ANALYSIS OF OPTCAL TRANSMISSION ARCHITECTURE FOR INTEROPERABILITY OF ELECTRONIC HEALTH RECORD OVER A DISTANCE OF 209KM COVERING FIVE SELECTED HOSPITALS

Nwokedi, C. N.[1], Nwokoye, A.O. C.[2], Uzoka, E. C.[3]

[1,2] *Department of Physics and Industrial Physics,*
Nnamdi Azikiwe University, Awka, Nigeria
[3] *Destinet Research Group, Enugu, Nigeria*
*Corresponding author email: chizzy4tiana@gmail.com

Abstract
The analysis of optical transmission architecture for the interoperability of electronic health record between five selected hospitals is presented. It is to communicate real time patient health information between hospital specialists for further, fast and better quality of medical service. It tries to facilitate the quality of services rendered to patients when transferred from one hospital to another thus eliminating delay and time wasted to perform new series of test and check-up before treatment begins. This was achieved using single mode optic fiber, power amplifiers, converters, modulators, optical connectors, circulators, among other major components listed in the methodology. The work was implemented using optisystem software and deployed at the University of Nigerian Teaching Hospital Enugu (UNTH) (Hospital A), Parklane hospital Enugu (Hospital B), Nnamdi Azikiwe teaching hospital Nnewi (Hospital C), Immaculate Heart and Maternity Hospital Ukwuani (Hospital D) and Delta state teaching hospital (DSTH) (Hospital E) with an overall distance of 209KM apart. The performance was tested between UNTH and DSTH and the result showed that when data was sent from UNTH, noise reduced to quality to -100dbm, however, the application of filters and amplifiers were used to boast the quality of the EHR data and at the receiver end (DSTH) quality of data collected has a power of -19dBm when measured with power meter.

Keywords: *Optic fiber, filter, electronic health record, power amplifier*

Introduction
According to [1], the country that budget most on healthcare is United States of America, with 17.7%. Other populated countries such as India are 3.89%, Nigeria 3.9% and among the few. The implication of this budget analysis is to show that health care sector is among the most neglected when it comes to global national budget sharing. This has been made evident in most of the hospitals especially in the underdeveloped and developing countries. It was observed that most of these hospitals lack adequate facilities, infrastructures, man power, and technology needed for better quality of

health care services. As a result, patients with critical health conditions are been transferred from one hospital to another in order to guarantee better treatment. However, the patients due to lack of communication scheme between health care settings and the confidential laws guiding patient health records suffer series of challenges when transferred. The ideal scenario is supposed to be when patients are transferred, their health record are equally sent to the secondary hospital for continuous treatment. According to [2, 3], the biggest obstacle to improving the quality of medical service is how to realize the (interoperability) sharing of medical information collected by different hospitals or specialist health agencies at a high speed and secured network. The implication includes repeated payment for new treatment, repeated series of medical test, complexity of treatment, time wasted and even death of patient due to time delay for treatment. Hence, there is need for digital communication scheme which is cost effective, easy to implement and reliable with the capacity to transfer patient health records on request from any hospital nationwide. This when achieved will go a long way to improve quality of health care services in Nigeria among other nations.

Methodology and Materials

The methodology for the work includes the necessary engineering components, transmission routes, theory of non-pulse propagation based on Maxwell relationship [4] taking into consideration fiber losses, dispersion [5], fiber nonlinearity [6, 7], wave division multiplexing [8, 9, 10, 11], laser rate equations [12, 13], and electronic health record dataset [14].

The Engineering Materials, are the tools employed in this work in developing the network structure for transmission of the electronic health record system as shown in the block diagram in Figure 1. They include optical signal, converters, single mode fiber, transmitter, receiver, power amplifiers, circulator, signal generator, filters, fiber cables, optisystem, photo detectors, attenuators, optical power meters and oscillators.

SYSTEM IMPLEMENTATION AND ANALYSIS

The work is implemented using optisystem development environments and analyzed using one or more of the following instrumentation toolbox; power meter, time domain analyzer, frequency analyzer, oscilloscope, spectrum analyzer, polarizer and eye diagram. The implementation is divided into three main blocks which are the transmitter section, the amplifier section and the receiver section. The communication network between the five selected hospitals which are the University of Nigerian Teaching Hospital Enugu (UNTH) (Hospital A), Parklane hospital Enugu (Hospital B), Nnamdi Azikwiwe teaching hospital Nnewi (Hospital C), Immaculate Heart and Maternity Hospital Ukwuani (Hospital D) and Delta state teaching hospital (Hospital E) with an overall distance of 209KM apart in the circuit diagram of Figure 2.

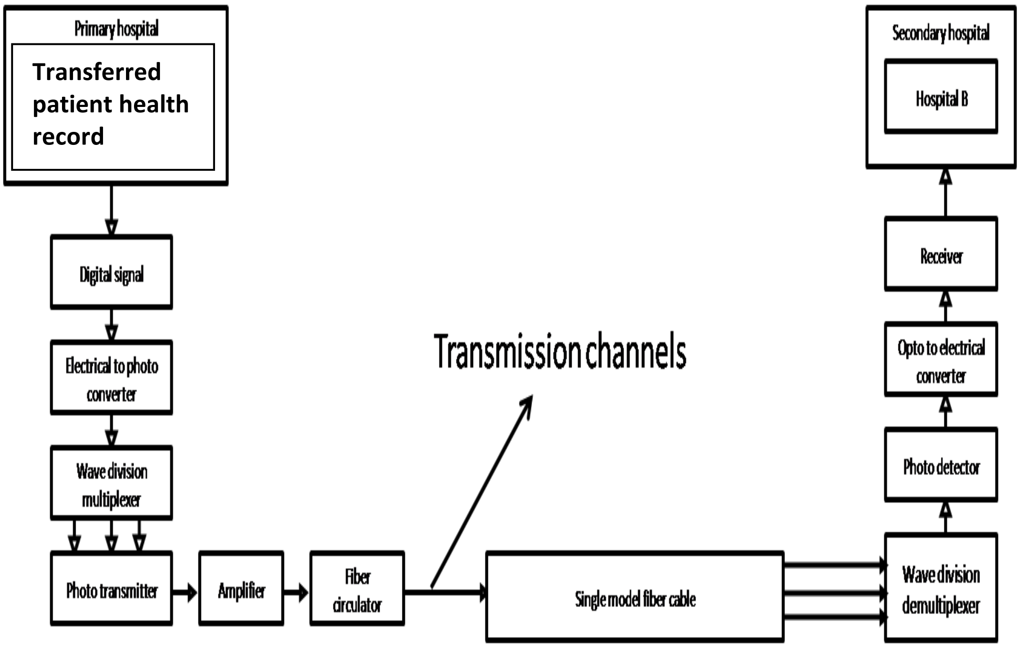

Figure 1: System block diagram

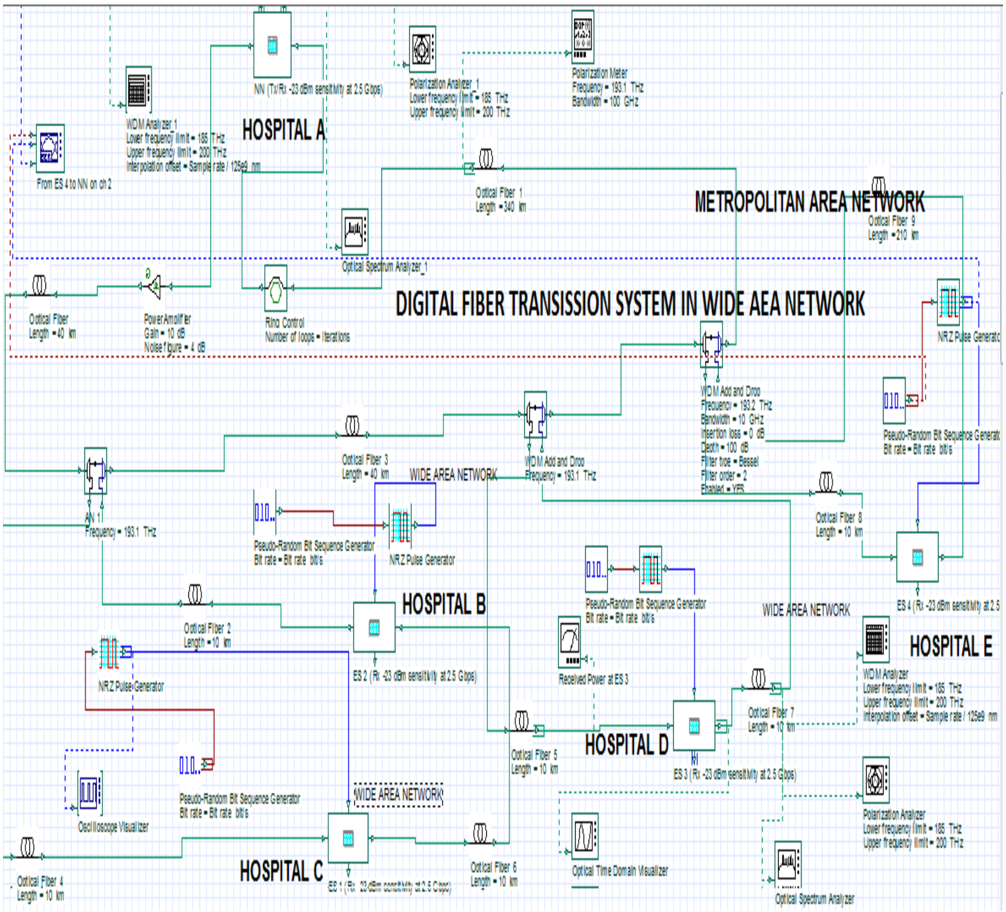

Figure 2: Optical transmission system between five hospitals

The implementation model in figure 2, presents the optical transmission architecture between five selected hospitals of various distance specified from the network, Hospital A serves as the primary hospital which transmit EHRs to other hospitals (B, C, D, E). The other secondary hospitals can transmit information between themselves as shown in the transmission system using the single mode fiber. This is because each hospital is designed with its own communication structure as shown in Figure 3. The choice of the single mode fiber type is due to its ability to transmit at a very long distance unlike the multi model type. Secondly, they are already installed nationwide by telecommunication companies, so the dark reserved part was used for the transmission (eliminating implementation cost). The circulator regenerates the signal which will be further amplified and demultiplexed at a wavelength of 1550nm while the optical isolator is essentially the passive device which allows flow of the optical signal (for a particular wavelength or a wavelength band) in one band preventing reflections in the backward direction. This data is transmitted at about 25GB with better quality due to amplification and filtration to the receiver end (secondary hospital). The set up designed for the transmission system in each of the hospital is presented in Figure 3.

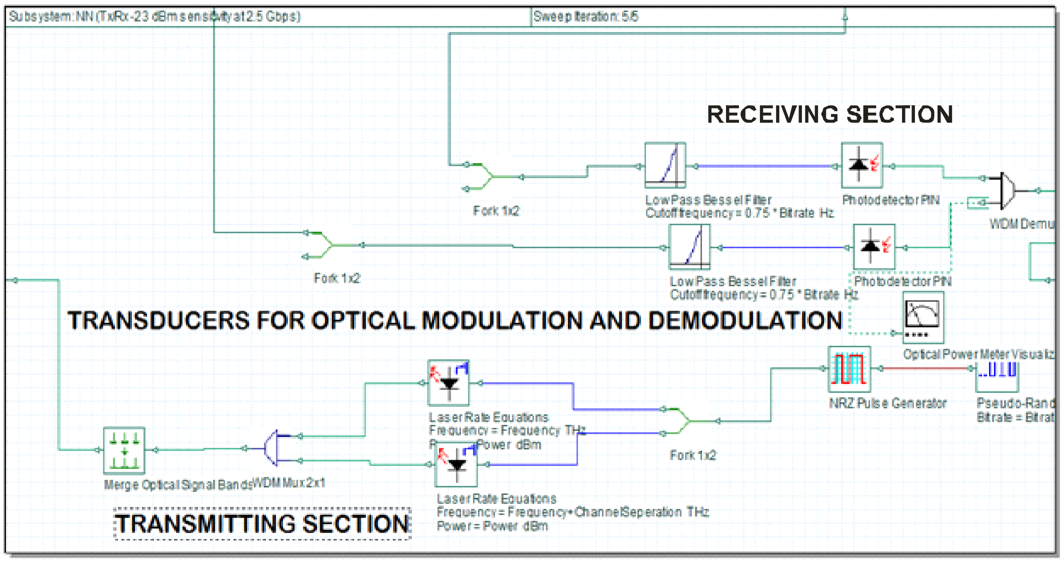

Figure 3: Architecture of the transmitter and receiver design for each hospital

Figure 3 is the communication setup for transmission of EHRs, the model is designed using low pass basel filter with the specified cutoff frequency (0.75 * bitrate Hz). The filter is used for optical ripples filtration, removing unwanted laser signals which are generated from the basic electronics components used for the system design such as the amplifier. The need for this amplifier is to help increase the signal strength and gain to ensure quality of received data at the receiver end, despite the losses which will be experienced during transmission due to distance. The amplifier model is presented in Figure 4.

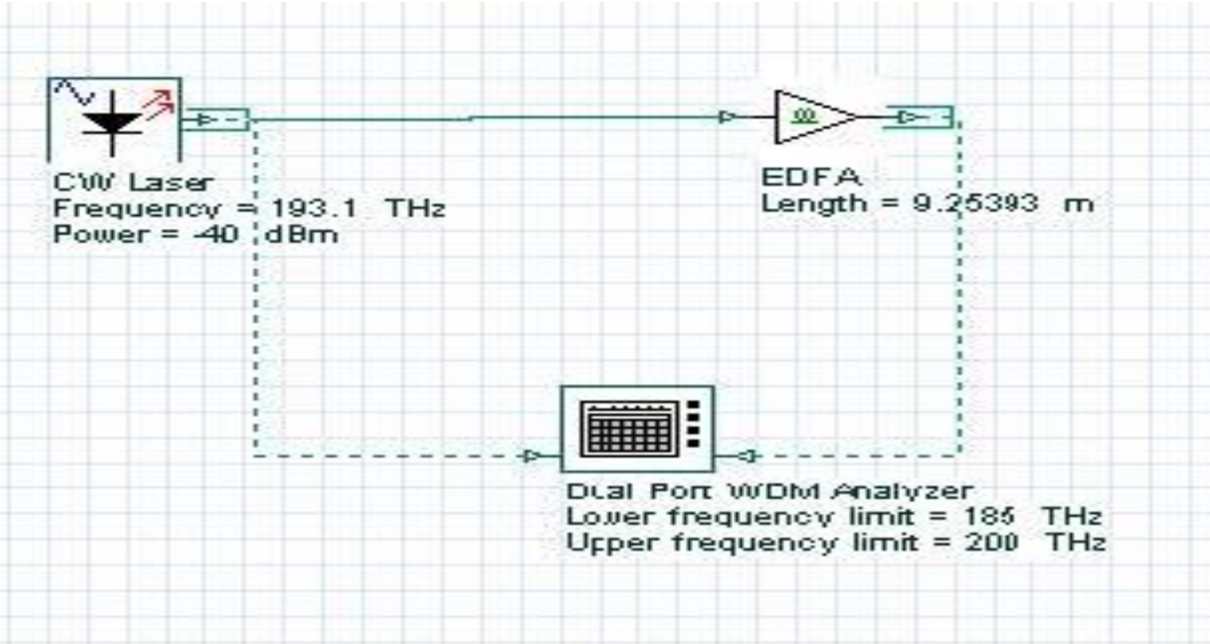

Figure 4: The optical power amplifier model

Results

In this section, the performance of the data transmission system between hospital A and Hospital E 209Km apart was simulated analyzed, considering the transmitter and the receiver performance using the parameters in Table 1.

Table 1: Simulation Parameters

Parameters	Values
Input power	7dBm
Laser frequency	193Hz
Frequency of transmitter	1550nm
Hospitals	A,B,C,D,E
Attenuation of the cable section	0.2Db/km
Fiber core	8-10m/d
Cut off frequency	0.75 * bitrate Hz
Reserved dark fiber bandwidth	25GB
Distance	209km

The simulation result will characterize the transmission interoperability between hospital A and B, since all the other hospitals are designed with similar communication infrastructures. This analysis will be done considering the signal quality at the transmitter, the amplified signal strength after some distances and the receiver signal. The data (EHRs) to be transmitted is converted from digital file to photon and transmitted as shown in Figure 5, at a wavelength of 1.55m to hospital B;

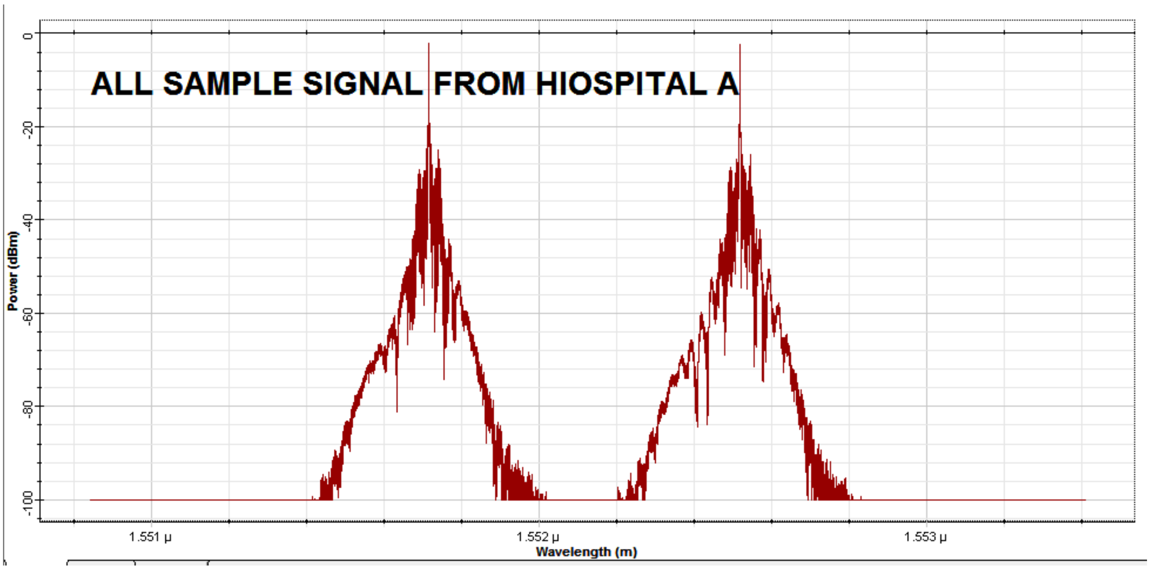

Figure 5: Signal from UNTH (Hospital A)

Figure 5 reveals the whole optical signal to be transmitted from hospital A. This signal is measured using the power meter.

From Figure 5, the performance of the transmitter was analyzed using power meter considering the signal, noise and signal to noise ratio performance. These analyses were measured and from the result it was observed that a signal strength of -100 dBm was transmitted to hospital B. However, due to the distance of transmission, there is need for amplification to boast the signal strength and compensate for loss due to dispersion and signal reflection during transmission. The result of the amplified signal is presented in Figure 6.

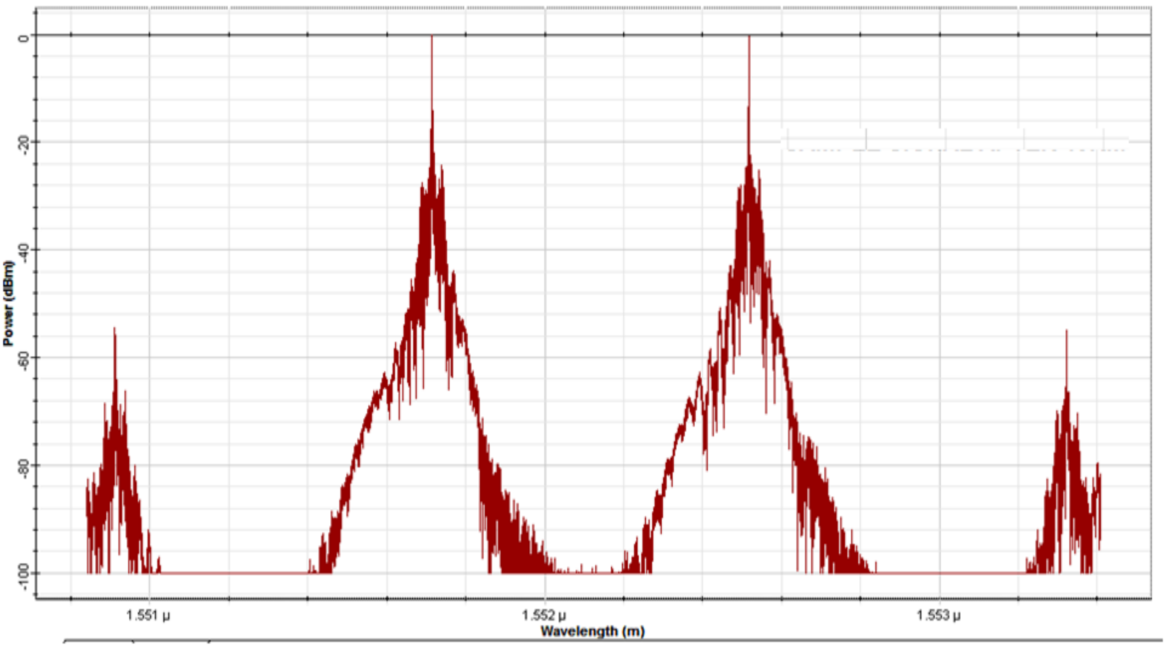

Figure 6: Result of the amplified signal

The result in Figure 6 presents the amplified signal transmitted from hospital A. The aim was to improve the signal strength and also to compensate for loses which is inevitable due to the long transmission distance. The result showed that the amplifier increased the transmission cycle from two to four within the same wavelength which is evidence of speed due to improved signal strength by the amplifier. However, harmonics was also introduced to the signal by the amplifier, coupled with the other noise associated with the transmission signal. Hence, to combat this challenge, filter was used to mitigate ripples from the main signal and improve quality of service at the receiver end. The performance of the filter is presented in Figure 7.

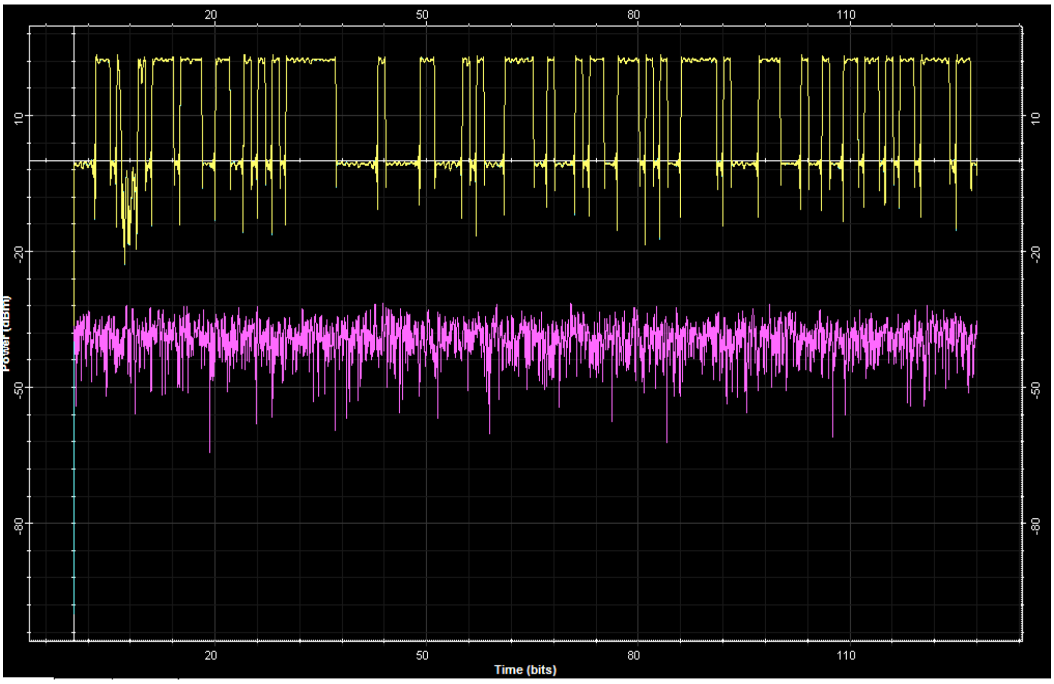

Figure 7: Receiver signal at hospital E

From the result in Figure 7, it was observed that the receiver signal was accompanied with noise as some degrees of noise is expected to be induced in the signal after amplification. The noise signal is presented in Figure 8.

The figure 8 presented the noise signal removed from the EHR during transmission. The implication was to isolate the noise gain so as to guarantee stable signal strength received at the end as shown in data received at the Delta state teaching hospital in Figure 9.

From the result in Figure 9, it was observed that quality signal was received at hospital E with an improved gain of -20 dBm from the original -100dbm due to noise. The implication of this result shows that the patient data requested at the Delta state hospital from the UNTH hospital Enugu was delivered at the speed of light and at good service quality of -19 dBm.

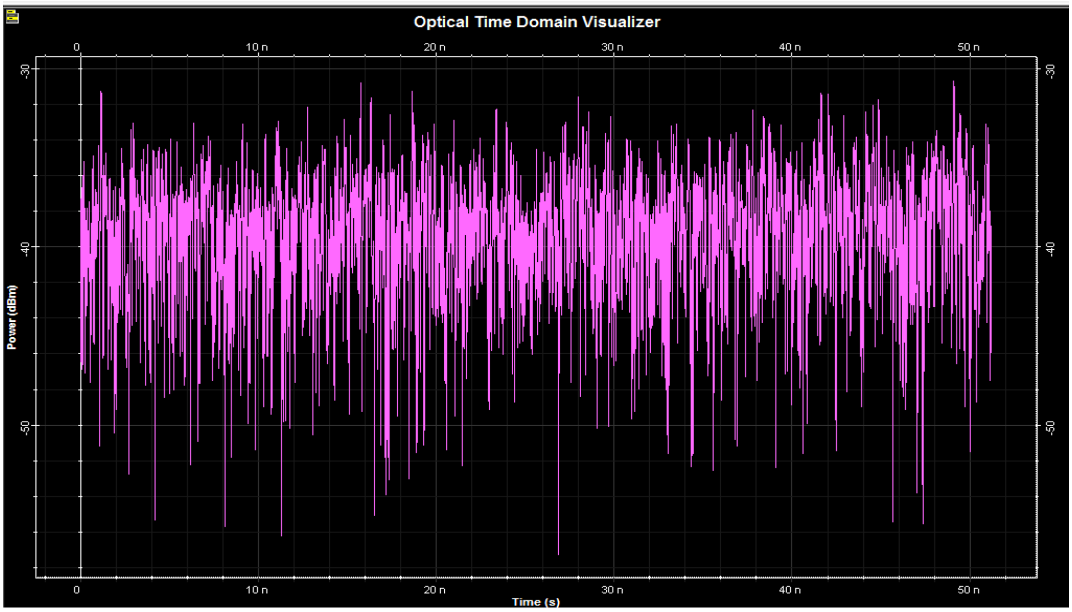

Figure 8: Result of the noise signal

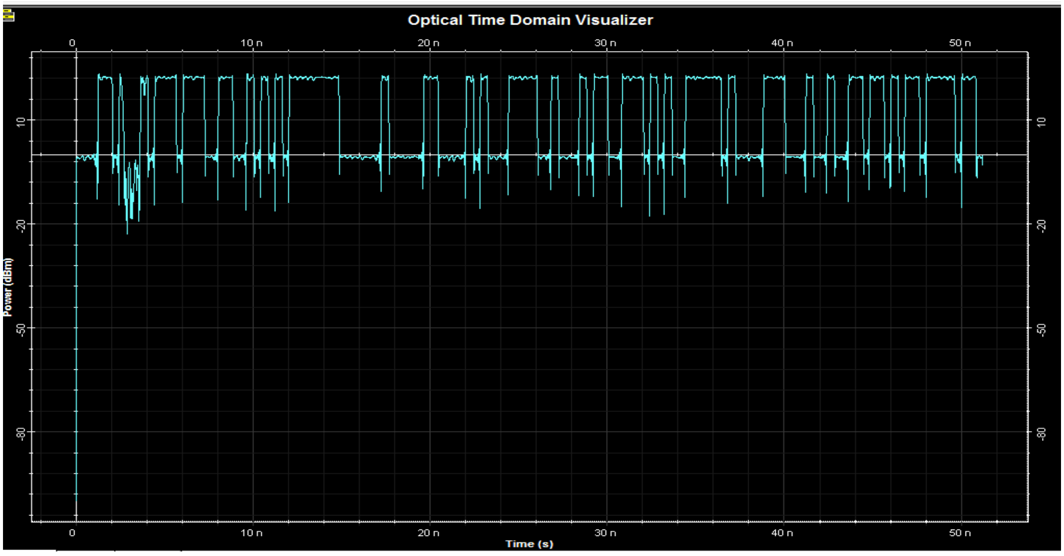

Figure 9: Received health record at hospital E

Conclusion

This paper has successfully presented an optical communication architecture which connected five different hospitals spread between Enugu, Anambra and Delta state within a cumulative distance of 209Km. The performance of the network was tested at the Delta state teaching hospital where a transferred patient recorded file from the UNTH was requested and the data was delivered in the speed of light due to the optic fiber used. Also, the signal was of good quality despite the distance and limitation factors like noise as a result of the effectiveness of the filters and power amplifiers.

Acknowledgement
I would like to thank the IT Consultant of Destinate Research Groups Enugu for his contribution, assistance and efforts in the practical part of this project and sourcing of relevant materials from two foreign companies in the United States of America (USA) - Optiwave Technologies (Pvt) Limited and Ciena Corporations.

References

[1] World health organization global health expenditure database; Current health expenditure (% of GDP); World Bank group (2019). All rights reserved.

[2] Kalra, D. (2006). Confidentiality and consent in medical research; *Journal: BMJ (Clinical research)* 333(7560): 196-198.

[3] Kierkegaard, P. (2014). "Cross-Border and Interoperable Electronic Health Record Systems", *Journal of Medical Systems* 37(6): 9991.

[4] Freeman, T. (1995). Maxwell's equations with optical fibers in mind; *Proceedings of the SPIE,* 2525, 473-482.

[5] Raza, G., Geffrin J. M., García-Cámara B., Albella P., Froufe-Pérez, L. S., Eyraud, C., ... and Moreno F. (2006). Magnetic and electric coherence in forward- and back-scattered electromagnetic waves by a single dielectric subwavelength sphere; *Nature Communications*, 3 (1171).

[6] Chuan, H. (2015). The analysis of Optical Fiber Transmission Maintenance and Management in Communication Engineering; *4th International Conference on Mechatronics, Material, Chemistry and Computer Engineering* (ICMMCCE), pp. 123 – 126.

[7] Yousif, J., and Senior, J. M. (2009). Optical fiber communication; *Principles and Practice;* Prentice Hall Europe; Pearson Education Limited, p.127.

[8] Lee, W., Park, M. Y., Cho, S. H., Lee, J., Kim, C., Jeong, G., and Kim, B. W. (2014). Bidirectional WDM-PON based on gain-saturated reflective semiconductor optical amplifiers, *IEEE Photonics Technol. Lett.*17(11), 2460–2462.

[9] Sang-Mook, L., Sil-Gu, M., Min-Hwan, K., and Chang-Hee, L. (2012). Demonstration of a long-reach DWDM-PON for consolidation of metro and

access networks, J. Lightwave Technol., 25(1), 271–276.

[10] Stopczynski, Arkadiusz, Sekara, *Vedran*, and Sapiezynski (2014). Missing data in multiplex *networks*: A model for the multiplex dynamics of two-*mode* and one-*mode networks;* A preliminary study. Pp. 401–407 in Third International.

[11] Xiaodong, W., Weisheng, H., and Yunfeng P. (2007). Lightpath-based flooding for GMPLS controlled all-optical networks, IEEE Commun. Lett., 11(1), 91–93.

[12] Feng, M., Shiwen, M., and Tao, J. (2016). Enhancing the performance of future wireless networks with software-defined networking; *Frontiers of Information Technology and Electronic Engineering*, 17(7), 606 – 619.

[13] J*oel,* S., Paul, B., and Mukta, G. (2007). Towards secure and dependable software defined networks; *Software-defined networking*, INFOCOM keynote talk, SIGCOMM Computer Communication Review, 37(3).

[14] Bridget, A. S. (2009). Electronic medical record implementation; *National Electronic Health Record Surveys* (researchgate).