AttentiveSDN:
EndHost Awareness-Based Power-Optimized Software-Defined Networks

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ABSTRACT

Internet users are increasing day by day due to its support for many applications and creation of innovative services. Along with this, energy consumption is also becoming an important concern in networking. Several researchers have investigated energy saving schemes for networks. Software-defined networking (SDN) is an excellent choice that improves network functionalities with flexible management aided by centralized control. Recent studies designed efficient algorithms for advancing SDN with overall energy savings. Shutting down idle links and switches are among numerous solutions available for SDN. In this paper, the authors proposed a novel algorithm named AttentiveSDN for reducing the energy consumption in SDNs. Here the controller collects the traffic and the link status from the switches involved in network operation and takes the decision to put which idle links and switches into sleep state. The authors evaluated the performance of the AttentiveSDN algorithm using Mininet. The result has shown that the proposed approach saves more power than existing solutions.

KEYWORDS

1. INTRODUCTION

A lot of researches have been conducted in order to save battery energy in a wireless network as its battery power is limited in nature. In order to maximize network lifetime energy expenditure of the wireless network should be minimized. Now a day's researchers put their attention in wired network also to minimize the energy utilization of the whole network (Molina et al., 2018). Software Defined Networking (SDN) is an important name in the field wired network. The popularity of SDN network

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is due to its separation of control and data plane of the network. It provides the application with an abstracted distributed state in a centralized manner. Figure 1 (a) and Figure 1(b) are illustrated the traditional network and general architecture of SDN respectively. This unique characteristic of controlling the network centrally has attracted many companies such as Amazon, Google, Microsoft *etc*. to deploy SDN network as its backbone network.

The three-layer structure of SDN architecture has shown in Figure (2). With the rise in popularity of this network energy consumption of this network is also increasing at an alarming rate (Jia et al.,2018). The energy consumption puts a serious limitation on SDN. The internet energy consumption is almost 10% of the total energy consumption of the world (Assefa et al.,2015) There are many reasons to focus on energy saving characteristics of wired networks like SDN. The former one is due to environmental alertness. This is a global alarming and pressure from both political and social points. Another reason is due to the tremendous growth of internet traffic, which is increasing rapidly every year. To increase in internet traffic there is also an incremental growth of network energy consumption. Therefore, this terrific amount of energy consumption is not only an issue as per the environment or society is considered, but also it is frightening due to rapid growth and popularity on the internet, due to energy requirement for running of the network equipment and heat dissipation in data centers. The amount of energy consumption in 2010 is estimated as 21.4 TWH in European Telecom by Global E-Sustainability Initiative. At the same time, it also forecasts that the figure of energy consumption in 2020 as 35.8 TWH if no initiatives for power savings is taken into consideration (Webb et al.,2008).

Unlike wireless network, in wired networks, there is no burden on the networking components, to find out the route(Sahoo et al.,2016; Bhushan & Sahoo, 2018 ; Bhushan & Sahoo, 2019 ; Bhushan & Sahoo, 2020). Each router and switch in wired network are connected with the links. In order to construct a fully robust network link bandwidth and redundancies are adopted. Which result in more power consumption of the link. It is observed in wired link that whether the link is idle or fully utilized the amount of energy spent in the link is same. Energy consumption in the switch is not relative to the utilization of its links, which implies that energy consumption in the switch has no relation with incoming traffic in the network. In the network it is found that almost all the switches are active at all time, but only 40% of the link capacities is used, whereas by turning off the unutilized switch and its corresponding links can save most of the network power. A switch consumes most of its power when it is on, whereas in the transition period from idle state to fully utilize will consume only 8% of power (Bista et al.,2014). Therefore, to save the maximum amount of energy in the network proper power measures must be taken in order to identify the unutilized links and switches and making them turn off. Energy savings can be achieved in a precise manner by controlling the flow table of the forwarding path from the controller. It is also observed that in wired network energy consumption is more with high link speed. Energy consumption of 1 Gbps Ethernet link uses 4W more than 100 Mbps link.

**Figure 1. (a) Traditional Networking, (b) Software Defined Networking**
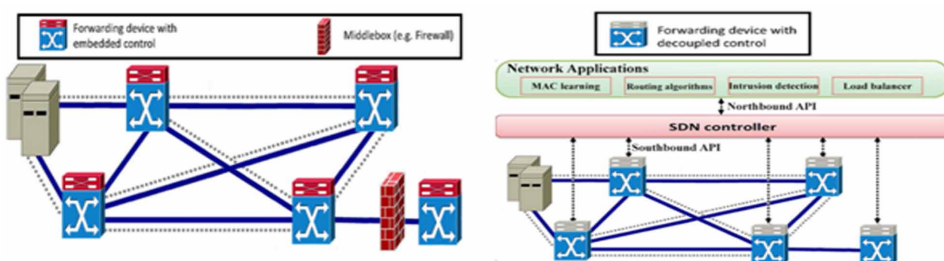
By considering all the characteristics of wired network like SDN to save energy in maximum amount proper care should be taken for underutilized links and network device. There are different methods proposed either to switch off unutilized network devices or varying the link speed as per the traffic volume. In both the cases the input traffic volume should be measured at the first. Based on which the decision can be taken to shut down the unutilized links or decrease the link speed such that there is no adverse effect on the network performance. (Zhu et al,2016) have discussed the energy saving techniques using rate adaptation technique in .

This article discusses the techniques to achieve energy savings with the end host awareness. This article proposed one approach for the achievement of energy savings by carefully monitoring the end devices to select when to turn off based on the incoming traffic.

The article is organized as follows. The Background and the Motivation is discussed in section 2. The related work in explained section 3. the system description is depicted in section 4. The energy saving algorithms is discussed in section 5. The simulation results are presented in section 6. Finally, the conclusion is given in section 7.

Figure 2. General three layer structure of SDN architecture (Tuysuz et al,2017)
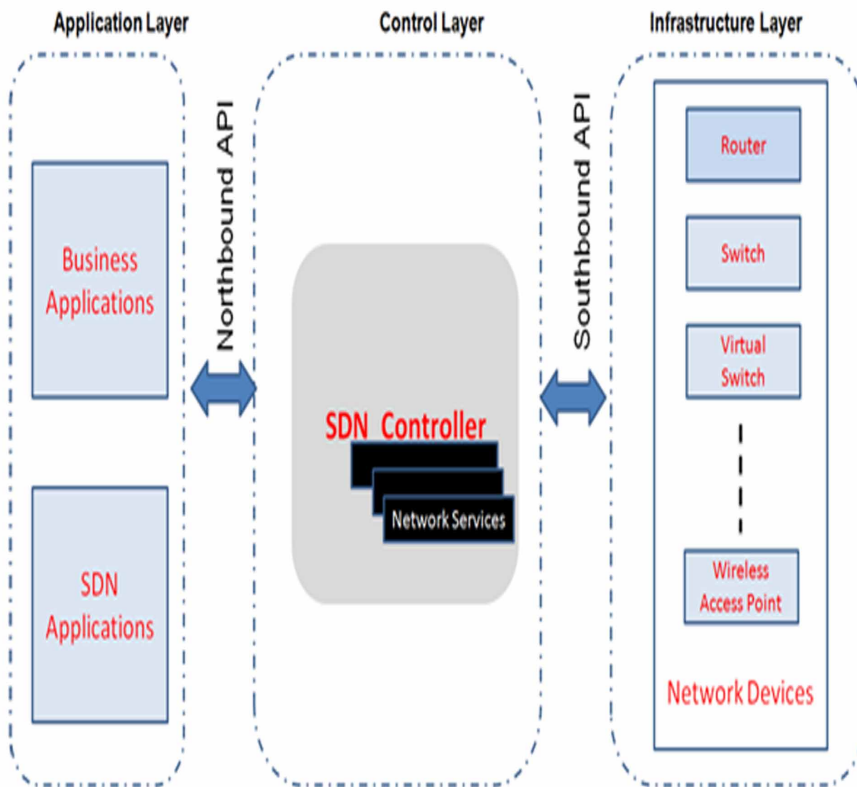
2. RELATED WORK

There are various energy aware approaches proposed by several researchers in the past several years. They put light on various areas. Gupta et al.,2007 have proposed an algorithm to find out the total inactive time period for the links. For energy saving purposes the links are decided to be powered off for those periods. They have not mentioned about the duration of sleep and also not considered the incoming traffic pattern.

Nedevschi et al.,2008 and Christensen et al.,2004 proposed power management approach in SDN to save a major amount of power by using the sleep state of end devices. Rout et al.,2018 in used rate of traffic flow that vary as per the incoming traffic status. In all these paper link utilizations is a vital parameter to take the decision regarding link usage. In SDN, right number of choices of switches and links can save energy to a certain amount. The switch or link consumes power at its maximum level when it is on provided there is not much to carry traffic. In order to overcome this problem and giving maximum energy efficiency Heller et al.,2010 proposed elastic tree. This concept is based on the selection of the right number of switches and links as per the traffic status. This is based on three-layer Fat-tree architecture.

Shang et al.,2010 proposed an approach for finding the route with the help of minimum number of switches in data centers. However, it introduces a delay in data transmission. This is a good solution for energy saving in data centers to meet the network demands for delay sensitive operation. However, this is not an acceptable one for delay insensitive operation. In (Li et al.,2014) for uniform distribution of network traffic author proposed FSR (Fair Share Routing) algorithm. It is based on the fact of equal sharing of load among all the switches and links involved in the network. Here a subset of links is selected, and the total traffic is uniformly distributed to avoid delays. But the link utilization is not 100% of its total capacity. Here the author assumed that full utilization of links and switching off idle links will increase energy consumption. The controller manages whole processes. Thus, the proposed one is not suitable in the condition of faults and challenges to normal operation.

In several literatures, it has been observed that green networking is extensively studied, and numerous solutions are proposed and implemented. SDN is adopting most of the concept. For example, the authors in (Bolla et al.,2011) have depicted an analytical model which compares the trade-offs between energy saving and performance of the network. Their models are adaptive in nature and they use Low Power Idle (LPI) and Adaptive Rate (AR) techniques for transmission and performance as well as standard power levels of Advanced Configuration and Power Interface (ACPI). As per the study the authors described, packets are transmitted in the medium for a longer time using the AR. However, LPI causes a retard, as there is a need for the system to frequently go into the sleep mode or to the wake-up mode. LPI also causes in the increase in burstiness of the traffic medium because of the similar sleep mode or wake-up mode initiations. In a contrary, the AR try to be smoothing the traffic medium. Using these considerations and trade-offs, the authors have proposed the analytical model that minimizes the power consumption in accordance to latency and loss probability constraints. They evaluated the proposed model with a router having AR and LPI capabilities for constant power and with performance levels which shows that their proposed optimization model outperforms the different energy saving models of about 16 to 17% in comparison to the fixed configuration situations.

SDN has the following three classifiable functionalities: (i) Data and control plane separation (ii) Control unit managed centrally (iii) Network programmability strategy. In contrary Network Function Virtualization (NV), generates logical segments of an existing network by the logical division of the network at the flow level regardless of the programmability of the network. It makes a tunnel in the used network without physically connecting to the two domains, and therefore makes the management tasks of the network administrators. Though NFV is used widely for decades, NFV is one of new model which referred to put a network/service functionality on a tunnel by virtualization of various network functions.. In this way, the NFV tries to minimize the system and network deployment costs for services i.e., the firewall setup and the load balancing. The unique difference between SDN from

NFV is that SDN modifies the physical network whereas NFV are added virtual tunnels and functions to the physical network. In adverse to this, SDN is a unique concept to provision and manage the network. With the increase use of mobile and handheld devices, network operators require to offer new services and add to capabilities to meet the growing demands.

Currently implemented network systems as well as the devices used for are well specialized and is still firm to grasp the speed in change of the network environment. The mobile networking cost and the physical infrastructures cost of mobile systems are still very high physical resource sharing may be used to reduce the cost. But it is not preferred service by the mobile network operators because of lack of regulations by the regulatory authority(Naudts et al.,2012) . In this circumstance, authors demonstrated that the sum of the devices used in the network, related to the anticipated measure of the power consumption, will be decreasing in a scenario of SDN . Besides this, the cost needed for repairing as well as testing reduces, since networks are consisting of lesser number of devices. the separation of control and data plane in SDN and layer-based architecture enable dynamic network configurations, gives rise to number of energy aware new techniques. The following are the energy-efficient techniques in SDN:

2.1. SDN Approach for Energy-efficient Flow-control

In (Bolla et al.,2013) the authors have proposed green abstraction layer (GAL), is one of the new traffic-aware energy-efficient SDN approach. GAL implants internal communication in between the network equipment to exchange power specified data, for e. g., the power consumption by a specified switch, a device or a state. Then the data is received by the controller and the controller incorporates real-time control schemes within networking devices. in GAL, Energy Aware States (EASs) are determined by logical attributes of the network (i.e. the ports, switches, actions on traffic flow, etc.), energy consumed by the point, such as at a particular state the energy consumption or at largest affirmed data rate. The information collected used by the energy Optimizer module takes the information on EASs and computes the best possible state for getting minimum energy. GAL comprises of three phases: such as discovery, provision and monitor. Discovery stage allows the controller to get information on power consumption for every attribute. Provision stage fixes the network nodes as per the optimal energy state based on the network.

After rearranging the state of the network, the monitoring phase has sent the processed information about the recent state. At last, Local Control Policies (LCPs) has optimized the choice between network performance and energy saving. It has also provided the energy efficiency and has managed the availability of resources in SDN framework. The authors in (Bolla et al.,2015) have proposed the management of the network system with the support of GAL (Markiewicz et al.,2014; Rodrigues et al.,2015). The proposed work in (Rodrigues et al.,2015) also tries to minimize the energy consumption in SDN framework. The authors have provided Mixed Integer Linear Programming (MILP) formulation and then proposed a Strategic Greedy Heuristic algorithm. In their proposed algorithm, it accesses the initial nodes of the traffic flows inform the rest of the nodes about their traffic load. In order to optimize the energy efficiency in SDN, authors in (Gunaratne et al.,2008) has presented Green SDN approach. It has integrated the three different protocols which have operated at different layers (Mostowfi et al.,2011; Li et al.,2014). In (Wang et al.,2014) authors have proposed Exclusive Routing (EXR) to improve Fair Sharing Routing (FSR), which is a general routing method for allocation. FSR has selected subset of links and spreads uniformly across the numerous links with no delay.

2.2. SDN Approaches for Energy-aware Data Center Networks

The recent advancement of IT technologies, including cloud computing, headed an enormous increase in the number of Data Center Networks (DCNs). The data centers are 7/24 available and bid whole time qualitative service experience and the situation consumes an overweening use of energy. In the year of 2018, DCNs have accounted for 5% of the global energy consumption with an economic impact of US $80 billion. Every year the expected rate of energy consumption grows dramatically as the hardware

expenditures in the data center are growing very rapidly (Gartner Group,2015) . DCN related surveys for energy-aware algorithms found in (Bilal et al.,2013; Bilal et al.,2014). A characteristic DCN is the home to thousands of hosts. It stores and manages many processors, cooling systems, thousands of networking equipment, power providers etc. All these parts need to be turn on for proper utilization of the network(Abts et al.,2012). On an account of decreasing the energy consumption by DCNs, it needs to minimize the power utilized by the servers and the other numerous networking equipment as these resources are the main reservoir of power consumption (Abts et al,2012)

2.3 Rule Placement Approach with TCAM SDN Technique for Energy-awareness

Authors in (Giroire et al.,2014) proposed a technique to carry out the rule space difficulty of existing energy-aware routing (EAR) techniques. EAR approach considers there is an infinite number of rule space and therefore an OpenFlow switch holds an innumerous number of rules. But the presumption is abstract in actual, because the implementation of the flow tables uses Ternary Content Addressable Memory (TCAM), which is very costly and need a lot of power in its implementation. The authors implemented the default rule to overcome the difficulty. In a routing procedure according to the research, if no predefined rule for a specific packet is there, the default rule is taken into consideration for the packet.

2.4. SDN Approaches for Energy-aware VM Placement

Energy Efficient with QoS aware VM Placement (EQVMP) (Wang et al, 2014) is a technique that develops energy saving techniques for the placement of VM's. The energy optimization placement of VM policies decreases the performance of the network. Aggressive bringing down of the usage of energy, traditional techniques of routing methodologies fails to determine the optimizing routes for flow networks. SDN overcomes this difficulty by the implementation of effective algorithms used for routing and necessary allocations for VM to acquire high throughput and low latency and so a qualitative network.

3. BACKGROUND & MOTIVATION

In the data center networks the energy consumption model woks as follows in which a great number of links are under utilized, which leaves rooms for more energy efficient approaches.

3.1. Data Center Networks: Energy Consumption Model

In data centre networks the power consumed by an active switch is comprised of the fixed components and the dynamic components. The fixed components of the power consumption comprises of fans, switching fabric, chassis etc., that consumes fixed power always whenever the switch is in working state. The ports include the dynamic components of the power consumption. The component which is in the active state consumes nearly full power has to be put into sleep state with negligible power consumption. As the energy consumed by a switch is not proportion to the load of the traffic (Mahadevan et al,2009) and since the dynamic component carries a large amount of power of the whole switch, a promising technique of the data centre network is to put the switches which are idle or components to enter into the sleep mode to save energy. IEEE 802.3az standard also recommends this (Law, 2014). Eq. (1) is used for calculating the maximum energy used in the network for the transmission of a collection of flows of data centre traffic. $S(i)$ and $P(i)$ represents the collection of the switches and the collection of ports in switch i, respectively. C_i represents the constant power need in switch i, d_i represents working length of switch i in active mode, $W_{i,j}$ depicts the power consumption by port j in switch i, and $x'_{i,j}$ depicts the working length of port j in active mode in switch i.

$$NE = (\sum_{i \in S(i)} C_i * d_i + \sum_{j \in P(i)} W_{i,j} * x'_{i,j}) \tag{1}$$

Many data centre networks have a homogeneous collection of switches to interlink servers. Let us consider all the switches consumes a constant power C and all of the ports having equal power consumption W. It can further assume that the bandwidth capability of each port is B. Then energy consumption by the whole network can be calculated as Eq. (2), here q_i and $q'_{i,j}$ are the combined traffic through the switch i and its port component j respectively, while A_i and $A'_{i,j}$ denotes the mean utilization ratio of the switch i and its port component j in the duration of transmission, respectively,

$$NE = C * \sum_{i \in S(i)} \frac{q_i}{A_i * B * |P(i)|} + W * \sum_{i \in S(i)} \sum_{j \in P(i)} \frac{q'_{i,j}}{B * A'_{i,j}} \tag{2}$$

From Eq. (2) one can conclude that the consumed energy in the network of data centre reduces promisingly by the increase in utilization ratios of the switches as well as ports/links those are in active state, while the idle switches/ports has to put in sleep mode. Therefore, for improving the utilization of active switches or links an efficient energy saving flow scheduling mechanism can be used.

3.2. Utilization of Switch/Link in Data Center Network

Figure 3 (a) and 3 (b) respectively describes the utilization of active switches and active links by a cumulative distribution graph. It shows that less than 5 percent switches or links are having zero utilization . Many switches and links are active having low utilization. Around 80% switches owns a utilization ratio less than 55%, and around 20% switches are having utilization ratio less than 40%. In case of links, the utilization of 80 percent links is below 65%, and around 24% links possess below 40% utilization. Less than 1% switches and below 10% links owns a utilization higher than 90%. The less utilizations of active switches/links come from prevented bandwidth contention among the flows. These flows moderately share the bandwidth of bottleneck links with TCP congestion control, and only fully utilize the bandwidth of the bottleneck links. In the meantime, many number of links are less utilized, which motivates us to think for efficient energy flow scheduling algorithms.

Figure 3. Cumulative distribution formulation (CDF) of active switch and link utilizations, (a) Switch utilization, (b) Link utilization (Li et al.,2014)
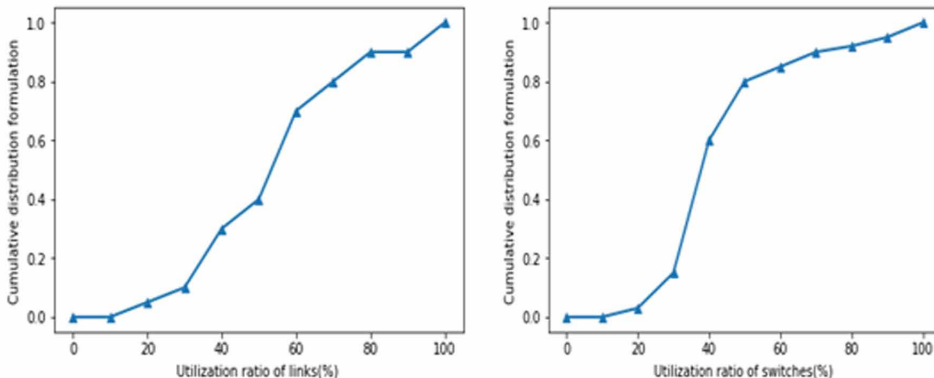
The efficiency of energy consumption can be accomplished through two different ways: (i) the rate of data transmission has to be increased, or it can say, the packet formation delay (the time necessary to push the bits of the packet to the wired or to the wireless medium) to be minimized and then the switches can go to sleep mode for a longer time and consumes minimum power within the network transmissions, or (ii) rate of data transmission can be minimized and hence lower energy consumption is acquired at the expense of larger data transmission times (Davoli,2013) . In counterpart, the network management by SDN, several components of the SDN construction can be set up dynamically for minimizing the energy consumption.

One of the ways is to put the flow as per the network traffic and by keeping the currently unused equipment in the network into the sleep mode. As there is a need of low network traffic load, without the complete device, some of the ports may be go into the sleep mode. The other technique can be used to minimize the energy is by optimizing or reducing the memory size used by forwarding switches as flow tables has to be store in Ternary Content Addressable Memory (TCAM), which in contrast is expensive and power-hungry. But, the reduction of TCAM may cause frequent flow entry replacements when there are new flows installed. Hence, as more accesses to TCAM consumes more energy, the algorithms should be designed in a way such that access to the TCAM must be as minimum as possible. Also, SDN controller places new rules of energy efficiency into the switches with some constraints, including number of switches and the routing policies. The controller in SDN aims to optimize the energy consumption also by the reconfiguration of new rules as per the system demand. Virtualization of the server is another method to reduce energy consumption by virtualizing multiple VMs on a same physical VM in a data center. Thus, without using many servers inefficiently, one physical machine can run many virtual machines and run several applications with the help of a hypervisor and save additional energy (Assefa et al.,2015).

4. SYSTEM DESCRIPTION

Energy saving is one of important factor in SDN. In wireless networks nodes are battery operated, and the battery is limited in nature. Energy saving is a big question in wireless networks as it may lead to network partition. This is a major issue in a wireless network as there is no means to improve battery power during network operation. In a wired network, though there is a constant power supply and no such fear of network partition due to plentily availability of power supply to the network. But from the point of the environment, energy expenditure in wired network is a more serious issue than wireless networks. SDN is known as intelligent wired network as here the network operation is controlled by a piece of software intelligently. The controller, which puts in the central part of the whole network is responsible for all the network management operation.

So, in SDN energy consumption issue can be degraded to a great extent with the help of energy efficient algorithm in the controller. As the controller decides the route of all incoming packets and the forwarding path, so the controller at the same time can decide the utilization of each node and link. The switch has no decision taking capabilities; it just acts as a forwarding device to forward the packet as per the instruction of the controller. Each switch is either in active state or sleep state. In active state the switch consumes maximum power, whether it is fully utilized or in idle state. But in sleep state this value is almost zero. All the links connecting more than one switches have the same power profile as a switch. The link consumes no power in idle state and maximum power when it is active. In active mode a link can be fully utilized or in idle state, but power consumption is same as per the active state. In this paper, it focuses on idle links and switches of the network in which the utilization is not at its maximum point. The energy saving mechanism is considered to put the idle links in, switch off state with a condition not to hamper the network related operation.

In this work, it calculates the link utilization using the formula:

$$U_{ij} = T_{ij} / (C_{ij} \times t) \tag{3}$$

Where U_{ij}=Link utilization for link between node i and j
T_{ij}=Total traffic through link ij in time t
C_{ij}= Link capacity of the link ij

In SDN the power consumption of link has no relation to the link utilization. Once any link is active means it is the cause of power consumption, no matter whether it is idle or fully utilized link. In order to save energy at its maximum level, it can put an idle link into power off state provided all the other network operation related to other components should not hamper. For making it convenient it assumes two threshold values for the link: sleep threshold sleep and awake threshold T_{awake}. From network experiments these two values will be set for each network. It will vary from network to network and time to time. For any link if the link utilization value is less than T_{sleep} then this link is considered as idle link. Though it is considered as an idle link, but it will not set to power off state if it is connected to the switch or it will cause network partition. On the other hand, if link utilization value is greater than that of T_{awake}, this means it is a fully utilized link and not a candidate for sleep. Depending on requirements the other links related to this fully utilized link must be active at all time as per network requirements.

The controller decides the route for all the incoming packets to the network. The routing table of a switch is updated as per the routing instruction given by the controller. Along with this the controller also requests all switches to send the status of the traffic and links connecting to the switch. From this information the controller prepares the statistics based on the incoming traffic to a switch and its corresponding link status. From the link status the controller makes the decision about the link whether it is idle or fully utilized.

Let us assume the network consists of a V number of nodes and E number of links. One node is connected to more than one link as per the network requirements and incoming traffic. To denote the power cost of a node it can use the notation P_u and for the link we use P_{ij}. Power is consumed only for the networking components, whether a link or a switch till the packet flows through it. It is denoted as $Time_{ij}$ for a link and $Time_u$ for a node. The binary variables x_{ij} and y_u denotes whether the link ij and node u are active respectively or not. The variable value 1 denotes that the link is active, otherwise it is 0. In a network the total energy consumption is calculated as given in equation 2.

$$Power - \cos t_{Network} = \sum Power - \cos t_{switch} + \sum Power - \cos t_{link} \tag{4}$$

In order to maximize energy savings of whole network the power consumption of link as well as switch should be minimum. So, the objective function is to minimize

$$Power - \cos t_{Network} = \sum_{L_{ij} \in E} Time_{ij} P_{ij} x_{ij} + \sum_{u \in V} Time_u P_u y_u \tag{5}$$

For any link, traffic load of a link denoted as f_{ij} should not exceed its link capacity C_{ij}. It is given in equation 4.

$$f_{ij} \le C_{ij} \tag{6}$$

For a switch, if it's interconnected links are decided to be powered off by the controller then the switch must be powered off. This is given by equation 5.

$$\sum_{k=1}^{n} x_{vk} \geq y_v \qquad\qquad (7)$$

Here x_{vk} denotes all the neighboring links of a node v.

For saving energy in a required amount, the controller needs to take powerful decision based on the statistics collected from switch profiles. The link can be either put in either switched off state or active state. This decision is based on two threshold values T_{sleep} and T_{awake}. If a link is decided to be switched off state, then new routing tables need to be updated by the controller at the switch. In the same manner if any link is decided to be powered on from power off state, then new routing tables are prepared using the new available links in the network. The same is intimated to the corresponding switches. For a node if all its connecting links are put to power off state, then the switch is decided to be in off state. Let us assume a network structure as given in Figure 4. Here the controller is connected to the end host devices (switches) as shown by the dashed lines. The links are represented by solid lines as indicated by the solid lines between the switches. As per the rule of SDN the controller updates the routing table of all the switches in the network depending upon the routing requirements. The controller collects the incoming traffic statistics from the switches and takes decision regarding links whether fully utilized or in idle state. The idle link is then put to sleep state provided it should not result in any network partition. Let's assume that in Figure 4 the link utilization value for link CA and GI are below T_{sleep}. But these two links if put to sleep state will do the partition of the network. Thus, these two links will never put into a sleep state.

Figure 4. SDN Controller connected to the host devices
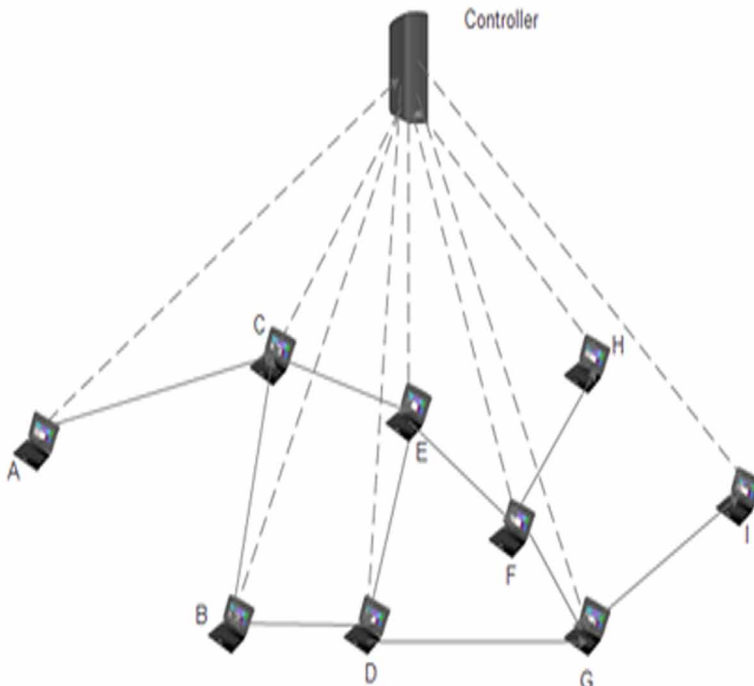
In the above network let link utilization for link DE and FG are found to be below T_{sleep}. There will be no network partition if these two links will put to sleep state. After the links DE and FG are put into sleep state the controller finds a new routing table excluding links DE and FG. These new routing tables are updated in the flow table of each switch by the controller. New routing paths from node C after excluding route DE and FG from node C are C-A, C-B, C-E, C-E-F, C-B-D, C-E-F-G, C-E-F-H, C-E-F-G-I. As per the new links added or old links removed from the network the controller updates the routing table of the switch. The routing table, decision is solely based on these tables. By this our objective is fulfilled, that energy of the network is saved by making idle links to switched off link and network is operational as before. In the same manner if some links are awake from sleep state, then based on the necessity routing tables can be reformed once again by using newly available links. This procedure is stated in Algorithm 3.

5. ENERGY SAVING ALGORITHMS IN SDN

The existing approaches are defined in section 5.1 and 5.2 and our proposed approach is defined in section 5.3.

5.1 Fair Share Routing (FSR) Scheduling Algorithm

It is based on the fact of equal sharing of load among all the switches and links involved in the network [44]. Here, a subset of links is selected and the total traffic is uniformly distributed to avoid delays. But the link utilization is not 100% of its total capacity. The full utilization of links and switching off idle links will increase energy consumption. The controller manages whole processes. But however this proposed one is not suitable with the fault in normal operation. The pseudo code for FSR scheduling is mentioned in Table 1.

Objective: To reduce the routing updates overhead in big ad-hoc networks.

- ◦ It is link-state routing protocol.
- ◦ It is a proactive in nature.
- ◦ Similar to link state protocol at each node it maintains a full topology map which helps in
- ◦ Exchanging the Hello packets periodically.
- ◦ Exchanging the topology tables within the local neighbors rather than flooding the entire network.

- Topology tables update frequently.
- Updates for a closer destination propagate more frequently then updates for a remote destination
    Each node of the network holds:
- ◦ Neighbor list
- ◦ Topology table
- ◦ Next hop table
- ◦ Distance table
- For bigger networks, for reducing the size of the routing update messages, the FSR technique implements distinct exchange periods for distinct entries in case of the routing table.
- The network is divided into different assesses relative to each node.
    The link state updates of the nodes in assess k are sent every $2^{k-1} T$ to all the neighboring nodes.
- Hop distance is denoted by K.
- The link state transmission period update is represented as T.

Table 1. Pseudo code for FSR algorithm

Algorithm: FSR Scheduling
1. For the immediate neighbors routing information has to be maintained. 2. Progressively update the routing information as the distance increases. 3. The link state for the immediate neighbors is often exchanged. 4. The distance and the exchange frequency are inversely proportional to each other. 5. The accuracy gets increases as the packet gets closer to the destination.

5.2. EXR (Exclusive Routing) Scheduling Algorithm

Exclusive Routing minimizes energy expenditure of network (Li et al.,2014). It is based on two facts. First, it operates active links at its maximum capacity. Second, it increases energy savings by turning off maximum number of switches. It takes several performance measures to decrease number of active links and switches with low utilization value. Maximum amount of energy savings is done in EXR by using a link structure to be utilized efficiently. Priorities are set for different flow. This helps in easy management of network. The pseudo code for EXR scheduling is mentioned in Table 2.

Table 2. Pseudo code EXR Scheduling

Algorithm: EXR Scheduling

Input: T, the network topology of data center
X_{active}: collecting the active flows, $X_{suspend}$: collecting the suspended flows
Output: {<y.state, y.path>, for all y € $X_{suspend}$ U X_{active}, Scheduling status and the flow path of each flow
  1. if a flow x in X_{active} finishes then
  2. $X_{active} = X_{active} - \{x\}$
  3. return ScheduleSuspend(T, $X_{active,}$ $X_{suspend}$)
  4. elseif a new flow x arrives then
  5. <p,w> = CalculationPath (T, $X_{active,}$x)
  6. if (p== IDLEPATH ot p==PREEMPATH) then
  7. x.state= ACTIVE
  8. x.path=w
  9. $X_{active} = X_{active} + \{x\}$
  10. if (p== PREEMPTPATH) then
  11. SCHEDULESUSPEND(T, $X_{active,}$ $X_{suspend}$)
  12. end if
  13. endif
  14. if (p=NOPATH) then
  15. x.STATE= SUSPENDED
  16. x.path=w
  17. $X_{suspend=}$ $X_{suspend}$ + \{x\}
  18. endif
  19. endif
  20. endif
  21. return {<y.state, y.path>, for all y € $X_{suspend}$ U X_{active}}
  22. end

5.3 Reducing Energy In Sdn Using End Host Awarness (AttentiveSDN) Algorithm

The proposed AttentiveSDN algorithm is described in Table 3. Initially on the arrival of incoming packets the packets need to go through the controller. The controller finds the route for packet if it is not available in the flow table of the switch. The controller collects the status information related to traffic and links and prepare a statistic. From this statistic, it finds the link utilization of a link. The

link utilization factor gives an idea about idle link and fully utilized link. The controller takes decision to put idle link to sleep state or not depending upon some network criteria. This criterion includes the sleep state of a link should not be the cause of network partition and hamper network related operation. The controller also can select the link from sleep state to an active state. The controller finds a new routing table based on the available links in the network and update the same to all the switches. The controller installs a set of proper rules on top of SDN-enabled switches to steer the traffic of the network. The switch forwards the packet as per the new routing table prepared by the controller. The major amount of energy savings is done in network by putting the idle links and its related switch to sleep state.

Table 3. Pseudo code for AttentiveSDN algorithm

Algorithm: AttentiveSDN

Input: Incoming Packets
Output: Flow table for the incoming packet
   1.for all the incoming packet
   2.do
   3. if routes available then
   4. Forward packets using predefined routes
   5. else
   6. The controller finds the route and update routing table of the switch
   7. end if
   8. end for
   9.for all available routes in network
   10. do
   11. Periodically controller collects traffic and link status
   12. The controller calculates link utilization value for the link
   13. if (link utilization £ T_{sleep}) // here T_{sleep} is the threshold value for sleep state link
   14. Link is decided idle link
   15. The controller decide to put which idle link and switch to put into
   16. end if
   17. if (link utilization ^{3} T_{awake}) // here T_{awake} is the threshold value for active link
   18. Link is decided as a fully utilized link
   19. end if
   20. controller finds a new routing table based on new links available in network
   21. Flow table at the switch is updated based on a new routing table
   22. end for
   23. return Flow table.

6. SIMULATION RESULTS

It can evaluate the network performance using mininet (Kaur et al.,2014). It constructs the topology consisting of 1000 nodes. Sleep threshold is considered as 10% of link utilization and wake up threshold as 30%. For links if link utilization is below 10%, then it is decided to be in, switch off state and if it is more than 30% it is put into awake state. It considers the network traffic for 20 seconds in order to calculate link utilization. It studies the network behavior in different value of network speed varying from 30 Mbps to 70 Mbps. It measures the amount of energy consumption as performance metrics and compare its value with existing FSR and EXR protocol.

Figure 5 shows the energy consumption by various protocols in different values of network speed varying from 30 Mbps to 70 Mbps having a network traffic of 1000 GB and considered for a network traffic of 20 seconds. Figure 6(a) shows the average Flow Completion time Vs flow arriving rate and (b) shows Network Energy Vs the power state transition time of switches. Figure 7(a) shows the

average flow throughput Vs the expected flow size and (b) shows the network energy Vs the expected flow size for different protocols. It can be seen that AttentiveSDN is outperforming everywhere.

Figure 5. Energy consumption at traffic of 1000GB and speed of (a) 30 Mbps (b) 40 Mbps (c) 50 Mbps (d) 60 Mbps (e) 70 Mbps
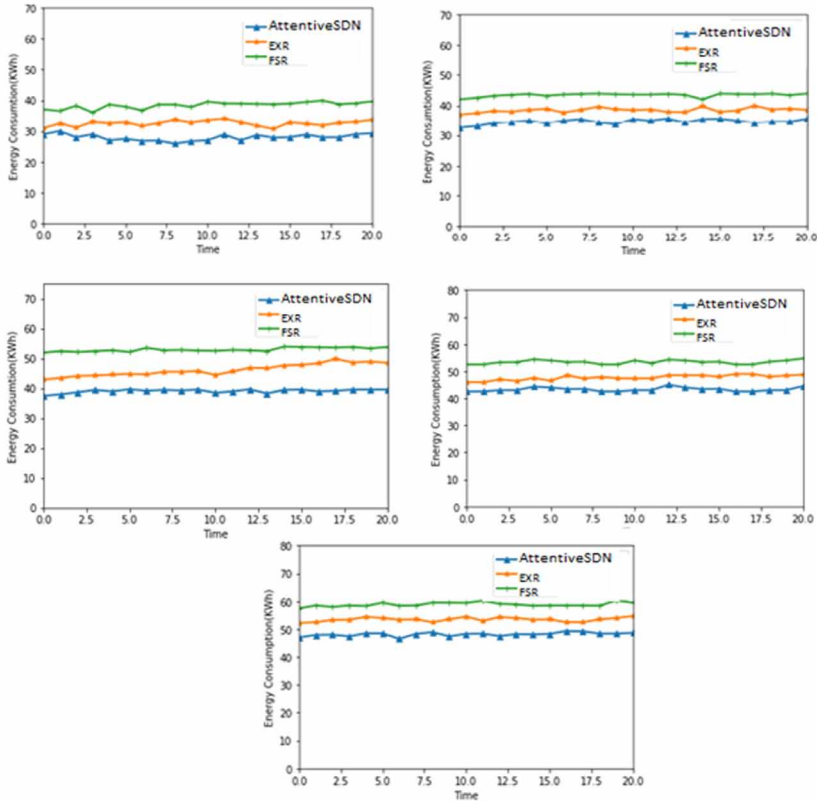

Figure 6. (a)Average Flow Completion time VS flow arriving rate, b)Network Energy Vs the power state transition time of switches
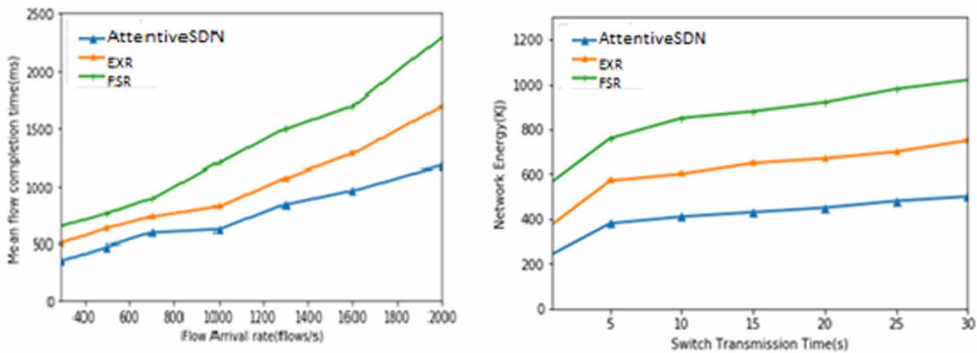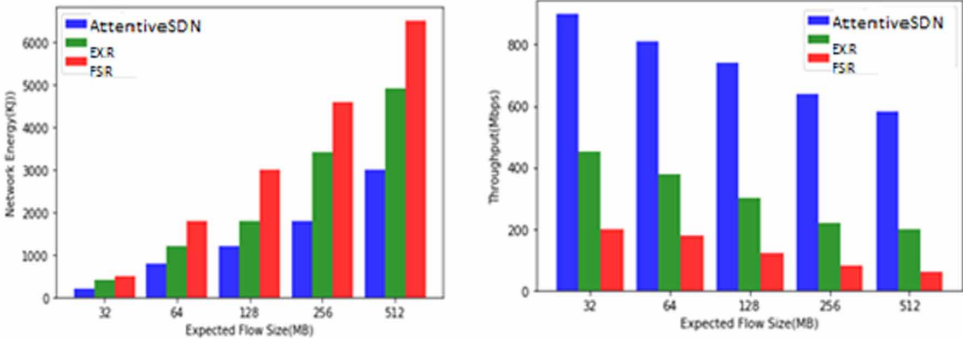
Figure 7 (a) Average flow throughput VS the expected flow size, (b) Network Energy VS the expected flow size

The effective link utilization is measured, which indicates the average utilization ratio of all the active links. It shows, higher the effective utilization ratio of links, the more efficient energy usage of switches and ports. In Figure 8, it finds that the effective link utilization ratio under AttentiveSDN almost reaches 100 percent at most of the time. It is because when using the AttentiveSDN scheme, the competition among the link bandwidth flows, are negligible. Hence, every flow utilizes the link bandwidth of its routing path fully. In contrast, it gives when using FSR and EXR there is a competition in bottleneck links and also under utilization in other links.

Figure 8. Effective utilization ratio of links
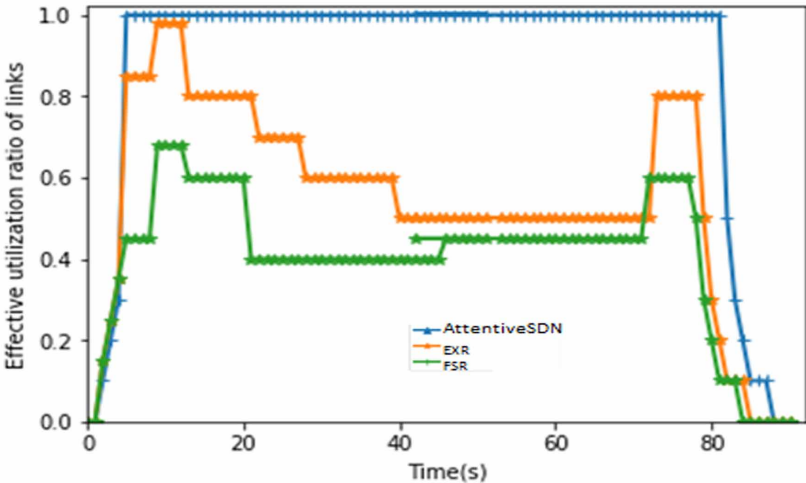
The other performance measures are studied in this section. Basically, it has considered control overhead, weighted routing inaccuracy and packet delivery.

6.1 Control Overhead (Mbps/node)

It is the control information sent divided by the actual data received at each node in the network. (i.e., Control O/H = The control information sent / the actual data received at each node of the network). It can also be represented as the processing time necessary to transmit a data by a node, which comprises of all the bearing functions including link maintenance, node discovery, the net-work size, network latency and the data transmission. Table 4 depicts the network size Vs the control overhead for all the existing algorithms and the proposed AttentiveSDN. The proposed algorithm AttentiveSDN reduces the control O/H. As the mobility increases the control O/H increases.

Table 4. Control Overhead Vs Network Size

Mobility(km/hr)	DBF	LS	GSR	FSR	EXE	AttentiveSDN
50	0.04536	0.03739	0.02354	0.02171	0.01627	0.01292
100	0.15373	0.10838	0.05827	0.03661	0.02356	0.02357
200	0.19283	0.12827	0.13724	0.10272	0.08918	0.03416
300	0.20727	0.16827	0.15246	0.12123	0.07161	0.05416
400	0.30827	0.25253	0.26282	0.21812	0.06716	0.06362
500	0.32127	0.28197	0.27373	0.25272	0.12272	0.08628
600	0.34173	0.31182	0.31028	0.29171	0.25252	0.10372
700	0.45373	0.41516	0.35645	0.33542	0.27257	0.17718
800	0.46292	0.41622	0.38826	0.34252	0.29027	0.22910
900	0.54254	0.51311	0.42345	0.36287	0.31872	0.25390
1000	0.62527	0.56282	0.47039	0.42542	0.35172	0.27389

6.2 Weighted Routing Inaccuracy

Inaccuracy in routing is determined with the help of comparison of the next hop table of every active node by the tables obtained by an off-line methodology or an algorithm. The algorithm has the information of the instantaneous topology of the network and can able to calculate the optimal routes. For a nearer destination, a wrong calculation in the next hop table is more vital than for a distant destination. With this consideration, It can mention the weighted routing inaccuracy for node i, W_i, as:

$$W_i = \frac{1}{D} \sum\nolimits_{next_i(k) \neq next^i_N(k)} (D - hop^i_N(k) + 1) \tag{8}$$

Where D is the network diameter. $next^i_N(k)$ and $hop^i_N(k)$ is the next hop and hop distance to destination calculated by the off-line algorithm respectively. The overall routing inaccuracy is computed by averaging W_i for all i € M.

Table 5 shows the inaccuracy of different routing algorithms with various average speeds (in km/hr). The AttentiveSDN performs best in all speed ranges, since it reacts fastest to the topological changes. Table 6 shows the AttentiveSDN accuracy degrades as the update interval increases. Table 7

shows the weighted inaccuracy Vs the network size for different algorithms. AttentiveSDN performs better as compared to all the existing algorithms.

Table 5. Weighted Inaccuracy Vs Mobility

Mobility(km/hr)	DBF	LS	GSR	FSR	EXE	AttentiveSDN
0	0	0	0	0	0	0
10	0.45536	0.42352	0.38928	0.35172	0.32425	0.30272
20	0.53837	0.51526	0.36292	0.34717	0.30272	0.29726
30	0.54938	0.52617	0.35282	0.32717	0.28262	0.28672
40	0.55890	0.51727	0.32483	0.30171	0.26272	0.26525
50	0.56727	0.50171	0.29273	0.27182	0.24252	0.25867
60	0.57211	0.49189	0.27828	0.24171	0.22725	0.24627
70	0.58355	0.47282	0.26828	0.22028	0.21762	0.22415

Table 6. Inaccuracy Vs Update Interval (AttentiveSDN)

Mobility(km/hr)	T=1	T=2	T=3	T=4	T=5	T=6
0	0	0	0	0	0	0
10	0.34262	0.22383	0.34928	0.35172	0.42425	0.54272
20	0.05162	0.36273	0.36292	0.39287	0.46272	0.59726
30	0.07256	0.35276	0.42282	0.44536	0.49262	0.68672
40	0.08262	0.41626	0.45628	0.48284	0.52272	0.69525
50	0.09263	0.42625	0.48736	0.52526	0.54252	0.75867
60	0.10373	0.43525	0.50262	0.56374	0.61125	0.78627
70	0.10921	0.45267	0.52626	0.58799	0.63562	0.80415

Table 7. Weighted Inaccuracy Vs network size

Mobility(km/hr)	DBF	LS	GSR	FSR	EXE	AttentiveSDN
0	0	0	0	0	0	0
10	0.45536	0.42352	0.35634	0.33837	0.30183	0.291918
20	0.53837	0.51526	0.34722	0.32827	0.29182	0.281718
30	0.54938	0.52617	0.32772	0.30172	0.28262	0.271827
40	0.55890	0.51727	0.31727	0.28192	0.25272	0.262723
50	0.56727	0.50171	0.29171	0.26162	0.24252	0.258273
60	0.57211	0.49189	0.26172	0.23828	0.23727	0.243737
70	0.58355	0.47282	0.25839	0.22817	0.20828	0.213737

6.3 Packet Delivery Ratio

The packet delivery ratio can be defined as the packets consisting of data hand overed to the destinations divided by the packets generated from the sources. The generated number represents the effectiveness of a routing protocol. Figure 9 shows a bar graph to depict the packet delivery ratio as function of node mobility in all different algorithms such as Link state approach (LS), Global label Routing (GLR), FSR, EXE and AttentiveSDN. As soon as the node mobility increases, the performance of the Link State is dramatically degraded due to flooding O/H. The advantage of AttentiveSDN is clearly shown as it maintains high delivery ratio across different network sizes.

Figure 9. Delivery Ratio Vs Mobility (for 500 nodes)
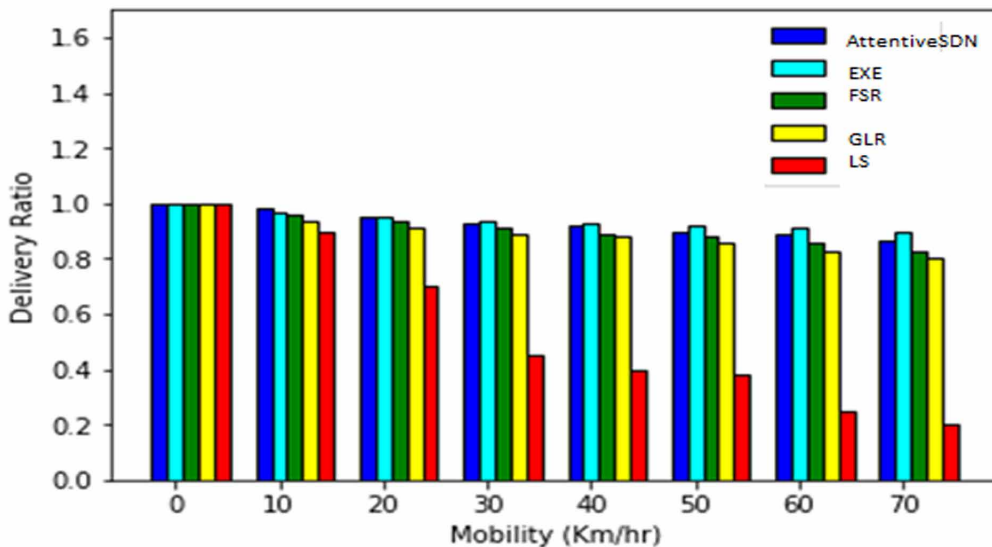
7. CONCLUSION & FUTURE WORK

SDN is becoming a significant name in the field of wired networks. Energy consumption becomes a crucial point in today's networking industry. SDN takes many steps forward in the direction of energy savings in the data center. Various methods have been proposed by several researchers to save a major amount of energy in networking. Shutting down idle network devices is one of the approaches to save energy for a required amount. This paper proposes a novel algorithm named AttentiveSDN for reducing energy consumption in SDN using end-host awareness. Here, the controller takes decision to put idle links and switches in the sleep state. The decision is based on the link utilization value calculated by the controller periodically based on link and status collected from the network. The new routing table is prepared using the available links in the network and the same is updated at each switch. It evaluates the performance of AttentiveSDN algorithm in mininet and also possess more energy savings.

The proposed algorithm is designed by keeping a single controller in the system. In the future work it is desirable to implement the algorithm by taking multiple controllers in the system and placing them in the appropriate positions so that latency should be minimized and energy consumption also be maintained.

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