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Energy Saving Based Routing Algorithms in SDN Environment

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Abstract: ***Saving energy has many profits such as reducing the costs which lead to saving money, reducing the risk. This paper aims to reducing a cost of computer network communication by reducing the energy consumption based on selecting appropriate shortest path routing algorithm, We used two algorithms Dijkstra's algorithm and new novel algorithm(energy saving algorithm) and depicted the most different between these algorithms which serve our object, we used SDN network environment where the network can be changed dynamically easily and the control over all the network logically centralized which facilitate re-configuration of the data path without need for individual modification for each switch as in the traditional network .***

Keywords: SDN, Routing algorithms, openflow, mininet, energy reduction

1. Introduction

Because of acceleration development in human interconnection over recent years this lead to become information and communication technology (ICT) [1] [2]. a fundamental part of human daily life style. and because this development is accompanied with rapid growth in communication devices such as portable devices, mobiles and computers and developing a new technologies like cloud computing, data center networks, this lead to raising significant cost anxiety, since the ICT consume about 4.6% of electricity around the world [3].this percentage stress for enhancing energy saving in (ICT).

The nature of new paradigm, software defined network (SDN) of the computer network (separation the central decisions from the forwarding device, routers and switches) [4] [5]. Make it more fixable in controlling and managing the network and this leads for developing many energy saving techniques.

In section II we introduce a background of overall requirements that are wanted in any energy saving technique in SDN network next in section III we use explain the routing algorithm in general and shortest path algorithm(Dijkstra algorithm) in specially and depicted our heuristic algorithm and its role in reducing the energy consumption.

Finally in the section IV support our idea with simulation environment, at the end this paper will depict how the energy conservation will be reduced by select appropriate paths.

2. Background

There are three pillars for saving energy in SDN in software solution in generally and traffic aware in specially [6] . Power management method, traffic engineering (in case of traffic-aware energy saving) and SDN environment and as show in the Fig.1.

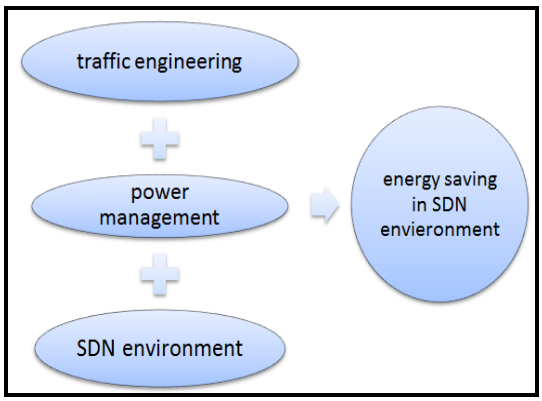


Figure 1: Three pillars for saving energy in SDN

At the first we should choose an appropriate method for saving energy from power management methodology then we will decide the reason for using traffic engineering based on the method and finally where we will apply our method by using SDN network.

2.1 Power management methodology (1st pillar)

The author in[6]. produce that there are set of methods for power management that are used for enhancing power consumption can be categorized as *sleeping and standby*, *dynamic adaptation* and *re-engineering* in this paper we use a dynamic adaptation as manner for reducing energy.

2.2 Traffic engineering (2nd pillar)

According to [8] in chapter 10 we can say about traffic engineering is the attempt to find another path from that one founded by routing protocols which is the best- cost path (lowest-cost) between two hosts (source and destination). There are many reasons for using traffic engineering such as reducing the congestion on the lowest-cost path. The most important reason is choosing a path without considered to the numbers of hops that use in the shortest path algorithm but we will take another consideration such as path capacity for choosing suitable algorithm (ability to share more than one flow the same link) which serves our idea .

2.3 SDN environment (3rd pillar)

In this topic we will cover the general idea of the SDN, its components and most important protocol (open flow protocol) and shows the main difference upon the traditional network that play a big role in energy saving . Software defined network (SDN)[7] [8]. Is new network paradigm that base on stripping the control from the network devices and make this control logically centralized. With traditional network the control plane is built in the NW appliance (data forwarding plane). The Fig. 2.a and Fig. 2.b demonstrates this difference [9] [10].

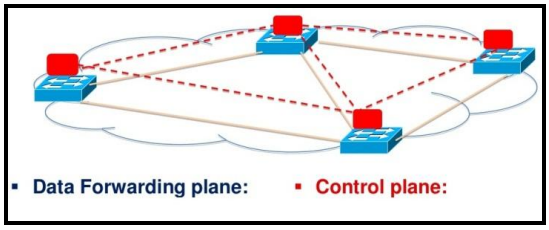


Figure 2 (a): traditional network

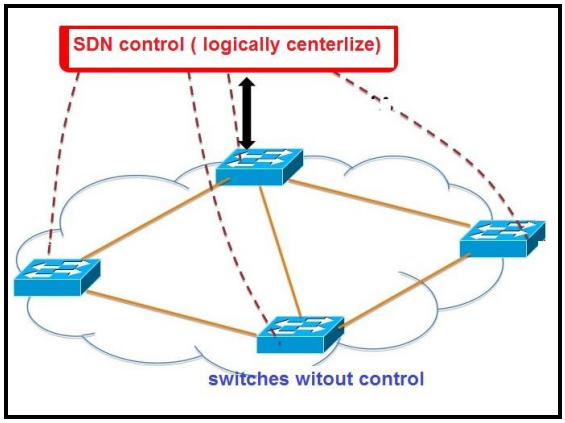


Figure 2 (b): SDN network.

As show in the figure3 the SDN architecture composed of three layer the **infrastructure layer** (data plane) which consist of forwarding devices (switches and routers) that be controlled from the upper layer **(controller layer)** which considered as network brain, openflow protocol represent the application program interface (API) between these two layers also called (south-bound interface), **application layer** or application plane represent the top layer that is used for managing the network by application programs such as (QoS applications) and communicate with the controller via (north-bound interface) .

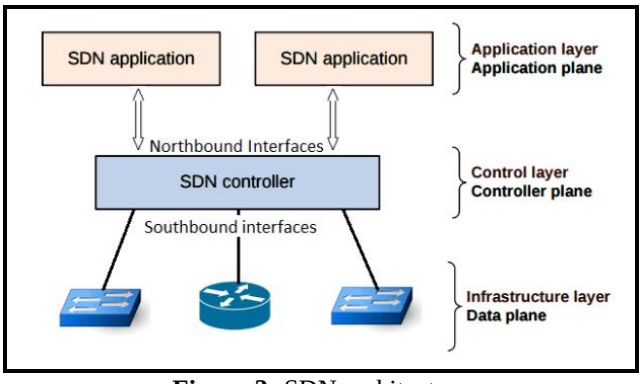


Figure 3: SDN architecture

One of the most important controller responsibilities is data flows definition that occur in the network infrastructure (data plane), at the begin the flow should be permissioned by the controller (ensure the flow not violate the network policy) then the controller will determine the flows path along from source to destination by adding the flow entry in all switches in that path, This paper will depict how the energy conservation will be reduced by select appropriate shortest path routing algorithm [11].

3. Routing Algorithms

Communication network consist of number of nodes in SDN network the node will be routers or switches and links that connect these nodes such that each node represent one of two sides either source (side that send the packet) or destination (side that receive the packet) [11]. The process of forwarding the packet along path between source and destination nodes called routing [12]. Routing algorithms are used for determine the most suitable path in the network for forwarding the packet based on algorithm class either **user-oriented class** which is used for satisfy a specific users needs such as provide them with a good services or **network-oriented class** that work to provide most users with an acceptable service. The optimal path is not necessarily be the path with the shortest distance between source and destination nodes but can be a path that saves the energy in the network by allowing the link to forwarding more than one flow and turn off the reset of links [13].

3.1 Dijkstra algorithm

Dijkstra is one of the earliest Single-Source Shortest Paths algorithms [13]. Suppose we have a graph G (N,E) which consist of set of nodes N and set of weighted edges E (non-negative edges) and a single source node S, Dijkstra algorithm and as show in the figure 4,compute the shortest path to the destination node and in addition compute shortest path for all destinations nodes.

3.2 Energy Aware Routing Algorithm

Because the energy saving problem based on the routing solution in the backbone network is NP-hard [], so it's difficult to find the optimal solution. Therefore the proposed algorithm gave near to optimal solution according to the set of constraints such as the volume of traffic between the source and destination node and capacity of the link.
The objective function of proposed algorithm is minimizing the number of active links in the network by the investments the residual of the link capacity after forwarding the traffic (enable more than one traffic to share the same link). Proposed algorithm decompose to the three sub-algorithm :

- Algorithm (A): This algorithm explain in Fig. 4, takes a traffic matrix and network topology as input where each entry in the traffic matrix consist of the pair of hosts associated with traffic demand. The algorithm initially generates all the possible paths between the source and sink nodes then select the most appropriate path(Path with least energy-consuming) as the objective function where

the path is consist of a set of nodes and edges that connect between these nodes.

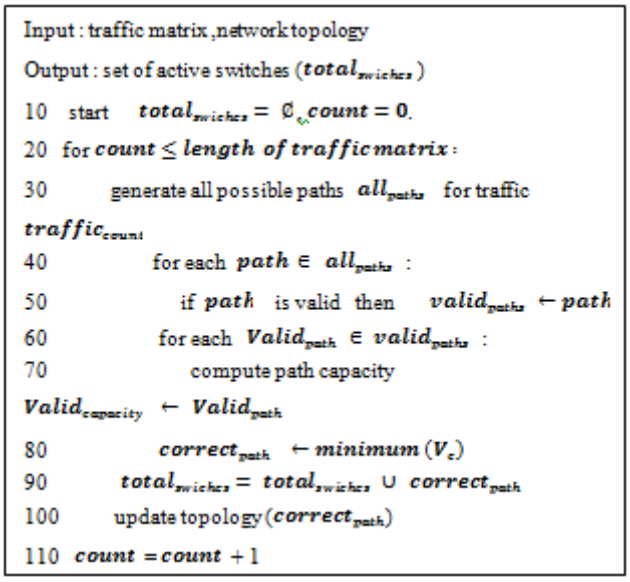


Figure 4: pseudo code algorithm (A).

- Algorithm (B): this algorithm and as shown in the Fig. 6, take all possible paths as input and generate set of paths that pass through constraint checkpoint which is the amount of traffic most be less than or equal to each link in the selected path where each path consist of set of links.

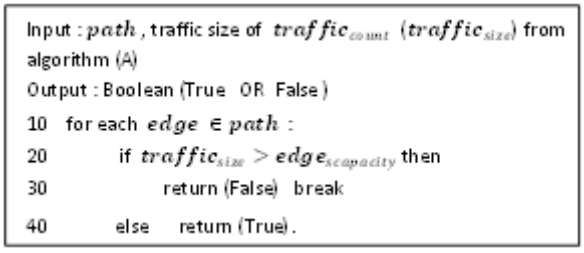


Figure 5: pseudo code algorithm (B).

- Algorithm (C): the goal of this algorithm updates the links capacity of the virtual network topology after forwarding the traffic to the selected path and deactivate the unused paths Fig. 6.

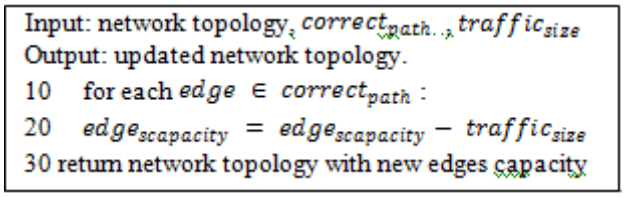


Figure 6: pseudo code algorithm (C)

4. Simulation Scenario

We testing our algorithm by using a datacentre topology with different types (three tier, fat tree tier) that constructed by using python language. Mininet simulator is used for implementing the algorithm and the power model in the [14] as default switch.

4.1 Three tier topology

At the first we will run pox controller by using set of command, then we will convert python code for creation network topology and run proposed algorithm to the executable file run within mininet environment next the controller will discover network topology and setup a proper flows inside flow table for each switch and forwarding the traffics in the traffic matrix. Table (1)shows the traffic matrix with five flows that is used within simulation .

Table 1: Traffic Matrix

Source Node	Destination Node	Traffic Volume
30	46	100 k
45	27	100 k
39	24	100 k
42	48	100 k
32	33	100 k

The power consumption of the network will minimize each time a new flow forwarded prior to the full active network where the power consumption will be in the maximum rate and as shown, in the table (2) because the proposed algorithm will active just the needed switches and ports for forwarding the traffic.

Table 2: Power Consumption

Flow Number	Proposed Algorithm		Full Active NW	
	Switches	Ports	Switches	Ports
1	5	10	46	104
2	7	16	46	104
3	10	24	46	104
4	13	32	46	104
5	14	36	46	104

Table (3) describe the a mount of energy saving prior to the number of active switches and ports per switch and compare to the Dijkstra algorithm.

Table 3: Energy Saving

Dijkstra algorithm			proposed algorithm		
switches / w	ports / w	total / w	switches /w	ports / w	total / w
590	10	600	590	10	600
944	20	964	826	16	842
1416	30	1446	1180	24	1204
1770	40	1810	1534	32	1566
1888	42	1930	1652	36	1688

Fig.7. demonstrate the delay time between two hosts, h1 and h2 in two cases full active network and after using proposed algorithm where the delay time in the second case will be greater from the first one because of the proposed algorithm used off -line, so it will select the links that already visited although it has a longer path instead of selected shorted and this will effect on the delay time, while this increase the links utilization of the network since the link will carry more traffics.

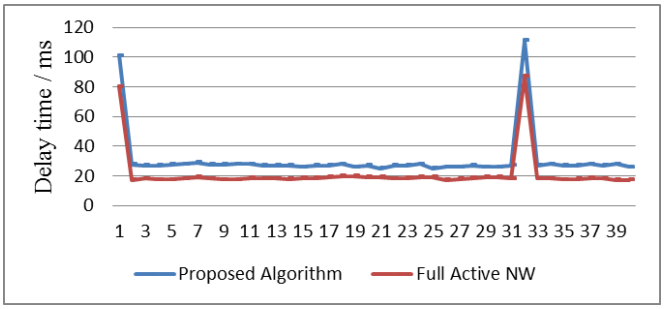
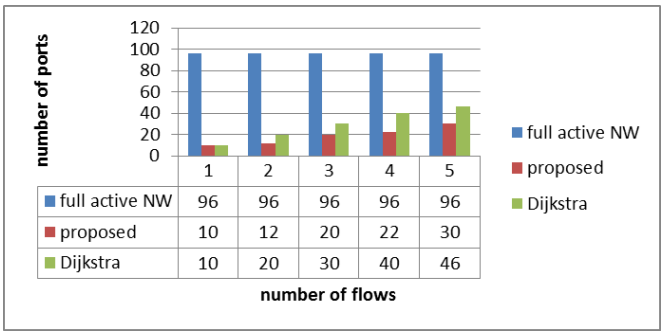


Figure 7: Delay time

4.2 Fat tree Topology

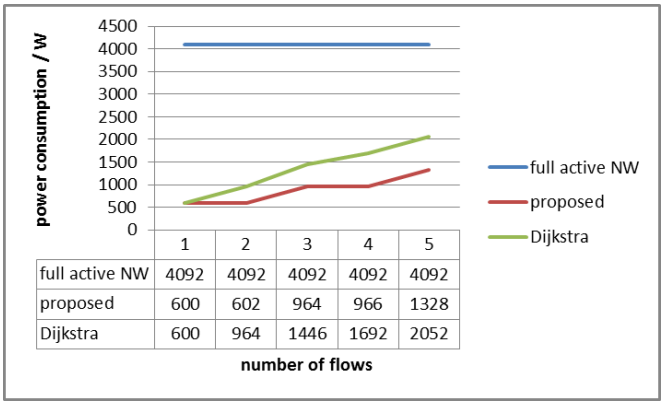
This type of topology consist of three layer (edge, aggregation and core) where each pod connected to $(n/2)^2$ of servers and each aggregation switch connect to (k/2)core switch and (k/2)edge switch and each switch in edge level connected to (n/2) server and (n/2)switches in aggregation level.

Fig.8.explain the number of active ports in three cases and because proposed algorithm based on sharing the same link with more than one flow so the number of active links will be less than other cases and as result the amount of energy saving will be bigger and as show in Fig.9.



	1	2	3	4	5
full active NW	96	96	96	96	96
proposed	10	12	20	22	30
Dijkstra	10	20	30	40	46

Figure 8: number of active ports



	1	2	3	4	5
full active NW	4092	4092	4092	4092	4092
proposed	600	602	964	966	1328
Dijkstra	600	964	1446	1692	2052

Figure 9: amount of energy consumption

5. Conclusion

In this paper we present a novel algorithm that used for saving energy in ICT in general and specially in computer network that based on SDN architecture and clarify amount of energy could be saved compared to Dijkstra algorithm the proposed algorithm works by concept of energy aware routing and by exploit the residual of the link capacity after forwarding the traffic so it will be enable to share more than one traffic the same link.

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