Matlab based Simulink Modelling and Performance Analysis of Free Space Optical Communication System: A Review

Kavita[1], Jagtar Singh[2]
[1] NCCE Israna, Department of ECE, Panipat, Haryana, India
[2] NCCE Israna, Department of ECE, Panipat, Haryana, India
kavita.ece87@gmail.com
jagtar_nit@rediffmail.com

Abstract— Free Space Optical communication is extended and compatible technique with the radio frequency technology. FSO provides BW spectrum that is in terahertz besides this speed of the data transfer is very fabulous. Due to these advantages FSO is becoming very popular communication technology for satisfying the growing demand of bandwidth traffic mainly for the long-distance communication. FSO communication has achieve important attention between various researchers for more BW and to transmit data securely in various domains. There must be integrated environment for FSO system which have robust mechanism to overcome signal loss under turbulence condition varies from medium to strong. During data transmission BER must be minimized otherwise significant information may be lost. There are various mechanism to control BER against various parameters like path loss factor, distance and atmospheric condition. After investigation various research paper, a robust

Keywords— FSO, BER, Path Loss Factor, LOS, Turbulence

I. INTRODUCTION

The development of Optical fiber took place around 1970 and given by Corning Glass Works. Also, around this time, Gallium Arsenide SC (semiconductor) lasers were being generated for ray transfer from the fiber optic wires. GaAs material used for developing 1G FOS and invented in 1975 which works at a wavelength of 0.8 μm, 45 Megabits/second bit rate having 10Km repeater spacing. 2G FSO system was developed in 1980's using semiconductor material InGaAsP and works at a wavelength of 1.3 μm. By the year 1987, FSO were able to operate at a speed of 1.7 Gigabits/second for an individual fiber that has the repeater on a distance of 50Km. FSO is also having same configuration as possessed by another communication system. FSO also having three prime systems which are listed below:

- Receiver
- Transmitter
- Communication Channel

There are two types of communication channel exist which are listed as:

- Wired Channel
- Wireless Channel

When signal transmitted from transmitter to receiver end then different types of noises automatically added with original signal due to atmospheric disturbance.
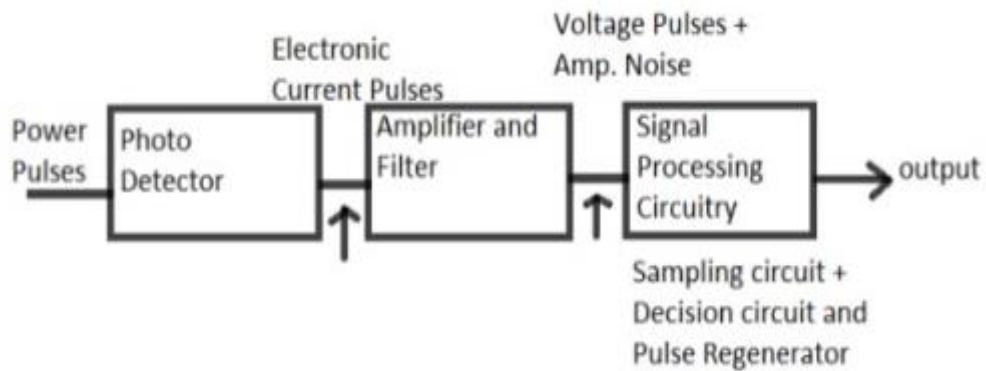
Fig.1: Optical receiver block diagram [5]

Table 1: Types of Photodiodes

Material and Structures	Wavelength (nm)	Responsivity	Gain	Sensitivity
Si P-I-N	300-1100	0.5	1	-34dBm@155Mbps
InGaAs P-I-N	1000-1700	0.9	1	-46dBm@155Mbps
Si APD	400-1000	77	150	-52dBm@155Mbps
InGaAs APD	1000-1700	9	10	-33dBm@1.25Gbps

II. LITERATURE SURVEY

Hennes Henniger et al (2010): Since past 20 years FSO emerged as an alternate advanced technique having so many advantages with respect to RF (radio frequency) communication. This research mainly focuses on problem encountered when FSO system is being implemented. This research paper also covers various losses and gains encountered during transmission of information from transmitter to destination point. As we know when information transmitted per channel various noises came into existence and loss occurred in signal [9].
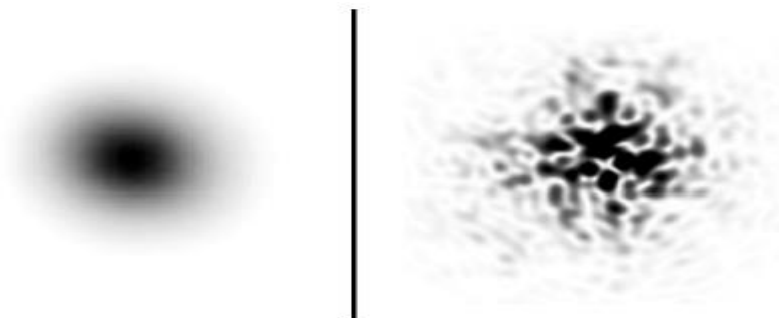
Fig.2: Transmit beam intensity (left), receiver beam intensity (right) when Laser beam passes via turbulent atmosphere [9].

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Ashish Kumar et al (2013): From last 25 years FSO system is given more importance than RF and MW due to its unlicensed BW operation making it faster than other two techniques.
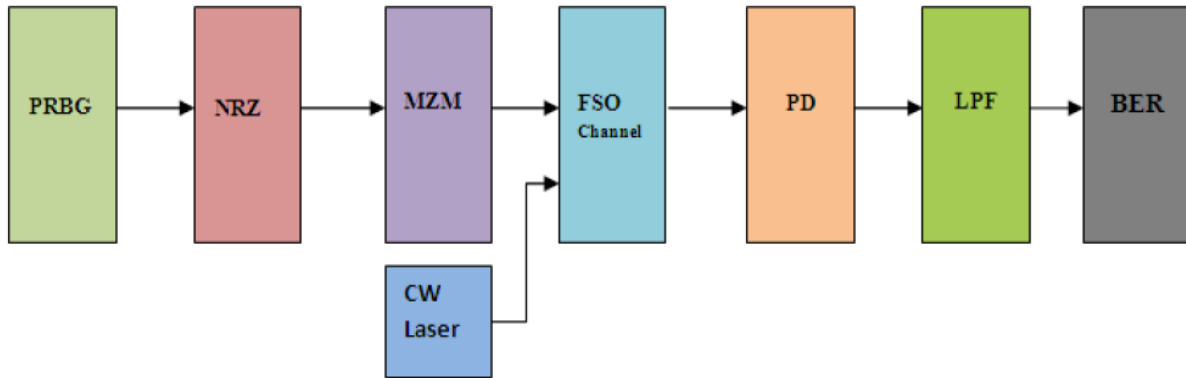

Fig.3: FSO System Design [10].

FSO system has many merits for example

- Small size,
- High BW
- Economical
- Lease of deployment.

Besides this some of FSO demerits are beam dispersion, scintillation etc.

Francis Idachaba et al (2014): FSO is very crucial telecommunication framework for broadband networks in entire world. There is requirement of abundant BW which can transfer signal with minimum delay so that optimized result can be achieved. Optical fibers gives huge and unsurpassed transmission BW with negligible latency, and now this medium is best suited for long range transmission and also for very high-speed data rate transmission in telecommunication networks [12].
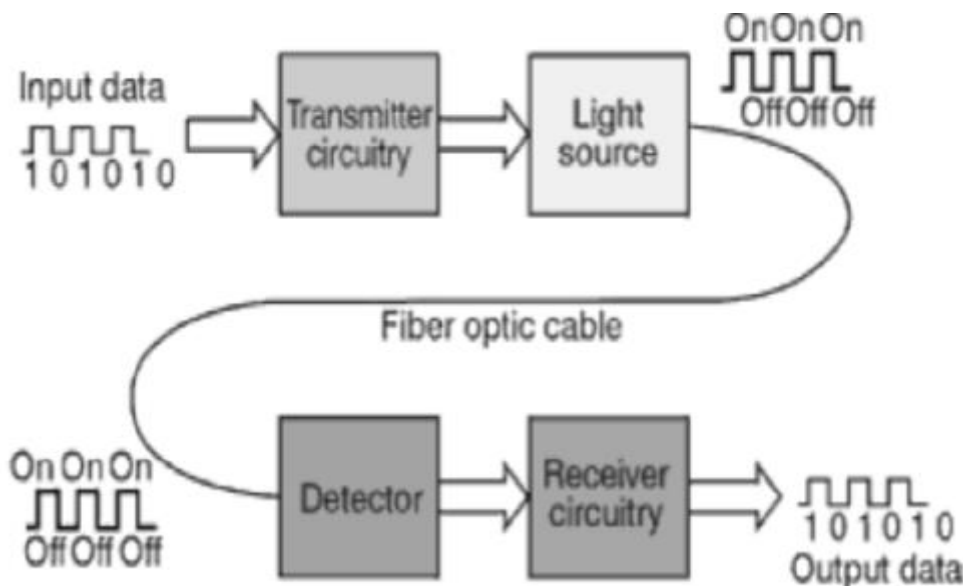

Fig.4: Basic fiber optic communication system [12].

Bhanu Priya (2015): In this article by implementing MD code researcher analyzed the performance of SACOCDMA system at a speed of 10 Gbps. In these days MD codes are much more interested domain of research in optical communication system due to its ability to accommodate huge numbers of client at high speed, flexibility to select weight parameters. The

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implemented system was analyzed with above mentioned technique which incorporates RD codes for various circumstances. By analyzing simulation results it is very clear that MD codes are superior than RD codes [13].
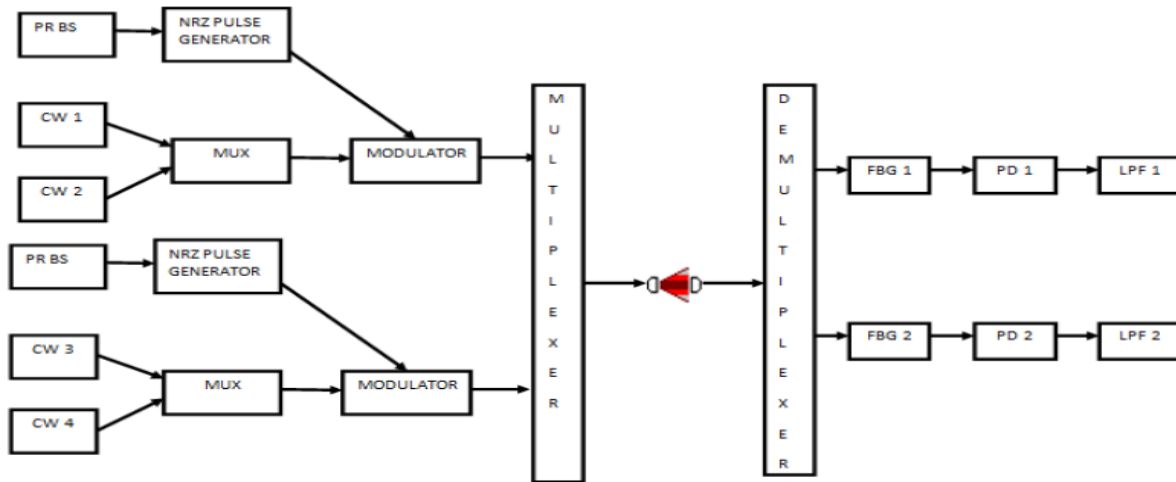

Fig.5: Block Diagram of SAC OCDMA-FSO System Using MD Codes [13].

Mohamed Bouhadda et al (2016): This article depicts impact of the dispersion effect, caused by temperature and atmospheric pressure, on Non-Return to Zero –On off Keying scheme. In this research a very essential parameter of dispersion executed in Fiber Space Optics via atmospheric channel [15].

S. H. Alnajjar et al (2017): FSO communication is a LOS technique which utilizes lasers to assist optical BW connections. In this article, a comparative analysis of 2 bi-directional FSOs system executed.
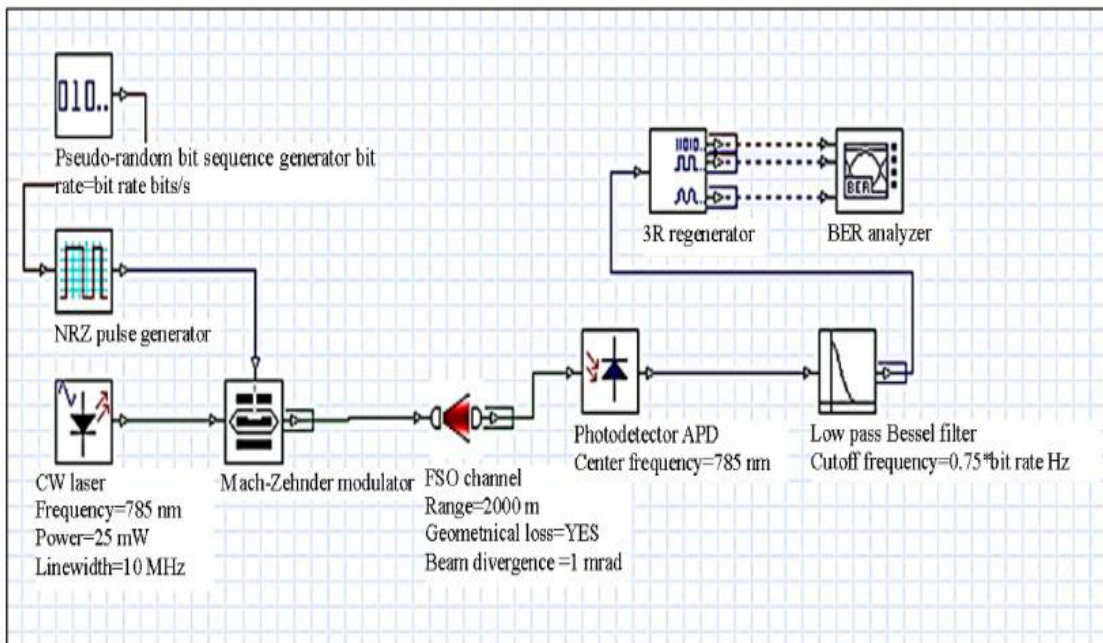

Fig.6: Simulink model of One-channel FSO using Opti system [17].

One is the basic link, and another one is advance model of existed one technology under various conditions. The proposed design having two FSO channels and each one has EDFA optical amplifiers. The final output depicts that overall performance is increased by analysing Q-factor [17].

Toshimasa Umezawa et al (2018): We present a newly developed 2-D photo detector array device and its application

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for limited-range FSO communication system which utilize a WDM beam. The 2D-PDA enab1es direct optica1 coup1ing to the FSO beam, ease the optica1 a1ignment procedure required for 10 micro meter sing1e-mode fiber and diminishes requirement of tracking function for beam [19].
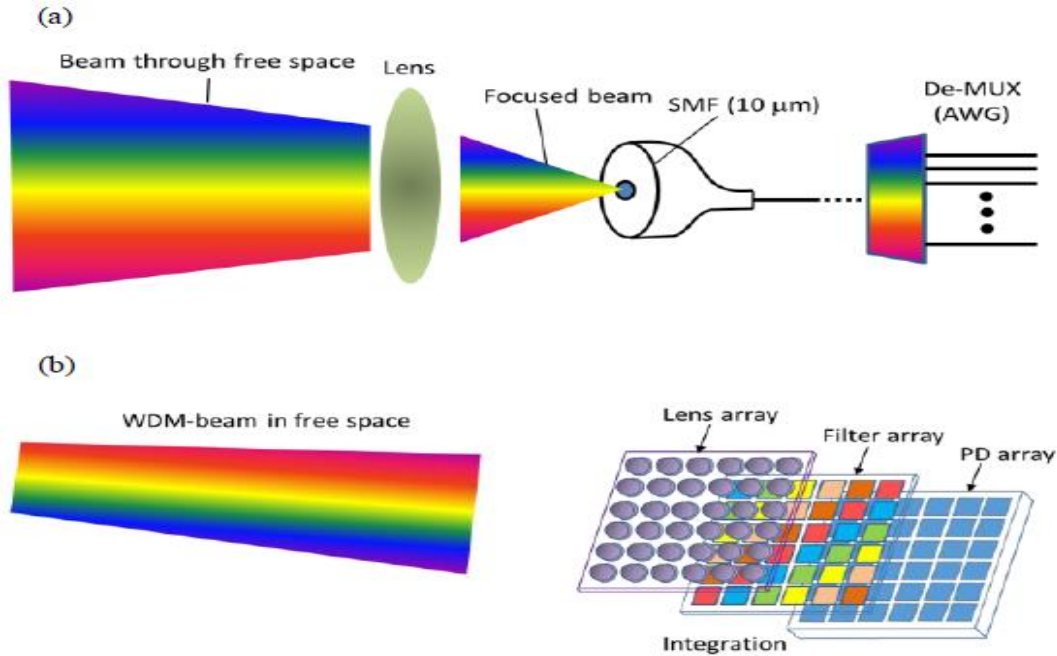

Fig.7: (a) FSO system layout, (b) WDM-FSO system incorporating 2D-PDA system using MLA and MFA [19].

Varun Srivastava et al (2019): FSO communication has achieve important attention between various researchers for more BW and to transmit data securely in various domains. This article depicts an integrated FSO system which having robust mechanism to overcome signal loss when turbulence condition varies from medium to strong. For these two prime parameters are considered which are BER and outage probabi1ity employing gamma distribution function.
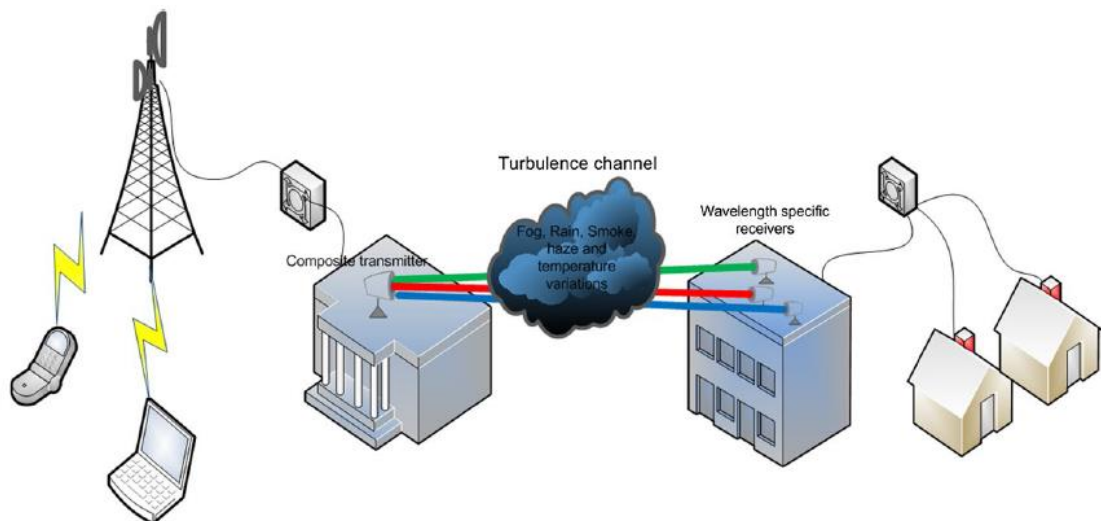

Fig.8: Schematic diagram of FSO system [20].

Performance of integrated FSO device with wavelength diversity scheme and increment in reliabi1ity observed [20]. The asymptotic attenuation value which is average specific attenuation in three cities in the UK which is in a different

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geographical location (with different weather dynamics) can be very misleading and inaccurate when applied in tropical Africa. The link margin formula for scintillation does not take into account the signal wavelength and random nature of the refractive index profile along the propagation path. Again, the number of transmitters used cannot necessarily reduce the scintillation fading if the signal fluctuation is correlated among the transmitters.

III. FSO ARCHITECTURE

Designed system must be reliable, robust and should be compatible enough to work in any environment and configuration like ring topology, PTP, mesh topology, PMP and many more as per requirement. With time populations increasing exponentially so to meet the demand of people especially in metropolitan zone, vendors must assist with all types of service with standard QoS band prepares their network as a giant and extend all the services to last person with FSO.

FSO Mesh Configuration: Figure 9 represent FSO mesh configuration which is made up of various sensing nodes couples with each other in series with minute angle of lay-off. In this kind of configuration each node is coupled to each node of network directly or multiple hops in series.
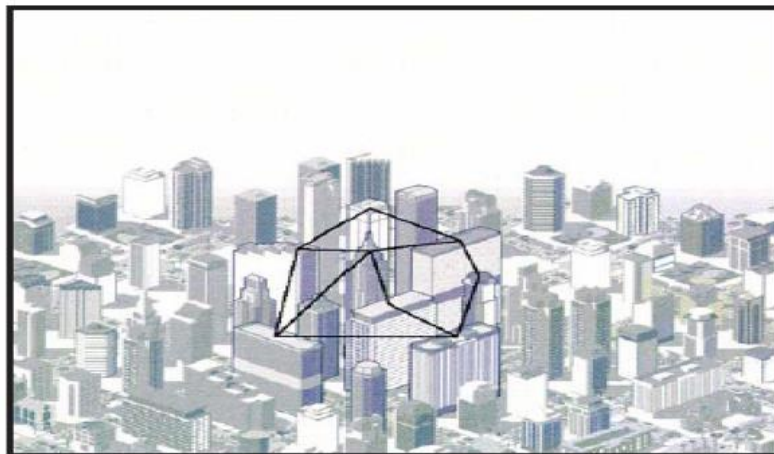

Fig.9: Mesh architecture [10].

Redundancy level play very eminent role in this configuration which help in to examine the level of connection among nodes. In mesh configuration we can add nodes easily and this system is highly reliable. When large numbers of node will be there in network then system will be more robust.

FSO P2M Configuration: In this configuration there would be a single node which generate message and work as a server for other sensing nodes. This node is coupled with many nodes to which information will be shared. Figure 10 represent best suited technique of point to multipoint configuration and sites must be close enough. Links are fiber connected to router and must be fixed at random position for example in office, rooftop of building, in living room. With help of this configuration beam is split into many beams with suitable gadget and serve many clients at same time from single node. Only disadvantage of this configuration is its limited power forced by regulatory authorities. P2M configuration provides economical connections and addition of node smoothly with minimum bandwidth with respect to P2P configuration.
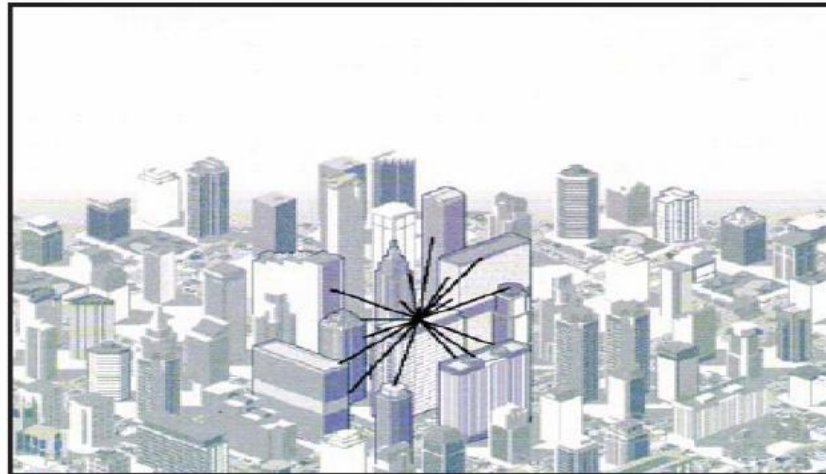
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Fig.10: Point to multipoint architecture [10].

Multiple PTP Architecture: Figure 11 layout multipoint PTP configurations and it is best suited for large scale network to manufacture sensible connection path. In this configuration there is some standard weather parameters must be in consideration during employment of this technique. Multiple PTP configuration provide devoted link with superior bandwidth. When bandwidth will be higher them huge amount of data can be transferred in limited time.
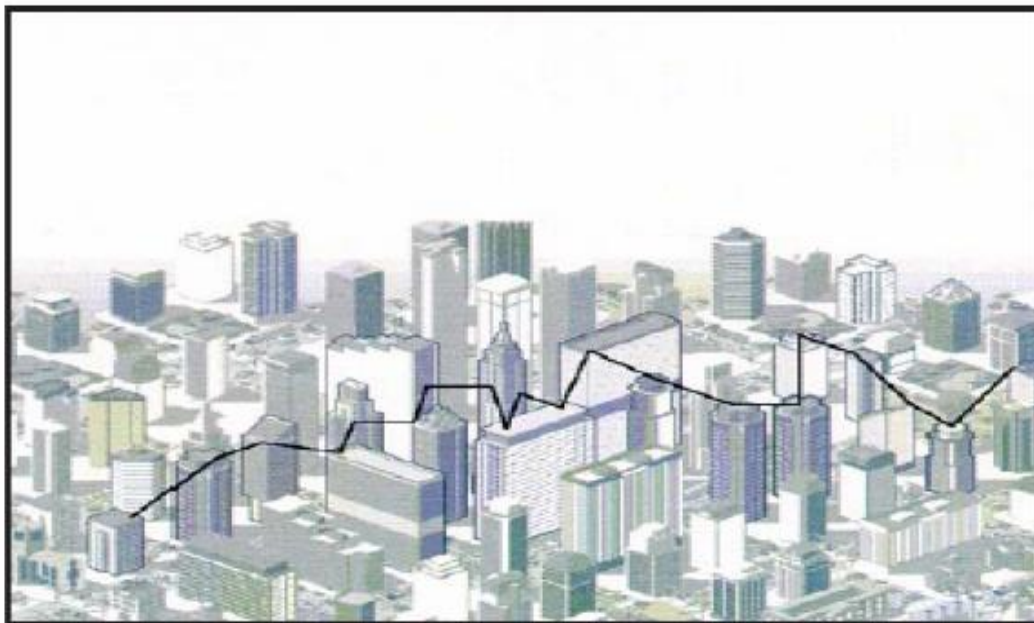

Fig.11: Multiple PTP architecture [10].

IV.FSO APPLICATIONS

FSO have tremendous characteristics of FSO which make it very attractive for various application scenarios. Again, FSO communication system can be deployed in various domains of application like military, civilian [3].

Deep Space Probes: In mission like deep space investigation there are huge restriction on various parameters like mass, volume and power of onboard devices is severely limited and hence therefore size of antenna and transmission power are also limited. According to, lasercom terminals for space investigation have much lower mass with respect to radio frequency unit [5].

Links involving Satellites: FSO path can be used in SC (satellite communications) to establish a global backbone

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network. Optical links which incorporate satellites provide very high-quality service (Gigabits data) even to remote areas such as an island, a rural area or an isolated country. FSO Links involving satellites includes satellite to ground and air, ISL.

Terrestrial Networks: FSO utilized in terrestrial networks to establish a PTP and line of sight optical connection between two transceivers through the atmosphere. Propagation range of light signal through atmospheric channel can be 100 m to 10

Km due to the LOS property. Since data rates of FSO are approximate to FO (fiber optic) this telecommunication pattern can be crucial for broadband internet access.

Temporary Links: Using this technique we can create a non-permanent link in circumstances of a disaster and even when present network breakdown. This is possible only due to FSO simple installation technique.
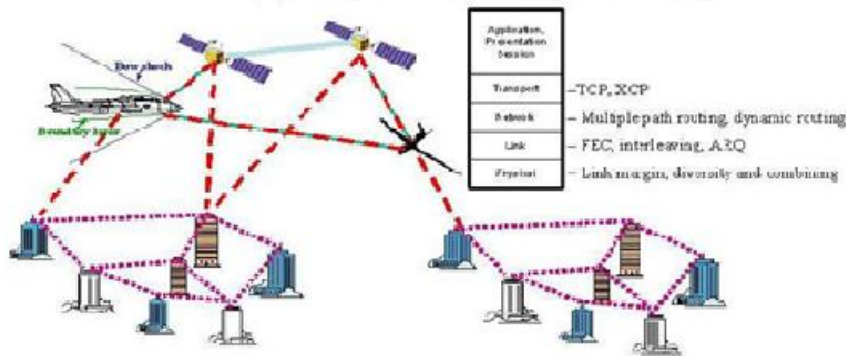

Fig.12: Free Space Optical network [12].

V. CONCLUSION

Since last two decades FSO emerged as an alternate advanced technique having so many advantages with respect to RF (radio frequency) communication. FSO is very crucial te1ecommunication framework for broadband networks in entire world. There is requirement of abundant BW which can transfer signal with minimum delay so that optimized result can be achieved. Optical fibers give huge and unsurpassed transmission BW with insignificant latency, and now this medium is best suited for long range transmission and also for very high-speed data rate transmission in telecommunication networks. FSO communication is replacing RF communication system. Long distance communication is not possible due to increment in BER so the data cannot be transferred easily. Therefore, there must be an integrated environment for long distance communication system and energy required for this communication system should be minimized for successful data transmission.

REFERENCES

[1]. M. A. Al-Habash, L. C. Andrews, R. L. Philips, "Mathematical model for the irradiance probability density function of a laser propagating through turbulent media," *Optical Engineering,* vol. 40, no. 8, pp. 1554-1562, Aug. 2001.

[2]. X. Zhuand, L. M. Kahn, "Free space optical communication through atmospheric turbulence channels," *IEEE Trans. Communi*cation, vol. 50, no. 8, pp. 1293-1300, Aug. 2002.

[3]. X. Zhu, L. M. Kahn," Performance bounds for coded free-space Optical communications through atmospheric turbulence," *IEEE Trans. Communication*, vol. 51, no. 8, pp. 1233-1239, Aug. 2003.

[4]. M. A. Naboulsi, H. Sizun, and F. de Fornel, "Fog attenuation prediction for optical and infrared waves", *Optical Engineering,* vol. 43, no. 2, pp. 319-329, Feb. 2004

[5]. X. Wang, K. Kitayama, "Analysis of beat noise in coherent and incoherent time-spreading OCDMA," *IEEE/OSA, Journal of Light wave Technology*, vol. 22, no. 10, pp. 2226-2235, 2004.

[6]. T. H. Shake, "Confident performance of encoded optical CDMA", *IEEE/OSA, Journal of Light wave Technology*, vol. 23, pp. 1652- 1663, 2005.

[7]. A. Ahmed and S. Hranilovic, "Outage Capacity Optimization for Free-Space Optical Links with Pointing Errors," *IEEE, Journal of light wave technology*, vol. 25, no. 7, July 2007.

[8]. V. Jyoti and R. S. Kaler, "Performance analysis of one-dimensional and two-dimensional codes in optical Code

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division multiple access system", Department of Electronics & Communication Engineering, Thapar University, Punjab, India, 2009.

[9]. H. Henniger, O. Wilfert, "An Introduction to Free-space Optical Communications", *Radio Engineering*, Vol. 19, No. 2, June 2010.

[10]. Ashish Kumar, Aakash Dhiman, Devender Kumar, Naresh Kumar, "Free Space Optical Communication System under Different Weather Conditions, *IOSR Journal of Engineering (IOSRJEN)*, Vol. 3, Issue 12, ||V2|| PP 52-58, (December. 2013).

[11]. Ritesh A. Jadhav, Dattatraya S. Shitole, "Fiber Optics Communication and Applications", *International Journal of Innovative Research in Engineering & Science,* ISSN 2319-5665, Vol. 4, Issue 2), (April 2013).

[12]. F. Idachaba, D. U. Ike, O. Hope, "Future Trends in Fiber Optics Communication, *Proceedings of the World Congress on Engineering. London U.K,* Vol 1, WCE 2014, July 2 - 4, 2014.

[13]. B. Priya, "Performance Analysis of SACOCDMA-FSO System Using MD Codes", *International Journal of Hybrid Information Technology,* Vol.8, No. 5, pp. 187-194, 2015.

[14]. M. Singh, "Simulative Analysis of 10 Gbps High Speed Free Space Optical Communication Link", *International Journal of Future Generation Communication and Networking,* Vol. 9, No. 3, pp. 139-144, 2016.

[15]. M. Bouhadda, F. M. Abbou, M. Serhani, F. Chaatit and A. Boutoulout, "Analysis of dispersion effect on a NRZ-OOK terrestrial free-space optical transmission system", *Journal of the European Optical Society-Rapid Publications, Society-apid Publications*, 12:18 (2016).

[16]. D. Jain, Dr. R. Mehra, "Performance Analysis of Free Space Optical Communication System for S, C and L band", *2017 International Conference on Computer, Communications and Electronics (Comptelix) Manipal University Jaipur*, Malaviya National Institute o/Technology Jaipur & IRISWORLD, July 01-02, 2017.

[17]. Satea H. ALNAJJAR, Ammar A. Noori, and Arwa A. Moosa, "Enhancement of FSO Communications Links Under Complex Environment", *Photonic Sensors*, 2017, DOI: 10.1007/s13320-017-0336-1

[18]. Simran Kaur, Priyanka Bhardwaj, "Performance of FSO Communication in the Atmospheric Turbulence for Various Modulation Schemes", *International Journal of Engineering Trends and Technology (IJETT)*, Volume 55 Number-3 January 2018.

[19]. T. Umezawa, T. Sakamoto, A. Kanno, A. Matsumoto, K. Akahane, N. Yamamoto, T. Kawanishi, "25-Gbaud 4-WDM Free-Space Optical Communication using High-Speed 2D Photodetector Array", *Journal of Light wave Technology*, 2018.

[20]. Varun Srivastava, Abhilash Mandloi, Gireesh G. Soni, "Utage probability and average BER estimation of FSO system employing wavelength diversity", *Optical and Quantum Electronics*, 51:229 (2019).

[21]. M M. Hassana, G M Rather, "Free Space Optics (FSO): A Promising Solution to First and Last Mile Connectivity (FLMC) in the Communication Networks", *I.J. Wireless and Microwave Technologies*, 4(1), 2020.

[22]. A. Thakur, A. Gupta, H. Singh, S. Bakshi, R. Goyal, G. Singh, "Performance evaluation of SS-FSO communication system incorporating different line coding", *Optical and Quantum Electronics,* volume 53, Article number: 330 (2021).

[23]. D. Arora, H. S. Saini, V. Bhatia, J. Kaur, "Enhanced Spectrum Slicing: Wavelength Division Multiplexing Approach for Mitigating Atmospheric Attenuation in Optical Communication", *Optical and Quantum Electronics,* Volume 54, Article number: 258 (2022).

[24]. Q. Yang, L. Tan and J. Ma, "Doppler characterization of laser inter-satellite links for optical LEO satellite constellations", *Optical Communication*, vol. 282, no. 17, pp. 3547-3552, Sep. 2009.

[25]. D. Bhattacherjee and A. Singla, "Network topology design at 27000 km/hour", *Proc. 15th Int. Conf. Emerg. Netw. Experiments Technol.*, pp. 341–354, 2019