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ภาคผนวก
บทความที่ได้รับการตีพิมพ์เผยแพร่

รายชื่อบทความวิจัยที่ได้รับการตีพิมพ์เผยแพร่ในระดับนานาชาติ

1 P. Nualmuenwai and C. Prommak, "On the Analysis of IP Traffic Distribution in the Network of Suranaree University of Technology", World Academy of Science, Engineering and Technology, vol. 60, pp. 362-366, 2011.

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On the Analysis of IP Traffic Distribution in the Network of Suranaree University of Technology

Paramet Nualmuenwai and Chutima Prommak[*]

Abstract—This paper presents the IP traffic analysis. The traffic was collected from the network of Suranaree University of Technology using the software based on the Simple Network Management Protocol (SNMP). In particular, we analyze the distribution of the aggregated traffic during the hours of peak load and light load. The traffic profiles including the parameters described the traffic distributions were derived. From the statistical analysis applying three different methods, including the Kolmogorov Smirnov test, Anderson Darling test, and Chi-Squared test, we found that the IP traffic distribution is a non-normal distribution and the distributions during the peak load and the light load are different. The experimental study and analysis show high uncertainty of the IP traffic.

Keywords—IP traffic analysis, IP traffic distribution, Traffic uncertainty

I. INTRODUCTION

UNDERSTAND the IP traffic characteristics is essential to manage the network resource utilization effectively. Various applications transferred over IP networks require different levels of service quality and guarantee. The network service providers need to manage network resources available to accommodate traffic demands and compromise between the limited network capacity and the service performance. The uncertainty behavior of IP traffic brings challenges to the IP network provisioning and management.

Several works in literature have paid attention on the study of the IP traffic characteristics. In [1], the authors present the implementation of the network traffic supervision system by using the method that analyzing traffic feature parameters distribution. In [2], the internet traffic model with a linear-time generation algorithm was proposed. The generated traffic trace is long-range dependent and its rates are distributed with a shifted gamma distribution. In [3], the authors present the internet aggregate traffic analysis at the flow level, in both spatial and temporal dimensions. In [4], a close relationship among network traffic, network user and network application in the complex network environment were studies and analyzed. The authors proposed a new network traffic model based on the use of Gini coefficient. The proposed model takes into consideration the network traffic profiles, user behaviors

and the network applications. In [5], the authors report the growth of the internet traffic and bandwidth availability of three major Internet service providers in Thailand.

Most existing works in literature focused on the study of traffic applications and interested in management and analysis of traffic network. While the results and finding reveal crucial characteristics, the literature lacks of the study on the aggregate traffic behaviors. Therefore, this paper presents the study of the temporal characteristics of the aggregated traffic that was collected from the network of Suranaree University of Technology using the software based on the Simple Network Management Protocol (SNMP). In particular, we analyze the distribution of the aggregated traffic during the hours of peak load and light load and derive the traffic profiles including the parameters described the traffic distributions.

The rest of this paper is structured as follows. Section II presents the network structure and the experiment setup. Section III presents the IP traffic characteristic and the distribution analysis. The parameters of the distribution are derived. Finally, we conclude the paper in section IV.

II. NETWORK STRUCTURE AND EXPERIMENT DESIGN

Network for the distribution feature analysis in this study is network within Suranaree University of Technology. This is internal network connected to external networks, which the network spend Firewall between internal network and external network to network security. Firewall is protected safety for network by the traffic connect to multilayer switch of internal network through optic cable size 10 Gbps and then distribute to switch of building through optic cable size 10 Gbps and forward to subswitch of the agency or organization through optic cable size 1 Gbps and distribute to Access Point, which Access Point is wireless local area network (WLAN) that connect through Unshielded Twisted Pair cable (UTP) size 1 Gbps. We select feature analysis of traffic internet of dormitories within campus. As shown in Figure 1, which network of dormitories within campus use volume of traffic as 80 percent of all volume of traffic.

For analysis of traffic feature, we are operation using monitor traffic program for traffic detection to save data of traffic. The monitor traffic program will run in the application layer of OpeSystem Interconnection Reference Model (OSI), which protocol is Simple Network Management Protocol (SNMP). But, some programs might use other protocols tohelp for monitor traffic. In this research, we operate using PRTG Traffic Grapher Program [8] to save data of traffic.

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We operate to save data of traffic in one month by collection data on both main switch and subswitch. we are show example of main switch (Switch S4) in Fig. 2 and subswitch (Switch S13) in Fig. 3, which both shows an example usage around traffic within 7 days (1 week) by this is saved to every 1 minute. We observe that more volume of traffic on main switch than volume of traffic on subswitch explicitly. In Fig. 4 shows the comparison of traffic in each day of each week, by show an example on Thursday which is working day and Sunday which is a holiday. Both show that volume of traffic for each day of each week is used in the same way, which working day will be running volume of traffic rather than the holiday. For analysis of traffic feature, we have analyzed symmetric and outlier and then consider histogram of data. We operate using EasyFit program [9] to analyze the distribution of traffic in Peak-load hour and Light-load hour with Kolmogorov Smirnov test, Anderson Darling test and Chi-Squared test. The results of these analysis show that distribution feature and we check the accuracy of the distribution feature of traffic with P-P Plot.
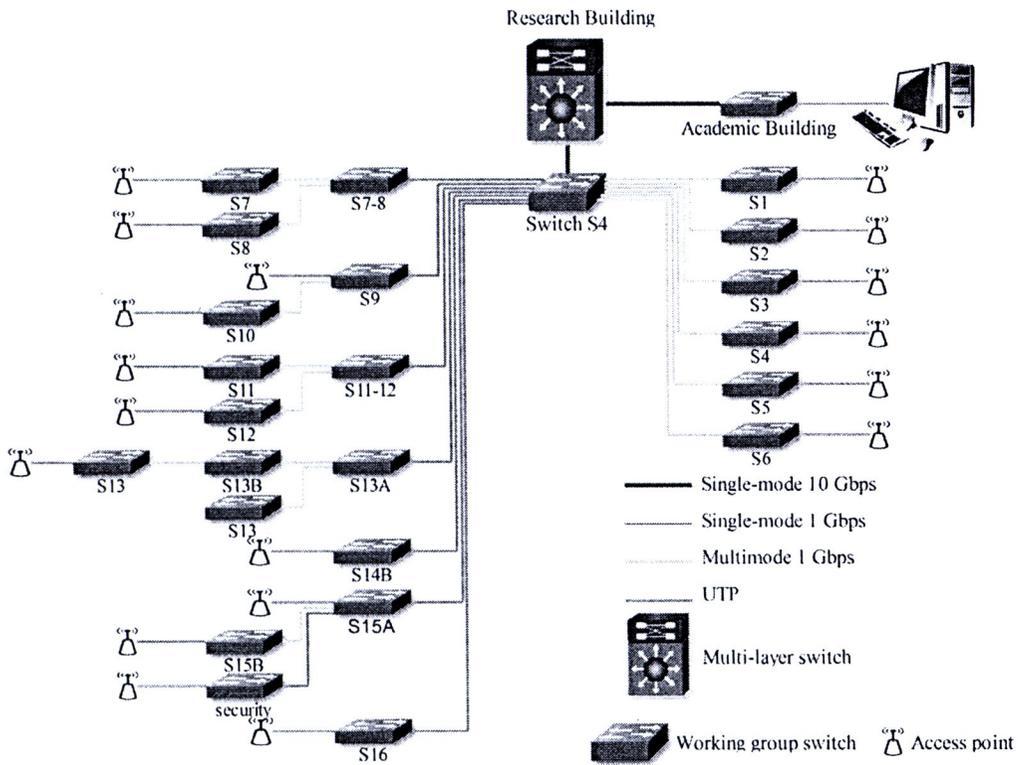

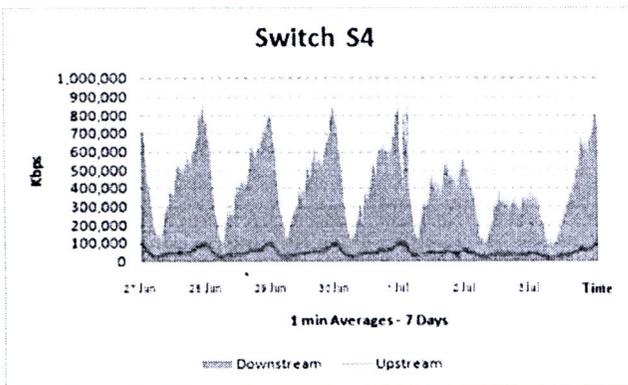Fig. 1 Structure of the network in Suranaree University of Technology
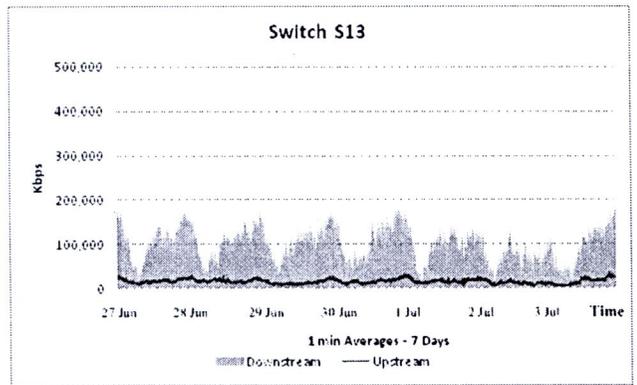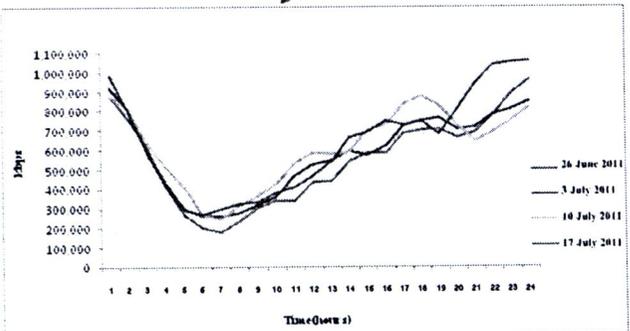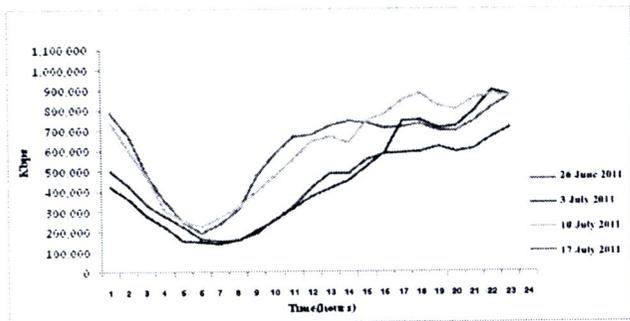

Fig. 2 Traffic volume at Switch S4

Fig. 3 Traffic volume at Switch S13

(a) Thursday

(b) Sunday

Fig. 4 Comparison of traffic at Switch S4

Fig. 5 Histogram of traffic during peak-load hours at Switch S4

Fig. 6 Histogram of traffic during light-load hours at Switch S4

III. ANALYSIS DISTRIBUTION FEATURE OF TRAFFIC

We obtained data of traffic from monitor traffic program. We analyze of traffic feature during peak-load hour and Light-load hour. First, the traffic data is outlier analysis, and select devoid outlier data. We obtained data set into histogram to symmetric analysis. In Fig. 5-6 show the histogram of Switch S4 (main switch) for Peak-load hour and Light-load hour respectively. In Fig. 7-8 show the histogram of Switch S13 (subswitch) for Peak-load hour and Light-load hour respectively. We found that distribution feature of data for histogram in the Peak-load is left skewed and distribution feature of data in the Light-load is right skewed which represent is asymmetric, this means that traffic data feature is non-normal distribution.

Due to traffic data is non-normal distribution. Thus, we analyze traffic data using EasyFit program to rank distribution with Goodness of fit tests by Kolmogorov Smirnov Test, Anderson Darling Test and Chi-Squared Test, which we obtained the distribution feature [6] as shown in table I. Switch S4 in Peak-load hour is Beta distribution, Switch S4 in Light-load hour is Johnson SB Distribution, Switch S13 in Peak-load hour is Gen. Extreme Value Distribution and Switch S13 in Light-load hour is Johnson SB Distribution, by we show parameter value for the distribution feature [6] of traffic data in table I.
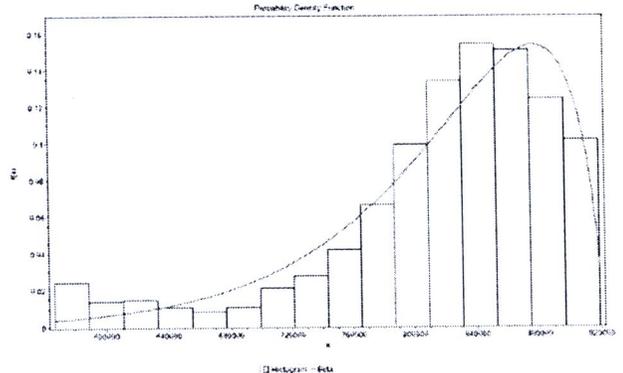

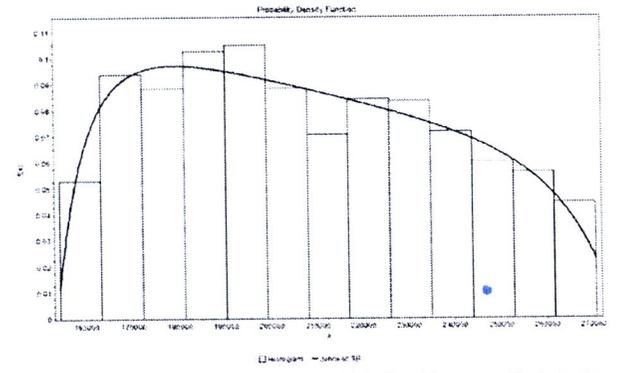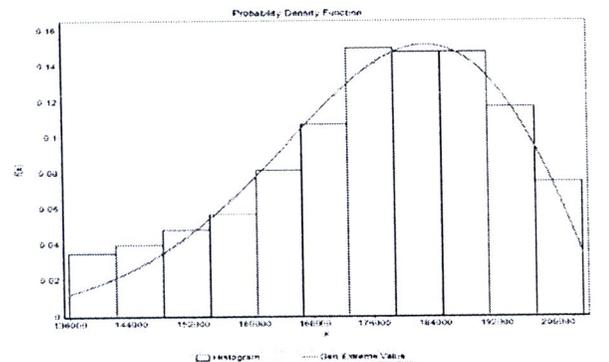Fig. 7 Histogram of traffic during peak-load hours at Switch S13
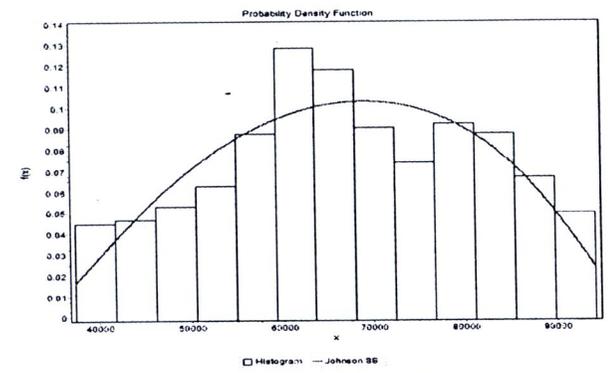

Fig. 8 Histogram of traffic during light-load hours at Switch S13

We analyzed distribution feature of traffic using Goodness of fit tests with Kolmogorov Smirnov Test, Anderson Darling Test and Chi-Squared Test which we obtained distribution feature of traffic, and then we check the accuracy of the distribution with P-P Plot analysis, as shown in Fig. 9-10 which each figure represents that probability of data traffic for the distribution feature is similar to probability of theory for the distribution features. This means that traffic is the distribution feature according to distribution features of traffic that obtained from Goodness of fit tests.

TABLE I
DISTRIBUTION PARAMETERS

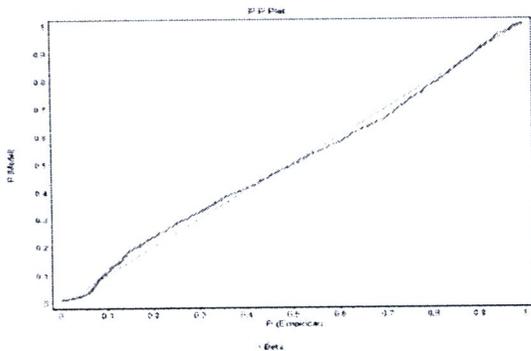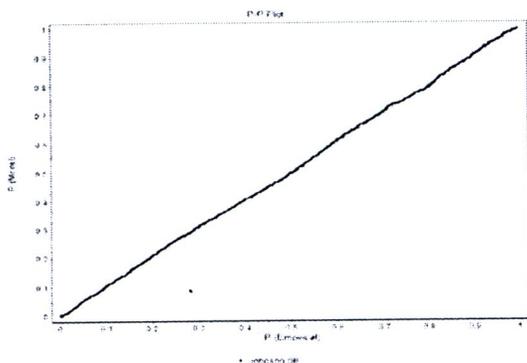| Switch	Distribution	Parameters
S4 peak-load	Beta	$a_1 = 36.612$ $a_2 = 1.6628$ $a = -1.4285 \times 10^6$ $b = 9.2046 \times 10^5$
S4 light-load	Johnson SB	$\gamma = 0.21722$ $\delta = 0.74927$ $\lambda = 1.2320 \times 10^5$ $\xi = 1.5313 \times 10^5$
S13 peak-load	Gen. Extreme Value	$k = -0.52069$ $\sigma = 17618.0$ $\mu = 1.7224 \times 10^5$
S13 light-load	Johnson SB	$\gamma = -0.1054$ $\delta = 1.0219$ $\lambda = 69493.0$ $\xi = 30793.0$

Fig. 9 P-P Plot of the peak-load hour at Switch S4

Fig. 10 P-P Plot of the light-load hour at Switch S4

IV. CONCLUSION

In this paper, we analyzed the distribution feature of traffic with Monitor Traffic for Internet Traffic of dormitories within Suranaree University of Technology. Furthermore, we consider used in the Peak-load hour and Light-load hour by analysis the distribution feature of traffic with histogram that represents the data that is non-normal distribution. Therefore, we analyzed of feature of traffic using Goodness of fit tests with Kolmogorov Smirnov Test, Anderson Darling Test and Chi-Squared Test, and check the accuracy of the distribution feature of traffic with P-P Plot to indicate the traffic distribution feature of property.

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Logical Topology Design in IP over WDM Networks with Load Balancing under Traffic Uncertainty

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Abstract— Traffic demand uncertainty could affect the reliability of the logical connectivity in IP over WDM networks. In this paper, we investigate the effects of traffic uncertainty and load balancing in IP over WDM networks and propose new techniques for logical topology design. In particular, we model the logical topology design in IP over WDM networks as the integer linear programming problems. Our key contribution is that the proposed model can address three important issues including (a) ensuring connectivity of the IP layer (logical topology) (b) balancing traffic load in WDM networks and (c) ensuring network capacity to accommodate traffic demand under traffic uncertainty scenarios. We observe that the proposed logical topology design method with load balancing enables much higher traffic distribution across the physical links allowing up to 63 % decreasing in unbalancing index and up to 8 % increasing in the resource utilization needed to support IP traffic demand with traffic uncertainty considerations.

Keywords- IP over WDM Networks; Logical Topology Design; Network Optimization; Traffic Uncertainty

I. INTRODUCTION

IP over Wavelength Division Multiplexing (WDM) networks have played essential role in transporting large volume of IP traffic across backbone networks of the Internet Service Providers (ISP). Efficient traffic engineering in such core networks is needed to achieve high reliability of data transportation.

Growth of IP traffic and increase in variation of the applications that require different levels of service quality and guarantee contribute to higher degree of traffic uncertainty of IP traffic. The network service providers need to manage the available network resources to sufficiently accommodate traffic demands and compromise between the limited network capacity and the service performance. The uncertainty behavior of the IP traffic brings challenges in provisioning and managing traffic demand in IP over WDM networks.

Several works in literature have devoted to study the network planning and traffic engineering in IP over WDM networks. In [7], the authors analyzed the cost and reliability issues in designing the IP over WDM backbone networks. [5] - [6] involved the logical topology design in IP over WDM networks. In [5], the authors proposed the optimal logical topology design with QoS constraints that guarantees the end-to-end QoS requirements such as call blocking rate. The

logical network configuration is assigned for each service class to minimize the network cost. In [6], the authors proposed the survivable lightpath routing of the logical topology in IP over WDM networks with the objective to maximize the logical capacity available before and after a single physical link failure.

While the studies in those previous works are significant and show interesting results, an important issue of the traffic uncertainty is not considered. There have been some works that paid attention on the traffic uncertainty in the network planning. In [2], the authors discussed the uncertainty characteristics caused by the dynamic nature of the IP-based traffic and proposed the network planning method that incorporated such nature of traffic in the network design procedures. They aimed to determine routes in the single layer networks with an objective to minimize cost of the network capacity used to accommodate the traffic demand at the specified level of traffic uncertainty. In [3], the authors considered the traffic uncertainty for the two-layer network architecture by using the same objective as in [2] to minimize cost of the network capacity usage.

Although some works have considered the traffic uncertainty in their network planning procedures, their main focus was on minimizing the network cost. The literature lacks of the study that considers load balancing and traffic uncertainty in two-layer networks such as those in the IP over WDM networks. In this paper, we not only consider the traffic uncertainty but also incorporate the load balancing issues in the traffic engineering for the backbone IP over WDM networks. In particular, we present the study of the logical topology design for IP traffic transported across IP over WDM networks. We formulate the logical topology design as an integer linear programming (ILP) problem. Our key contribution is that the proposed model can address three important issues including (a) ensuring connectivity of the IP layer (logical topology) (b) balancing traffic load in WDM networks and (c) ensuring network capacity to accommodate traffic demand under traffic uncertainty scenarios.

The remainder of this paper is organized as followed. Section II provides the problem definition and describes the problem formulation. Section III presents experiment setup and shows results and analysis. Finally, section IV concludes the paper.

II. PROBLEM DEFINITION AND FORMULATION

Traffic engineering in IP over WDM networks aims to efficiently layout large amount of IP traffic from core ISPs across backbone optical nodes. Specifically, this task is called logical topology design in which a logical connectivity in an IP layer represents IP traffic demand between a source-destination node pair whereas a physical path in a WDM layer is a set of optical fiber links connected by optical nodes.

Fig.1 shows an example of a two-layered IP-over-WDM network in which nodes of the IP layer are core routers whereas nodes of the WDM layer are optical cross connects (OXC). Fig.1 also shows examples of mapping logical links of the IP layer onto physical links of the WDM layer. The logical link (A,D) of the IP layer is routed through the physical link (1,3), (3,6) and (6,9) of the WDM layer.

This paper focuses on the logical topology design problems that aim to balance traffic demand of the IP layer onto the optical links of the WDM layer. Specially, traffic uncertainty characteristics of IP traffic are taken into account so that the provisioned capacity of the WDM layer can accommodate the variation of IP traffic.

We apply an Integer Linear Programming (ILP) approach to mathematically formulate the logical topology design problem. The proposed model aims to maximize the balance of IP traffic across optical links of the WDM layer. This objective is mathematically realized by minimizing the mean absolute deviation of IP traffic volume transported onto optical links of the WDM layer as written in the objective function, (1). (We denote the proposed model as *MAD*, shorten from *Minimizing mean Absolute Deviation.*) Other requirements such as traffic uncertainty characteristics, the network budget limitation, and the optical module specification are incorporated into the mathematical model through a set of constraints (2)-(11) presented below. Table I defines notations used in the proposed models.
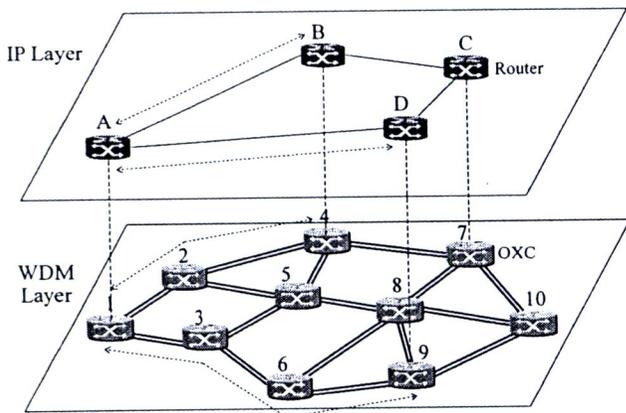

Figure 1. Network model

Objective:

$$Min \; \frac{1}{n} \sum_{j \in A} \left| r_j - \frac{\sum_{j \in A} r_j}{n} \right| \qquad (1)$$

Subject to:

$$\sum_{j \in A} C_j y_j + F_j z_j \le C_L \qquad (2)$$

$$\sum_{k \in D} \sum_{p \in P^k} \delta_j^{k,p} f^{k,p} x_k \le M y_j \qquad \forall j \in A \qquad (3)$$

$$M y_j \le B_j \qquad \forall j \in A \qquad (4)$$

$$\sum_{p \in P^k} f^{k,p} = 1 \qquad \forall k \in D \qquad (5)$$

$$\delta_j^{k,p} f^{k,p} \le z_j \qquad \forall j \in A, \forall k \in D, \forall p \in P^k \qquad (6)$$

$$r_j = \sum_{k \in D} \sum_{p \in P^k} \delta_j^{k,p} f^{k,p} x_k \qquad \forall j \in A \qquad (7)$$

$$y_j \le r_j \qquad \forall j \in A \qquad (8)$$

$$z_j \le r_j \qquad \forall j \in A \qquad (9)$$

$$r_j \ge 0 \qquad \forall j \in A \qquad (10)$$

$$y_j \ge 0 \qquad \forall j \in A \qquad (11)$$

Constraint (2) specifies budget limitation on the network cost, including the cost of using network capacity and the fixed cost which covers the optical modules and the installation cost. Constraint (3) ensures that the sufficient number of optical modules is provided for an optical link j so that link j can accommodate fluctuation of all IP traffic demands transported over link j. Variation of IP traffic demand is incorporated into the parameter x_k which can be calculated as written in (12) [8]. Let us consider the following form of chance constraint to ensure that capacity or bandwidth allocated on link is greater than or equal to an uncertain traffic volume (ξ) with probability can be written as $P(x \ge \xi) \ge \alpha$ where $0 \le \alpha \le 1$, and the traffic demand can be carried with α-level of guarantee. Assume that the traffic is normally distributed with mean (μ) and variance (σ^2). The random variable (ξ) has cumulative distribution function $\Phi(.)$ and its inverse transform $\Phi^{-1}(.)$. Thus, the parameter x_k can be written as

$$x_k = \mu_k + \Phi^{-1}(\alpha_k)\sigma_k \qquad (12)$$

Constraint (4) specifies capacity limitation (B_j) on an optical link j. Constraint (5) states that the traffic demand k can select one path from the predetermined path set P^k. Constraint (6) states that link j must be installed if the traffic demand k uses path p that routes through link j. Constraint (7) calculates total amount of IP traffic demand that is transported over an optical link j. Constraint (8)-(9) specify that if no traffic demand transported through an optical link j, the optical module y_j and the optical link z_j are not installed, i.e. enforcing y_j=0 and z_j=0. Constraint (10)-(11) state that r_j and y_j are non-negative variables.

TABLE I. NOTATIONS

Sets:

A	A set of optical links in IP over WDM networks
D	A set of IP traffic demands
P^k	A set of predetermined paths for demand k, $\forall k \in D$

Decision variables:

r_j	Real number indicating capacity required for link j, $\forall j \in A$
y_j	An integer indicating number of optical modules required to route traffic on link j, $\forall j \in A$
z_j	A binary {0, 1} variable that equals to 1 if link j is used ; 0 otherwise
$f^{k,p}$	A binary {0, 1} variable that equals to 1 if the demand k selects path p from the predetermined path set P^k; 0 otherwise

Constant parameters:

M	The capacity unit of an optical module
B_j	The capacity limitation on an optical link j, $\forall j \in A$
C_j	The cost of an optical module used on an optical link j, $\forall j \in A$
F_j	The fixed cost for an optical link j, $\forall j \in A$
C_L	The network cost limitation
x_k	The volume of traffic demand k, $\forall k \in D$
$\delta_j^{k,p}$	A binary {0, 1} parameter that equals to 1 if path $p \in P^k$ for demand k uses link j ; 0 otherwise
n	The number of optical links in set A

TABLE II. CONSTANT PARAMETERS USED IN THE EXPERIMENTS

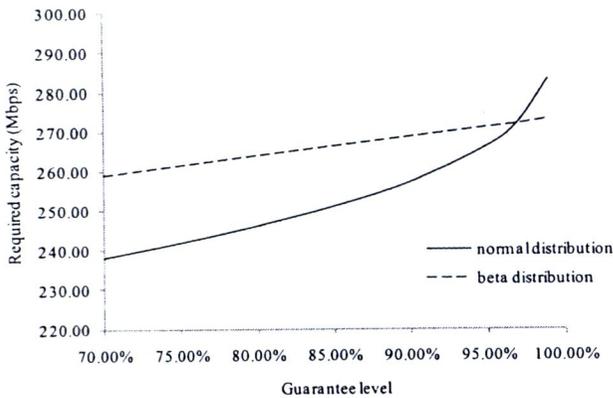| Parameters	Values
Capacity unit of an optical module	STM1 (155.52 Mbps)
The capacity limitation on an optical link	5000 Mbps
The cost of an optical module	150k
The fixed cost for an optical link	15k

Figure 2. The traffic volume at different levels of traffic uncertainty

III. NUMERICAL EXPERIMENTS AND ANALYSIS

In this section we present numerical evaluations on the effectiveness of the proposed MAD model. In our experiment, we adopted the IP over WDM network shown in Fig. 1 in which the WDM layer consists of ten OXC nodes and sixteen physical links. We considered ten logical links in an IP layer which represents ten IP traffic demands between ten source-destination node-pairs which were randomly selected.

The constant parameters used in our experiments are given in table II. The unit cost of an optical module and fixed operational cost are normalized based on the industrial pricing in Thailand. We considered the traffic uncertainty based on the normal and beta distribution which are the traffic characteristic described in [1] and [4], respectively. The mean and standard deviation of the traffic are 225 Mbps and 25 Mbps, respectively. Fig. 2 depicts the volume of traffic demand at different level of traffic uncertainty. In particular, we conducted experiments for three levels of uncertainty guarantee, including 90%, 95%, and 99%. In case of the normal distribution, the values of x_k for each guarantee levels are 257.04, 266.12, and 283.16 Mbps, respectively. In case of the beta distribution, the values of x_k for each guarantee levels are 266.84, 271.75, and 280.01 Mbps, respectively.

First we compare our proposed MAD model with those presented in [3] of which the objective function is to minimize the network cost with constraints on the optical link capacity and the amount of traffic demand. We denote this approach as *MC (Minimize Cost)* model. Unlike MC model, MAD model aims to minimize the mean absolute deviation of IP traffic volume transported onto optical links of the WDM layer. The logical topology design was solved by implementing the mathematical formulations with the ILOG-OPL development studio and inputting a set of predetermined paths for each traffic demand (P^k) to the model. Then it was solved with CPLEX 5.2 optimization solver. Computations were performed on an Intel Centrino Core2 Duo Processor 2.0 GHz and 2GB of RAM.

Fig. 3 and 4 illustrate traffic distribution across the network links for the case of traffic uncertainty guarantee at 90% and 99%, respectively. The figures compare traffic volume on each link which was resulted from using MC and MAD model. We can see using MC model some links carry high amount of traffic demand whereas many links carry very little or no traffic demand. Using the proposed MAD model, on the other hands, load balancing could be achieved across most of the physical links, except on the link 17th which was unavoidable because it is a bottleneck of the physical connectivity of the WDM layer. Note that the normal distribution was applied in this comparison.

Next we further investigate the effects of the network cost limitation on load balancing of the proposed MAD model. In order to evaluate this factor, we define a performance measure called an unbalance index which is the mean absolute deviation of IP traffic volume transported onto optical links of the WDM layer as written in (1). Fig. 5 and 6 compare load balancing in the network when enforcing different network cost limitation on the logical topology design. The normal and

beta distribution were applied in experiments of Fig. 5 and 6, respectively. We can see that in both figures unbalance index decreases as the budget for the logical topology design increases. However, there is limitation on the level of load balancing regardless of how much we increase the budget value. It appears that although the budget was increased higher than 10,500 units, the load balancing did not improve. This limitation may be caused by how optical links were layout in the WDM layer.

Next let's consider different level of traffic uncertainty guarantee. Fig. 5 and 6 also shows results of 90%, 95% and 99% uncertainty guarantee. We can see that at any value of the network budget, a higher level of uncertainty guarantee results in less load balancing, i.e. higher value of unbalance index. Fig. 7 – 9 compare load balancing in the network when applying different traffic distribution at 90%, 95% and 99% uncertainty guarantee, respectively. Fig. 9 shows that at high level of uncertainty guarantee (99%), using either normal or beta distribution would yield similar level of load balancing at any value of the network budget. Types of traffic distribution affect level of load balancing when the traffic uncertainty guarantee decreases as illustrated in Fig. 7 and 8. We can see that using the normal distribution results in lower value of unbalancing index, i.e. higher level of load balancing in the network.

Finally, we analyze the utilization of the provisioned capacity on optical links in the WDM layer. Link utilization is defined as the percentage of traffic volume carried on an optical link compared with the provisioned capacity on the link. Table III reports link utilization when applying different levels of traffic uncertainty guarantee at different values of the network budget. The table also compares link utilization when using the normal distribution versus the beta distribution. We can see that at 90% traffic uncertainty guarantee, the mean link utilization is around 83% and 86% for the normal and beta distribution, respectively. As the percentage of traffic uncertainty guarantee increases, the mean link utilization increases whereas the standard deviation decreases.
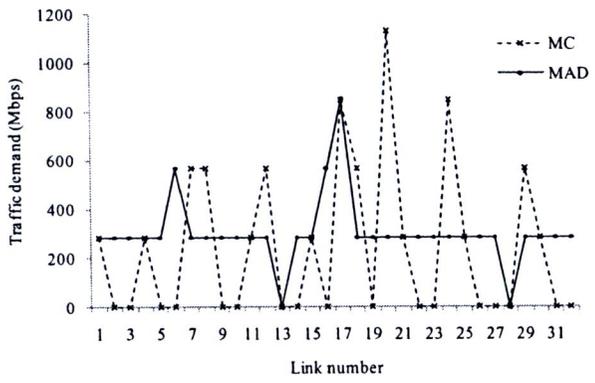

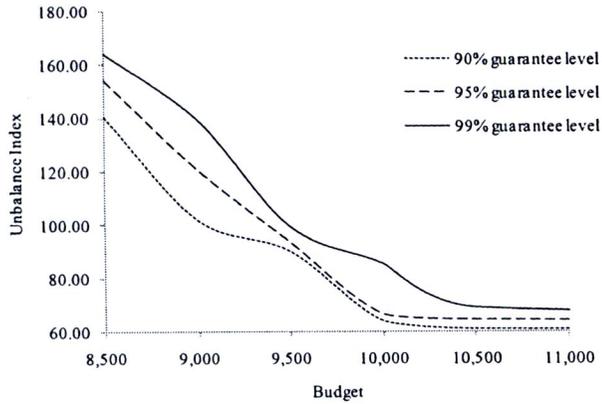Figure 4.   Traffic demand on network links for 99% uncertainty guarantee

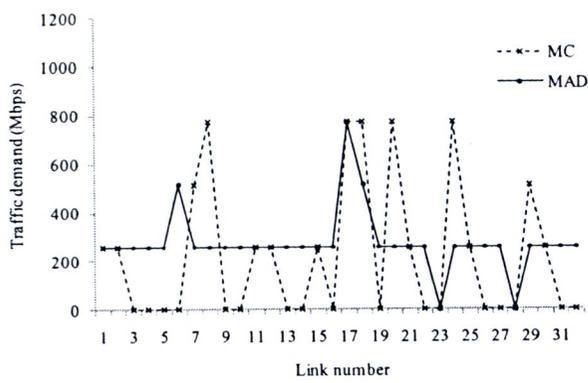Figure 5.   Unbalance index in case of normal distribution

Figure 6.   Unbalance index in case of beta distribution

Figure 3.   Traffic demand on network links for 90% uncertainty guarantee

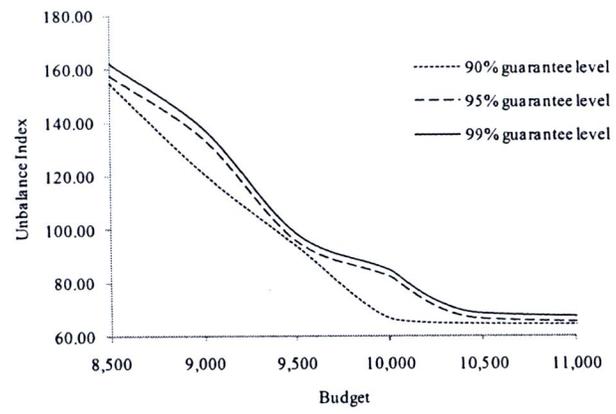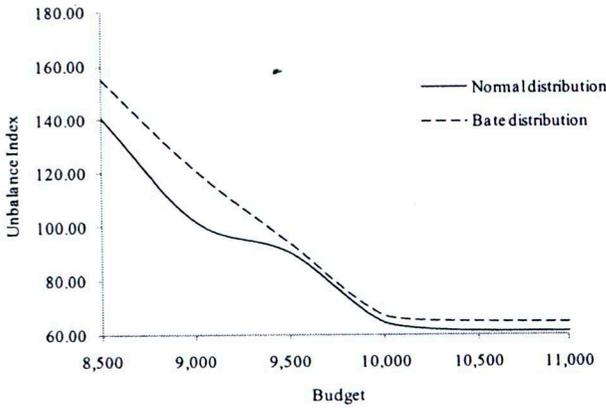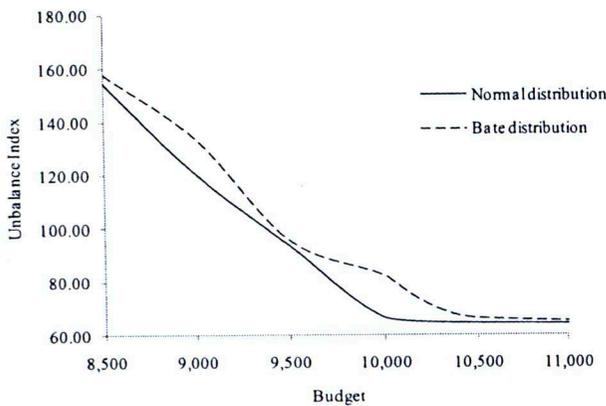Figure 7. Unbalance index in case of 90% uncertainty guarantee

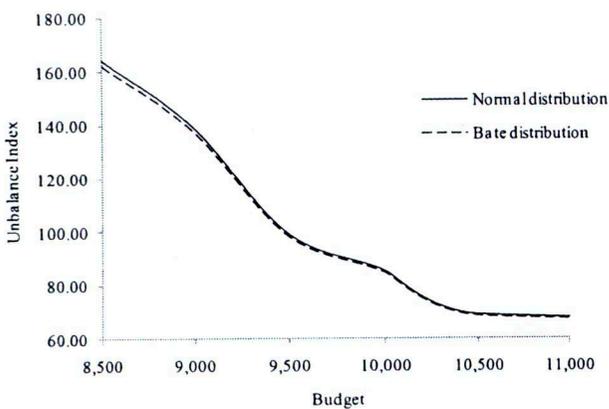Figure 8. Unbalance index in case of 95% uncertainty guarantee

Figure 9. Unbalance index in case of 99% uncertainty guarantee

TABLE III.   LINK UTILIZATION

Guarantee Level	Budget ($\times 10^3$)	Normal Distribution		Beta Distribution	
		Mean	SD	Mean	SD
90%	8500	84.42%	4.88%	86.08%	0.00%
	9500	82.49%	6.43%	86.08%	0.00%
	10500	83.47%	3.03%	86.49%	2.25%
95%	8500	85.85%	0.00%	87.66%	0.00%
	9500	85.85%	0.00%	87.66%	0.00%
	10500	86.25%	2.24%	87.66%	0.00%
99%	8500	91.34%	0.00%	90.33%	0.00%
	9500	91.34%	0.00%	90.33%	0.00%
	10500	91.34%	0.00%	89.29%	5.59%

IV.   CONCLUSION

This paper has investigated the load balancing problems with special consideration of traffic uncertainty for efficiently transporting IP traffic across IP over WDM networks. We propose a novel mathematical formulation as an integer linear programming that can determine optimal paths and sufficient optical capacity to accommodate traffic demand at a desired level of traffic uncertainty guarantee. Numerical experiments illustrate that the proposed method yield more efficient logical connectivity of IP traffic demand compared with other methods in term of load balancing and link utilization on the optical links of the WDM layer. Our ongoing works further investigate performance and effectiveness of the proposed approach. Specially, we are interested in the diversity of traffic transmission paths to enhance the quality of delivery in real network deployment scenarios.

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ประวัติผู้วิจัย

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