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Reduction of Energy Consumption based on Replacement of Routers with SDN Switches

Suada Hadzovic, Irena Seremet, Sasa Mrdovic and Samir Causevic

***Abstract*— Software Defined Networking (SDN) is a promising solution because of many advantages over the traditional network. Due to these advantages, SDN can be considered as a tool for energy efficiency in ICT (Information and Communication Technology) networks. In this paper, we have made a comparison between energy consumption in real IP/MPLS (Internet Protocol/Multi-Protocol Label Switching) network and designed SDN network. The results show that a significant reduction of energy consumption is achieved for a scenario with designed SDN solution.**

I. Introduction

Internet traffic is on the rise, according to a forecast in the Cisco Visual Networking Index [1], annual global IP traffic is forecast to reach 4.8 ZB per year by 2022. The growth of the ICT sector is followed by greenhouse gas impact growth. Precisely, ICT footprint is estimated to rise from 1,6% in 2017 to 1,7% in 2030. [2].

The share of ICT global electricity usage by 2030 have been estimated in the study [3]. In this study, three different scenarios are set up, depending on the scenario, the estimated share of ICT global electricity usage is 8% for the best case, 21% for the expected case and 51% for the worst case as it is presented in Fig.1. The worst case will happen unless enough electricity efficiency improvement of the wireless and fixed access network is achieved.

Having all these facts in mind, it is logical that energy consumption is becoming a key challenge for ICT for both economic and environmental reasons. In recent years, numerous studies have been conducted on the topic of cost reduction due to unnecessary energy consumption, often referred to as greening of ICT network technologies and protocols.

Redundancy is a common practice where devices are added to the infrastructure for the sole purpose of taking over the role in case the other device breaks down, adding to the share of total energy consumption. While on the one hand redundancy increases the reliability of the network, the energy efficiency of the network is reduced because all network devices are powered at a full capacity, while they are largely unused most of the time.

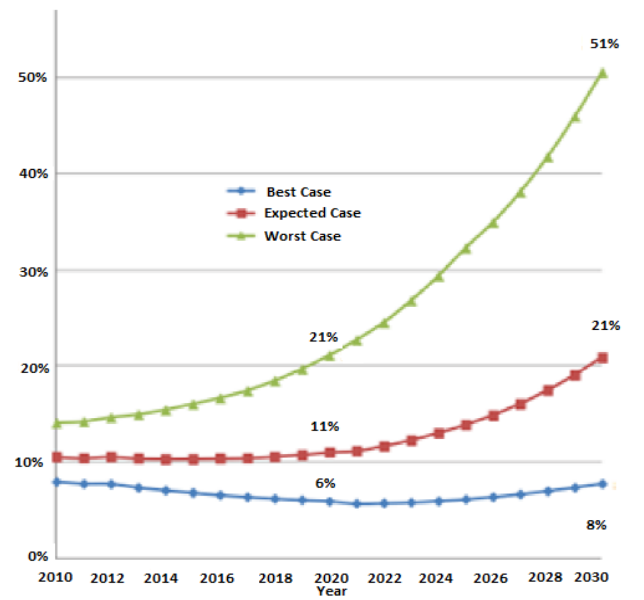

Fig. 1. The share of ICT global electricity usage

These goals are radically opposed to environmental protection and solving these problems make green ICT networks an interesting and technically challenging area of research and require efforts to bring energy awareness to network design without compromising on the quality of service or network reliability. Therefore, one potential energy-saving approach is to put unused devices into sleep mode in off-peak hours without affecting network performance and reliability. Energy savings can be achieved by reducing energy consumption due to unused network elements and increasing network utilization.

SDN offers numerous benefits in terms of efficient configuration, efficient management, network flexibility and many others [4]. It does have high development potential for overcoming the traditional network disadvantages and it is expected to have a globally significant increase in numbers of transition from traditional network to SDN. In this paper, we show potential energy saving that SDN can bring.

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We have designed a network with SDN switches and a controller as a replacement for a part of a real IP/MPLS network.

Results of energy usage comparison show a significant decrease in energy consumption in the SDN network.

This article is structured as follows. After this introduction, Section II deals with related work i.e. about energy efficiency and about SDN as a tool for energy efficiency improvement, Section III presents a study case that compares energy consumption in non-SDN network and SDN network. The conclusion is drawn in Section IV.

II. Related Work

Energy efficiency describes the ability of the network to reduce energy consumption per package, thereby contributing to carbon emissions, and extend the life of the network while maintaining the quality of QoS services.

Many researchers have studied the issue of energy efficiency in different parts of the network, using different technologies, methods and algorithms on different levels.

Authors in [5], focus on using SDN for energy-aware routing.

The problem of energy-aware routing in SDN-based carrier-grade Ethernet networks is addressed in [6]. Reducing energy consumption is based on turning off network nodes and links while respecting the rule space capacity for each Openflow switch and maintaining an allowable maximum link utilization.

Authors in [7] have proposed an energy efficiency metric named Ratio for Energy Saving in SDN that quantifies energy efficiency based on link utility intervals. The traffic and energy aware routing problem in SDN are addressed and link utility based heuristic algorithms are proposed in [8].

Authors in [9] analyze energy performance trade-offs and their implications on management and future network structure.

The trade-off between the energy amount that could be saved and the number and location of IP routers to be replaced with SDN switches is studied in [10].

Survey on the different strategies that are implemented to achieve network security and energy efficiency through SDN implementation is presented in [11].

A brief comparison of possible energy efficiency improvement of SDN approaches is given in [12].

Environmental variables have been taken in [13] where authors have introduced the term pollution-aware routing combining energy efficiency techniques (the first one is turning off the network links and nodes when they are not necessary and the second one is adaptive link rate) and environmental variables (carbon emission factor and non-renewable energy usage percentage) in finding a more pollution-aware solution from the point of view of a software defined network.

Having in mind that SDN has the possibility to directly control the network behavior and it offers to user possibility of direct interaction with the elements of the network, in this case, turning off network switches, links, or reducing the link rate, resulting in energy savings without affecting the service quality. Therefore, SDN can be considered as a proper tool to act over the network devices and configure them for energy efficiency improvement.

Therefore, we will analyze in the next section what is happening with energy consumption if we replace traditional routers with SDN switches.

III. Energy Consumption Comparison

To verify and measure energy efficiency improvement by replacing a traditional router with SDN switches, we have compared energy consumption in real non-SDN network and designed a SDN network that could provide equal throughput and number of ports.

As an example of a non-SDN network, part of the real service provider IP/MPLS network in Bosnia and Herzegovina is used. We measured the real energy consumption of all routers in that network. We then designed a SDN network that should be able to replace that IP/MPLS network. We calculated power consumption for all SDN switches and a controller to get total that we compared with the total for IP/MPLS network. Details of that process are given next. Each network device, in analyzed part of IP/MPLS network, has four main components of energy consumption calculation:

- Chassis equipment such as fan energy consumption.
- TCAM (Ternary Content Memory) energy consumption.
- Line cards energy consumption.
- Ports energy consumption.

The topology of considered IP/MPLS network contains:

- One Cisco ASR 9010 Aggregation Services Router.
- Two Cisco 7606 routers.
- Five layer 3 ME3400 Series Ethernet Access switches.

This IP/MPLS network topology is presented in Fig. 2.

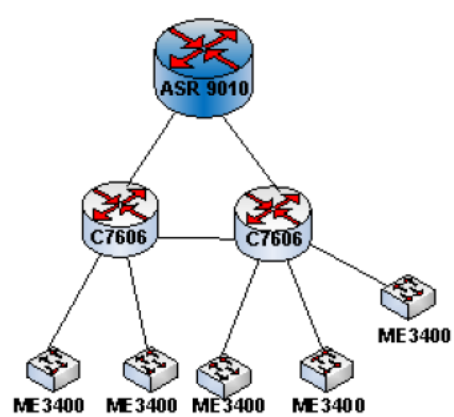

Fig. 2. Used IP/MPLS network topology

Cisco ASR 9010 router has two fans, six line cards with 56 Gb Ethernet ports and 22 10Gb ports.

Each Cisco C7606 has one fan, six line cards with 64 Gb Ethernet ports and 4 10Gb ports. Each ME3400 switch has one fan and 16 Gb ports. In total, IP/MPLS network has eight different devices, 8 TCAMs, 21 line cards, 9 fans, 264 Gb Ethernet ports and 30 10Gb ports. Each device measures the current energy consumption by line cards, ports and fans. Results of the measured values can be seen through the output of certain show commands, such as show power on C7606 device. Average measured energy consumption in considered IP/MPLS network is presented in Table I.

TABLE I
ENERGY CONSUMPTION IN IP/MPLS NETWORK

Device	FAN	TCAM	Modules	Number of ports	Energy Consumption
ASR 9010	400 W (2x200W)	~30 W	A9K-RSP440-TR(Active)	\	350 W
			A9K-RSP440-TR(Standby)	\	350 W
			A9K-8T-L	8	575 W
			A9K-8T-L	8	575 W
			A9K-8T-L	8	575 W
			A9K-2T20GE-L	22	320 W
			A9K-2T20GE-L	22	320 W
			A9K-2T20GE-L	22	320 W
			A9K-MOD160-TR	8	590 W
In total: 4405 W					
7606 I	180 W	~30 W	76-ES+T-40G	40	418 W
			76-ES+T-2TG	2	300 W
			76-ES+T-2TG	2	300 W
			7600-ES+20G3C	20	276 W
			RSP720-3C-GE	2	310 W
			RSP720-3C-GE	2	310 W
In total: 2144 W					
7606 II	180W	~30 W	76-ES+XC-40G3C	40	399 W
			76-ES+T-2TG	2	300 W
			76-ES+T-2TG	2	300 W
			7600-ES+20G3C	20	276 W
			RSP720-3C-GE	2	310 W
			RSP720-3C-GE	2	310 W
In total: 2125 W					
ME3400	20 W	~30 W	\		35 W
ME3400	20 W	~30 W	\		35 W
ME3400	20 W	~30 W	\		35 W
ME3400	20 W	~30 W	\		35 W
ME3400	20 W	~30 W	\		35 W
In total: 425 W					
Entire IP/MPLS network: 6974 W					

In the next step, alternative SDN network, that could replace this IP/MPLS network, is designed. In order to prove energy savings by replacing current devices in IP/MPLS network with SDN switches, attention should be paid to:

- Finding the right switches for replacement
- Designing the right network topology

When finding the right switches for replacement, it is very important that new SDN switches support the same features as the current routers. Also, new SDN switches should have the same or higher number of ports, and the same or higher throughput. By analyzing current IP/MPLS network, we concluded that new SDN switches in total should have at least 264 Gb ports and 30 10Gb ports. Also, new SDN switches must support VLANs, QoS features, IPv4/IPv6 routing protocols such as OSPF and BGP, MPLS, VRFs, multicast routing protocols such as PIM, Policy-based routing, SNMP, NTP, VPNs and STP. After some research, we concluded that for replacement we could consider SDN switch by FS series: N5850-48S6Q. This SDN switch supports all of the above features and it is compatible with SDN via OpenFlow 1.3.11.

Each N5850-48S6Q has 48 10Gb ports and 6 40Gb ports which can be configured as 4x10Gb ports, which is in total 72 10Gb ports. ASR9010 and two C7606 will be replaced with 3 N5850-48S6Q, and since each ME3400 has only 16 ports all 5 ME3400 devices can be replaced with 2 N5850-48S6Q. Since whole IP/MPLS network had in total 294 ports, only five SDN switches will be enough for replacement. Each port has equal or higher bandwidth since every port on SDN switch is 10Gb port. Also, each N5850-48S6Q SDN switch has five fans. According to official specifications of N5850-48S6Q SDN switch, average energy consumption of each switch is 200W. Designed SDN topology must also include at least one controller, which can be installed on server with average power consumption of 500 W.

Finally, designed SDN topology contains five SDN switches and one SDN controller.

Designed SDN logical network topology is presented in Fig. 3. where solid lines represent the data links between the switches and the dashed lines represent the links between switches and controller.

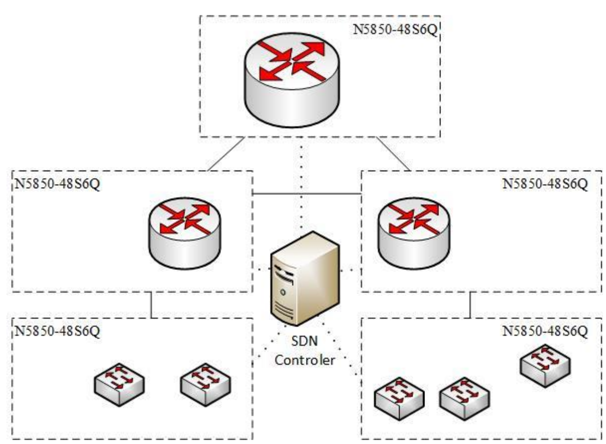

Fig. 3. SDN logical network topology

Designed SDN physical network topology is presented in Fig. 4.

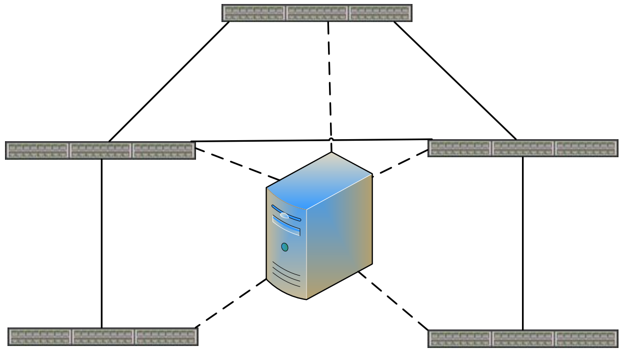

Fig. 4. SDN physical network topology

Maximum energy consumption of considered SDN network is presented in Table II.

TABLE II
ENERGY CONSUMPTION IN SDN NETWORK

Device	Number of ports	Energy Consumption
N5850-48S6Q	72	200 W
N5850-48S6Q	72	200 W
N5850-48S6Q	72	200 W
N5850-48S6Q	72	200 W
N5850-48S6Q	72	200 W
Server with controller	\	~ 500 W
Entire SDN network: 1500 W		

In total, IP/MPLS network has eight different devices, 8 TCAMs, 21 line cards, 9 fans, 264 Gb Ethernet ports and 30 10Gb ports. Measured energy consumption in whole IP/MPLS is 6974 W.

On the other hand, alternative SDN network is designed with one controller and five SDN switches. Designed SDN network has one server with installed SDN controller, five network devices, 25 fans and 360 10Gb ports. According to official specifications of N5850-48S6Q SDN switch, maximum energy consumption of each switch is 200W, and one server consume on average 500W. In total, designed SDN network consumes on average 1500 W.

When compared to existing IP/MPLS network, designed SDN network has a higher number of ports with higher bandwidth but at the same time has almost five times lower energy consumption. This confirms the idea that replacement of traditional IP/MPLS routers with SDN switches could bring substantial energy savings.

IV. CONCLUSION

Transition to SDN is the clear objective for service providers and enterprises, enabling them to keep pace with business demands. This transition would require time and preparation and a substantial amount of money on new equipment, so it is more likely to have a hybrid network by selectively adding SDN equipment while minimizing the disruption to service.

The most likely scenario of transition to SDN is a scenario in which legacy and SDN hardware and protocols are coexisting. In order to prove energy efficiency in SDN network, we compared energy consumption in non-SDN, real, IP/MPLS network and alternatively designed SDN network. SDN consume less power than traditional and MPLS (same generation) routers because SDN devices only have a data plane and do not calculate the route. This computation is done centrally. The overall power consumption is lower because the devices work less. This is a consequence of SDN and this example was used to show that concrete savings canbe achieved in the real system. Average energy consumption of SDN network was more than four times lower than average energy consumption of IP/MPLS network. This is the simplest form of savings that SDN can bring with the simple replacement of boxes. SDN controllers could be made energy aware. This awareness could enable them to use energy more efficiently by shutting down unnecessary interfaces and cards in SDN switches. This will be the next step in our research.

ICT itself produces greenhouse gases mainly due to energy consumption. Therefore, ICT industry, policy makers and community need to support work on minimizing energy consumption. It is up to us to choose the share of ICT global electricity usage. SDN seems to be the right direction.

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