

Transforming ICT Networks into Energy Efficient 'Green Optical Network'

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ABSTRACT

The concept of energy-efficient networking has begun to unfold in the past few years, gaining increasing popularity. Reduction of unneeded energy expenditure is turning into a major concern in wired networking, because of the potential cost-effective benefits and of its anticipated environmental impact. These kinds of issues, usually referred to as "green networking", in relation with embedding energy-awareness in the design, devices and in protocols of networks. Apprehension of environmental issues tied to Green House Gases increased during the recent years.

Keywords

Domains, Fabric, Energy Consumption, IP Packet, Network, Energy, Optical, Optical Switching, Routers.

1. INTRODUCTION

Green Optical Networks are energy efficient optical networks. They specialize on the energy efficient methods such as sleep mode, traffic grooming and optical bypass etc. The global telecommunications network plays an ever-increasing role in all dimensions of society. However, as the network grows, so does the energy consumption of the transmission and switching equipment used. It is anticipated that all information and communication technology (ICT) related activities contribute up to 10% of global carbon footprint today [1].

In 2012, the Information and Communication Technology (ICT) sector was responsible for 5% of global carbon productions and speedily growing at a year rate of 10%. This means that the global carbon productions will be doubled in 2020. The ICT sector is including personal computers and peripherals, telecoms networks and devices, and datacenters. As focused in the telecommunication's core transport networks, energy utilization of network equipments is rising speedily, due to the discharging number of Internet users and increasing network transmission speed [1]. It is estimated that the backbone network infrastructures, including IP/MPLS routers, transmission systems, and optical/electrical cross-connect systems (XCs), consume approximately 14% of total Internet energy consumption, which is assumed to increase to 25% in 2020 [6].

2. ENERGY EFFICIENCY IN OPTICAL NETWORKS

A comprehensive study on new solutions for energy-efficient optical networks is a very timely and constructive contribution, since researchers working on energy-efficient optical networks may advantage from having a helpful collection of basic information on the energy utilization of the various components of an optical network. Minimizing energy utilization of optical networks can be usually addressed at four levels as defined below:

2.1 Component level

In this level, highly-integrated all-optical processing components such as optical buffers, switching fabrics, and wavelength converters are being developed, which will significantly reduce energy consumption. Optical Switching Fabric (OSF) is more energy efficient than electronic backplanes and interconnects.

2.2 Transmission level

At the transmission level, low-attenuation and low-dispersion fibers, energy efficient optical transmitters and receivers, which improve the energy efficiency of transmission, are also being introduced.

2.3 Network level

Energy-efficient resource allocation mechanisms, green routing, long-reach optical access networks, etc. are being explored at the network level to decrease energy utilization of optical networks.

2.4 Application level

At the application level, mechanisms for energy-efficient network connectivity such as "Proxying" and green approaches for cloud computing are being proposed to reduce the energy consumption.

This paper mainly focuses on the energy efficiency in Optical Network and Application layer. The discussion of the first two ie Component Level and Transmission level is beyond the scope of the current discussion. Henceforth only Network Level and Application Level are discussed.

3. OPTICAL NETWORK DOMAINS

3.1 Core Network

As shown in Fig. 1, the core network is the central part of the telecom hierarchy, and it makes available nationwide or global coverage. Links in the core network span long distances – a link (employing optical fibers) could be a few hundreds to a few thousands of kilometers in length, e.g., links providing connections between the main cities of the United States.

Usually, core networks rely on mesh topologies that provide increased protection flexibility and efficient utilization of network resources. In core networks, energy is mostly consumed in network transmission and switching equipment such as routers, OXCs (Optical Cross-Connects),

EDAs (Erbium-Doped Fiber Amplifiers), and transponders. The amount of energy consumed by core networks is huge [9]. Therefore, many recent research efforts focus on energy-efficient core network. The approaches to reduce energy consumption in core networks can be divided into following categories:

3.1.1 Selectively Turning Off Network Elements

A major approach to save energy in the core network consists of selectively switching off idle network elements when traffic load decreases (e.g., at night), while still maintaining the vital functions of the network in order to support the residual traffic. If we consider a representation of the network hierarchy as in Fig. 1 we can see that there is often enough redundancy in the network so that some of the nodes can be completely turned off when they are not used as source or destination of traffic.

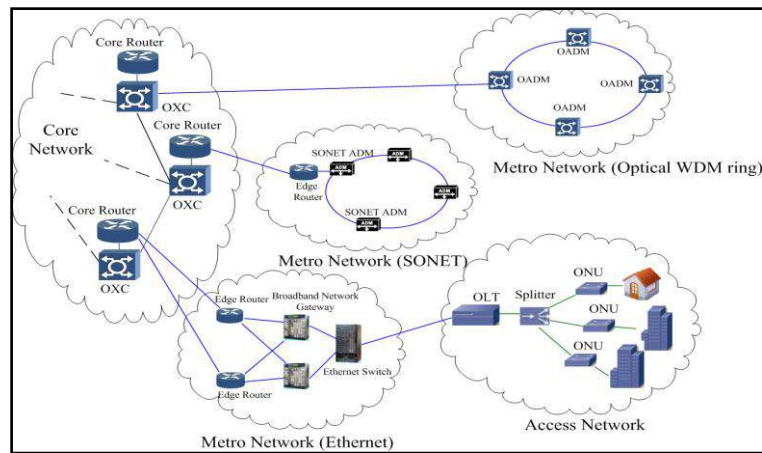


Fig.1: Telecom network hierarchies

In this context, a node can be turned off only when it is totally unused, when the traffic goes below a given threshold, leaving the accountability to reroute the remaining traffic to upper layers and after proactively rerouting the traffic along other routes, in order to avoid traffic disruptions. In a similar way, links can be switched off when there is no traffic on them, or when traffic goes below a given threshold, or when it is possible to re-route the traffic flowing along them [10]. Shutting down an intermediate core node may cause the connection to be rerouted over a longer route, which may sometimes not be acceptable due to various reasons: congestion, extra delay, etc. So, the possibility of turning off nodes or links has to be carefully evaluated under connectivity and QoS (Quality-of-Service) constraints.

3.1.2 Energy-Efficient Network Design

Another possible way to achieve energy efficiency is to devise energy efficient architectures during the network-design stage. For example, consider a design approach for an IP-over-WDM network where the energy consumption of IP routers, EDFAs, and transponders is jointly minimized. There are two possible ways to implement IP-over-WDM networks Light path non bypass and Light path bypass [12]. In the former method all the light paths incident to a node must be terminated, i.e., all the data carried by the light paths is processed and forwarded by IP routers while the later approach allows IP traffic, whose destination is not the intermediate node, to directly bypass the intermediate

router via a cut-through light path. Results show that light path bypass can save more energy than non-bypass, leading to the conclusion that the number of IP routers can be decreased while using the light path-bypass scheme in designing an energy-efficient core network [2].

3.1.3 Energy-Efficient IP Packet Forwarding

Energy-aware packet forwarding has been proposed to lower energy consumption at the IP layer. The size of IP packets impacts the energy consumption of routers. For constant bit rate traffic scenario, the smaller the IP packets the routers transfer, the more energy they consume. Thus, new IP packet forwarding schemes can be designed to be energy-efficient. The size of IP packets can be optimized to save energy when they are being forwarded through routers. However, a tradeoff exists between packet switching delay and energy efficient IP packet forwarding [3].

The pipeline forwarding is another approach in the energy-efficient IP packet forwarding. It is a “time-based” or Time-Driven Switching IP packet-switching scheme, and which makes it enable to extend the energy efficient time-based IP packet switching all the way to the limits of the network in Fig 2. The most of video based services are required large bandwidth, which is expected to increase by more than 90% of future Internet traffic. This pipeline forwarding parallel network is may be consider as a “superhighway”, which will take a large part of the traffic with dedicated performance, as packets will flow faster and smoothly through it. Optical implementation of the Time-Driven Switching paradigm promises to enable even more significant energy savings [7].

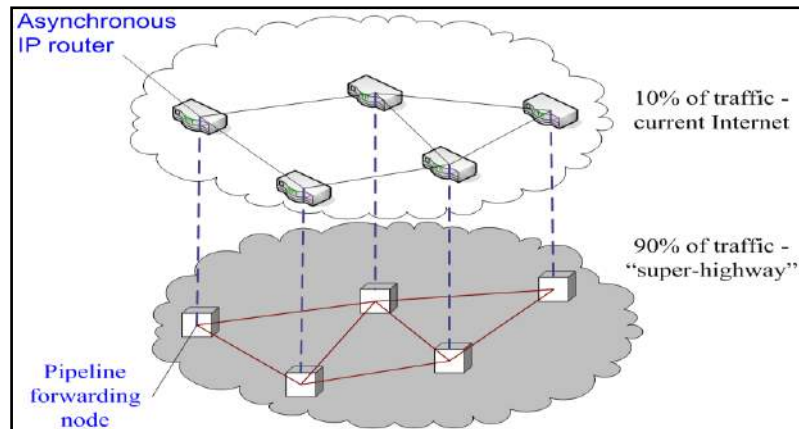


Fig.2: Pipeline Technique

3.1.4 Green Routing

In core networks, energy-aware routing is proposed as a novel routing scheme, which uses energy consumption of network equipment as the optimization objective. Compared to the traditional shortest-path or non-energy-aware routing scheme, energy-aware routing is expected to save a large amount of energy. In this energy-aware routing scheme, energy consumption of IP routers in core networks is minimized [4]. In addition, future energy-efficient routing schemes may tend to be more dynamic, which can reroute the traffic and save energy according to the traffic variation during the day or the season.

To reduce the carbon footprint the renewable energy is a great idea. Installation of core servers, switches, and data centers are the locations where renewable energy can be established to reduce the carbon footprint, and then to route the traffic to the "Green areas". Since many network elements which consume energy will be deployed at the locations of renewable energy, zero carbon footprint can be realized. In this case, elements from other part of the network may have to request the equipment in "Green areas" to transfer their traffic demand by remote control [5]. This approach sets up a connection between the energy-efficient network and renewable energy utilization, which should gain more research interest in the near future.

3.2 Metro Network

The metro network typically spans a metropolitan region, covering distances of a few tens to a few hundreds of kilometers and is dominantly based on a deep-rooted legacy of SONET/SDH optical ring networks. The access network connects the end users to their immediate service provider.

3.3 Access Network

To connecting, telecom networks with end users access network is the "last mile". These access networks

encompasses with the huge part of the telecom network. It is also a main user of energy due to the existence of a vast number of active elements. The several access technologies proposed, existed and deployed in the market such as Digital Subscriber Line (xDSL), Cable Modem (CM), Wireless-Optical Broadband Access Network (WOBAN), Cellular networks and FTTx, etc. These technologies can be broadly classified into two categories as wired (such as xDSL, CM, FTTx, etc.) and wireless.

4. OPTICAL APPLICATION LAYER

In the application layer of computers and, more generally, telecom networks, turning idle devices to sleeping mode appears to be the most plausible way in which energy conservation can be well achieved. However, in order to implement algorithms for sleeping, several aspects have to be considered, e.g., (i) software should be designed to enable hardware of network equipment to sleep, (ii) Internet routing protocols, such as TCP/IP, need to be modified to adapt to energy-efficient design, and (iii) hardware of network equipment needs to be reconfigured to accept control signals from the software [3]. Several approaches have been identified that satisfy the above requirements, and they target energy conservation at the application layer. Proxying, Green TCP IP Protocol and Green Grid Computing are discussed in subsequent sections.

4.1 Proxying

A first possible approach for reducing power consumption at application layer consists of using network connectivity commonly known as 'Proxying'. Since much of the network connectivity should be maintained at all times to allow remote access and/or operations of network-centric applications, the PCs and servers involved have to be kept always on (day and night). In this case, a large amount of energy will be consumed. However, these PCs and servers are probably idle for significant durations of time. The structure of this "Proxy" scheme is shown in Fig.3.

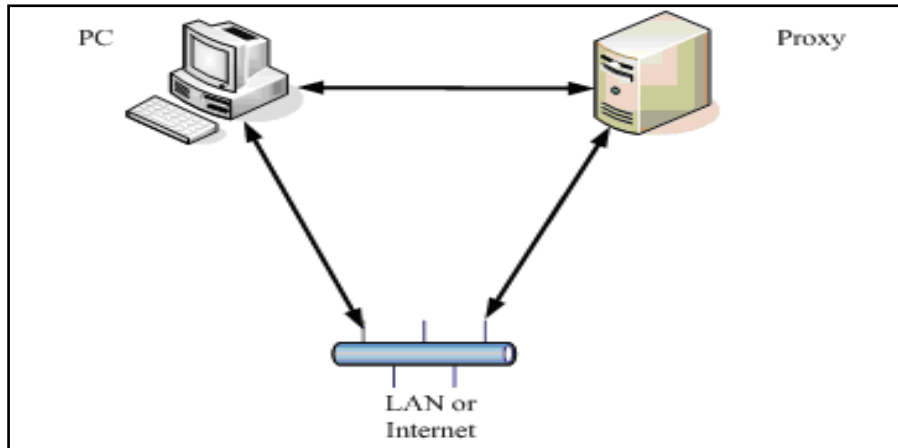


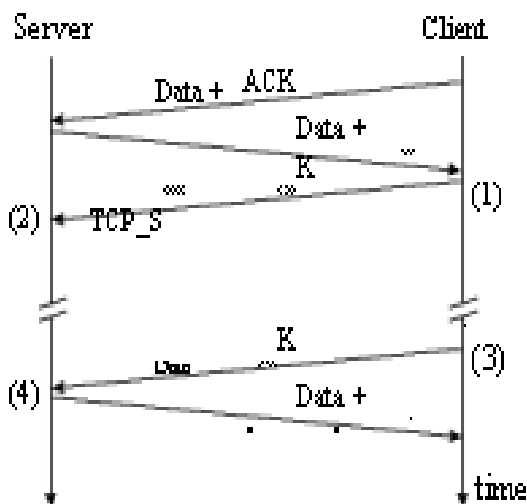
Fig.3: Proxying

When a PC becomes idle, it transfers its network presence to the proxy before going to sleep, and then the proxy responds to route network traffic for the sleeping PC. When the PC is needed, the proxy wakes it up. In this case, the energy consumption of the system can be reduced because the proxy consumes much less energy than the monitor, hard disk, or CPU of a PC does[11]. At the same time, TCP connections can be kept alive during the PC's sleep period by using a SOCKS-based (Protocol for sessions traversal across firewall securely) approach called green SOCKS (gSOCKS) as part of the Network Connectivity "Proxying".

4.2 Green TCP/IP Protocol

New connection sleep option is a key component in Green TCP/IP. This sleep option permits the power-managed Green TCP/IP client to inform a Green TCP/IP server so as it is 'going to sleep'. Depending on this announcement, the server logically keeps the connection alive, but does not repond or sends any data or acknowledgement packets to the sleeping

client. Then at the server end, the socket linked with the connection is blocked to stop unnecessary queuing of data. When the Green TCP/IP client wakes-up, it informs the server so that data flows can be immediately resumed [9][16]. The changes in TCP/IP for the implementation of the connection-sleep must be well-matched so that Green TCP/IP hosts can co-exist with non-Green, or regular, TCP/IP hosts. In TCP header, an option must be created named "TCP_SLEEP", as a solution. This option informed time to time to server that client is willing to be in sleep mode. As soon as server receives a packet having this option, it will bypass all internal TCP/IP instructions. Then server would drop the connection and stop sending the data for particular client. As per the TCP standard, a client machine does not understand this option. When the client wakes-up due to finding of user activity, it can start sending a data packet on the sleeping connection, which can cause to active the connectivity between the server and client. The Fig.4 shows the sending of a TCP_SLEEP packet, subsequent connection sleep, client wake-up, and resumption of normal connection activity.



(1) = Client begins shutdown by sending TCP_SLEEP
 (2) = Server blocks socket and connection enters "sleep"
 (3) = Client wakes-up and sends data to server
 (4) = Server receives data and resumes connection
 Between (2) and (3) the client can be fully powered-off and the connection is "sleeping"

Fig.4: Connection state diagram showing new sleep state for Green TCP/IP

4.3 Green Grid Computing

The Green Grid a global consortium dedicated to advancing energy efficiency in datacenters and business computing. The Green Grid works with governments, technology

providers and end-users around the world to create standards for more efficient use of energy in data center [8]. The one and only objective of the consortium is to decrease energy costs by 80%, Power down servers without affecting applications or users and to turn the Data Centers into Green while decreasing costs and improving service levels.

5. CONCLUSION

Energy efficiency in telecom networks is a current study issue, but it is gaining fast recognition in the research society, motivated by the peoples for the ever-increasing energy utilization of ICT. This survey evaluated energy-conservation code of behavior and energy-efficient architectures on diverse field of telecom networks: core, metro, and access networks, with a explicit weight age on telecom networks based optical. The grid computing and various data centers networks are also considered for optical networks. In addition to standardization efforts by various telecommunication institutions on the way to energy efficiency were summarized, which may give a good practical material to researchers scholars. With this study we provided a very useful suggestion for researchers, those who are interested in energy-efficient telecom networks, and remain helpful to grow future directions on "green-networking" study.

6. REFERENCES

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