the next generation solution, in addition, require of opportunity networks to increase bandwidth with low cost available in WDM. Wavelength spacing of extra than 20 nm is generally called coarse WDM (CWDM). Optical interfaces, which have been standardized for CWDM, can be found in ITU G.695, at the same time as the spectral grid for CWDM is defined in ITU G.694.2. If the inclusive wavelength range of 1271 nm to 1611 nm, as defined in ITU G.694.2, is used with 20 nm spacing, then a total of 18 CWDM channels are accessible, as can be seen in Figure 2. [7,8].

3. Next Generation WDM-PON Networks Model Architecture

In our model, we assume a four channel C WDM (1490-1550nm), 2.5 GB/s directly modulated light wave system over a passive optical network. The source is DFB-LD
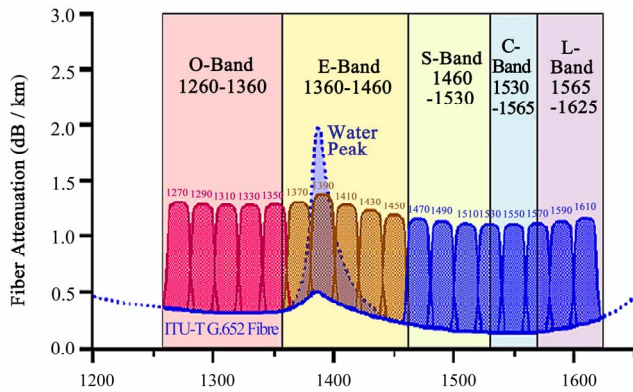
Figure 2. Metro CWDM wavelength grid as specified by ITU-T G.694.2.

modules with (1270 nm ~ 1610 nm) wavelength, and the bandwidth is 2.5Gbps.

The passive optical network utilizes one 2:2 splitter and four 1:16 splitters. Atypical topology for a CWDM metro network is shown in Figure 3. Metro network is linked via Central Office (CO) by PON. On the other hand, the CO consists of transmitter and receiver each of them has four lasers. These lasers have different wavelengths: 1490nm ($\lambda1$), 1510nm ($\lambda2$), 1530nm ($\lambda3$), 1550 nm ($\lambda4$) respectively for the upstream transmission. The receivers are consisted of four wavelengths: 1290($\lambda1$) nm, 1310($\lambda2$) nm, 1330($\lambda3$) nm, 1350($\lambda4$) nm respectively as the downstream transmission.

In this architecture, a single-mode optical fibre (SMF) connects the CO and the subscribers' site. The suggested distance for our estimations is 60 km. Four channels each of 2.5Gbps are multiplexed using OLT to achieve the suggested 10Gbit/s bandwidth. In addition long haul reach and narrow channel spacing are to be verified using the new arrangements.

4. Model Evaluation

4.1. BER versus SNR

The bit error rate (BER) is defined as the probability that a bit is inaccurately detected by the receiver, i.e., that a transmitted (0) is detected as a (1), or a (1) is detected as a (0). A theoretical bit error rate, as a function of signal to noise ratio (S/N), is known as a result of formula [9,10]:

$$BER = \frac{1}{2}\left[1 - erf(\sqrt{\frac{I_s^2}{I_n^2}})\right] \quad (1)$$

In our CWDM system, we suppose the episode optical power on photodiode detector is P_r W, and the responsivity of the detector is l A/W, the signal current in photodiode is could be written:

$$(I_s) = P_r , R_\lambda \quad (2)$$

The noise originating in the detector is thermal noise current and generated within the photo detectors load resistor R_L, the thermal noise current is given by:

$$(I_{th}^2) = \frac{4KT\Delta f}{R_L} \quad (3)$$

where k is the Boltzman constant ($1.3805*10$-23 J/K), T is the temperature is 300K Δf signal bandwidth is 2.5Gbps, R_L is load resistor in Ω.

Therefore the total current noise is:

$$I_n = I_{th} + I_d \quad (4)$$

The signal to noise ratio(S/N) is given by:

$$\left[\frac{S}{N}\right]_{dB} = 20 Log\left[\frac{i_s}{i_n}\right] \quad (5)$$
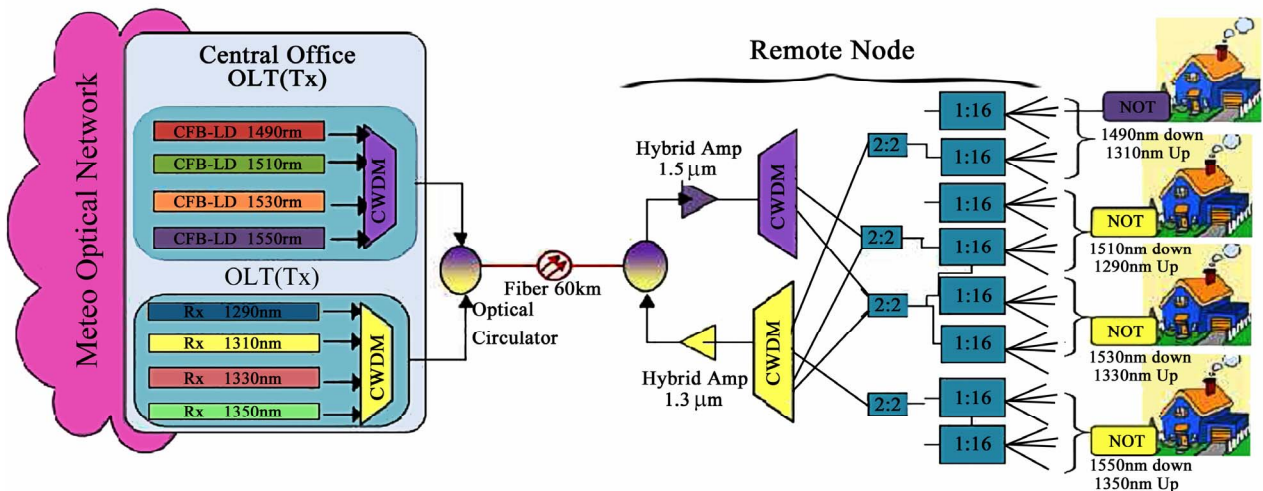

Figure 3. Model of next generation CWDM network architecture.

The signal to noise ratio of this model is about 41.4dB, as shown in Figure 4, then BER for the proposed system is about $5*10^{-8}$.

Noticeably, the bit error rate (BER) decreases, as the signal to noise ratio (S/N) increases. Hence, data can be transmitted with high superiority as the expectation of error decreases.

4.2. Coverage of WDM-PON

For different splitter ratio the insert loss is different, with the insert loss of splitter is given by [2]:

$$L_{splitter} = 10\,Log_{10}\frac{1}{splitter\_ratio} \qquad (6)$$

The maximum coverage distance of the N remote node is given by:

$$D_{N\text{-}Max} = \left[\frac{\{(P_{Tx} - P_{Rx\text{-}Min}) - [N*(2*L_{TFF} + L_{TFF\text{-}other}) + L_{TFF}] - +Lspliter - +Lothers\}}{Fattenuation}\right] \qquad (7)$$

where l is the average transmit power, P_{RX}-1 is the minimum receive optical power with error free in ONU/ONT, or it can be describe as the receive sensitivity of ONU/ONT, L_T is the insert loss of TFF, L_{TFF-ot} is some other attenuation connected to TFF, L_{oth} is other attenuations, such as the interface loss, $F_{attenuat}$ in different CWDM wavelengths have different attenuation.

As we show in the Figure 5. The relation between distance and nodes with different number of splitter, with increase in the splitter value the PON coverage it become less.

5. Conclusions

An innovative solution is presented to increase the bandwidth for optical access networks. The projected broadband access network is the key solution for point-to-multipoint optical communications. High data
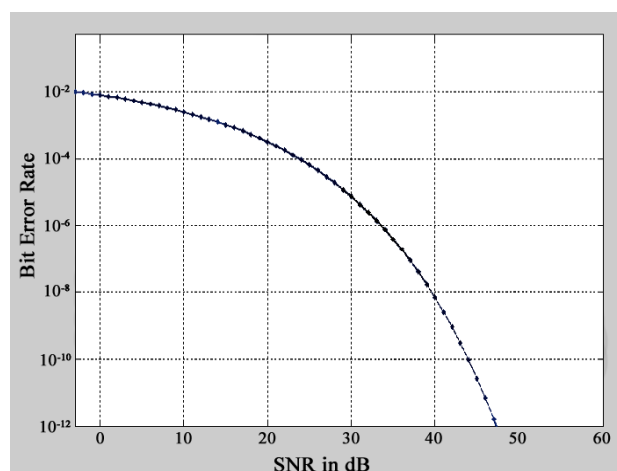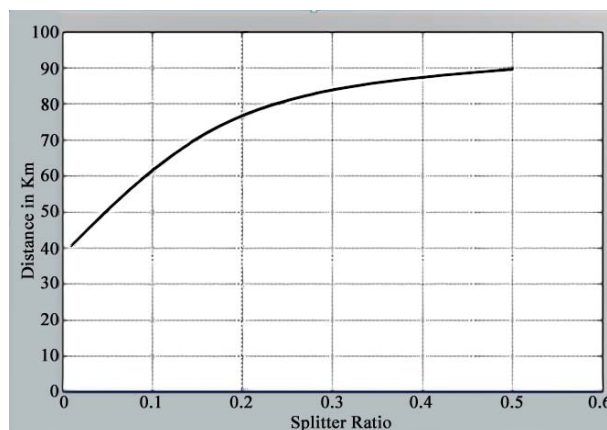

Figure 5. Illustrate the coverage distance of remote node with different splitter.

rates are achieved using low price infrastructures. In this paper CWDM is approved to be an extremely exceptional adjustment for the main optical core to edges providers. Reliable cabling can be achieved instantaneously using current modified technologies. Our evaluations show highly performance for the suggested model. The data bit rate achieved was 10Gbit/s resulting from four attached optical fibre wavelengths. The presented scenario used the passive optical network technology as the casting media between the central office and the end-users. Ultimately, further research may be done to the using of CWDM-PON in metro and long-haul fibre routes.

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Figure 4. BER as function of SNR of CWDM.

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