Performance Enhancement of Star-Ring LAN for University Campus Using Optical Fiber

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Abstract – The use of LANs such as campus networks has become the features of the world that we live-in. In this paper, a detailed studying is presented for designing and analyzing computer networks for University of Technology campus into 19 buildings.

A Star-Ring topology was proposed and implemented using an Optiysystem software simulation. This software was used because it can simulate the design system with a much more realistic modeling to reduce cost and time of practical work and achieve high accuracy of the designed system before implementation. All the data used to build this optical LAN are in accordance with real existing data.

The results appear with the range, the qualification depends on the result of design simulation for good quality result and which are targeted to all design.

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Keywords – Star-Ring LAN, LAN & fiber optic, LAN for campus.

1. Introduction to Optic Communications System Components

The purpose of the physical layer is to transport a raw bit stream from one machine to another. Various physical media can be used for the actual transmission. Each one has its own niche in terms of bandwidth, delay, cost, and ease of installation and maintenance. Media are roughly grouped into guided media, such as copper wire and fiber optics, and unguided media such as radio and lasers through the air [1].

The choice of topology depends on a variety of factors, including reliability, expandability, and performance. This choice is part of the overall task of designing a LAN and thus cannot be made in isolation, independent of the choice of transmission medium, wiring layout, and access control technique.

An optical communication system has three basic components, as shown in Figure (1).

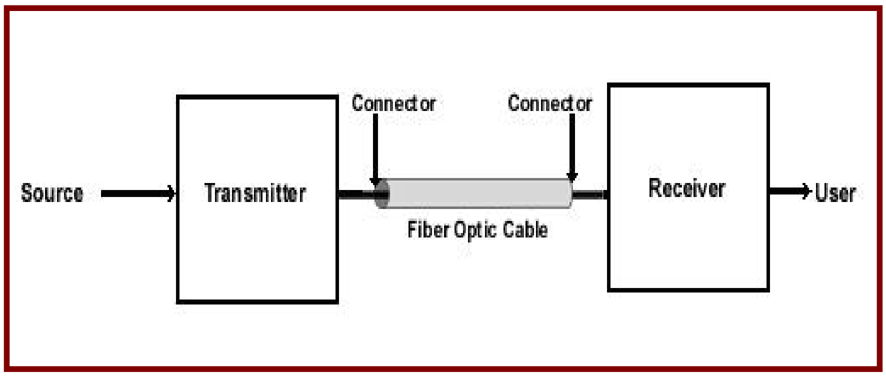


Figure 1. Optical communication system

The illustration indicates the Source-User pair, Transmitter and Receiver. It also clearly shows the fiber optic cable constituting the Transmission Medium as well as the connectors that provide the interface of the Transmitter to the Transmission Medium and the Transmission Medium to the Receiver [2].

The basic Wave Length Division Multiplexing (WDM) system depends on number of channels and spacing, see Figure 2. A brief description of each type is as follows [3]:

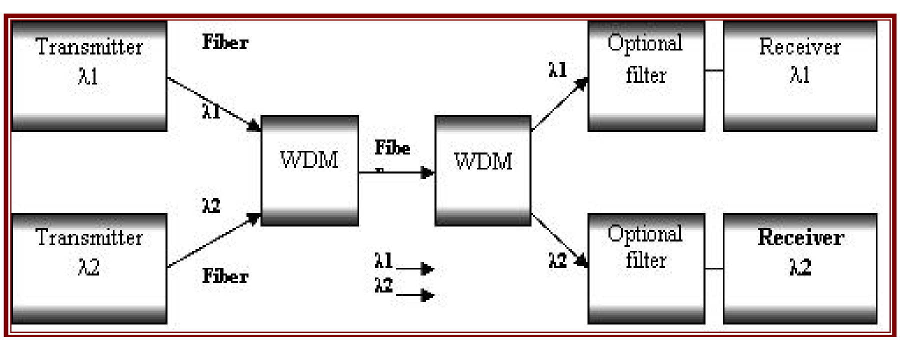


Figure 2 Basic WDM System

- Dense Wavelength Division Multiplexing (DWDM) is an implementation of WDM technology that is used for metro and long haul networks. Small wavelength ranges (1530nm to 1565nm) are used and the spacing between wavelengths is typically around 0.8nm. This is often referred to as 100GHz spacing.
- Coarse Wavelength Division Multiplexing (CWDM) is an implementation of WDM technology that is used mainly for short haul and metro networks. Wide wavelength ranges (1200nm to 1600nm) are used and the spacing between wavelengths allows for the use of less accurate un-cooled lasers, which are less expensive than those used with DWDM components [3].

The key to the definition of a LAN is that all of the computers on the network are grouped together in some fashion and connected somehow, and in some sort of cable, see Figure (3).

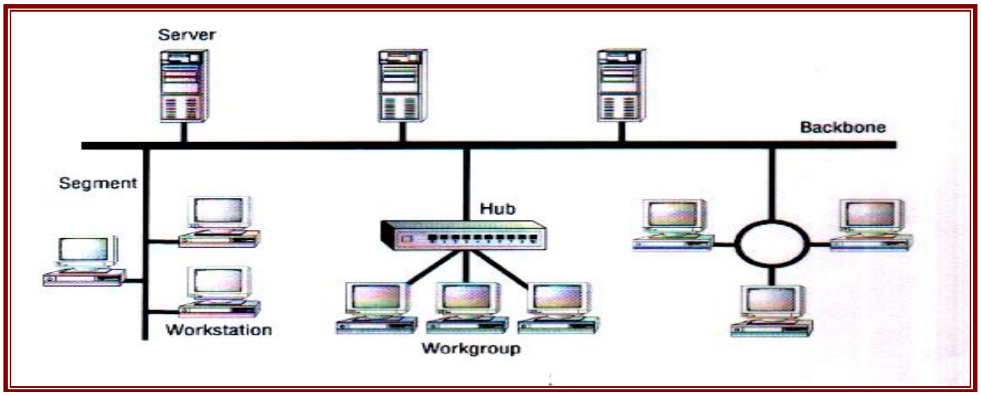


Figure (3) A small LAN

2. Optical LAN Design Tool

OptiSystem 4.0 Design Software, a license product of Optiwave corroboration, a Canadian base company used for to design the optical LAN. This alleviative approach uses computer-aided design (CAD) techniques are very helpful to design the LAN and can provide the different tools verify and calculate values of various system parameters, such that the design objectives are met at minimum. Therefore, to reduce cost, time of practical work firstly, and for high accuracy secondly, also for testing physical effects, all these can be examined by using CAD package. In addition the requirements are given for the hardware and the software, the spread ATM technology in LANs is limited by high cost [4].

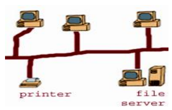
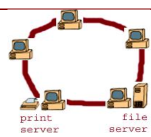
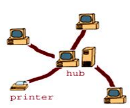
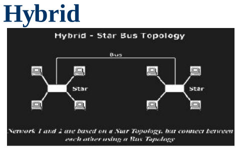
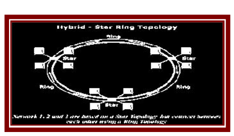
The Range of applications for LANs is wide. There are many environments where LANs are suitable such as: offices, companies, universities, factories and bank applications.

The physical topologies to be chosen for a network are influenced by several factors:

First, there is the simple matter of looking at how your office is arranged i.e. the layout Those people setting up only a few computers in a single room will have more options than those with many computers distributed throughout several floors of a building. ***Second,***

troubleshooting techniques and requirements are determined to some degree by the physical topology you use. For example, some topologies have built-in physical redundancy to prevent breaks in the cable from interrupting communications. Other topologies isolate each cable in the network so that a single break will not bring everything down. ***Third,*** not all physical topologies are equal in terms of installation cost. Some of this cost is going to depend on your office layout, to be sure; it's more work to wire a network that extends over a larger area, and cost will reflect that extra effort. However, some of the cost will be affected by the complexity of the topology you choose. ***Finally,*** to a significant degree, the physical topology you choose for your network determines what kind of cable will be got for it and vice versa[5]. Table 1 summarizes these points.

Table (1) Advantages and disadvantages of topologies

Topology	***Advantages and Disadvantages***
BUS 	• is simple to install • is relatively inexpensive • uses less cable than other topologies • is difficult to move and change • has little fault tolerance (a single fault can down the entire network) • is difficult to troubleshoot
RING 	• is relatively easy to troubleshoot • expensive, because multiple cables are needed for each workstation • difficult to reconfigure • not fault tolerant. A single cable fault can bring down the entire network
STAR 	• new stations can be added easily and quickly • a single cable failure won't bring down the entire network • it is relatively easy to troubleshoot • total installation cost can be higher because of the larger number of cables, but prices are constantly becoming more and more competitive • it has a single point of failure (the hub, or other central device)
Hybrid  	• one company can combine the benefits of several different types of topologies. • workgroup efficiency and traffic can be customized. • devices on one topology cannot be placed into another topology without some hardware changes.

Optisystem 4.0 software simulator is adopted for being flexible and robust to integrate layouts, components with all their features and with minimum errors.

This software is built on Visual C++, which offers advanced object oriented programming language (OOP). The objects (Optical Components) send messages to each other and to their classes to perform their jobs and the goal of the projects. Optisystem 4.0 offers high flexibility for the user to create a new component based on MATLAB component.

The design of –a fiber-optic Communication system in software involves using a large number of Active and Passive components such as transmitters, optical fibres, receivers, Global parameters, subsystems that help in creating the required components based on the component library without programming and BitRate that used to predict the systems performance.

3. The Idea of the Project and Case Study

A Star-Ring topology was proposed and implemented using an Optisystem software simulation. This software was used because it can simulate the design system with a much more realistic modelling to reduce cost and time of practical work and achieve high accuracy of the simulate system before implementation. All the data used to build this optical LAN are in the accordance with real existing data. As a case study, an optical fibre based LAN is designed to connect different parts of the building of UOT presidency. The building consists of three floors in addition to the Shelter. The middle floor was selected to be the central place. To give the project realistic and functional (Practical) characteristics, the actual University Map, see Figure 4, and designs of the building of the University Presidency, see Figure 5, were used, and the scaled distances were calculated. The length of the fibre depends on these distances.

Before describing the design, two points have been taken into account:

- Each node is connected to distributive hub/switch, which has been considered. This is responsible for selecting the path for sending and receiving data in the floor.
- Because of similarity of the floors in the building, Star Topology is proposed for each floor.

When optical fibers are used to implement LANs, the relatively short distance between network interfaces involved in LANs permits the use of fibers with modest bandwidth distance product values.

3.1 Designing Star-Star Topology

In this design, each floor is designed to use one hub/switch. The power of the hub/switch depends on the number of users of that floor. Figure (6) illustrates the typical design of that building. The first step of the design is the choice of the interconnections between users and the hub/switches. The main hub/switch is connecting the three hub/switches at each floor via optical fiber backbone.

In order to connect the three floors together, the same simulated system can be used, but with three hub/switches, one in each floor. The length of Linear Multimode Fiber equals four meters since the length of optical fiber is fixed, which represents the height between two adjacent. The final layout is shown in Figure (7).

One advantage of this design is the scalability. Hence, new department or floor can be easily added without changing the design. Users are connected together via a local hub/switch at that floor. Every sub-system includes 11 channels in each floor with main hub/switch as shown in Figure (8).

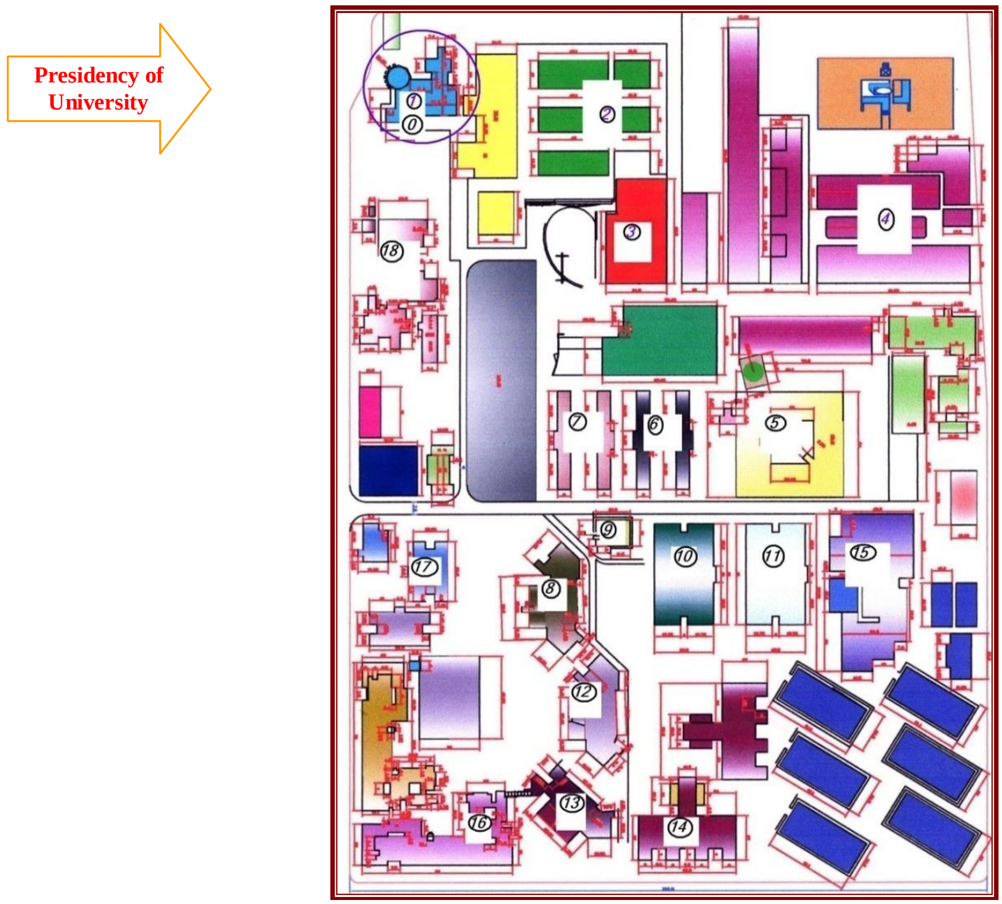


Figure (4) shows general UOT Maps highlighting Presidency of Technology site

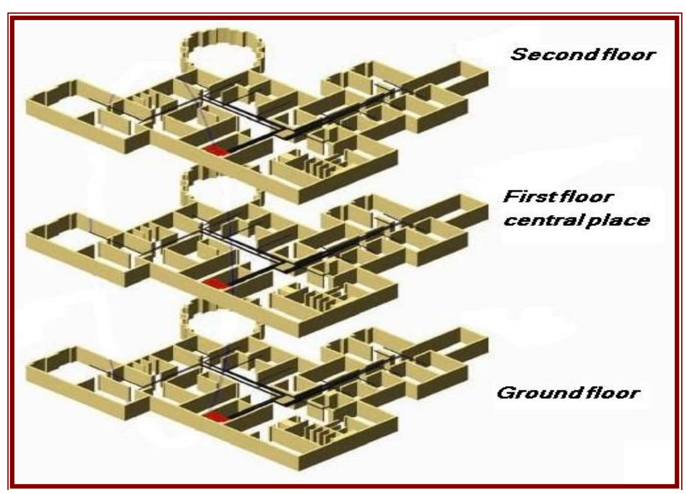


Figure (5) Floors within the building of UOT Presidency

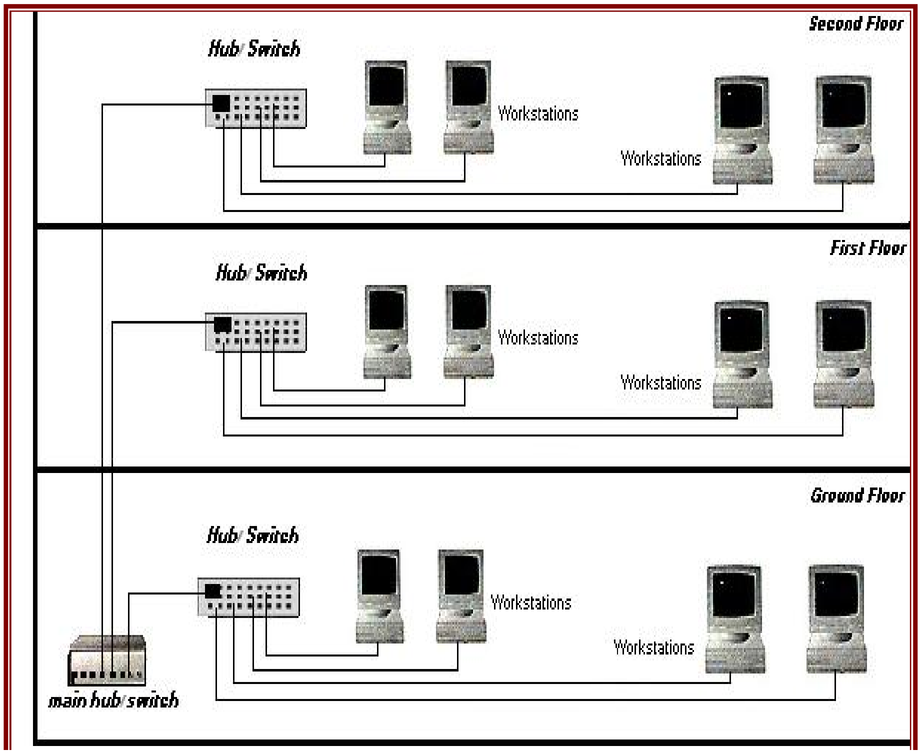


Figure (6) Typical network layout for a building with three floors

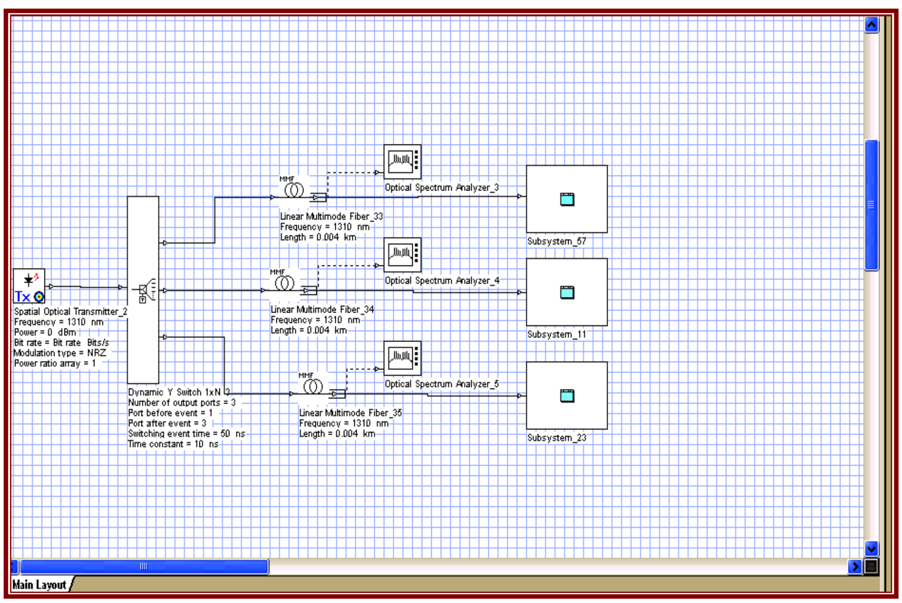


Figure (7) The whole building final layout

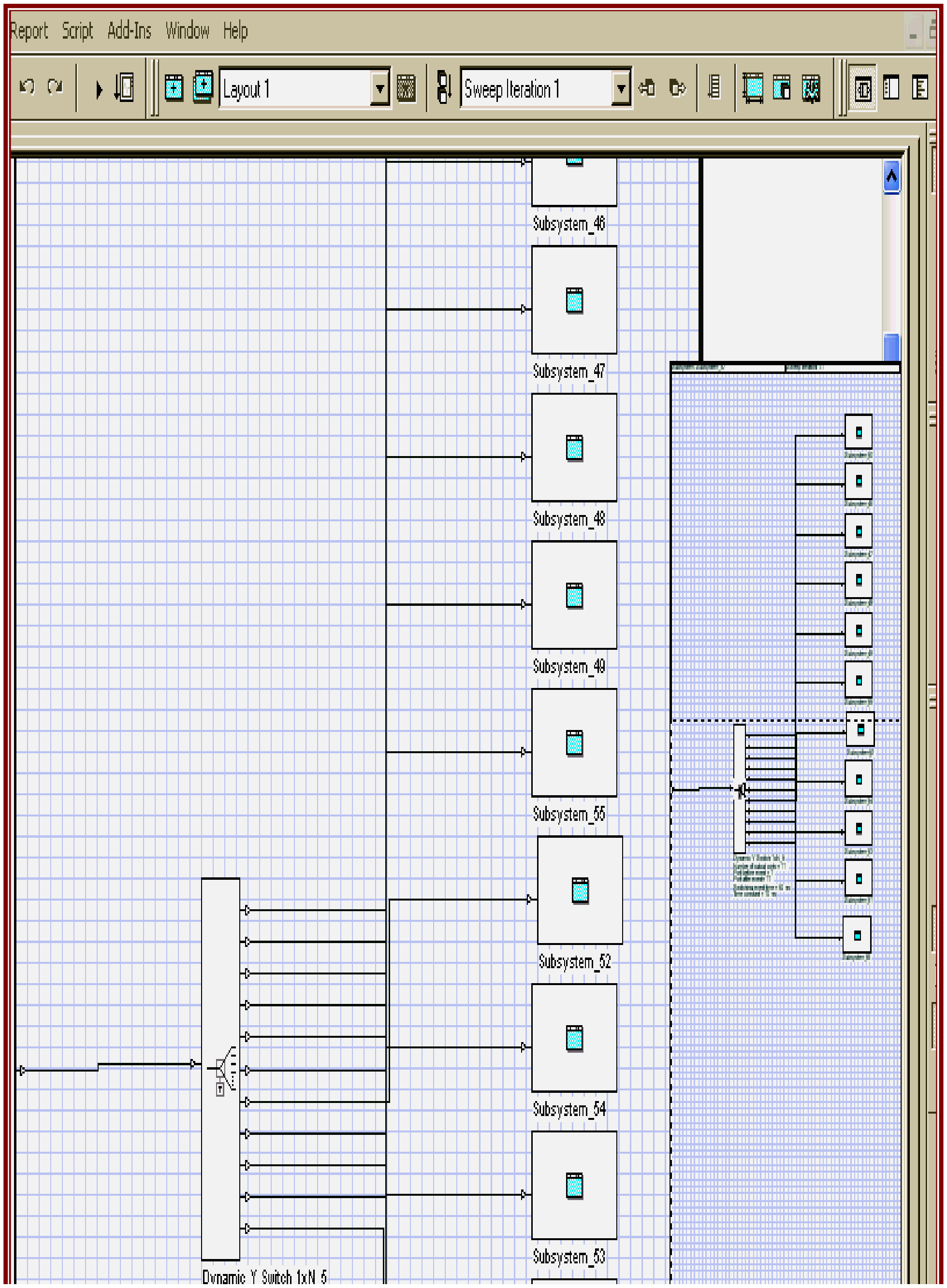


Figure (8) A block diagram using sub-system for 11channel

3.2 Design *of a floor network*

The enterprise server is used in the LAN, which includes e-mail server, web server, multimedia server, central database server, and so forth. These are included to be available to almost everyone on the network accesses.

The server is located within the Internet room at the floor. The star topology that is selected here represents the topology with minimum requirements to represent the department's rooms of the Presidency of University of Technology, which are connected as shown in Figure (9). In this design, every department can communicate with others through the central node (Hub switch). The Figure shows the Star topology with its distances, where each department room is represented as a node.

The connection design between Hub/Switch and any Room in the floor requires knowledge of the number of Rooms and the distances between Hub/Switch and these Rooms.

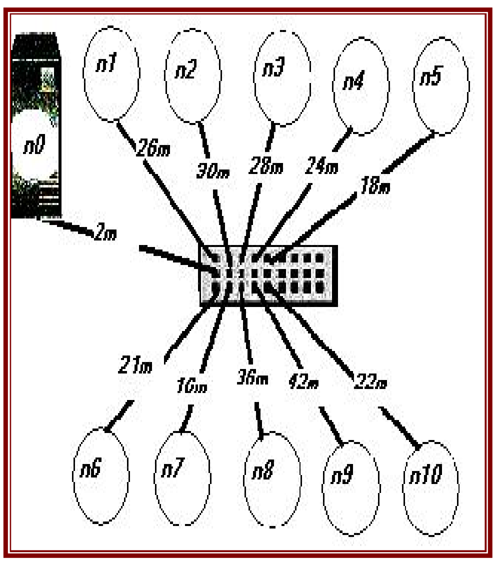


Figure (9) The star topology with distances

3.3 Optical System Design of the First Floor

In order to implement the suggested design the following requirements are taken into consideration:-

The Global parameters of design layout are shown in Figure (10) and are as follows:

- Bit rate: 40 Gbits/s.
- Sequence length: 128.
- Time window: 3.2E-009 s.
- A light-wave system (transmitter – channel - receiver) with switch required to be designed using the Opti-system software.
- A transmitter of 11 channels has been built using spatial optical transmitter and switch component.
- Linear Multimode Fiber from components library is inserted, then its properties are updated as given in the test result of final report from CORNING Incorporated [6]. Figure (11) shows linear multimode fiber properties.
- A Spatial Optical Receiver for each channel consists of, PIN photo detector, electrical low pass Bessel filter, a 3R regenerator, and BER visualizer. Figure (12) shows spatial optical receiver properties.

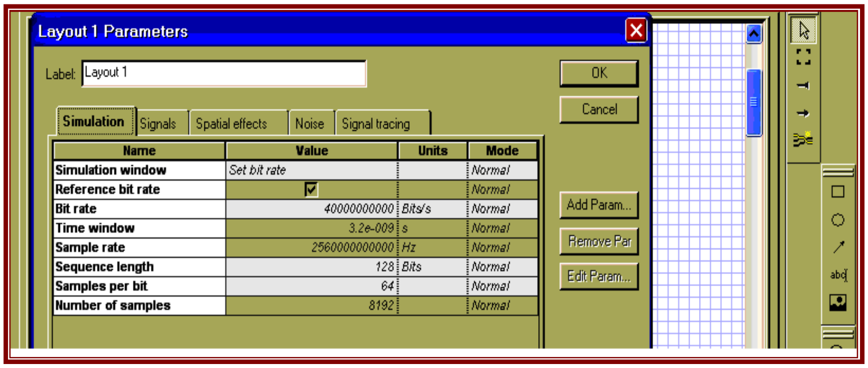


Figure (10) The global parameters of the layout

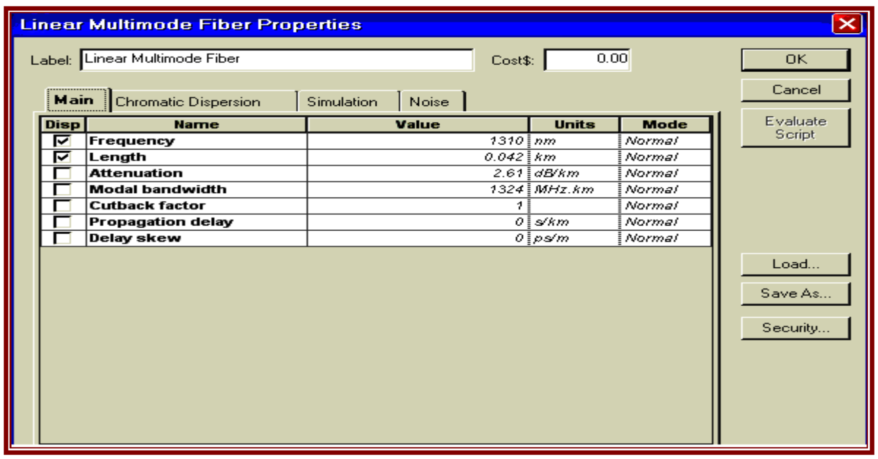


Figure (11) Linear multimode fiber properties

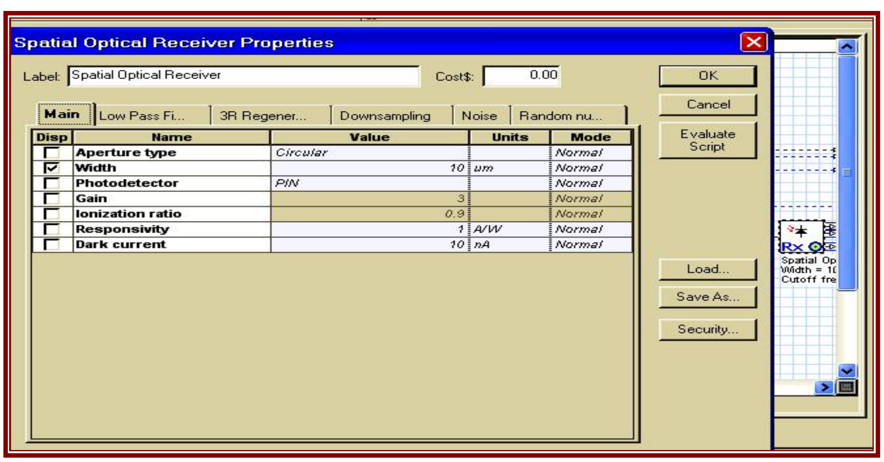


Figure (12) Spatial optical receiver properties

Sub-System facilities from Optisystem 4.0 were used to integrate transmitter and receiver layouts in the whole project. The final layout is shown in Figure (13).

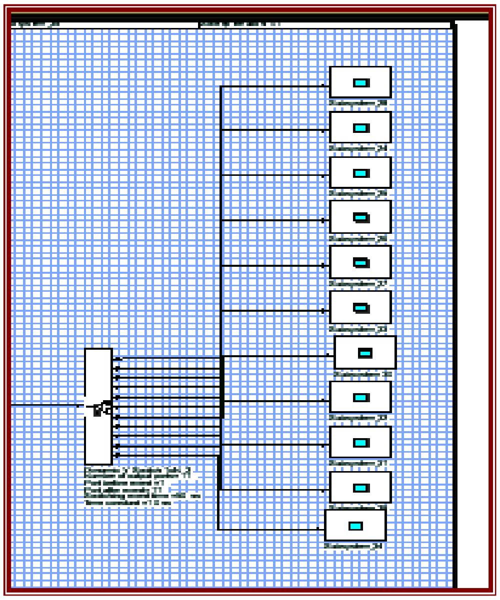


Figure (13) Subsystems final layout

When one looks inside the Sub-system and has eye diagram analyzer, the good open eye diagram with very good quality factor (Q_{max}) and (BER_{min}) is shown in Figure (14).

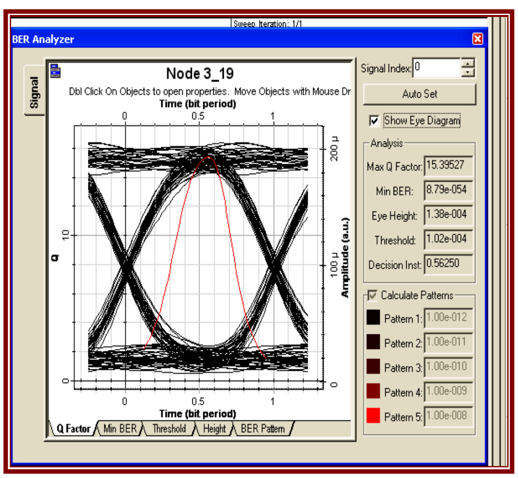


Figure (14) BER analyzer shows good Q_{max},, BER_{min} when the distance equals 26m

When all sub-systems of Figure (13) are calculated, the results of calculation of the system are shown in Table (2). It is clear from this table that the maximum value of Q factor is (16.05446) at 2m distance, while minimum value of Q factor is (13.47571) at 42m distance.

When Q_{max} and BER_{min} values are arranged according to their distance's it is shown that maximum Q factor is (*16.05446*), and minimum BER is (*2.65E-58*) for distance 2 m as shown in that Table.

The plot shown in Figure (15) shows the effect of distances on the values of Q_{max} and BER_{min}. The results indicate that best Q factor and Min BER values are achieved with minimum distance 2m. Results from Table (2) have been achieved using the Min-Max functions within Microsoft Office Excel 2003 tool.

Table (2) The Q_{max} and BER_{min} distances arranging in ascending order

Distance	*(c) Max Q Factor*	*Min BER*
2 m	*16.05446*	*2.65E-58*
16 m	*15.80967*	*1.33E-56*
24 m	*15.51169*	*1.44E-54*
21 m	*15.6434*	*1.84E-55*
36 m	*14.44138*	*1.42E-47*
42 m	*13.47571*	*1.08E-41*
22 m	*15.60451*	*3.39E-55*
26 m	*15.39527*	*8.79E-54*
18 m	*15.7501*	*3.42E-56*

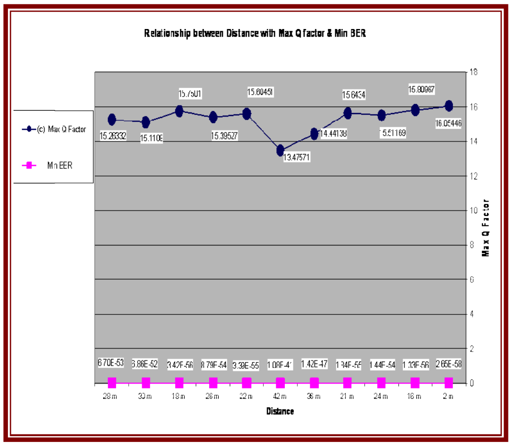


Figure (15) The relationship between Distance, Q_{max}, and BER_{min}

4. Designing of Topology for the University Campus

The Ring topology is proposed to connect (19) buildings of the campus, see Figure (16). The design consists of a number of building blocks (n0-n18). These blocks represent the 18 departments of the UOT, which are to be connected via the optical fiber. Table 3 shows the name of blocks and their distances and each building represents a node as shown in Table 3.

Table (3) The distances of building blocks

The distance between blocks adjacent	
n0- n1= 32 m	*n9-n10= 164m*
n1-n2= 128 m	*n10-n11= 148m*
n2-n3= 272 m	*n11-n12= 496m*
n3-n4= 288 m	*n12-n13= 160m*
n4-n5= 372 m	*n13-n14= 208m*
n5-n6= 192 m	*n14-n15=556m*
n6-n7= 100 m	*n15-n16=628 m*
n7-n8= 240 m	*n16-n17=56 m*
n8-n9= 136 m	*n17-n18= 610 m*
	n18-n1=52

4.1 Experimental Set Up For A Ring Topology

Figure (16) shows the software simulation of the suggested Ring topology to connect the 19 buildings within the UOT.

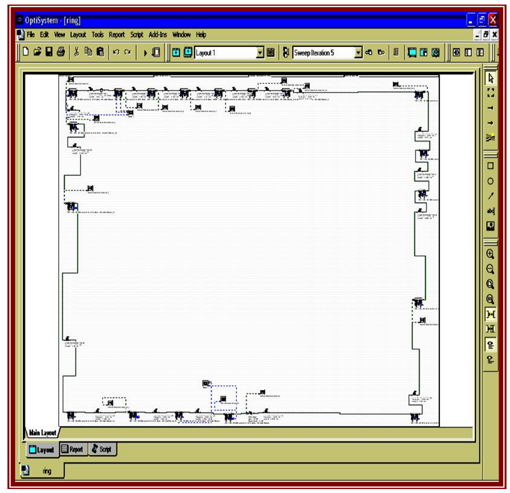


Figure (16) The single ring topology

The main idea of the Ring topology is to show the add-drop function, where different wavelengths ranging from (193.1 – 194.8) have been added in sequence to each node as shown in Figures 16 and 17.

One disadvantage of this design is its difficulty to reconfigure, and single cable fault can bring down the entire network.

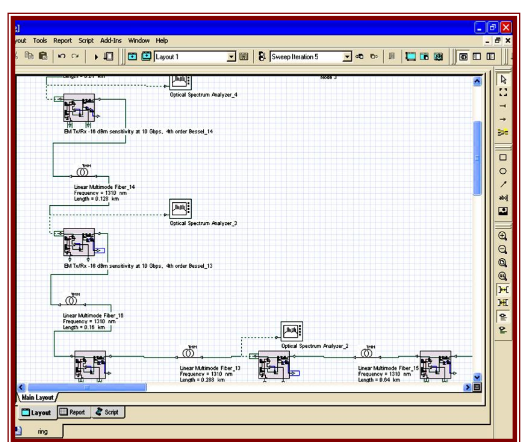


Figure (17) The detailed selection of Figure (16)

4.2 ADD/DROP Multiplexing

To design WDM Add/drop, an Optical Add-Drop Multiplexing (OADM) was used. An Add/Drop Multiplexer component takes a single wavelength from a trunk, pulls the signal out, and allows a new signal at the same wavelength to be inserted into the trunk at (Roughly) the same spot. All the other wavelengths passing through the add/drop multiplexer with only a small loss of power (usually a few db). Optical Add/Drop Multiplexers (OADMs) introduce insertion loss that contains two parts: deterministic and random. In fact, loss varies with the wavelength. This concept is especially important when planning WDM networks, and plays an important role in the overall distance a WDM networks can span. Metropolitan networks using ring topology are expected to have more dynamic traffic patterns compared to most long-haul networks. Figures (18) and (19) show the add/drop properties and how the signal of 194.6 frequency is added.

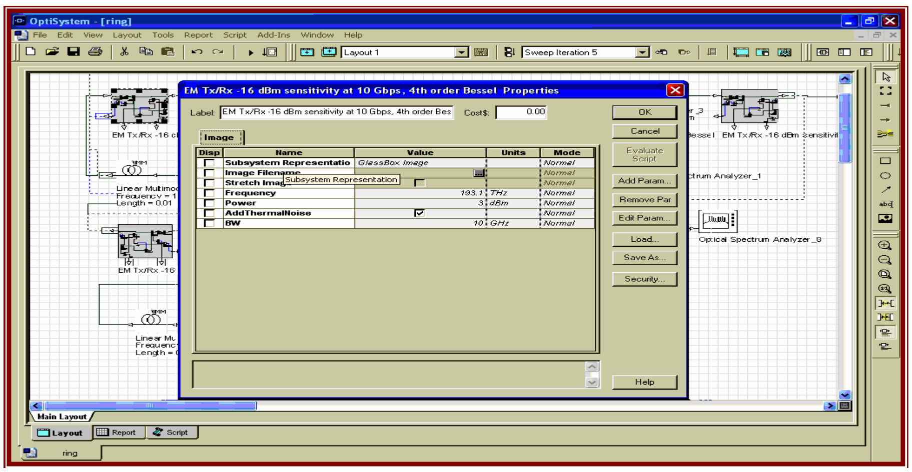


Figure (18) The add-drop properties

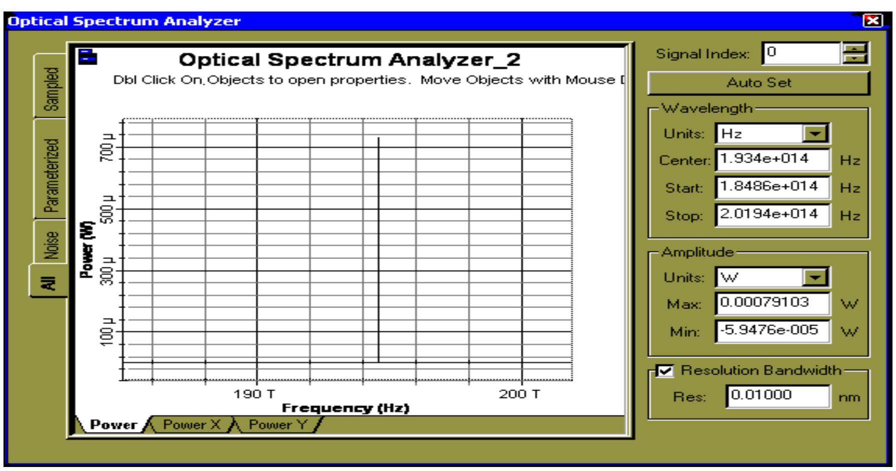


Figure (19) The added signal of 194.6 frequency

5. Conclusions

In this paper, a detailed study of design and analysis of fiber optic link as a communication media is carried out. The Presidency of the University of Technology building was chosen as a case study. This study can be considered as a basis for campus any future LAN, since it provides many features. One of these features is the local connection that can handle many different network technologies. The following points are concluded:

1- The Presidency of University of Technology LAN was designed using star-star topology that supports scalability. Hence, it supports adding new floors without the need to change the structure of the design. But it is important to take into account the high quality switch in the central of the network to achieve high reliable system.

2- The proposed design supports the ability to connect the campus with other network types of whatever technology of these networks are. Hence, it was emigration towards Optical fiber system.

3- Dual Ring topology connects all the campus buildings, is the optimum solution.

References:

1. William Stallings, " Data and Computer Communications", 7th Edition by Person Edition, Inc., 2004

2. David R. Goff, President And CTO Force, Incorporate Fiber Optic Reference Guide, Third Edition, 2002.

3. NORTEL NETWORKS, Connectivity For Tomorrow's Applications, http://www.Nortel Networks.Com, 2004.

4. Ibtsam R. Karkhiy, Design and Analysis of a Simulated LAN Campus ATM, Ph. D. Thesis, University of Technology, Baghdad 2002.

5. GOVIND P. AGRAWAL, Fiber Optic Communication Systems, 3rd Edition, Copyright By John Wiley & Sons. Inc., New York, 2002.

6. Christa Anderson And Mark Minasi, Mastering Local Area Networks, Sybex Inc., 1151 Marina Village Parkway, Almeda, CA9450, Copyright @1999.