Research Paper Engineering

Multi-Objective Traffic Engineering for Future Networks

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ABSTRACT

Traffic engineering is "concerned with the performance optimization of networks". It has became a challenging task for network management and resource optimization due to traffic uncertainty and to predict traffic variations. It is address the problem of efficiently allocating resource in the network so that user constraints are met and operators benefit is maximized. An important goal towards the design of Future Networks is to achieve the best ratio of performance to energy consumption and at the same time assure manageability. Existing work on energy saving considers local adaptation relying primarily on hardware based techniques, such as sleeping and rate adaptation. We argue that a complete solution requires a network-wide approach that works in conjunction with local measures. However, traditional traffic engineering objectives do not include energy. This paper presents a general problem formulation for Energy-Aware Traffic Engineering and proposes a distributed, heuristic Energy-Aware Traffic Engineering scheme (ETE) that provides load balancing and energy-awareness in accordance with the operator's needs. Simulation results of ETE compared to the optimal network performance confirm the capability of ETE to meeting the needs of Future Networks. Simulation results of ETE compared to the optimal network performance confirm the capability of ETE to meeting the needs of Future Networks.

Keywords : Energy-awareness; load balancing; network management; traffic engineering.

INTRODUCTION:

Energy consumption as an important problem. Although the networking equipment consumes only a fraction of the total energy used for IT, it is important to reduce the networking devices' energy consumption to cut energy costs in absolute terms. An additional important side effect of reduced energy consumption is reduced carbon dioxide emissions. Cheaper operating costs will also enable developing countries to deploy fast networking infrastructure, thereby bringing important content to more users. The Internet's energy consumption is likely to increase as operators deploy faster, more power-hungry equipment to handle popular bandwidth-intensive services, such as streaming and video on-demand. A large fraction of Internet traffic is generated by home users, which are currently limited by the asymmetric nature of ADSL and cable modems that have constrained uplinks. As the access links become symmetric with 50+Mbps to home users (e.g., fiber-to-the-home), the traffic volume could dramatically increase. In addition, the cloud computing initiative proposes to locate the users' data and computation within the network. If this paradigm takes root, network traffic is bound to increase even further. Recently, *Network Operators* realized their interest in achieving *energy-aware* network operation, and added this objective in their goals list. The successful spreading of broadband access, the consequential increasing number of customers, the versatile spread of services that need to be supported day by day, and last but not least the increasing energy prices raised the demand to provision broadband services more energy effectively. Unfortunately, the today's network infrastructures, namely routers, switches and other network devices, lack effective energy management solutions. Traffic Engineering (TE) plays a crucial role in determining the performance and reliability of the network deployments. The prime challenge of TE is to handle unpredictable traffic changes, both, in capacity demands and actual loads. Load balancing and congestion avoidance schemes are applied to cope with sudden load changes, vital for reliable service maintenance, and on demand connection management is provided to perform efficient service provisioning. Taking into account the TE objectives, we present a join problem formulation **for load balancing** with energy awareness. We follow a TE problem formulation where the main objective is to minimize the maximum link utilization in the network. By maintaining low link utilization, our approach allows the network operators to optimally exploit the capabilities of the existing infrastructure for a longer time and avoid buying new equipment. Therefore, this policy reduces the Capital Expenditures (CAPEX). Furthermore, we minimize the energy consumption by turning the idle and the inefficiently utilized links (lines of the networks cards), into sleeping mode. In other words, based on the network conditions and the traffic requests we try to find the optimal set of links that can be turned into sleeping mode. In this way we achieve improved Operational Expenditures (OPEX). The solution of the previous problem formulations leads to improved load balancing and energy-consumption levels in the network. Therefore, they could be used as a performance benchmark. In order to smoothly introduce the aforementioned major issues in real network deployments, we propose a distributed Energy-Aware Traffic Engineering (ETE) scheme. ETE is"directed "by low-complexity heuristic algorithms that are executed in an autonomous manner, through monitoring of the status of the network and making"intelligent" decisions. TE receives huge attention as one of the most important mechanisms seeking to optimally maintain network performance.

Energy-efficient traffic engineering approach

We consider that multiple paths (MPLS tunnels) are used to deliver traffic from the ingress to the egress routers. Formally, we assume that for each ingress -egress node pair i the traffic demand is Ti and multiple paths Pi could be used to deliver the traffic from the ingress to the egress node. Therefore, a fraction of the traffic is routed along path p ($p \in Pi$). In addition, the energy consumption of an active link is affected by the maximum rate that the link can support (10Mbps, 100Mbps, etc) and the current utilization of that link. The calculation of the energy consumption of link l, e_l, with capacity c_l, is

$$e_l = c_l \times l$$

Power Consumption= (c_l) is the base power consumption of a link with capacity *cl* and Utilization Factor= (*l*) is the scaling factor to account for the utilization of *link l*.

In our formulation, the optimal splitting of the traffic is performed with the objective: Assure that the maximum link utilization (total traffic on an active link divided by the link capacity) in the network is minimized. In this way resource-efficient (in this case link utilization/bandwidth) and balanced/stable network operation is achieved.

In order to introduce energy-awareness, we raise a second objective: Assure that the energy consumption of the active routes is balanced in the network. That is, find the route with maximum energy consumption and minimize it. We combine the previous single objectives in a unified objective function that takes into account the link utilization and the energy consumption

$$\min_{x_{ip}} \max_{l \in L_p} \sum_{i \in IE} \sum_{p \in P_i} \left(\frac{x_{ip} T_i}{C_l} \times \sum_{k \in L_p} e_k \right)$$

Subject to:

$$x_{ip} \geq 0, \forall p \in P_i, \forall_i \in IE$$

$$C_l \geq \sum_{i \in IE} \sum_{p \in P_l} x_{ip} T_i, \forall l \in L$$

$$\sum_{p \in P_i} x_{ip} = 1, \forall i \in IE,$$

$$x_{ip} = [0,1], \forall p \in p_i, \forall i \in IE$$

The fraction of traffic for a specific IE node pair sent across a path cannot be negative and the capacity of each link cannot be outreached.

Where:

Variables used for our problem formulation as

L= Set of links in the network.
IE =Set of Ingress to Egress node pairs.
el, Eip= Energy consumption of the port connected to link l, path p.
P_i =Set of paths of Ingress to Egress node pair i.
T_i =Traffic demand of Ingress to Egress node pair i.
u_l, Uip= Utilization of link l, path p
c_l= Capacity of link l .
xip= Fraction of traffic of Ingress to Egress node pair i, sent through the path p.
r_{ip} =Traffic of Ingress to Egress node pair i, sent through path p.
P_l =Set of paths that go through link l.
L_i =Set of links that are crossed by the set of paths Pi.
B_p t_m =Number of bits sent along the path p during tm seconds.
TE, TU =Thresholds related to utilization and energy consumption.

We now present an *ENergy-Efficient TRaffic Engineering (ENTRE)* heuristic that follows the previous model and applies an online distributed Traffic Engineering approach that jointly balances load and energy consumption in real-time, responding to actual traffic demands. The main contribution of our approach is to provide dynamic and lightweight management of the load and the energy consumption, avoiding in this way "resource gluttony" in the network. Each ingress egress node pair i measures every tm seconds a change in the fraction of traffic (Δxip) sent along path p. Furthermore, *ENTRE* measures the energy "distance" (ΔEip) of path p from the average energy consumption of the paths between ingress-egress node pair IE:

$$\Delta x_{ip} = \left(\overline{U_i} - U_{ip}\right) r_{ip} / \sum_{k \in p_i} r_{ik when} \; U_{ip} > U_{min}$$

$$\Delta E_{ip} = \left(\overline{E_i} - E_{ip}\right), when \; E_{ip} > E_{min}$$

Where:

$$r_{ip} = {}^{B_{pt_m}}/_{t_m}, \forall p \in P_i, \forall i \in IE$$

$$\overline{U_i} = \sum_{p \in p_i} r_{ip} U_{ip} \Big/ \sum_{k \in p_i} r_{ik}, \forall p \in P_i, \forall i \in IE$$

$$\overline{E_i} = \sum_{p \in p_i} r_{ip} E_{ip} \Big/ \sum_{k \in p_i} r_{ik}, \forall p \in P_i, \forall i \in IE$$

In case that Δxip >0 (p is underutilized), the fraction of traffic sent along path p must be increased by Δxip. Contrary, in case that Δxip <0 (p is over-utilized), the fraction of traffic sent along path p must be decreased by Δxip. It is obvious that a possible increase in the fraction of traffic sent along a path will lead to energy consumption increase (the increased maximum utilization of that path will affect the energy consumption). Since one of the main objectives of our energy-aware approach is to keep also the maximum energy consumption in low levels, we apply the same policy for improving energy consumption (ΔEip>0: Energy consumption could be increased in p, ΔEip<0: Energy consumption must be decreased in p). ENTRE combines the previous policies, balances the traffic every tm seconds and jointly keeps the maximum link utilization and the path energy consumption as low as possible. We summarize the basic rules in our heuristic mechanism

1. IF: Δxip >0 and ΔEip>0 DO: Apply Δxip to p
2. IF: Δxip <0 and ΔEip<0 DO: Apply Δxip to p
3. IF: Δxip >0 and ΔEip<0

a. IF: Ei-Eip>TE DO: Exclude p from the routing table and turn the corresponding links into sleeping mode. Traffic is proportion ally provisioned to the remaining paths.

b. ELSE DO: Nothing
4. IF: Δxip <0 and ΔEip>0
a. IF: Ui -Uip>TU DO: Apply Δxip to p
b. ELSE DO: Nothing

It is true that paths with higher minimum capacity need more traffic to achieve the same utilization as smaller capacity paths. This is the main reason why Δx_{ip} is normalized by the rates. This also makes the change in a path's traffic proportional to its current traffic share.

EVALUATION

In this section we present the evaluation study of the proposed scheme. We consider a network topology where four ingress nodes send traffic to four egress nodes. Except from these edge nodes, we support 15 core nodes randomly located in a mesh topology. We are using *IBM ILOG CPLEX* Optimizer to find the optimal solutions and evaluate the proposed mechanisms. Depicts the maximum link utilization in the networks. The total traffic demands (traffic that must be served in the network). We observe that the performance of ETE is bounded by the optimal solutions of the load balancing (OptLB) and the energy saving (OptES) problems and varies based on the operator's demands (e.g. Alg10 represents the performance of ETE when 10% energy saving is requested i.e. E=10%). Depicts the percentage of saved energy vs. the total traffic demands in the network. We observe that the operator's demands are satisfied by ETE while ensuring the balanced network operation (close to optimal)

CONCLUSION

In this paper we presented a TE analytic approach with main objectives to achieve balanced and energy-efficient network operation. The modeling of these problems inspired the design of an **Energy-Aware Traffic Engineering (ETE)** scheme that tries to meet the requirements of the future networks and pave the way for new "qualified" TE approaches. The simulation results show that *ETE* is capable to achieve performance closet optimal and meet the operator's needs. In other words, *Att*ends to behave like an optimal load balancer in the network, influenced by the minimum energy saving

ISSN - 2250-1991

level that is desired from the operator. *ETE* converges after a small number of iterations, proving in this way it's lightweight operation. Future plans include: extended analytical study, enhancement with learning and autonomic features and implementation.

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