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SIMULATION AND PERFORMANCE EVALUATION OF PASSIVE OPTICAL NETWORK SYSTEM

Saurabh Dubey*, Ashish Mishra
*National Internet exchange of India
Rajarshi Rananjay Sinh Institute of Management & Technology, Amethi, India

ABSTRACT

PON provides virtually unlimited bandwidth to the users. It do not use electrically powered components to split the signal. Instead the signal is distributed using beam splitters. Each splitter typically splits a fiber into 16, 32, or 64 fibers, 55 km. BPON uses ATM as the protocol. The Broadband passive optical network (BPON) was the first attempt towards a PON standard. It is controlled by the ITU-T and is designated as ITU-T G.983. This paper provides an overview of PON and analyses network architecture, and evaluate the system performance in terms of BER and Q Factor of the PON system. The performance of PON System is evaluated using Opti system version 12.0.

KEYWORDS: ATM, ONU, OLT, TDM.

INTRODUCTION

Fiber optics uses light signals to transmit data. As this data moves across a fiber, there needs to be a way to separate it so that it gets to the proper destination. There are two important types of systems that make fiber-to-the-home broadband connections possible. These are active optical networks and passive optical networks. Each offers ways to separate data and route it to the proper place, and each has advantages and disadvantages as compared to the others there are two type of optical networks.
   a) AON (Active Optical Network)
   b) PON (Passive Optical Network)

PON ARCHITECTURE

Optical Line Terminal (OLT)

The Optical Line Terminal is the most important element of the network and is basically situated in the Local Exchange [1]. It provides an interface between core network and PON network. A PON consists of a central office node, called an optical line terminal (OLT), one or more user nodes called optical network units (ONUs) or optical network terminals (ONTs) and the fibers and splitters between them is called optical distribution network (ODN). The OLT provides the interface between the PON and the backbone network. These are typically include: Standard time division multiplexed (TDM) interface .OLT's include the following features.

Passive Optical Splitter (POS)

Passive Optical Splitter is a passive device with single input and multiple outputs. It can transmit packets using time division multiplexing (TDM) in the downlink and gather packets using the time division multiplexing access (TDMA) protocol in the uplink. Optical signal travels from input to the outputs, optical signal can also travel from the output to the input [4]. Splitters can be placed anywhere in between CO and user premises. It is used to connect an optical port of OLT with multiple users

Optical Network units (ONUs)

Optical Network units (ONUs) provides an interface to the networks for accessing triple play services and on the upper side, it connects the OLT via optical splitter. ONT terminates the PON and presents the native service interfaces to the user. These services includes voice, data, and video. The ONT functions are separated into two parts: The ONU, which terminates the PON and presents a converged interface – such as multi-service Ethernet

– toward the user, and Network Termination Equipment (NTE), which provides the separate native service interfaces directly to the user. A PON is a converged network in that all of these services are typically converted and encapsulated in a single packet type for transmission over the PON fiber.

PON CONFIGURATION
Passive optical networks can exist in three basic configurations (tree, bus and ring), the tree topology is favoured due to smaller variation in the signal power from different end station. Passive optical networks uses different wavelength for downstream and upstream [2]. It uses 1490 nm wavelength for the downstream wavelength & 1310 nm wavelength for the upstream. Signals are inserted or extracted from the fiber using a coarse wavelength division multiplexer (CWDM) filter at the CO and subscriber premises.
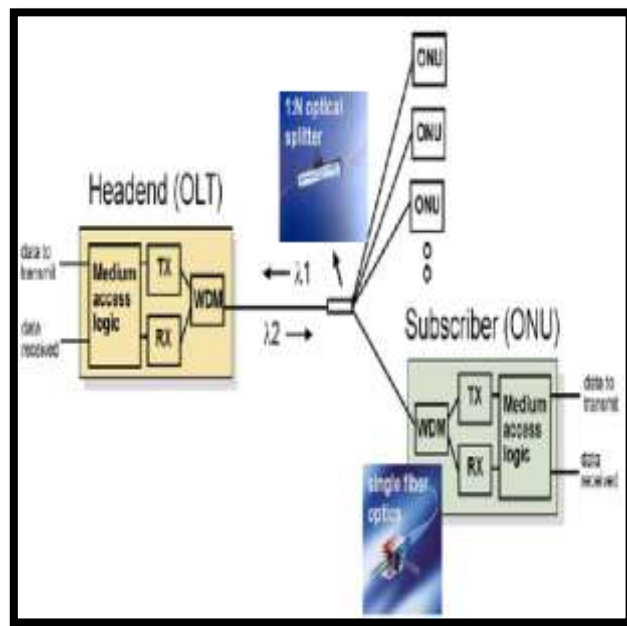

Figure 1 Basic PON Configurations

In the upstream direction, from ONU's to the OLT, different users signal arrives at ONUs and these are arrives at splitter's inputs. Although the signals can't reach different ONUs, as they propagates through the splitter they get mixed with each other and the superposition of all signals is received at the OLT [3].

BPON:
The Broadband passive optical network (BPON) was the first attempt towards a PON standard. It is controlled by the ITU-T and is designated as ITU-T G.983 [5]. It established the general requirements for PON protocols. BPON use Asynchronous Transfer Mode (ATM) as the underlying transport mechanism to carry used data. BPON did not obtain much popularity due to lack of bandwidth and widespread use of Ethernet protocol. BPON is the most popular current Passive Optical Network application in the beginning.

The coverage range of BPON is less than 20 kms. Downstream digital signals from the CO through the splitter to the home are sent at 1490 nm data rate. This signal carries both voice and data to the home. Video on the first PON systems are used the same technology as CATV, an analog modulated signal, broadcast the signal separately using a 1550 nm laser which may require a fiber amplifier to provide enough signal strength to overcome the loss of the optical splitter. Video service of PON could be upgraded to digital form of signal using IPTV, negating the need for the separate wavelength for video [1].

EPON:
This Ethernet-based PON is known as Ethernet PON (EPON) but is sometime also referred to as Gigabit EPON (GEPON). EPON is now a part of the IEEE 802.3 standard [IEEE08]. It offers the aggregate symmetrical line rates of: 1.25 Gbps in the DS, 1.25 Gbps in the US. EPON is based on Ethernet, unlike other passive optical network technologies which are based on ATM [5]. It provides simple, easy-to-manage connectivity to Ethernet-based IP equipment both at the customer premises and at the central office (CO). It is well suited to carry

packetized traffic as well as time-sensitive voice and video traffic. PON is a new physical layer for Ethernet with a shared medium, however, the medium access control will not be CSMA/CD based. Instead a centralized access control will be used, where the optical line terminal will send grants to the ONUs in order to coordinate the transmissions [2]. PONs can be divided into different types of network, but the functionality of EPON will be similar regardless of the higher layers. The common characteristics include the duplexing which is usually handled by wavelength division multiplexing (WDM). Due to different distances between the Optical Line Terminal (ONU) and the different ONUs the power can vary as much as 15 dB between transmissions from the different ONUs. Therefore, the receiver's needs a dynamic range of received power at least 15 dB. The changes distances also need to be taken into account by the multiple access protocol; therefore a procedure is used to estimate the delay between the Optical Line Terminal (ONU) and each ONU [2].

GPON

The most recent PON standard is the ITU-T G.984 Gigabit Passive Optical Network standard, which offers approx. 2.5 Gbps bandwidth and direct support of both TDM(POTs &E1) and Ethernet traffic at the edge of the network with possible three play voice, data and video services on the same PON [5]. GPON can support ONUs that is located as far as 30 Km from the OLT. GPON offer higher split ratio of which results in an OLT reduction by more than a factor of 2 over EPON.

SYSTEM DESIGN

Optical Software is an innovative, rapidly evolving, and powerful software design tool that enables users to plan, test, and simulate almost every type of optical link in the transmission layer of a broad spectrum of optical networks from LAN, WAN, MAN to ultra-long-haul. It offers transmission layer optical communication system design and planning from component to system level, and visually presents analysis and scenarios.
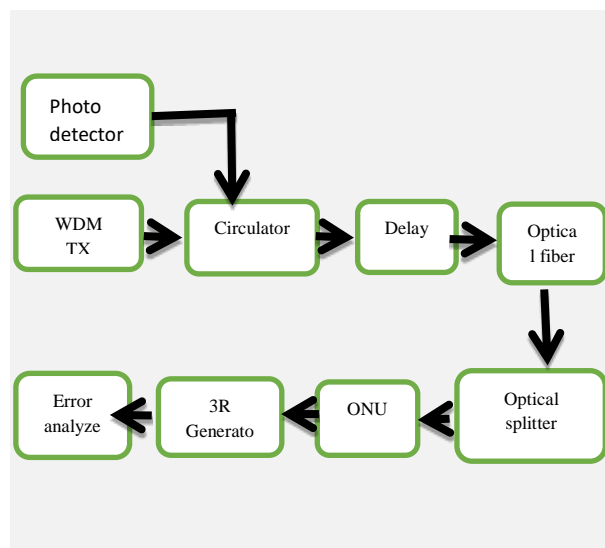
SYSTEM MODEL

Figure 2 Block Diagram of PON

SETUP

In this paper, we design the three Passive Optical Network standard systems. Simulation setup of these systems is discussed as following:
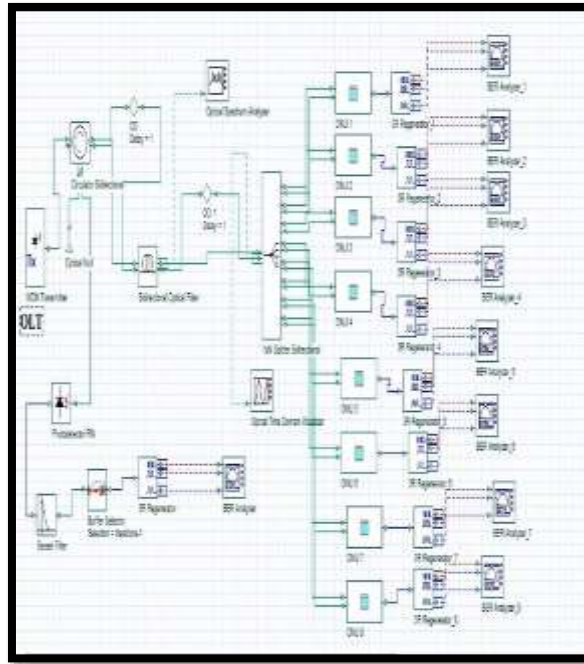
(b.1)Simulation setup of BPON

Figure 3 Simulation setup of BPON

Above figure 3 is the simulation setup of BPON, here WDM transmitter work as the Optical line terminal. Bidirectional circulator is used to circulate the information in both directions. At one side of circulator optical null is connected, on the other side of circulator photo detector is connected i.e. PIN photo diode. Bidirectional optical fiber is used as the communication channel. For evaluation of BPON system we simulate the system at different length of optical fiber. After the optical fiber channel delay component is connected for delay on data. Splitter is used to split the optical light source into N times; 1xN bidirectional splitter is used to split N times.
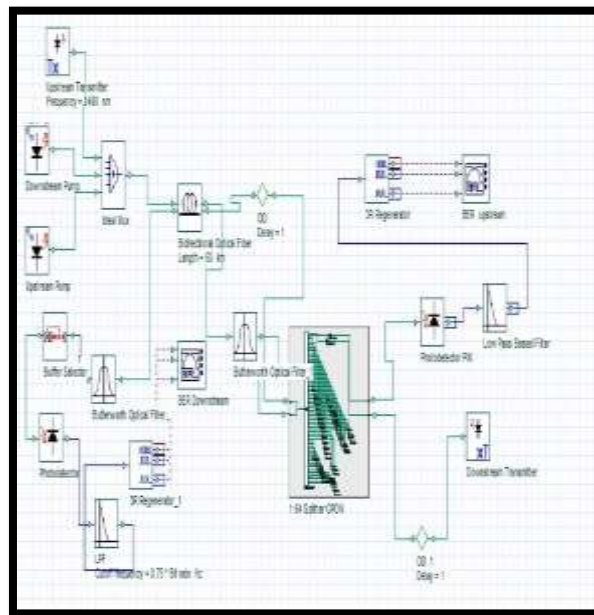
(b.2) Simulation setup of GPON

Figure 4 simulation setup of GPON

Above figure 4 is the simulated setup of GPON, here upstream transmitter at frequency 1490nm, downstream pump, and upstream pump light sources are transmitted and multiplexed by the 3 port ideal multiplexer. After that bidirectional optical fiber is used on the output of bidirectional optical fiber delay and butter worth optical filter is used. After that 1:64 GPON splitter is used to split the signals into 64 signals.

RESULTS
In this paper performance of PON system using bidirectional optical fiber is analyzed and discussed. The performance of an optical system is characterized through the bit error rate (BER). Although the BER can be defined as the number of errors made per second, such a definition makes the BER bit-rate dependent. It is customary to define the BER as the average probability of incorrect bit identification. Therefore, a BER of 10^{-6} corresponds to on average one error per million bits. Most optical systems specify a BER of 10^{-9} as the operating requirement; some even require a BER as small as 10^{-14}. The error-correction codes are sometimes used to improve the raw BER of an optical system. Performance of the system for different bidirectional optical fiber has been observed using BER analyzer and Eye Diagram.

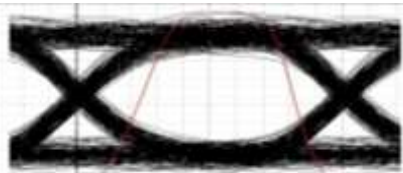**PERFORMANCE COMPARISON FOR DIFFERNT LENTH OF FIBER**
 Performance of the PON system using bidirectional optical   fiber at different length of fiber is analyzed with the help of Eye diagram, Q factor, and Timing Diagram and BER value.

(a.1) EYE DIAGRAM
The Eye diagram shows the superposition of all mutually overlapping bits in the signal. The **Eye opening** indicates the differentiability of the logic 1 from the logic 0. The more the Eye is wide open, the greater the differentiability is, because it's better signal noise to ratio. Other readable parameters are: **jitter** (delay fluctuation), inter-symbol interference (**ISI**) [8].
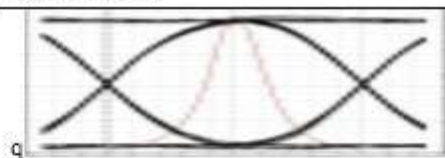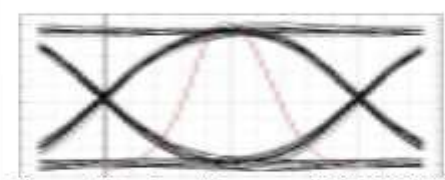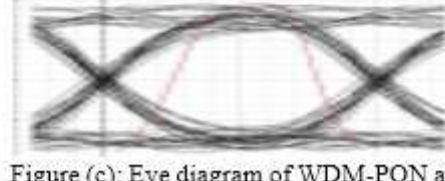
Here, the Eye diagram is analysed for different number of Users, for different data rates and for different length for the FSO channel assuming the attenuation parameters for clear atmosphere. Table 1and 2 shows Eye diagram comparison for different length of FSO channel and for different data rates. When there is only one user, the Eye diagram is clear, that means the bit level 0 and level 1 can be distinguished clearly. But when the number of Users increases the Eye diagram is not clear much that is the system performance is degraded due to interference[10].

Table 1: Eye diagram analysis of BPON system at different fiber length`

Fiber Length (km)	Eye Diagram
5 km	 Figure a: Eye diagram of BPON at 5 km distance
15 km	 Figure b : Eye diagram of BPON at 15 km distance

Here, table 1 shows the comparison of BPON of the Eye Diagrams at 5km, 10km, 15km, 20km, 25km, and 30km length of bidirectional optical fiber channel. It can be observed that the Eye is closing with the increase in length of the optical fiber channel. Eye Diagrams at 5 km are much clear and have more opening than that of 30km fiber length. As the length of the fiber channel increases from 5km to 30km the Eye height

Decreases.

Table 2: Eye diagram analysis of WDM-PON system at different fiber length`

Fibe	Eye Diagram
25 km	 Figure a : Eye diagram of WDM-PON at 25 km distance
40 km	 Figure (b) : Eye diagram of WDM-PON at 40 km distance
55km	 Figure (c): Eye diagram of WDM-PON at 55 km distance

Here, table 2 shows the comparison of BPON of the Eye Diagrams at 25km, 40km and 55km length of bidirectional optical fiber channel. It can be observed that the Eye is closing with the increase in length of the optical fiber channel. Eye Diagrams at 25 km are much clear and have more opening than that of 40km fiber length. As the length of the fiber channel increases from 25km to 55km the Eye height decreases.

(a.2) Q FACTOR
Q factor or quality factor gives us the quality of signal with respect to distance of signal from the noise. It covers all the noises, dispersions and nonlinearities, which deteriorate the signal quality and thereby increase the bit error rate. It follows that the higher Q factor, the higher signal quality. Q factor is defined according to the following formula [8]:
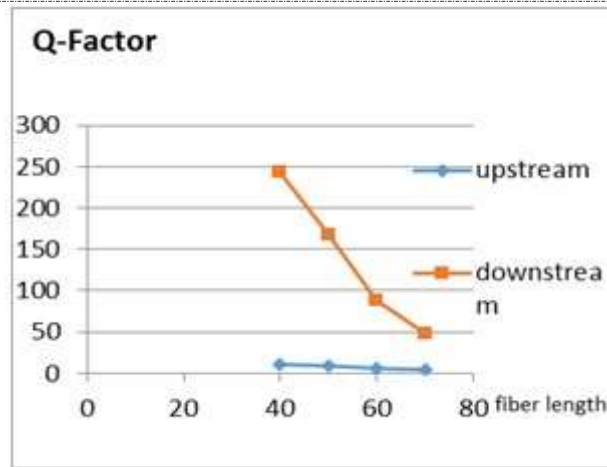
$$Q = \frac{v_1 - v_0}{\sigma_1 - \sigma_0}$$

Figure 5 Comparison of Q factor for 5Gbps and 10Gbps BPON system

where , $v1$ is a logic level "1", $v0$ is a logic level "0", $\sigma1$ is a standard deviation of a logic level "1", $\sigma0$ is a standard deviation of a logic level "0".

Here, performance of Passive Optical Network system at different length of bidirectional optical fiber channel for various data rates is analyzed. Figure 5-7 shows the Q factor values for different fiber length and various data rates.
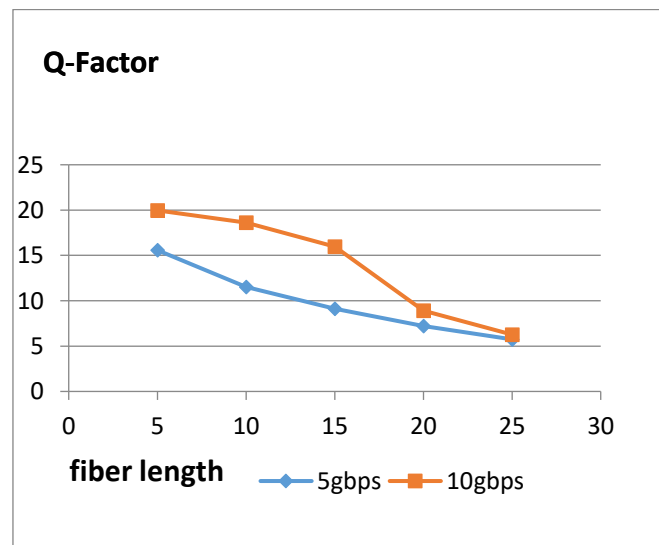

Figure 6: Comparison of Q factor for upstream and downstream GPON system

From figure 5 it is clear that the value of Q factor decreases with the increase in length of bidirectional optical fiber channel length. For 10 Gbps system maximum 20 Q-factor is accommodated with fiber channel length of 5Km. Figure 6 shows the Q factor values for GPON system.

From figure 6 it is clear that the value of Q factor decreases with the increase in length of bidirectional optical fiber channel length. For 10 Gbps system maximum 250 Q-factor is accommodated with fiber channel length of 40Km. Figure 7 shows the Q factor values for WDM-PON system.
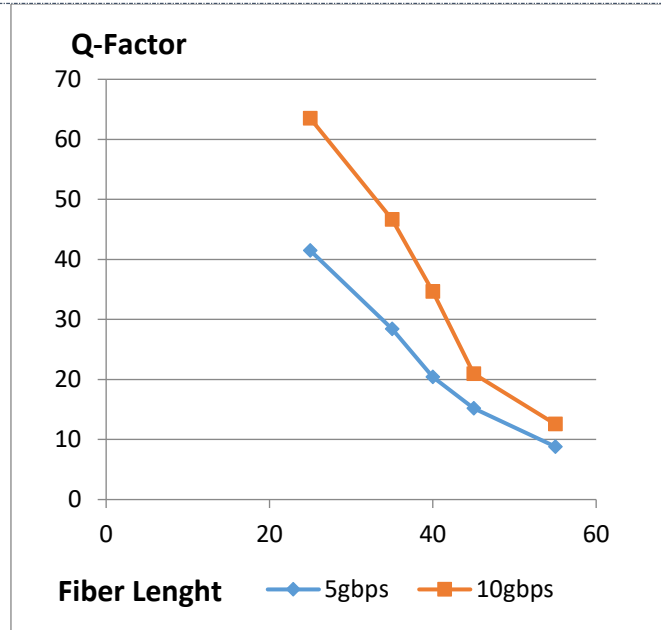
Figure 7: Comparison of Q factor for 5gbps and10gbps WDM-PON system

From figure 7 it is clear that the value of Q factor decreases with the increase in length of bidirectional optical fiber channel length. For 10 Gbps system maximum 63 Q-factor is accommodated with fiber channel length of 25Km.

BER value
Bit error rate is one of the main indicators of the quality of optical connection. It is under the influence of the same parameters as the Q factor. Bit error rate gives us the ratio between the numbers of mistakenly received *bE* bits and the total number of the received p bits in dependence on time. The relationship is given by the formula [9]:

$$BER = \frac{bE}{v.t}$$

Where *v* is bit rate and *t* is time of measurement.
The performance of the DWDM system using FSO channel as the transmission link can be measured by using BER analyzer. Figure 8 shows the BER values for 2 Users, 4

Users, 8 Users and 16 Users with data rates of 1Gbps, 5Gbps and 10Gbps respectively for different lengths of FSO channel.
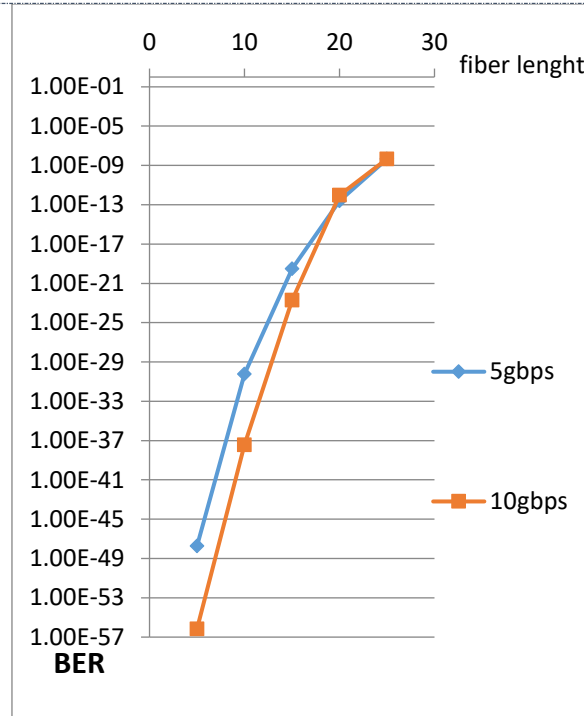
Figure 8: Comparison of BER values for 5Gbps and 10Gbps BPON system

CONCLUSION AND FURTHER SCOPE

The Passive optical system for bidirectional fiber communication is designed and results are analyzed using Q factor, Eye pattern, and BER value. The BER is the number of error bits divided by the total number of transferred bits during a particular time interval. Ideally, its value should be 10^{-9}. Ideally the value of Q Factor should be above 6 and as high as possible.

Simulated Passive Optical Network system shows that with the increase in length of bidirectional optical fiber the BER value increases whereas Q factor decreases. Performance of the system was analyzed for different length of the bidirectional channel and attenuation per kilometer. For 55 users the achievable length of the FSO channel is 5km with Q factor above 6. Significant reduction in BER and improved Q- factor have been observed with increasing number of users up to certain permissible value of data rate and fiber length. If the length of the FSO channel is taken above 5Km, the signal is attenuated such that the eye is closed.

The PON is one of the most successful access architecture that can provide high capacity and long reach abilities with high split ratios, thereby can support more users in wider areas. The implementation of a completely new access network that requires enormous investment should be target on the satisfaction of the subscribers' needs along with minimizing building and operational costs. Mathematical models are resourceful tools that can be used for the provision of the optimal network resources allocation that result in the highest QOS to the network subscribers.

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