A Novel Hybrid Passive Optical Network, Free Space Optical and Visible Light Communication System

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Abstract : In this work, a hybrid architecture employing Single Mode Fiber (SMF) link followed by Free Space Optic (FSO) transmission and Visible Light Communication is investigated. FSO is incorporated in the system after optical fiber in order to serve optical network units wirelessly where deployment of optical fiber is tedious or impossible such as in hilly areas, intra educational buildings etc. Further, VLC is incorporated in the system to serve ONUs inside building with Light Fidelity. For optical fiber based users, data rate of 10 Gbps is provided over 25 km and total 8 ONUs are served at guaranteed 2.5 Gbps. FSO link after 25 km SMF and 450 m free space distance served additional 8 users at same bit rate as optical fiber users. For LiFi link, total bit rate of 1 Gbps has been achieved over 2 m link. Therefore, our proposed system has provisions for optical fiber based users, wireless FSO based ONUs and intra building ONUs.

IndexTerms **– PON, FSO, VLC, OLT, ONU.**

I. Introduction

All Rapid growth in internet services and high definition video transfer has put a peer pressure on the communication mediums. Optical fiber is emerging as an ultimate solution to cater the demands of ever increasing population. With the explosive growth in population, bandwidth hunger is increasing day by day [1]. Optical access networks are an important candidate to provide cost effective way out and can also serve numerous users. Passive optical networks are type of optical access networks which do not need energy for user distribution. For fiber to the home services, passive optical network is taken as the ultimate way out to endow with greater bandwidth as well as rapid rate of data transmission. Dual directional or bidirectional passive optical networks are increasing to cater bandwidth hungry services [2] [3]. For performance enhancement in PONs, various research works are identified till now by altering the frequency of operation [4], incorporating optical amplifiers [5], diverse modulations [6], optical/electrical filters [7], dispersion compensation [8] etc. Researchers come across optical fiber deployment problems in areas such as hilly areas, intra universities, crowded areas etc where trenching and permit of way are near to impossible. In order to cope up with this issue, researchers suggested deployments of free space optical channel in which no optical fiber is used [9]. Optical network units receive signal either from optical fiber or from FSO and after that user is facilitated with internet. However, one more problem exits inside buildings such optical fiber deployments and to eliminate requirements of fibers, visible light communication is emerged as perfect candidate and has numerous advantages over RF communication [10] [11]. Therefore, in this work, a hybrid architecture employing SMF link followed by FSO and VLC is investigated. Proposed system serves wired as well as wireless ONU. Further, VLC is incorporated in the system to serve ONUs inside building with Light Fidelity.

SYSTEM SETUP

Figure 1 depicts the hybrid passive optical network, Free Space Optical and Visible Light Communication system. A 193.1THz laser light at 10 dBm is modulated with NRZ pulse data at the rate of 10 Gbps and fed to optical fiber of length 25 km.

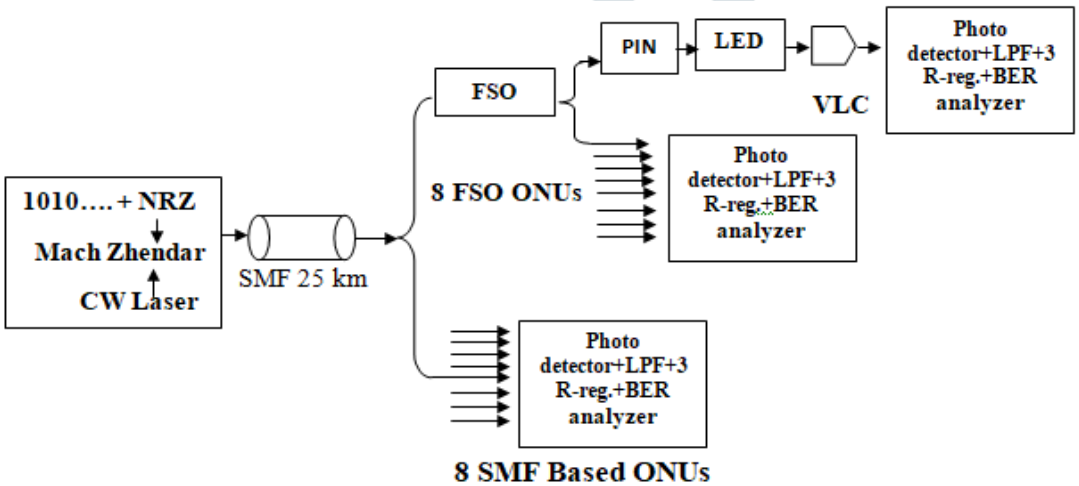


Figure 1 Proposed hybrid PON+FSO+VLC system

A power splitter is placed after SMF to divide two equal signals and out of two signals, one is given to wired optical network units which serve 8 ONUs and other is provided to FSO channel to serve 8 wireless users over 450 m. Each receiver unit in case of SMF, FSO and VLC are consisting of PIN photo detector, low pass Bessel filter, 3-R regenerator and BER analyzer. After FSO, an amplified signal from erbium doped fiber amplifier of gain 5 dB is further given to Visible Light Communication Channel to cater

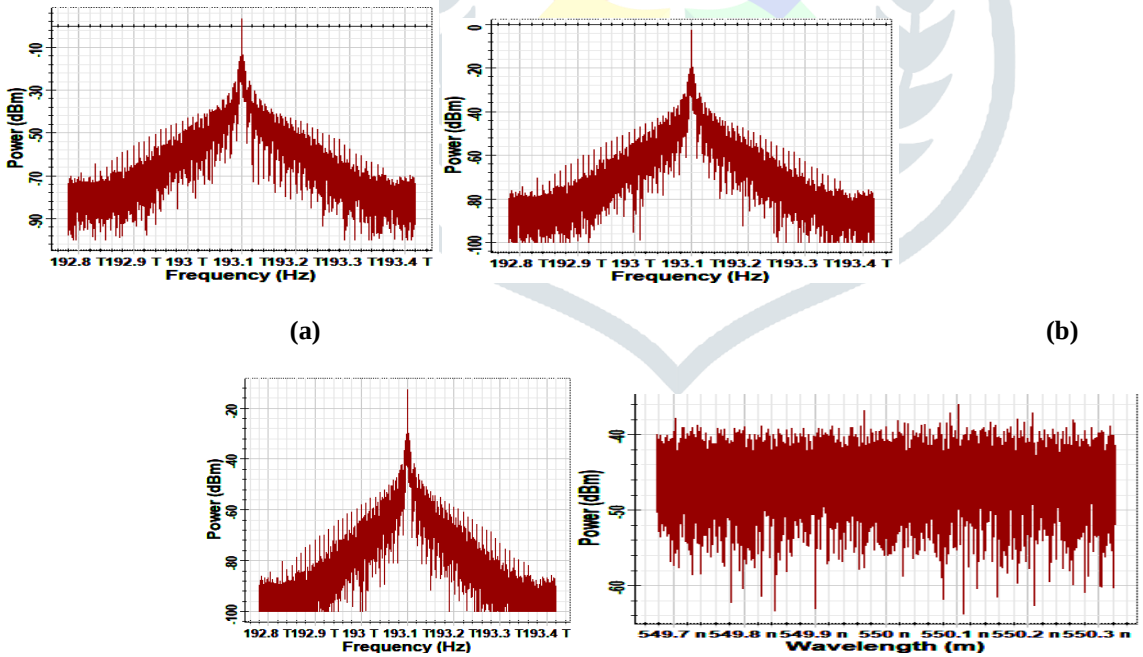
users inside building without any cables. Link length of the VLC channel is fixed to 2 m and data rate is 2. 5 Gbps. Data from FSO first passed through PIN and then modulated with white LED. Table 1 shows the values of proposed hybrid PON+FSO+VLC system.

Table 1 System specifications of proposed PON+FSO+VLC system

Parameters	Values
Bit Rate	10 Gbps
Input frequency	193.1 THz
SMF distance	25 km
FSO distance	450 m
FSO Weather condition (attenuation)	Clear weather (0.1 dB/km)
FSO Transmitter/Receiver antenna diameter	5 cm/20 cm
FSO Beam Divergence	1 mrad
Amplifier (Gain)	EDFA (5 dB)
LED frequency	550 nm
Electron life time	1e-009
RC constant	1e-009
Quantum efficiency	0.65
Bandwidth	50
VLC range	2 m
VLC attenuation	8 dB/km
VLC Tx/Rx antenna diameter	7 cm/1.5 sm
VLC Beam Divergence	1101.8 mrad

RESULTS AND DISCUSSIONS

A hybrid architecture employing Single Mode Fiber (SMF) link followed by Free Space Optic (FSO) transmission and Visible Light Communication is investigated. Optical spectrums of proposed hybrid system are given in Figure 2. Optical spectrums are depicted after optical line terminal, single mode fiber, free space optical communication and visible light communication channel in Figure 2(a), 2 (b), 2 (c) and 2 (d) respectively. It is observed that minimum power of optical spectrum is seen after VLC followed by FSO and single mode fiber which are due to high attenuation in VLC and FSO.



(a) **(b)**

(c) **(d)**

Figure 2 Optical spectrums of proposed system after (a) OLT (b) SMF (c) FSO (d) VLC

Figure 3 shows the performance of different transmission channels at ONUs in terms of Q factor when distance is varied from 5 km to 30 km. It is perceived that Q factor decreases as the distance prolongs because attenuation, dispersion and scattering increases. Performance of SMF based 8 ONUs is far more better than FSO and VLC ONUs. This is due to reason that FSO suffer from high degradation because of open air and it can provide worst performance when there is rain, haze and snow around. VLC is least performing because high beam divergence and interference of ambient light sources. Table 2 shows the Q factor values at diverse distances in case of SMF PON, SMF+FSO PON and SMF+FSO+VLC PON.

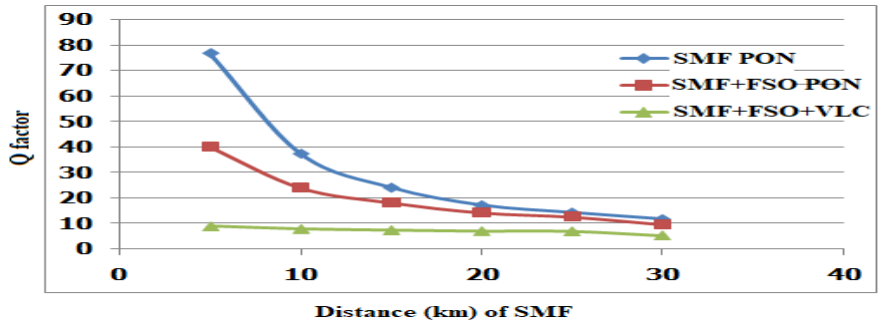


Figure 3 Q factor variations with distance of SMF alone, SMF+FSO and SMF+FSO+VLC

Table 2 Q factor values at diverse distances in case of SMF PON, SMF+FSO PON and SMF+FSO+VLC PON

Distance (km)	Q factor SMF	Q factor SMF+FSO	Q factor SMF+FSO+VLC
5 km	76.84	40.19	9
10 km	37.45	24.83	7.93
15 km	24.13	18.15	7.44
20 km	17.24	14.25	7.06
25 km	14.35	12.61	6.97

Figure 4 represents the performance of proposed system in terms of signal to noise versus BER for wired users, free space optical link based users and visible light communication based users. It is perceived that as the SNR decreases with distance, BER increases. Highest BER is seen in VLC because of scattering, attenuation and dispersion losses. Aforementioned losses are less in FSO and least in SMF.

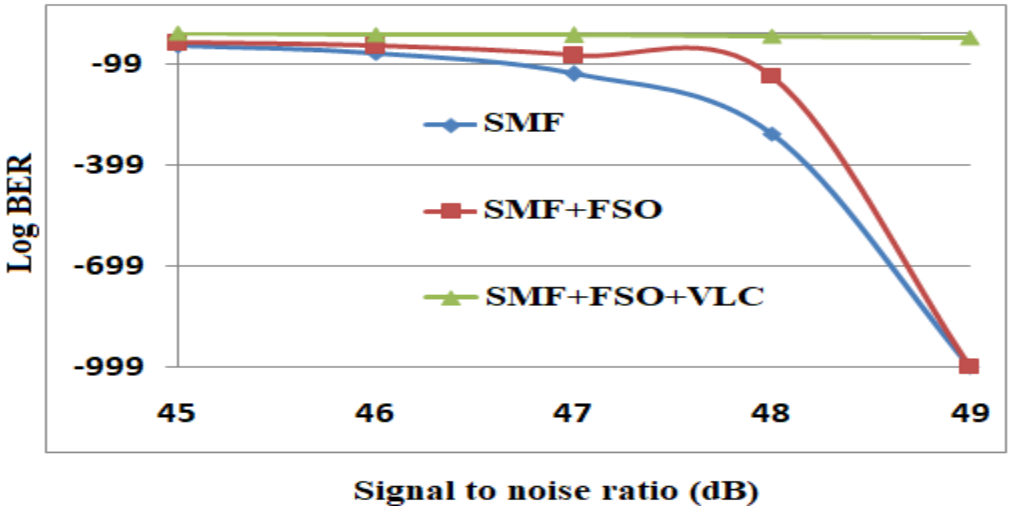


Figure 4 Variation of Log BER with signal to noise ratio

Eye diagrams for SMF based ONUs are shown in Figure 5 (a) and SMF+FSO eye diagram is depicted in Figure 5 (b). Figure 5 (c) shows the eye pattern for SMF+FSO+VLC link system. It is observed that eye pattern is maximum open and wide in SMF case followed by SMF+FSO and SMF+FSO+VLC link. Eye diagrams are taken at 25 km link distance it is the maximum distance for which proposed system remain under acceptable limits of Q factor and BER.

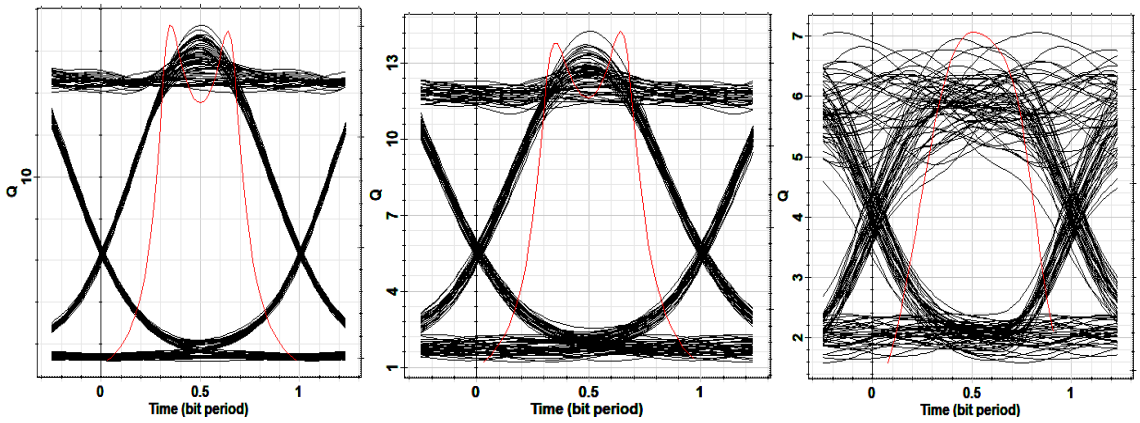


Figure 5 Eye diagrams at 25 km link length of SMF (a) SMF (b) SMF+450 m FSO (c) SMF+ SMF+450 m FSO+ 2m VLC

CONCLUSION

In this research article, a noval Hybrid Passive Optical Network, Free Space Optical and Visible Light Communication System is demonstrated. For optical fiber based users, data rate of 10 Gbps is provided over 25 km and total 8 ONUs are served at guaranteed 2.5 Gbps. FSO link after 25 km SMF and 450 m free space distance served additional 8 users at same bit rate as optical fiber users. For LiFi link, total bit rate of 1 Gbps has been achieved over 2 m link. It is perceived that due to least attenuation, dispersion and scattering, wired users facilitated with long distance and high speed, however distance is limited in FSO inspite of same data rate. VLC is limited in speed and distance both due to maximum scattering of LED light inside room. But, investigated system has provisions for optical fiber based users, wireless FSO based ONUs and intra building ONUs.

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