Simulation Study of Video Transmission by OpticalFiber

[1]Nadira BOUKHATEM, [1]Salah TOUMI,[2]El-Bey BOURENNANE,
[1]Abdelghani REDJATI, [1]Abderraouf FARES
[1]Laboratory LERICA
Department of Electronics, BadjiMokhtar University, Annaba,Algeria
E-mail:boukhatemnadira@yahoo.fr, salah.toumi@univ-annaba.org,
redjati@yahoo.fr,faresabderraouf93@gmail.com,

[2]Laboratory ImVIA
Burgundy University, Dijon, France,
E-mail:ebourenn@u-bourgogne.fr

Abstract: **The migration to the use of optical fiber has required several developments, because nowadays it is the most widely used transmission medium in vast fields, particularly video transmission. The work carried out made it possible to study, evaluate and analyze the implementation of this transmission system. We examined the characteristics of the operating techniques of each channel of the video transmission chain and found several problems, one of which is the performance of error-correcting codes based on coding and decoding algorithms, optical fiber and these several criteria for which we have the rate, propagation distance and good transmission quality, which implies that there is always research and improvements in this area.**

Keywords: Telecommunications networks; optical fiber; video coding; video transmission.

I. INTRODUCTION

The last decade has been marked by the rapid evolution of the information and communication technology (ICT) sector, including telecommunications and the Internet. Solutions have been developed by allowing devices to connect to the Internet from an access point without the need for a cable connection [1]. The rapid increase in video applications on wired (optical fiber...) and wireless (LTE, wimax...) standards allowing real-time video transmission for various applications such as video conferencing, telemedicine, video streaming, digital terrestrial television [2]. Thus the production of multimedia content has become accessible to all audiences and at a low cost. This development makes it possible to achieve better video quality, from the digital that is beginning to grow, to HD TV and then to 8k. Current researchers are working on a thorough analysis of video characteristics on different types of networks to optimize transmission and to efficiently and adaptively route video data from the source to the destination that requires a transport protocol. A network path includes a succession of links, each with its own bandwidth [3] which is not the only factor that affects network performance. The error rate in channels must be minimized by designing an appropriate transmission means that allows specific treatment for losses between connection on the wirelinenetwork and on the wireless network [4], i.e. compression is a viable part of video communication. A wide variety of codecs are available, none of which are suitable for all situations.

The first section is devoted to the theoretical study of optical fiber. In the second we studied the video transmission by optical fiber and the different treatments that video undergoes. Finally, the third section was devoted to the simulation of video transmission by optical fiber taking into account: compression, decompression, attenuation and length. And will conclude with a conclusion.

II. OPTICAL FIBER, ITS EVOLUTION AND USE

With the advent of the Internet, bandwidth requirements have become increasingly important in order to convey the growing mass of information on the various networks, with reliability and while maintaining a good quality of service. Indeed, this has required the development of communication systems that are efficient and reliable enough to interconnect a constantly growing number of users around the globe. Researchers and industrialists were able to propagate a deformation-free pulse at the speed of light over very long distances and with a wide bandwidth. The door to the transport of information in optical and binary form was broken and this was the starting point of the race for speed, which led to pharaonic progress in just 20 years [5].

A.Description and evaluation of optical fibers

The fiber is nothing more than fused silica glass filament[6] that can accept electrical signals as an input and convert them into optical signals (light) that are converted back into electrical signals at destination[7].The main element of the fiber is the central conductor called the fiber core or core. This conductor is surrounded by an optical sheath with a refractive index lower than that of the core. The whole will then be covered with a protective coating to mechanically protect the fiber; it plays no role in guiding light (Fig.1). The fiber optic cabling system is based on cabling with an even number of fibers (one for transmission, one for reception) [8].

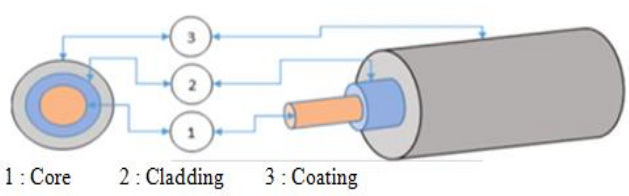

Fig.1.Optical fiber structure

B. Types of Optical fiber

To understand the applications of optical fiber, it is necessary to understand each type and its characteristics. Optical fibers can be classified into two categories according to their diameters and wavelength propagation. The dispersion phenomenon results in a widening of the pulses at the heart of their propagation; this widening limits the bandwidth of the optical fiber channel. The (Table 1.) provides a comparative summary of the advantages, disadvantages and practical application between the different types of optical fibers

TABLE I. COMPARISON BETWEEN THE DIFFERENT TYPES OF FIBER OPTIC

Number of modes	**single mode**	**multi-mode**	
Refractive index	/	Index jump fiber	Gradient index fiber
Corediameter (µm)	8à10	50 à 62.5	50 à 62.5
Sheathdiameter (µm)	125	125	125
Attenuation (dB / Km)	0.1 à 0.5	3	1.5 à 3
Bandwidth	In the order of THz.Km	<60 MHz. Km	De l'ordre de GHz.Km
Dispersion	Chromatic: Axial propagation	modal: Total reflection on fiber	modal: Forms a sinusoidal shape
Spectral Windows of use	1300nm 1550nm	850nm 1330 nm	850nm 1330 nm
Practical applications	Long-distance communications	Short distance communications, local networks	Short and mediumdistance communications

C.Optical fiber in telecommunications networks

At present the most efficient and widespread technology is based on the fiber optic transmission system. These offer a low attenuation physical support that is virtually insensitive to electromagnetic noise, easy to install and has a high transmission capacity. The optical fiber as we currently use it is the result of intensive research on new low-dissipative waveguides. Like all other transmission media, optical fiber has disadvantages but also offers many advantages for telecommunications [9][10].

III QUALITY CRITERIA FOR FIBER OPTIC VIDEO TRANSMISSION

The principle of any data transmission is to convey information from the source to the recipient (between a transmitter and a receiver) by minimizing the risks of distortion of the received signal, in order to ensure maximum reliability of the transfer of information by using a physical medium such as cable, optical fiber, etc. The heterogeneity of computer networks requires the implementation of a common network access interface to manage interoperability between the equipment of different manufacturers. The ISO organization has therefore specified a common structure describing the architecture of a network, called the OSI model (Fig. 2). The following section will be the subject of the presentation of the OSI model in a transmission context [11].

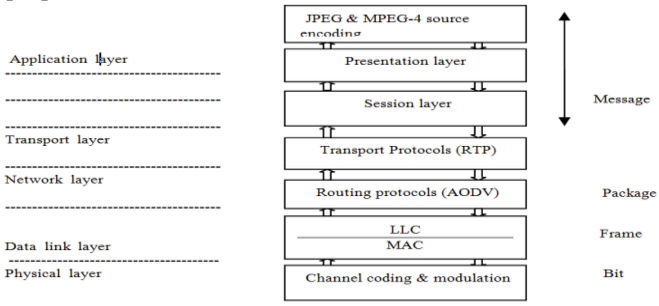

Fig. 2.Layered structure of the OSI model

The telecommunications network is a set of connected equipment that can be defined as an extensible web of interconnected nodes by physical lines: optical fibers in some places and, in others, by copper electrical wires; so we talk about afixed network.

Data Processing Terminal Equipment or any other source (Transmitter) of digital data is called DTE. They communicate with each other through a data circuit that consists of Data Circuit Termination Equipment (DCTE). All the functions necessary for the management of the data circuit by each DTE constitute the physical layer of the latter or it is carried out by joins or interfaces DTE/DCT.

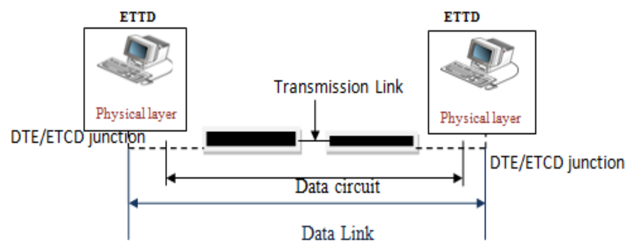

Fig.3.Basic component of a data link

A DTE is characterized by its rate (bits/s), the transmission mode (synchronous or asynchronous), and the type of transmission line, the operating mode of the circuit (simplex, duplex... etc.), the coding method, the modulation speed and the type of interface with the DTE (Fig.3).

An optical fiber telecommunications network can be divided into three categories according to their size (in terms of number of machines), data transfer speed and extent [6]:

- The access network - LAN (local area network) or local network, covering dimensions ranging from a few kilometers to a few tens,
- the metropolitan area network (MAN), with dimensions of the order of one hundred kilometers,
- The wide area network (WAN) or broadband network, the best known WAN is the Internet, extending over several hundred kilometers. It includes terrestrial or underwater systems.

A. *Error problems on transmission networks*

Although these networks have deployment advantages and user mobility, real-time video transmission over these networks for various applications such as Telemedicine, videoconferencing and video streaming is a challenging task[12] and that is why it is often necessary to implement devices to detect errors and if possible to correct them, however, if the high binary error rate ,error-resistant techniques are needed to protect encoded video bit streams For more information, the works[4],[13], detail all these aspects.Various Error Detection Codes (EDC) or Error Correcting Codes (ECC) have been used for years to increase the reliability of transmission systems [14].AlSo, it is necessary to provide in a transmission chain techniques for detecting and correcting errors within codecs. The figure below gives a simple summary of the large coding family. In the first category (block codes), let us mention the most famous codes such as BCH, Reed Muller, Reed Solomon and Goppa, Golay and Hamming. The second category (trellis codes) is less rich in variety but offers much more flexibility, especially in the choice of available parameters and decoding algorithms. For example, binary convolutional codes widely used in coded modulations (TCM) and parallel concatenated codes (Turbo Codes).

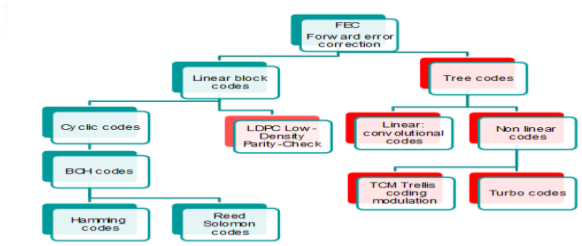

Fig.4.Hierarchy of correction codes [15]

In the case of optical fiber transmission and since the information is presented in multimedia form (text, still image, video), the video is first coded or modulated in a known sequence but the result is the same: the information then consists in transmitting bit streams, which can be controlled upon reception. This signal is injected into the optical fiber through the transmitter; there may be losses and degradation of the signal, caused mainly during dispersion within the fiber. At the output of the fiber, the signal is received and amplified before being decoded, however the signal will undergo reverse processing to be returned to its original form; a reconstructed video (Fig.5)[14].

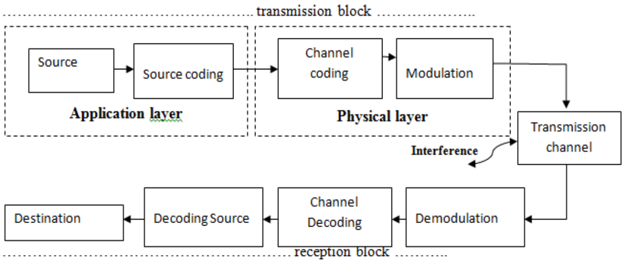

Fig.5.Schematic diagram of an optical link

The source: The message source transmits the information in digital form and will be encoded on "n bits"**.**

Source encoding/decoding: Source encoding consists of transforming the source message into a sequence of information. By reducing the redundancy (lossy or lossless) contained in the message and thus minimizing the amount of information useful for its representation. The source decoding performs the dual operation; the information message is decompressed in order to find its equivalent from the substitution sequence before transmission. It should be noted that the theoretical limits of source coding are set by Shannon's first theorem[16][17].The performance of a source coder is evaluated by the compression ratio parameter which represents the ratio between the size of the information before and after source coding (the principle of source coding for still image and video, commonly called compression).

Channel encoding/decoding: Channel encoding is an operation that reduces errors and protects transmitted information from transmission channel interference. To combat these transmission errors, it is necessary to add redundancy in order to detect and possibly correct errors during reception. It is therefore possible to improve the signal-to-noise ratio (SNR), which defines the difference between the power of the transmitted signal and the noise of the propagation channel. This is expressed in decibels (dB).

The signal strength is derived from the energy required to emit an Es modulation symbol.

The noise power depends on the density of the noise spectrum N0, so the SNR is defined according to the relationship (1.1).

$$SNR = \frac{E_S}{N_0} \qquad (1)$$

$$\boldsymbol{SNR_{db} = 20.log_{10}\left(\frac{E_S}{N_0}\right)} \, \textbf{(2)}$$

Modulation/demodulation: Digital modulation allows the coded information to be adapted to the transmission medium. The transmitter is in charge of the modulation operation which associates one or more binary elements with a symbol characterized by its amplitude and phase. Modulation acts on the parameters of a carrier signal to transmit the encoded data. There are several types of modulations that can be applied to optical channels [18], (Fig.6) The demodulator plays the dual role of the modulator and thus transforms the received signal into a bitstream.

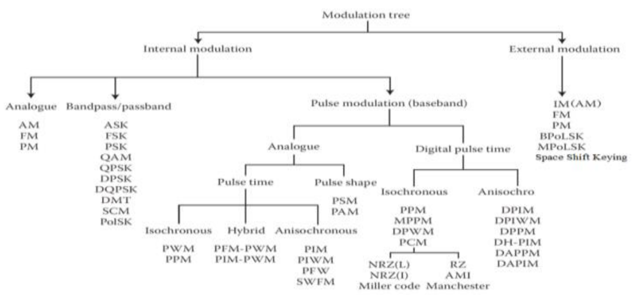

Fig. 6. Modulation techniques [18]

The transmission channel: It represents the link between the transmitter and the receiver and can be of different natures depending on the type of quantity it allows to convey. The transmission channel is characterized by its capacity and bandwidth. Note that the input of the transmission channel processes binary elements, while the output produces probabilistic information associated with the binary elements. There are several theoretical models of the transmission channel depending on the most frequent types of errors. The most commonly used channels in information theory are the Symmetric Binary Channel (CBS) and the Gaussian White Additive Noise Channel (BBAG) [19].

IV. STUDY AND SIMULATION OF THE PARAMETERS OF A TRANSMISSION CHAIN WITH THE MATLAB / SIMULINK SOFTWARE

In this section, we describe the motivation to better choose the components of an optical telecommunication chain; we need to calculate the optical link balance [20] which is summarized in the calculation of the energy balance and the bandwidth balance of the link. Two effects limit the transmission capacity: attenuation and dispersion. First of all, this paper provides an overview of the transmission chain and program architecture, each of the above blocks is used in the code as a subprogram. The script used for the simulation will therefore only pass the variables from one subprogram to another and calculate it.

A. *Attenuation*

Or loss of transmitted power, during propagation in the fiber, the power decreases as a function of the length of the fiber at a defined wavelength ʎ, according to the law:

$$P_L = P_0 e^{(-\alpha L)} \quad (3)$$

Instead, the attenuation is defined in dB/km:

$$A(dB/Km) = 10 log \frac{P_0}{P_L} \quad (4)$$

A: AttenuationP_0: Power of light at the entrance of the fiber

L: Length (Km) P_L: Power of light at the fiber output : absorption factor in Neper/m.

For practical reasons

$$A = -4{,}34\ \alpha L \quad (5)$$

The simulation is carried out for reference values for the attenuation: 0.17, 0.22, 0.50 associated with the single mode fiber F: (λ = 1550nm) for lengths ranging from 40km to 110km.In this part we tried to implement a Matlab code that allowed us to get as close as possible to the theoretical results. First we created a video file and saved it (the video must be in the same path as the Matlab code backup), then we started processing the video to send it correctly on the fiber. We will study the influence of transport with optical fiber, indeed we will see the influence of the attenuation on the quality of the video and the losses it will cause. The results obtained are summarized in table II:

TABLE II. ATTENUATION ACCORDING TO LENGTH

Att / Length (Km)	0.17	0.22	0.50
40	0.8350	0.7135	0.3266
50	0.6680	0.5708	0.2613
60	0.5566	0.4756	0.2177
70	0.4771	0.4077	0.1866
80	0.4175	0.3567	0.1633
90	0.3711	0.3171	0.1452
100	0.3340	0.2854	0.1306
110	0.3036	0.2594	0.1188

Fig.7. Attenuated video for Att= 0.17: [1- L=40km, 2- L=50km, 3 - L=60km, 4 - L=70km, 5-L=80km, 6-L=90km, 7- L=100km, 8- L=110km]

Fig.8. Attenuated video for Att= 0.22: [1- L=40km, 2- L=50km, 3 - L=60km, 4 - L=70km, 5-L=80km, 6-L=90km, 7- L=100km, 8- L=110km]

Fig.9.Attenuated video forAtt= 0.50: [1- L=40km, 2- L=50km, 3 - L=60km, 4 - L=70km, 5-L=80km, 6-L=90km, 7- L=100km, 8- L=110km]

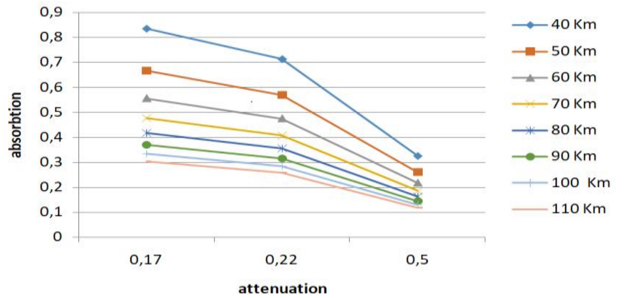

Fig.10. Absorption factor by attenuation value

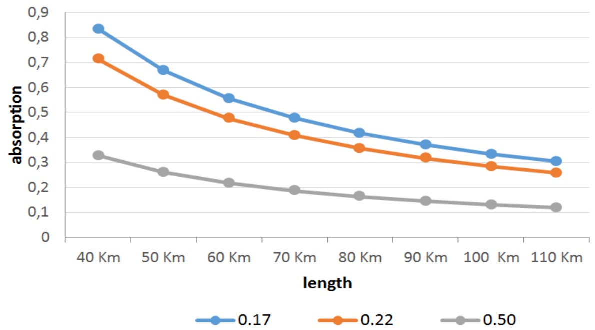

Fig.11. Absorption coefficient by length

B. Noise

The optical signal is propagated along the fiber as well as in the different components of a transmission chain, the latter will be assigned to the various types of noise so attenuation is not the only disadvantage there is also the influence of noise that distorts the video signal, such as the Gaussian additive noise channel. We present: the Gaussian model which is the most common in the literature for optical fibers. It is a rather simplistic model, it is the reference channel to study error-correcting codes and their decoding algorithms. The AWGN assumes that a noise element Bn is added to the emitted element: Hence:

$$Y_n = B_n + X_n \qquad (6)$$

Yn :received signal Bn : noisy signalXn : emitted signal

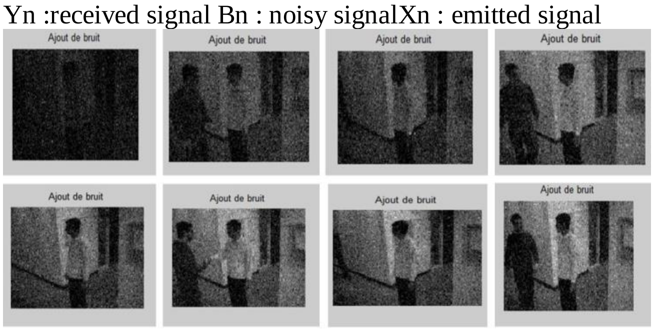

Fig.12. Video noisy for Att= 0.17: [1- L=40km, 2- L=50km, 3 - L=60km, 4 - L=70km, 5-L=80km, 6-L=90km, 7- L=100km, 8- L=110km]

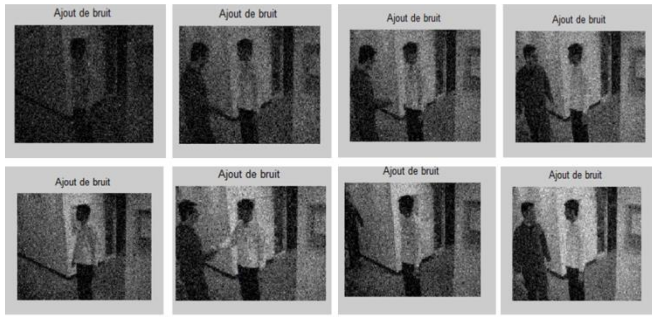

Fig.13. Video noisy for Att= 0.22: [1- L=40km, 2- L=50km, 3 - L=60km, 4 - L=70km, 5-L=80km, 6-L=90km, 7- L=100km, 8- L=110km]

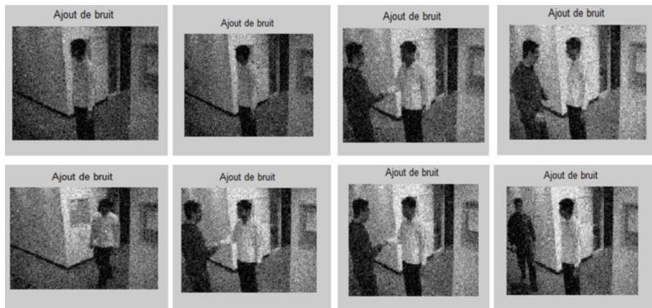

Fig.14. Video noisy for Att= 0.50: [1- L=40km, 2- L=50km, 3 - L=60km, 4 - L=70km, 5-L=80km, 6-L=90km, 7- L=100km, 8- L=110km]

C. Calculation of PSNR

The signal-to-noise ratio is often used as a measure of quality between the original image and a compressed image. For this fact, the square error (MSE) and the peak signal-to-noise ratio (PSNR) are the two error measures used to compare the quality of image compression. The MSE represents the cumulative squared error between the compressed image and the original image, while the PSNR represents a measure of the maximum error.It is calculated using two equations:

$$MSE = mean(mean(comp\_vidéo - s)^2 \quad (7)$$

$$PSNR = 10 * log10(255^2 / MSE \qquad (8)$$

The results obtained are summarized in (table III)

TABLE III. CALCULATION OF PSNR

Att	PSNR (dB)
0.17	22.3
0.22	17.11
0.50	10.02

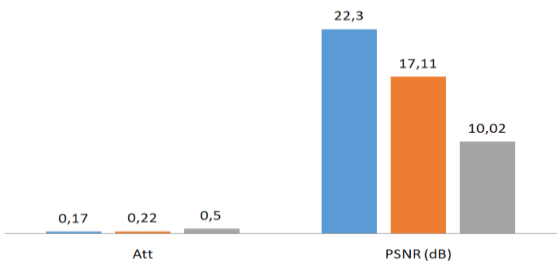

Fig.15. Calculation of PSNR

IV.SIMULATIONRESULTS

According to (Table II) and the plot of the curves, we notice that indeed the attenuation has an influence on the video, but whenever the attenuation increases the quality of the video becomes more and more mediocre more precisely to a distance of 80 km (According to Algeria Telecom) it is the maximum theoretical distance of sending the signal without amplifiers. Beyond 110km in cannot send. The length of the optical link affects the quality of the video transmitted, in addition it is long the attenuation increases and the quality of the video is degraded [22]. The attenuation of the fiber must be compensated periodically by optical amplifiers (AOSC, EDFA), the chromatic dispersion must also be compensated by (Bragg grating, fiber with two concentric cores) as well as the nonlinear effects [23].Other techniques, such as multiplexing are implemented to increase the flow in an optical link and improve service quality, and the design of new fibers for compensating polarization dispersion. For further details on attenuation and its causes, the interested reader may refer to references [21].

The PSNR is the most commonly used evaluation, which allowed us to conclude that: The higher the PSNR is, the better the quality of the compressed or reconstructed image. The lower the MSE value, the lower the error.

V. CONCLUSION

The progress made in the field of telecommunications systems is much important and rapid in terms of transmission capacity. This is why it seemed interesting to us to start this work with a simulation of the video transmission chain under Matlab. This simulation is important to determine the performance of this chain. A study that allowed us to visualize the video and also measure the quality of its transmission, and allowed us to give similar results of reality. Thus, in the rest of our work we are looking for other more efficient coding/decoding algorithms, and test various architectures with implementations.

References

[1] R.Wassim,“Improved video and data transmission in wireless networks,” Diss. Besançon, 2011.

[2] M.Ayyub Khan, “Video Transmission over Wireless Networks-A Survey,” International Journal of Electronics Engineering Research. ISSN 0975-6450 Volume 9, Number 2 (2017) pp. 207-216.

[3] S. Biaz ,X. Wang, “ RED for improving TCP over wireless networks”,In ICWN : International Conference on Wireless Networks, pages 628–636, LasVegas, USA, June 2004.

[4] A. Nafaa, T. Taleb, and L. Murphy, “Forward error correction strategies for media streaming over wireless networks,” IEEE Communications Magazine, vol. 46, pp. 72–79, January 2008.

[5] A.Hamouda , K.Saouchi ,“Breves generator of pulses has different flow rates(40 Ghz, 80 Ghz and 160 Ghz),”, journal of JNTM, Vol. 7(01), 27-32. 2017.

[6] P.G. Kokaje, Dr. R. S. Kawitkar, M. Selva Balan,“ Review of Recent Development in Optical Fiber Technology,”International Journal of Advanced Research in Electrical,Electronics and Instrumentation Engineering *(An ISO 3297: 2007 Certified Organization)*Vol. 4, Issue 3, March 2015.

[7] I. S. Chibueze, O. N. Henry, “ Review of the Security Challenges of Fiber Optics Technologies in Network Connection in Nigeria and the Countermeasures,” *International Journal of Engineering Science Invention, www.ijesi.org ,Volume 5,Issue 7, July 2016 , PP. 36-41*

[8] F. S.Madani, “Characterization and contribution of LEDs for the fiber optic transmission in a local network,” Diss.National Institute of Telecommunications and Information Technologies and Communication-INTTIC-Oran University of Science and Technology-USTO-2011.

[9] H.Yasmine Djazia,“ Study of a Radio link on fiber,”Institutional repository of the University Abu Bekr Belkaid Tlemcen UABT,2014.

[10] F. Raharimanitra, "Contribution to the study of architectures based on time and wavelength multiplexing in the access network, allowing migration to the new generation of 10 Gbit/s PON (NG-PON)," Diss. Télécom Bretagne, University of South Brittany, 2012.

[11] W. Hamidouche, C. Perrine, Y. Pousset, C. Olivier, "Effective power allocation solution for scalable video transmission in a realistic outdoor environment", CORESA 2010 (Lyon, France). Oct. 2010

[12] H. Lee, S. Lee, and A. C. Bovik, “Cross-layer optimization for downlink wavelet video transmission,” IEEE Transactions on Multimedia, vol. 13, pp. 813–823, August 2011.

[13] C.-H. Lin, C.-K. Shieh, N. K. Chilamkurti, C.-H. Ke, and W.-S. Hwang, “A RED-FEC mechanism for video transmission over WLANs,” IEEE Transactions on Broadcasting, vol. 54, pp. 517–524, September 2008.

[14] N.Boudrioua, "Study and optimization of a digital optical transmission chain: towards an electronic compensation of the effects of the PMD,". Diss. University Paul Verlaine-Metz, 2007.

[15] S .Cavaliere, “Forward Error Correcting (FEC) coding for SuperB serial links: a preliminary study,” Cavaliere - SuperB Workshop - march 2010.

[16] J. Oswald, Theory of Information or Diacritic Analysis of Systems, Ed Masson, 1986.

[17] A. Polite and Li. Huguet, Codes Correctors, Theory and Applications, Ed. Masson, 1989 .

[18] optical wireless communications :system and channel modelling with MATLAB/Z.Ghassemlooy,W.Popoola,S.Rajbhandari. ISBN978-1-4398-5188-3

[19] Erwan Piriou, “Contribution of high-level modelling and synthesis in the design of flexible architecture dedicated to block turbocodes,” Doctoral thesis: Engineering sciences: Institut TELECOM/ TELECOM Bretagne, University of South Brittany: 2007

[20] Telecom On Optical Fibers. 2nd revised and expanded edition, Pierre LECOY Hermés, Paris, 1992, 1997.

[21] W. Daum, J. Krauser, P. E. Zamzow et O. Ziemann. POF Handbook - Optical Short Range Transmission Systems, Springer, deuxième édition, 2008.

[22] I. Azusa,Y. Koike, “Unconventional plastic optical fiber design for very short multimode fiber link,” Optics express vol 27,N 9 ,pp 12061-12069,2019.

[23] P. A. FALL, M.FALL, “Experimental investigation of intensity modulator/direct detection (IM/DD) optical OFDM system with fiber bragg grating (FBG),”. Journal of Optical Communications, 2018.