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ENERGY EFFICIENCY ANALYSIS OF SOFTWARE DEFINED NETWORK IN BACKBONE TRANSMISSION NETWORK OF KATHMANDU VALLEY OFNEPAL TELECOM

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Abstract

In the past, research scope of the ICT (Information and Communication Technology) was mainly based on performance and cost. The research community put insufficient effort to the energy consumed by ICTs and their impact on the environment. Current trends, such as increasing electricity costs, reserve limitations, and increasing emissions of carbon dioxide (CO_2) are shifting the focus of ICT towards energy-efficient and well-performed solutions. Communication networks designed according to this energy efficiency criteria are called green networks. In this context, SDN architecture can have a significant role in reducing the energy consumption by decoupling control plane to a centralized controller that has global view of all underlying data plane devices. The research will be focused on energy efficiency analysis of Software Defined Network and financial possibilities for migration into SDN using LEAP taking the case study of Nepal Telecom's backbone transmission network in Kathmandu region.

Keywords: *Energy Efficiency, Software Defined Network (SDN), Open Flow*

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1. Background

The development of internet and ICT (information-centric technology) advances including mobile, cloud, social networking, big data, IoT (Internet of Things), multimedia and the tendency towards digital society, global IP traffic demand is increasing tremendously in recent years. Annual global IP traffic will surpass the zettabyte (1 ZB equals 1000 exabytes [EB]) threshold in 2016 and will increase nearly threefold over the next five years, and will have increased nearly 100-fold from 2005 to 2020[1]. Overall IP traffic will grow at a compound annual growth rate (CAGR) of 22 percent from 2015 to 2020[1]. With such increasing order of internet traffic, the management and configuration of networking devices have become complex, challenging and time consuming for service providers. Traditional network architectures are ill-suited to meet the requirements of today's enterprises, carriers, and end users. According to Open Network Foundation (ONF) – an organization formed to promote SDN (Software Defined Network) – conventionally operated networks face the following challenges [2].

i. **Device Configuration Costs**: The individual and often manual configuration of network devices impedes the swift provisioning of dynamic services. The configuration process cannot keep up with on-the-fly changes required by modern applications and does not scale with the requirements.
ii. **Vendor Dependence:** ISPs are dependent on the hardware of vendors when providing new services. This vendor lock-in may also increase the cost to make changes to the current setup.
iii. **Configuration Complexity:** The complexity increases the risk of implementing inconsistent policies, as configuration tools are device centric and require network operators to configure a large number of network nodes.
iv. **Customization costs:** It is difficult to achieve individual customization with manual configuration in large-scale service provider networks.

v. **Labor costs.** Customized solution for network configuration require a significant number of engineers to run these systems. This large scale human intervention in the manual configuration process results in higher OPEX
vi. **Over provisioning:** Inefficient use of network resources requires over-provisioning which leads to higher CAPEX to meet customer demands.

For solving the problems and limitations of traditional networks, a structure, known as SDN, was purposed which basically has 4 features [3]

- Separation of control plane and data plane
- Logically centralized control
- Open interface
- Programmability

SDN uses a controller which is logically centralized and has a global view towards the network and several simple packet forwarding devices (SDN switches) are controlled and configured through interfaces such as ForCES and OpenFlow. In other words, SDN switches are controlled and programmed in the controller (control plane). According to the policies implemented in the centralized controller, SDN switches can operate in the same way as Router, Switch, NAT, Firewall etc. Splitting control plane and data plane simplifies the management of modern networks and provides the opportunity for more innovations.

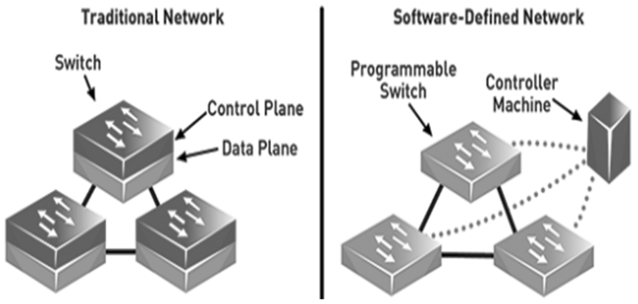


Fig. 1: Generic view of SDN and Traditional Network

Generic view of SDN architecture is shown in figure 1.1.2, where one SDN controller can control multiple SDN switches (data plane devices), but any two controller cannot control the same SDN switch as it is a conflict of interest. However controllers are normally deployed in 1+1 redundancy to ensure service availability in case of failure of one controller. How many SDN switches a controller can control depend on SDN switches capacity in data plane, number of Fig. 1 requests that a controller should handle per second, and the capacity of the controller. Controller is a software application installed on a high performance computing machine whose capacity mainly depend on its processing speed (processor) and physical memory (RAM). Since control plane is the main power consuming unit in a traditional switch, using a single controller for multiple switches lowers the power consumption of entire network.

Apart from the aforementioned issues with traditional network architecture, another inefficiency of the conventionally operated current networking technology is the high amount of energy it consumes. Current networks are inefficient both environmentally and economically (i.e. CO_2 emission, operational costs, etc.) and hence they should be reconfigured with some new architecture. In the past, research scope of the Information and Communication Technology (ICT) was mainly based on performance and cost. The research community put insufficient effort to the energy consumed by ICTs and their impact on the environment. Current trends, such as increasing electricity costs, reserve limitations, and increasing emissions of carbon dioxide (CO_2) are shifting the focus of ICT towards energy-efficient and well-performed solutions[4]. Even though governments and companies are now aware of the massive carbon emissions and energy requirements, it is obvious that carbon emissions and the amount of energy consumption will continue to increase [5]. In 2007, the total footprint of the ICT sector – including personal computers (PCs) and peripherals, telecoms networks and devices and data centers – was 830 $MtCO_2e$, about 2% of the estimated total emissions from human activity released that year [6]. As stated by the SMART 2020 study[6], ICT-based CO_2 emissions are rising at a rate of 6% per year. With such a growth ratio, it is expected that CO_2 emissions caused by ICTs will reach 12% of worldwide emissions by 2020.

Driven by so many benefits, network is moving towards SDN as SDN project is now funded by major network operators, vendors, system integrators and more (including AT&T, NTT, China Unicom, Cisco, Juniper, Huawei, Intel, NEC, Nokia, Samsung, FUJITSU, ERICSSON, Google, Facebook, Microsoft etc.) from around the globe. SDN deployed in Google to interconnect its data centers across the globe is helping the company to improve operational efficiency and significant reduction in operational cost [7].In this context energy efficiency analysis of SDN and identification of financial possibilities for migrating from current network to SDN are prerequisites for any operator to consider. The research will be focused on energy efficiency analysis and financial possibilities for migrating existing network into SDN taking the case study of Nepal Telecom's backbone transmission network in Kathmandu region.Findings from this research can be a valuable reference for any network operator who are willing to migrate into SDN.

2. Energy Efficient Routing Algorithm

The shifting of focus of ICT towards energy-efficient and well-performed solutions (commonly known as green networking) in recent years has purposed numerous solutions. Most of these work can also be adapted in SDN concept. [8]has presented an analytical model that compares the trade-offs between network performance and energy saving. Using Adaptive Rate (AR) and Low Power Idle (LPI) transmission technique authors have created their analytical model that minimizes the power consumption subject to latency and loss probability constraints. Their optimized model allows energy saving roughly about 16-17% in comparison to the fixed configuration scenario. Adapting these green networking solutions in SDN can give even more energy saving as there will be a single controller for multiple data plane devices.

[9] aims to improve the energy efficiency of backbone network by dynamically adjusting the number of active links according to network load. Using SPRING (Source Packet Routing in Networking) protocol, i.e. segment routing this paper has mentioned about 44% energy saving when considering real backbone network. SPRING protocol (RFC 7855) aims to replace MPLS + RSVP-TE for traffic engineering. It combines the power of source routing, allowing for flexible traffic engineering and specify a forwarding path other than the normal shortest path that a particular packet will traverse. The data plane used by SPRING utilizes the same concept of label switching of MPLS, but its control plane has been completely redesigned. The distribution of labels is done via an extension to the IGP instead of using special protocols such as LDP/RSVP-TE.

The work in [10] aims to optimize energy consumption in SDN and has purposed a Strategic Greedy Heuristic algorithm which can save upto 45% energy saving especially at night time

GreenSDN is another approach purposed by [11] to achieve energy efficiency in SDN, which integrates three different protocols that operate at different layers of the network: Adaptive Link Rate (ALR), which is a chip-level protocol, Synchronized Coalescing (SC), which is active at node-level, and Sustainability-oriented Network Management System (SustNMS), which operates at network level. ALR works on links and changes data rates according to the traffic load of the network, whereas SC protocol works as LPI (Low Power Idle). However, while LPI works on individual parts of the network devices, SC can put a whole device into the idle mode. SustNMS controls the network and balances the trade-off between QoS and energy efficiency to quickly respond to changing traffic patterns. The work makes use of Mininet as the emulation tool and POX as the controller. In addition, since it is important to control the QoS, check the efficiency of the traffic engineering, and compute the expected amount of energy consumption, authors also exploit OpenFlow protocol tools for network monitoring.

Another approach is Exclusive Routing (EXR) to improve fair-sharing routing (FSR), which is a common routing method for fair allocation of nodes and links. FSR selects a subset of links and uniformly spreads flows across the links without any delay. However, this behavior indicates that all links work with less than full capacity, lower than 55% of its full capacity[12]. In this context, the paper claim that efficient use of already activated links, i.e. full use of their capacity, and turning off more switches will decrease energy usage even more. Thus, the main idea is to eliminate low utilization of links and switches.

The work in [13] authors purposes a Correlation-Aware Power Optimization Algorithm (CARPO), which consolidates traffic flows by eliminating unnecessary link to decrease energy consumption. Authors implemented hardware test-bench consisting of 10 48-port OpenFlow Switch and 8 servers. The empirical result showed that CARPO leads to high amount of energy saving (upto 47%) and a limited increase in delay.

3. Software Defined Network Migration Use Cases

3.1 Case Study of Google

Google's datacenter-to-datacenter WAN successfully runs on an SDN and OpenFlow enabled network. It is the largest production network at Google. SDN and OpenFlow have improved manageability, performance, utilization and cost efficiency of the WAN [14].

3.2 Case Study of NTT, Japan

Nippon Telegraph and Telephone Corporation, commonly known as NTT, is a Japanese telecommunication company. Ranked 60th [15] in 2016, NTT is the fourth largest telecommunication company in the world in terms of revenue. The case study of NTT in particular for the migration into SDN can be a prototype and good reference for other telecom operators who are willing to migrate into SDN. Using mixed environment or ships in the night model approach NTT has migrated its edge network into SDN. The edge node can be any OpenFlow capable switch. NTT used an OpenFlow switch on the edge based on the Open vSwitch (OVS) and home-grown OpenFlow controller running overRyu[16].

4. Research Methodology

The calculation and analysis of energy efficiency of the communication network involve a set of procedure starting from data collection to final scenario analysis as outlined in the following flowchart (Fig. 2). Energy consumption in existing conventionally operated scenario and that of after migration into SDN will be analyzed using LEAP (Long Range Energy Alternative Planning System).

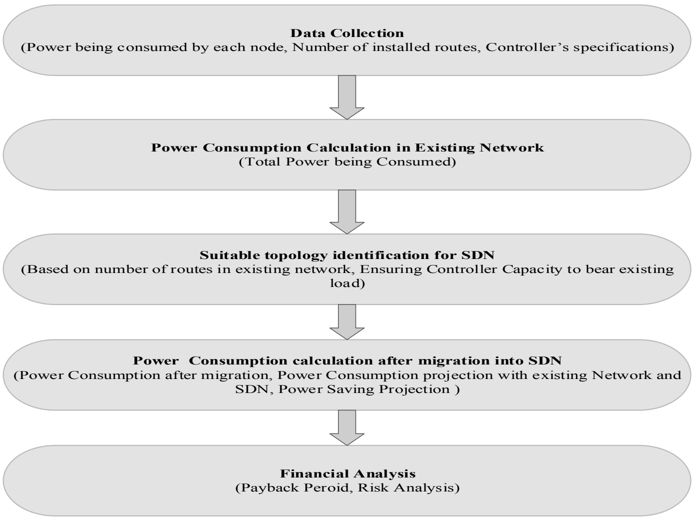
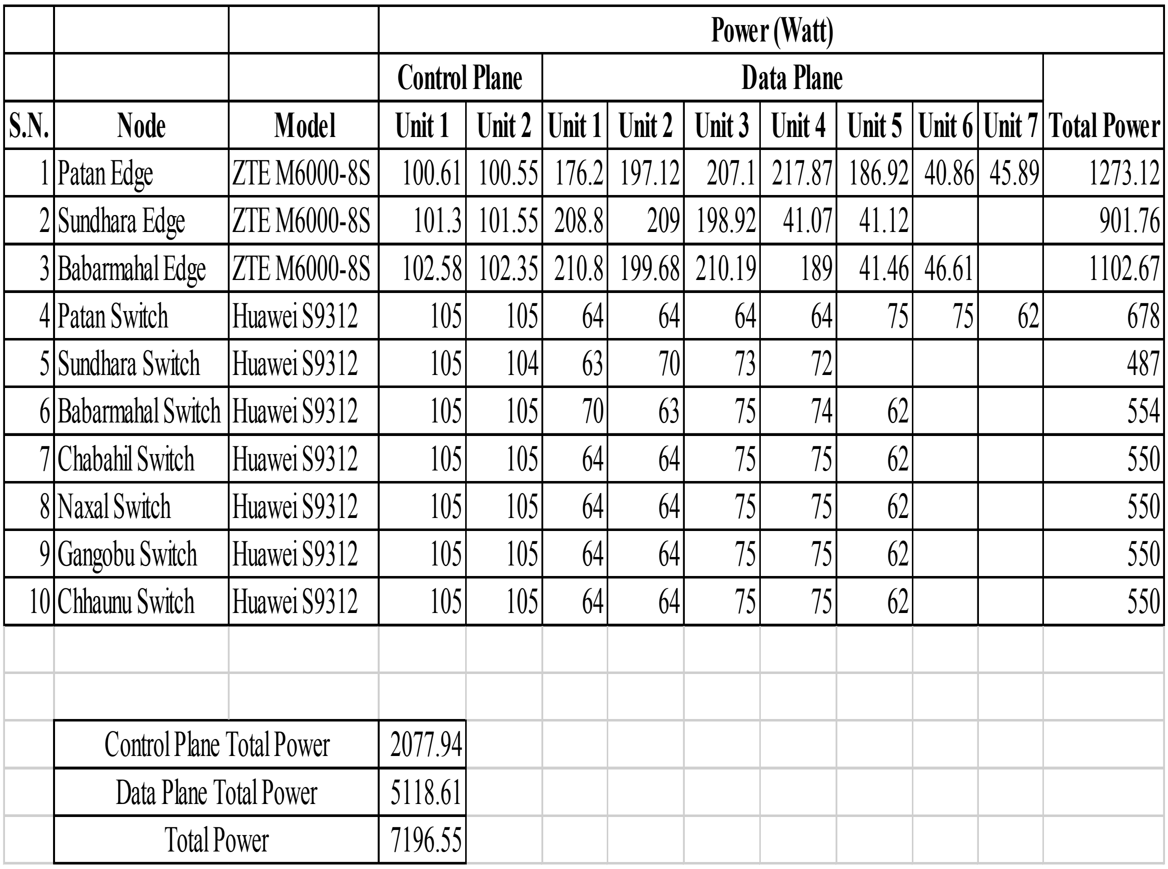


Fig. 2 Procedure to be Followed

4.1 Data Collection

By logging into individual equipment (Router and Switch), power consumption data are extracted. Power consumed by each module under control plane and data plane are extracted, summed up to find the total power consumed by individual equipment as shown in Table 4.1.1.

Table 4.1.1: Existing DC Power Consumption status (extracted on July 16, 2017)



			Power (Watt)									
			Control Plane		Data Plane							Total Power
S.N.	Node	Model	Unit 1	Unit 2	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	
1	Patan Edge	ZTE M6000-8S	100.61	100.55	176.2	197.12	207.1	217.87	186.92	40.86	45.89	1273.12
2	Sundhara Edge	ZTE M6000-8S	101.3	101.55	208.8	209	198.92	41.07	41.12			901.76
3	Babarmahal Edge	ZTE M6000-8S	102.58	102.35	210.8	199.68	210.19	189	41.46	46.61		1102.67
4	Patan Switch	Huawei S9312	105	105	64	64	64	64	75	75	62	678
5	Sundhara Switch	Huawei S9312	105	104	63	70	73	72				487
6	Babarmahal Switch	Huawei S9312	105	105	70	63	75	74	62			554
7	Chabahil Switch	Huawei S9312	105	105	64	64	75	75	62			550
8	Naxal Switch	Huawei S9312	105	105	64	64	75	75	62			550
9	Gangobu Switch	Huawei S9312	105	105	64	64	75	75	62			550
10	Chhaunu Switch	Huawei S9312	105	105	64	64	75	75	62			550

Control Plane Total Power	2077.94
Data Plane Total Power	5118.61
Total Power	7196.55

By calculating the efficiency of rectifier being used, considering total AC load and total DC load, as 90.15%, AC Power consumption is calculated in Table 4.1.2.

Table 4.1.2: Total AC Power Consumption Status

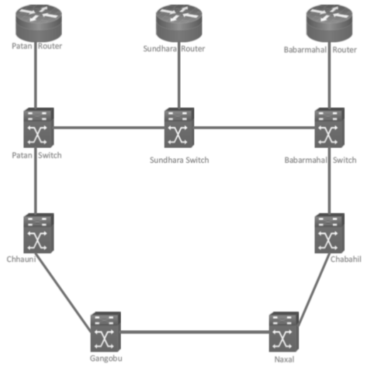
	Power (watt)			**Annual Energy (MWH)**		
	Control Plane	**Data Plane**	**Total**	**Control Plane**	**Data Plane**	**Total**
DC Power	2077.94	5118.61	7196.55	18.20	44.84	63.04
AC Power	2304.98	5677.88	7982.86	20.19	49.74	69.93

4.2 Suitable Topology for SDN

This basically involve finding number of controllers to be used to control all the equipments in data plane. Routers and switch in existing network forward traffic by looking routing table and MAC table. In SDN forwarding devices forward traffic by looking into flow table installed by the controller. So in this regard, routing tables in existing network are equivalent to flow tables in SDN. Table 4.2.1shows the number of routes on existing routers and switch. Considering the number of routes in existing network and the capacity of SDN controller, a single controller is sufficient to handle all the data plane devices (10 nodes) in our network of study. However, for redundancy purpose 1+1 architecture of controller is purposed. The network giant cisco has recommended hardware specification for controller as Intel quad-core (4-core) processor with 16GB RAM and 64 GB disk space [17] for controlling maximum of 100 data plane devices. Other vendors of SDN controllers has also similar requirements. So the purposed topology of SDN for this network will consists of 2 controllers (control plane devices) and 10 OpenFlow switches (data plane devices) as shown in Fig 4.

Table 4.2.1: Total Number of routes in Routing table

S.N.	Node	Model	No. of Routes
1	Patan Edge	ZTE M6000-8S	5966
2	Sundhara Edge	ZTE M6000-8S	14226
3	Babarmahal Edge	ZTE M6000-8S	17456
4	Patan Switch	Huawei S9312	4691
5	Sundhara Switch	Huawei S9312	3384
6	Babarmahal Switch	Huawei S9312	3487
7	Chabahil Switch	Huawei S9312	2077
8	Naxal Switch	Huawei S9312	3486
9	Gangobu Switch	Huawei S9312	3369
10	Chhaunu Switch	Huawei S9312	1994
	Total Routes		**60136**



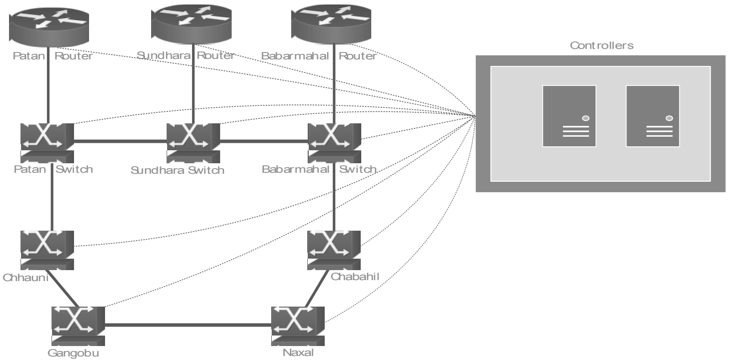


Fig.3 Existing Network Fig. 4 Proposed SDN Architecture

4.3 Energy Consumption After migration

If Dell PowerEdge T430 server with 2.2 GHz decacore processor and 16 GB RAM were used as controllers than the total maximum power consumed by two controllers would be 900 watt[18].So the power consumption by control plane and data plane in conventional and SDN architecture would be:

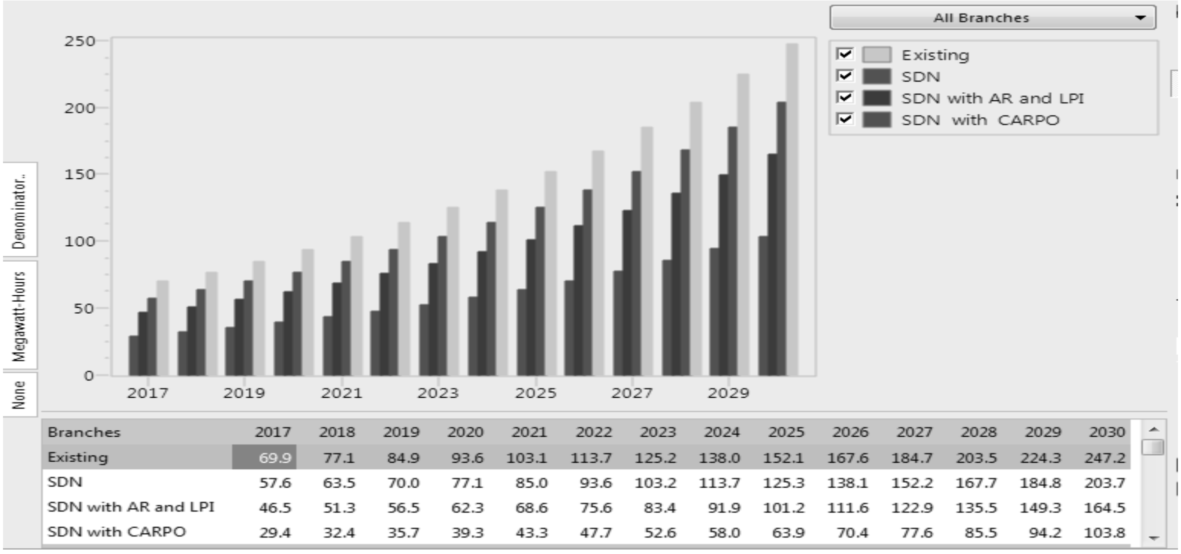
Table 4.3.1 Conventional and SDN Network Power Consumption

	Power (watt)			**Annual Energy (MWH)**		
	Control Plane	**Data Plane**	**Total**	**Control Plane**	**Data Plane**	**Total**
Conventional	2304.98	5677.88	7982.86	20.19	49.74	69.93
SDN	900.00	5677.88	6577.88	7.88	49.74	57.62
Annual Energy Saving (MWH)						12.31

Data plane devices' job is same in both traditional and SDN architecture. So from the energy consumption perspective they are more or less same. However the control plane in SDN is centralized for multiple routers and switches and hence SDN control plane is more efficient from energy consumption perspective.

4.4 Energy Demand Projection

The estimated annual growth of energy consumption by telecom sector is 10.2% worldwide which is a lot more than the overall consumption of around 3% [19]. In developing countries like Nepal this growth rate is even higher than the world average rate. However the 10.2% of global rate is considered for the projection of energy consumption from base year 2017 to 2030 using LEAP.A reference scenario of 10.2% annual energy demand increment has been created in LEAPand the result is shown in Fig. 5.



Branches	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing	69.9	77.1	84.9	93.6	103.1	113.7	125.2	138.0	152.1	167.6	184.7	203.5	224.3	247.2
SDN	57.6	63.5	70.0	77.1	85.0	93.6	103.2	113.7	125.3	138.1	152.2	167.7	184.8	203.7
SDN with AR and LPI	46.5	51.3	56.5	62.3	68.6	75.6	83.4	91.9	101.2	111.6	122.9	135.5	149.3	164.5
SDN with CARPO	29.4	32.4	35.7	39.3	43.3	47.7	52.6	58.0	63.9	70.4	77.6	85.5	94.2	103.8

Fig.5 : Energy demand projection with existing and SDN technologies

4.4 Financial Analysis

The cost of projected energy and saving of projected energy with respect to existing system, assuming the current tariff of electricity -NRs 11.20 per kilowatt-hour remains constant, from base year 2017 to end year 2030 is shown in figure 6 and 7.

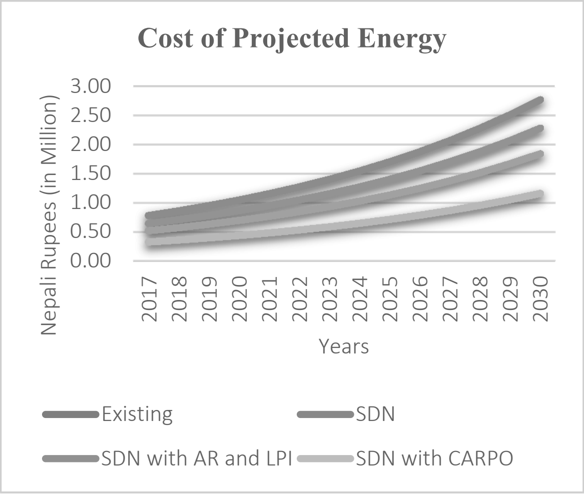


Fig. 6: Cost of Projected Energy

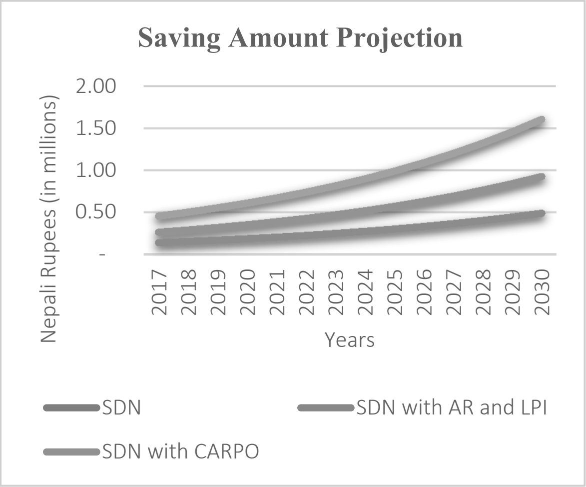


Fig.7: Saving amount Projection

5. Conclusion

Amount saved by SDN architecture due to their low energy demand is not much high, this only cannot bear the cost of migration into SDN. Existing devices cost lies in the range of 1 million NRs per node. SDN systems are even more expensive as it is a very new paradigm and mass production of SDN devices are on the way. Currently there are very few vendors that produces SDN systems suitable for Internet Service provider and Telecom service provider network. Payback period will be not acceptable to bear the cost of more than 10 million with saving of few lakhs per annum. However there are other benefits of SDN also that is motivating operators to migrate into SDN.

Normally the operational period of routers and switches are around 10 years, after which they need to be replaced/upgraded. This is because of the fast growing internet traffic. Older devices cannot meet the contemporary demand of high volume internet traffic. The manufacturers of the company normally provide support for a certain number of years after which they are not liable to provide any hardware or software support. As an option operator can make migration plan when these equipments are to be replaced. This would be a better option for Nepal Telecom.

In order to make the migration financially viable, this work has recommends the migration into SDN when the lifetime of existing devices expire or when these devices need to be replaced. This way the migration cost will be lower and the company can enjoy the benefits of low energy demand of SDN equipments in addition to low migration cost, low CAPEX and low OPEX.

References

1. cisco, *"Cisco VNI global IP traffic forecast,"* June 2016. [Online]. Available: http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.html.
2. ONF, *"Software Defind Networking: The New Norm for Networks, white paper,"* Open Networking Foundation, 2012.
3. IPKnowledge, *"Traditional vs Software Defined Network, white paper,"* March 2017. [Online]. Available: www.ipknowledge.net.
4. M. F. Tuysuz, Z. K. Ankarali and D. Gozupek, *"A Survey on Energy Efficiency in Software Defined Networks," Elsevier,* 2016.
5. S. Zeadally, S. Khan and N. Chilamkurti, *"Energy-efficient networking: past, present, and future,"* The Journal of supercomputing, 2012.
6. The Climate Group, *"Smart 2020,"* 2010. [Online]. Available: http://gesi.org/article/43.
7. S. Jain, A. Kumar, S. Mandal, J. Ong, L. Poutievski, A. Singh, S. Venkata, J. Wanderer, J. Zhou, M. Zhu, J. Zolla, U. Holzle, S. Stuart and A. Vahdat, *"Experience with a globally-deployed software defined network,"* SIGCOMM Comput. Commun., 2013.
8. R. Bolla, R. Bruschi, A. Carrega and F. Davoli, *"Green network technologies and the art of trading-off,"* Computer Communications workshop, IEEE Conference, 2011.
9. R. Carpa, O. Gluck and L. Lefevre, "Improving the energy efficiency of software-defined backbone network," *Springer, New York,* 2015.
10. A. Markiewicz, P. N. Tran and A. Timm-Giel, *"Energy consumption optimization for software defined networks considering dynamic traffic,"* IEEE, 2014.
11. B. B. Rodrigues, A. C. Riekstin, G. C. Januario, V. T. Nascimento, T. C. Carvalho and C. Meirosu, *"GreenSDN: Bringing energy efficiency to an SDN emulation environment in Integrated Network Management,"* in IEEE International Symposium, 2015.
12. D. Li, Y. Shang and C. Chen, *"Software defined green data center network with exclusive routing,"* in INFOCOM, 2014 Proceeding IEEE, 2014, 2014.

13. X. Wang, Y. Yao, X. Wang, K. Lu and Q. Cao, *"Carpo: Correlation-aware power optimization in data center networks,"* IEEE, 2012.

14. 2012 Google Inc., July 2017. [Online]. Available: https://www.opennetworking.org/images/stories/downloads/sdn-resources/customer-case-studies/cs-googlesdn.pdf.

15. Fortune, *"Fortune global 500,"* December 2017. [Online]. Available: http://fortune.com/global500/.

16. Open Networking Foundation, *"SDN Migration Considerations & Use Cases,"* December 2017. [Online].

17. cisco, *"Cisco Open SDN Controller 1.2 Data Sheet, Document ID:1472577934190228,"* August 2017. [Online]. Available: https://www.cisco.com/c/en/us/products/collateral/cloud-systems-management/open-sdn-controller/datasheet-c78-733458.html.

18. Dell, *"Dell Inc.,"* August 2017. [Online]. Available: http://www.dell.com/en-us/work/shop/cty/pdp/spd/poweredge-t430.

19. S. B. P. Nischal Regmi, *"An Insight into ICT's Energy Consumption and its Implications,"* Martin Chautari, The Fourth Annual Kathmandu Conference on Nepal and Himalaya, 22-24 July,2015, Kathmandu.