

Power Saving in Traffic Grooming WDM optical networks using Genetic Algorithm

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ABSTRACT: In recent years, the energy crisis is gaining increasing concern. It has been seen that Telecom networks also consume a largest amount of energy because more network equipments are added annually. In IP-over-WDM networks, network elements consumed energy not only at IP layers but also at WDM layers. At IP layer, the largest part of energy is consumed by Routers while on WDM layer, optical cross-connects (OXC)s consumed large energy. Generally in telecom networks, the network elements like the IP routers are usually kept powered on, each time without their proper utilization. So we have proposed an approach to save energy by shutting down line cards and chassis of routers when traffic load is low. In our approach Genetic Algorithm has been used to ensure that the cost of energy used by the IP routers and optical cross-connects is reduce and our attention is on minimizing the network elements reconfiguration, for minimizing traffic interruption .

KEYWORDS: IP-over-WDM Networks, Energy Optimization, Traffic grooming, Network Components, GA.

I. INTRODUCTION

In recent years, the energy efficiency and environmental protection play an important role. The energy consumption also increases in the field of ICT (information and communication Technology) because more equipment added annually in networking and communications areas. According to the data comes on 2009, the energy consumed by ICT is near about 8% of the total world electricity [1]. Telecom networks are a part of the ICT. As broadband telecom networks is increasing rapidly and thus energy consumption also increasing. So we need to develop an energy efficient telecom network. This is done by designing new networking paradigms which consume less energy.

The IP-over-WDM network is promising network architecture used for next-generation telecom networks. In an IP-over-WDM network, energy consumption occurred at IP layer as well as WDM layer [2]. Actually IP layer contains the equipments like routers, network gateways and switches, etc which consume maximum energy in electronics. WDM contains the equipments like transmitters, optical cross-connects (OXC)s, etc which consume energy basically in optics and is called as physical layer.

Traffic grooming provides provisioning connection requests of different bandwidth granularities on to wavelength channel of high bandwidth. The grooming node includes optical cross connects (OXCS), demultiplexers (DMUXs), multiplexers (MUXs) and / or digital cross connects (DXCs) that perform grooming as well as switching operations. These grooming resources efficiently multiplex several low speed traffic streams on to high capacity wavelength channels and also demultiplex those whenever required [3].

The recent research shows that electronic devices which belong to the IP layer consume maximum energy as compare to optical devices that belongs to the physical layer [4]. Especially routers in the IP layer are the devices which consume most of the energy. So, for this two layer network structure, it should be beneficial to save energy at the IP layer.

In the present research [5], it has been observed that the traffic load is continuously varied at various times of the day in IP-over-WDM network due to the use of network by the various users. Today telecom networks, for providing good

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services to users the network element like IP routers are always placed powered-on at the whole day & whole night without their proper utilization and thus a large amount of energy being wasted, when the traffic load is low. To overcome with this problem, in this paper we have proposed a plan which minimizes this energy consumption, particularly in the IP layer of IP-over-WDM network for varying traffic load during the day time.

It has been observed that at mid night or in early morning the traffic load is low [6], and thus there is very low utilization of network equipment like line cards & chassis of IP routers because they are idle during this period. In this paper, our aim is to temporarily shut down these line cards & chassis [7] when they are idle, and save energy consumed by them.

On the other hand, when there is an increase in traffic load occurs, then instantly they are turn on. Also when these equipments are shut down or turned on, re-routings needed, due to this, traffic interruption may occur. In this paper, our approach is to minimize the amount of reconfiguration of network elements and rerouting.

The rest of the paper is organized as follows: Section 2 introduces related work which has been published in recent year; Section 3 defines problem statement & assumption taken; Section 4 discusses proposed Objective function; Section 5 contains Genetic Algorithm procedure; Section 6 proposes results & discussion; and Section 7 gives conclusion of the paper.

II. RELATED WORK

Now a days, there has been many literature published for the energy efficiency in various telecom networks. According to related works done in these literatures are classified into three sub categories: (1) energy-efficient network design, (2) green traffic grooming, and (3) selectively turning down network elements.

(1) In “energy-efficient network design”, in [8] the authors have aimed to develop energy-efficient network architectures and operational strategies so as to minimize the energy consumption of IP-over-WDM networks. As well as, the proposed network designs can help to make equal distribution of the power at each network node which is also useful when used for real network, where each node constrained in such a way to provide minimum electrical power supply.

(2) In “green traffic grooming”, the authors in [9] have proposed that total power consumed by an optical WDM network is done in terms of the power consumption due to individual light paths. Also they defined an ILP (Integer Linear Programming) formulation for the energy-aware grooming problem.

The authors in [10] have proposed an MILP approach and a heuristic approach for solving RWA (routing and wavelength assignment) problem and also reduces the number of lightpath interfaces so as to minimize the energy consumed in the network.

The authors in [11] have considered the energy consumption in every network operation during traffic grooming for optical backbone networks. The Energy consumption of each network operation in traffic grooming is investigated and proposes a novel auxiliary graph, which can capture the flow of operations and their associated power and then conclude that by using energy-aware traffic grooming technique a significant amount of energy is saved as compared to the traditional traffic grooming scheme.

In [12] the authors have proposed an energy-aware dynamic traffic grooming approach for optical networks and they use the auxiliary graph methodology.

(3) On “selectively turning down network elements”, in [13], the authors have proposed a scheme in which the energy can be potentially saved when nodes and links in the network are turned off during off-peak periods i.e. during which the minimum network is accessed. But for some traffic demands shutting down the physical nodes or links result a much longer path, so the performance of the entire network may be reduced. In [14], the authors have proposed a simple heuristic algorithm for the considered network scenario to minimize the power consumption by the optical links. When there is a decrease in traffic load, the algorithm tries to switch off optical links so as to save energy. The authors

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in [15] proposed a scheme to shut down idle line cards when traffic load becomes minimum. But shutting down lightpaths results a disruptions in traffic, although this demerit is not mentioned

In our proposed work, we shut down network idle line cards as well as the chassis of the IP routers whenever the network traffic load is low. Thus during this approach only virtual-network connectivity is changed and it does not affect the physical topology of the network.

III. PROBLEM STATEMENTS & ASSUMPTION

Traffic load in telecom network is obtained in terms of the user's behaviours that are using the network. Generally it has been seen that, most enterprises and the residential network users uses the internet during the daytime or in the evening, respectively, and thus which make a high bandwidth requirement of the network during these times. On the other hand, after midnight or during early morning, the traffic accessed by users decreases through a much lower value.

There are some institutions those investigated on the user's behaviour for the telecom network. They have given the real-time variation of traffic load of internet in the Netherlands during different times of the day which is shown in Fig.1

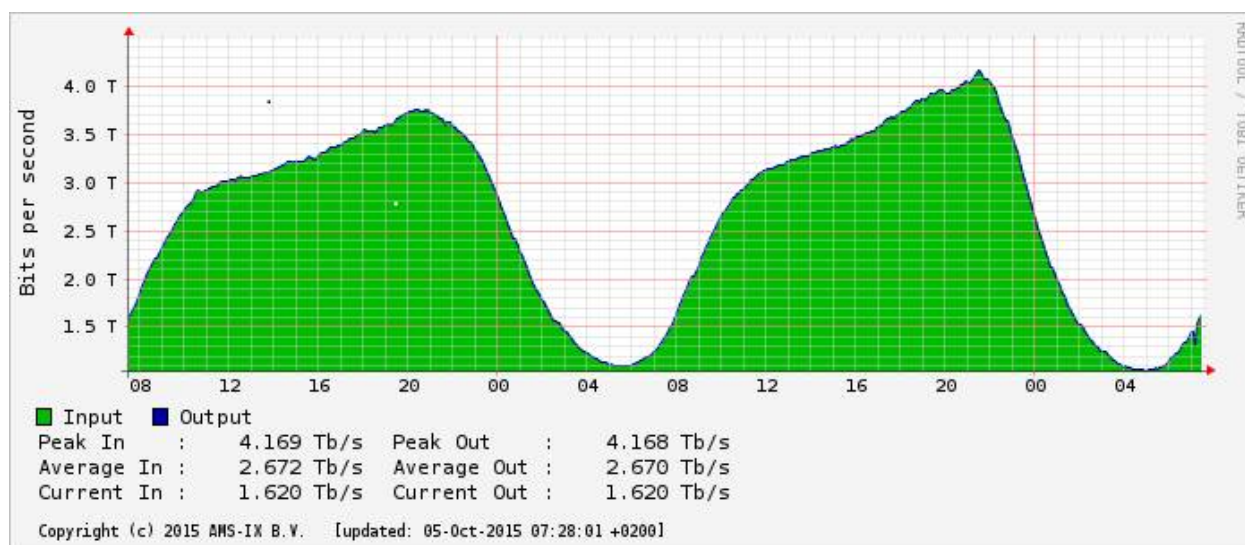


Fig.1. Daily graph for load in traffic (from AMS-IX) [16].

It has been calculated by the service provider AMS-IX in the Amsterdam [16]. From Fig. 1 it has been observed that during 6:00 to 16:00, there is a continuously increase in the traffic load, because during this time more use of the internet is done by enterprise users. During 16:00 to 20:00, there is a little faster increase in the traffic load because during this time residential users start to access the internet as well as there are some enterprise users who also working on the network. After that during 20:00 to 6:00, there is a rapid decrease in traffic load occurs because enterprise users as well as residential area users are going to sleep. It has been observed that the ratio between maximum load to minimum load is comes near about 4:1, which is a very large variation. Thus in our approach during off-peak hours, the network elements like line cards and chassis must be shut down so as to save 75% of energy.

Here, we put some assumptions for the network which are as follows:

- i) The links which are used are bidirectional links.
- ii) The capacity of one wavelength on one fiber is constant (OC-48).

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- iii) Here we considered static traffic demand i.e. the connection requests are known before demand.
- iv) The Number of wavelengths available for each fiber is not exceeded from eight.
- v) Here we assume that the traffic requests are done only for one of the speeds: OC-1, OC-3, OC-12 and OC-48.

IV. OBJECTIVE FUNCTION

Here we have used a 16-node WDM (Wavelength Division Multiplexing) mesh network shown in Fig2.

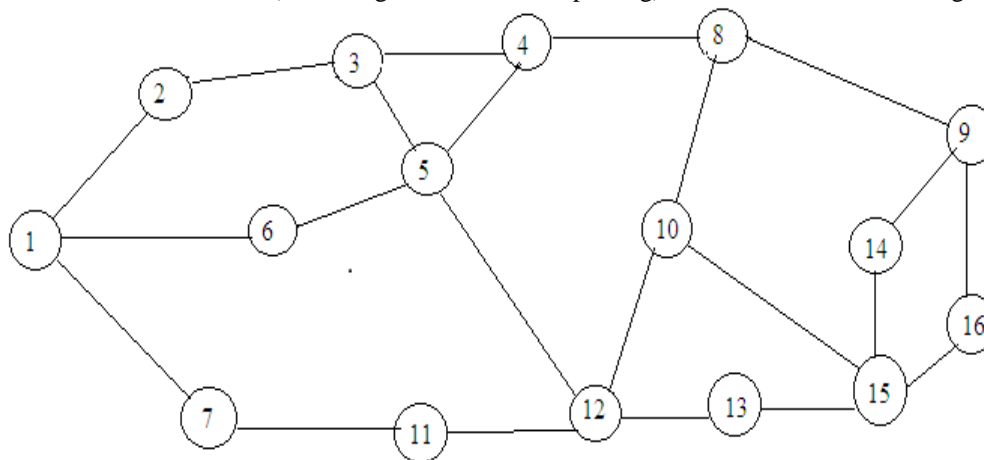


Fig.2. 16-Node WDM (Wavelength Division Multiplexing) mesh Network

In our work, we have applied the multi-hop bypass approach for routing and wavelength assignment. Here we have assumed that the traffic demand act as static for each period of time, i.e., 2 h durations. In this paper we have considered only static network planning problem. Here we considered to be run off-line based traffic variation during the various time of the day.

For the demonstration of different performance of minimizing energy consumption as well as minimizing traffic disruption, we have propose different schemes which are

- (a) Unconstrained Reconfiguration
Here we have obtained the minimum energy consumed by the network during each 2 h time period and reconfiguring the Chassis, line cards, lightpath etc., without any constraint taken in consideration.
- (b) Full-Constrained Reconfiguration
In order to reduce rerouting of the traffic and the reconfiguration of the network and here this scheme puts additional constraints for energy optimization and, as a result , the total energy consumption of the network becomes increase.

Minimize.

$$\sum_i [E_l * N_l(i) + E_c * N_c(i)] + E_{op} * \sum_{wl} \sum_{ij} (\sum_{m,n} \frac{p_{ij, wl}}{mn} + V_{ij} \cdot wl) \quad (1)$$

Where

E_l: Energy consumed in a line card placed on an IP router

E_c: Energy consumed in a chassis placed on an IP router

E_{op}: Energy consumed during a connection in an optical cross-connect.

N_l(i): The number of working line cards in node i.

N_c(i): The Number of working chassis in node i.

wl : wavelength ID in a fiber

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$P_{mn}^{ij, wl}$: The number of lightpaths present between nodes i and j are routed with the fiber link mn and using wavelength channel wl .

$V_{ij, wl}$: Number of lightpaths established from node i to node j , which use wavelength channel wl .

The formulation comes on by the multi-hop lightpath bypass scheme.

Eq. (1) shows the objective function, which contains two parts. Part $\sum_i [E_i * NI(i) + E_c * N_c(i)]$ is used to minimize the energy consumption occurs due to the chassis of routers and line cards in electrical layer where as Part $E_{op} \sum_{wl} \sum_{ij} (\sum_{m,n} P_{mn}^{ij, wl} + V_{ij, wl})$ is used to minimize the energy consumed by optical cross-connects at the optical layer, which is obtained by calculating the total number of physical connections required by the networks.

V. GENETIC ALGORITHM PROCEDURE

Genetic algorithms [17, 18] are the heuristic search algorithms and optimization techniques based on the principle of natural selection and natural genetics. A Genetic algorithm works on chromosomes [3], which gives a solution for the problem. Here we used a fitness function which evaluates the approximate value for the probability of a solution which is selected. First of all the initial population of individuals is produced and then estimate with the help of genetic operators, like crossover and mutation and thus build a new population, it is also called next generation which is wished to be more fitter than the first one. The benefit of the new set of solutions is judged by the help of the using fitness function. Thus the evolution process has been performed again and again for a number of predefined iterations or till some different criterion may occur.

A general sketch of the procedure:

- Creating AdjMat();
- Creating Load();
- Device Order();
- Creating and initializing Chromosomes:
 - For GenLimit > 0
 - For LPR > 0
 - Path selection and wavelength assignment
 - Checking fitness.
 - Cross over ()
 - Mutation ()
 - Checking fitness again and adding off spring to the population.
 - Use new generated population for a further run of algorithm.
 - Return number of successful paths.
 - Calculation of Minimal Energy consumption during unconstrained Reconfiguration
 - Calculation of Minimal Energy consumption during Full-Constrained Reconfiguration
 - Calculation of minimal interruption in network by applying Constraints for full-Constrained Reconfiguration.

For Full-Constrained Reconfiguration,

Constraints:

$$V_{ij, wl} \leq V'_{ij, wl} \quad \forall i, j \in N, \forall w \in W \quad (2)$$

$$\lambda_{ij}^{SD} \leq \lambda'_{ij}^{SD} \quad \forall i, j, S, D \in N \quad (3)$$

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Where $V_{ij, \omega l}$: Number of lightpaths established from node I to node j, which use wavelength channel ωl

$V'_{ij, \omega l}$: No. of lightpaths established from node i to node j, those used by wavelength channel ωl (When traffic load is higher).

λ_{ij}^{SD} : Traffic flow from the node S to the node D, says V_{ij} is an intermediate lightpath.

λ'_{ij}^{SD} : Traffic flow from node S to node D, employing V_{ij} is an intermediate lightpath (When traffic load is higher)

For Unconstrained Reconfiguration, we have run the GA without Equations (2) & (3), for every time period.

For Full-Constrained Reconfiguration, first of all we have run the GA in peak traffic time without the equations (2),(3) and then run the GA for lower traffic load i.e. during off-peak traffic time with using equations (2) and (3). Thus we have seen that a set of lightpath ,working line cards as well as chassis during low traffic load is a subset of the corresponding which occur at higher traffic variation load, so the total amount of reconfiguration of network elements is decrease when traffic load varies and also make to a decrease in actual traffic disruption. Thus Full-Constrained Reconfiguration removes the rerouting of traffic.

VI. RESULTS & DISCUSSION

The execution of our proposed Genetic Algorithm based procedure for solving energy optimization scheme have been described in WDM 16-node network topology as shown in Fig 2. The 16-node contains, a pair of bidirectional fiber in between every neighbouring nodes, and there are 8 wavelengths in each fiber, as well as the capacity of every wavelength channel is 40Gbps.

In Fig 3 we have plotted a graph which shows energy consumption due to chassis of IP routers and line cards during various times . Energy consumption due to OXCs is not considered because it gives small value as compared to the energy consumed by the chassis of IP routers and the line cards.

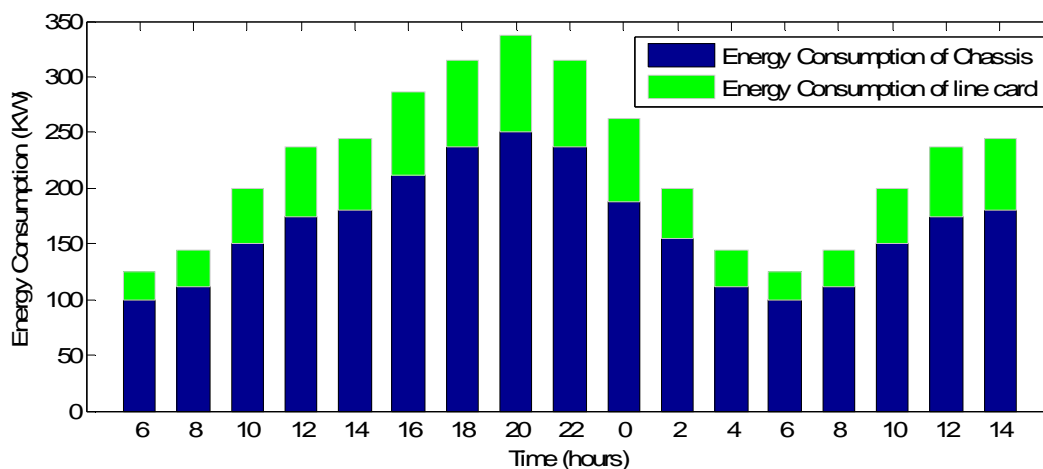


Fig. 3. Energy consumption by Full-Constrained Reconfiguration

However, when we put more constraints for minimizing the rerouting then we has founded that performance of energy consumption degraded. We have plotted a graph for comparing the energy consumed during Full constrained reconfiguration and Unconstrained Reconfiguration in Fig.4. From figure it has seen that due to applying more

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constraints to minimize the rerouting, result is a decrease in the performance in energy consumption in Full Constrained Reconfiguration i.e. energy consumption degrades as compare to Unconstrained Reconfiguration.

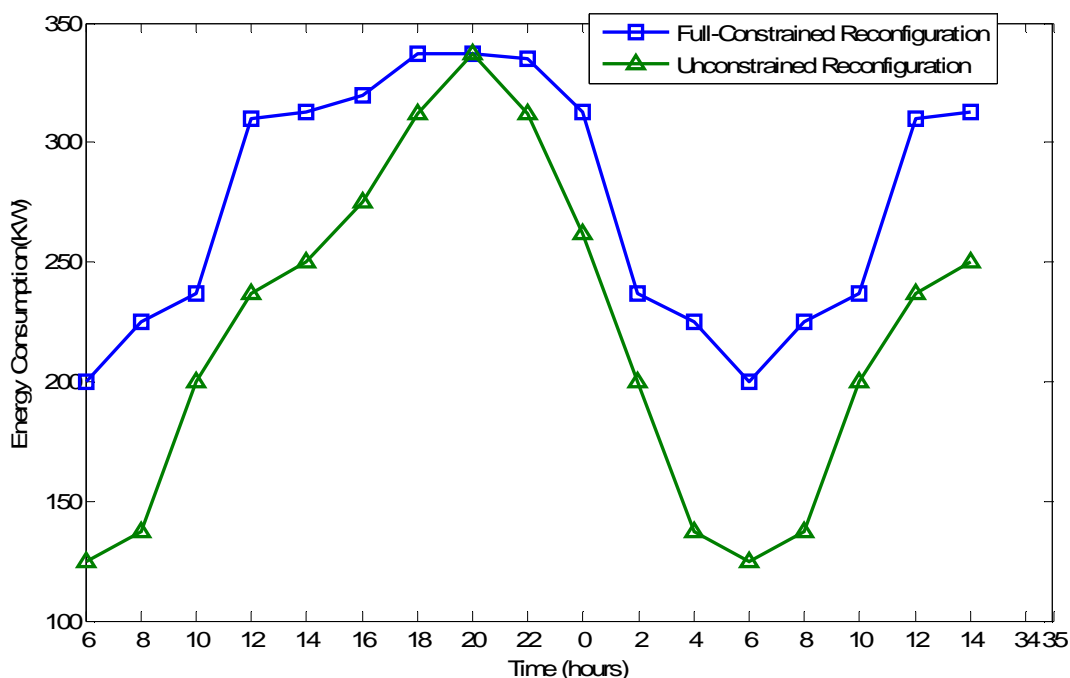


Fig.4. Energy consumption during various time for two approaches

VII. CONCLUSION

In recent years, the energy efficiency and environmental protection play an important role. In IP-over-WDM networks, network elements consumed energy not only at IP layers but also at WDM layers. At IP layer, the largest part of energy is consumed by Routers while on WDM layer, optical cross-connects (OXC)s are the main energy consumers.

In this paper, we have performed saving of energy at both the layers. Here we have proposed a scheme for saving energy at IP-over-WDM networks by shutting down idle chassis of routers and line cards during various day times.

In our proposed work we have also minimize the traffic interruption by reducing the amount of reconfiguration of network by using Genetic Algorithm approach. Also in our work, we have compared the performance of energy consumed and rerouting in unconstrained and full constrained reconfiguration.

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