Comparative Analysis of Energy Saved Approaches in Software Defined Networks

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Summary
The new paradigm of software defined network SDN has attracted much attention of researchers mainly for flexibility of handling and processing, since the separation of the control plane to the data plane. On the other hand, the energy consumption of information and communications technology, ICTs, has become a field of research given the high energy dissipation due to the manufacture of high-tech equipment and the direct use of electricity. Our study is part of the energy economy in the Software Defined Networks by assembling and classifying several approaches of them.

Key words:
sdn, energy efficient, traffic engineering, tcam

1. Introduction

Updated analysis of the SMART 2020 report [1] shows a change in the energy footprint of the ICT sector, smartphones and mobile phones to datacenters and networks that count each 25% energy consumption of ICT [1, 2]. This increase in energy consumption is mainly due to the proliferation and widespread wireless broadband access and the mass migration of services to the cloud. The ICT sector alone consumes 3% of the energy in the world and its carbon footprint was 2% in 2010.
The principle of the SDN is the separation of the control plane and forwarding network elements. This concept has several advantages, the control plane can be a software program executed on the basis of hardware, and this separates the monolithic device control plane and enables the development and adaptation of the control plane without the need for new hardware. Moreover, the data plane is now interchangeable and may be made of material constructed from standard components. Fig 1.
At this architecture, the separation of the control functions and data transfer is called "disaggregation" as these blocks can be purchased separately, rather than deployed as a single integrated system. The SDN topology gives applications more information about the status of the entire network from the controller, as opposed to traditional networks that it is application-aware.
SDN can be defined as a way to simplify over conventional networks because the control plane is separated from the data plane or forwarding, this separation simplifies the treatment of the energy efficiency of the network.Energy efficient solutions can be easily implemented in a SDN than a traditional network. [3]
Energy optimization in SDN can be applied to several elements either hardware, affecting in this case switches or software for controller. Hence our classification which is based on these two elements of SDN networks, switches and controllers.
This paper is organized as follows: the second section is an overview of SDN energy efficient approaches, which will be described in detail in the third section, after the section of comparative analysis where we will make a comparison of various energy optimization strategies in SDN, the paper will finish with a conclusion.

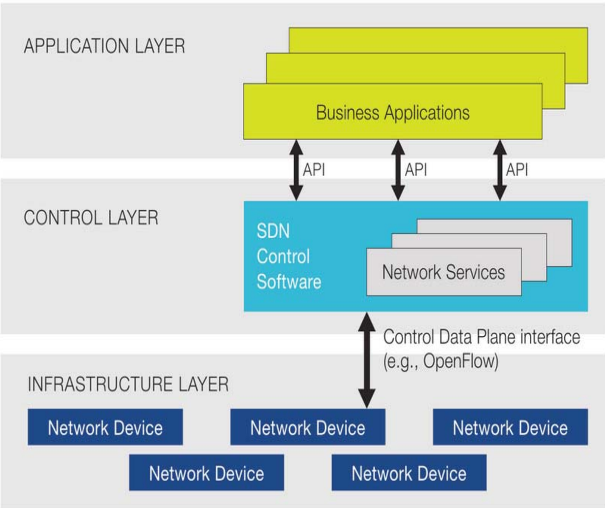

Fig. 1 Architecture sdn drawn of ONF 2014

2. Energy Efficient Approaches in SDN

In our previous study [4] we classified energy efficient approaches in computer networks into 2 policies:

- Local policies: Affecting equipment or sub network equipment regardless of its network location.
- Global policies: it has one or more local policies in the overall network topology.

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The SDN networks give an overview of the collaborative network and operation of the various network elements controllers, switches and routers; therefore energy optimization approaches in SDN following a global strategy, not local.
Energy efficient approaches to SDN networks can affect either the hardware, cases of switches, which can manage their TCAM memories to optimize the energy consumed, or the software that is manifested in the controller. We propose a classification of energy optimization approaches to SDN as follows:

(i) **Traffic management:** The approach is to direct traffic on a path selected to save energy. It is to adapt the routing of traffic on the network conditions, with performance goal for the efficient use of resources to the network operator.
(ii) **TCAM management:** TCAM (Ternary Content Addressable Memory) it is expensive, high energy consumed and limited in terms of storage capacity. Management TCAM regarding energy-efficient approaches that aim to reduce data storage at the memory switch, these approaches can be organized into 2 groups: 1) rule placement and 2) compression TCAM.
(iii) **Virtualization final host:** Virtualization affects the energy efficiency of Datacenters that implement SDN networks, this energy saving can be handled either by traffic management or the final host approach; and it is this matter which will be studied in more detail since the traffic is treated in a separate category.

See Fig 2 which represents a Classification of energy efficient Approaches

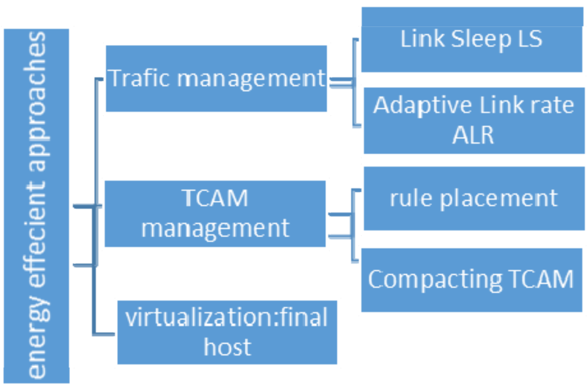

Fig. 2 Classification of energy efficient Approaches

3. Classes of Energy Efficient Approaches in SDN

3.1 Trafic Management

The traffic SDN approach is inspired by the fact that multiple network elements are underutilized, given the redundancy of network paths, so the principle is to put these elements in standby (sleeping) when there are no packets to transmit; it is to save energy; this technique is called Link sleeping LS [5]. Or it is sufficient to adapt the rate of the connections depending on the traffic frequency, this method is Link Adaptation Rate ALR [6]. In the SDN several research have emerged to optimize the energy consumed by using the approach traffic.
Wang et al. [7] Studying the optimization problem of energy SDN by re-routing traffic ,similarly to Green-TE approach by formulating a programmable model putting the idle elements idle, as used in sleeping under the constraint of link utilization and packet delay, two algorithms are proposed to solve this problem: Alternative greedy algorithm and greedy algorithm overall
In a second work [8], they define an efficient routing energy to optimize control and data traffic in SDN, this approach adds traffic control stress in the statement of the traditional routing problem to achieve energy savings, they propose an algorithm using dynamic heuristic weighting to calculate the sensitive routing path energy.
Celenlioglu [9] considers the SDN network with MPLS. The work involves a set of MPLS paths are pre-established and installed. The controller performs the admission control. The authors propose a flow placement algorithm in active paths that aggregates traffic in order to sleep and an algorithm to distribute the load on congested roads multiple streams.
The challenge is to decide which paths combinations can be actively used so that the maximum number of switches will be in standby mode. To solve this equation the PLSP selection algorithm (PSA) takes into account both the capacity and the power consumption of each PLSP when enabling or disabling PLSP (Pre-established Label Switching Paths: MPLS is used for large-scale networks.
GRECO a solution of energy traffic engineering, which aims at cutting as many links as possible while ensuring that all switches have a path to a controller with a given period and that the charge controller is balanced.
Rivera [10] interested in a multi network controllers, which operates with a distributed control between controllers and studying the distribution of switches and controllers to save power, Modeling aims to put to sleep the maximum lines but this time making sure that all switches have a road with a controller that has a limited time, and that controllers have limited support so that they work as quickly as possible. The problem is solved by

considering the SDN as a directed graph G (V, E), with the set V containing nodes and E is the set of links.
Another technique referring to GRECO technique is that of Fernandez [3], which addresses the problem of optimizing energy consumption in SDN minimizing the number of connections that can be used to satisfy a given traffic demand, the idea is to find the routes between network elements that minimize the number of active links used. Since they consider that the control messages required in SDN are exchanged in-band mode, you must also establish control paths between controllers and switches (and between controllers). Given the location of the controllers in the network topology, the model determines the optimal distribution switches between controllers in terms of energy efficiency, also taking into account load balancing between controllers. In addition, this solution takes into account the use of links and the time of control paths. Therefore, the two are forced in this technique, unlike Greco [10], they establish that communications in the data plane cannot be routed through the network controllers.
In [11] the main idea is to find a flow distribution on pre-established paths that reduces the energy consumption of the network by the dynamic adaptation of bonds transmission rates. The problem is formulated as a full linear programming problem (ILP). Next, the authors present four different algorithms efficient from the standpoint of processing time namely, the First Fit algorithm, the Best Fit algorithm, the Worst Fit algorithm and a genetic algorithm (GA) to solve the problem for the realistic network topology.
In [12] describe a technique to save energy in hybrid SDN networks by answering two key questions: 1) given the limited number of SDN switches, how to place them to allow getting the maximum improvement NCA (the sum of switches SDN control flow in the network), 2) switch fixed location deployment SDN, how to maximize energy savings by redirecting flows, heuristic algorithms are proposed for a solution.
This system can reach 95% of the number of flow controlled with a cost of upgrading only about 10%. It also saves more than 10% of total energy consumption compared to existing solutions.
Assefa [13] propose replacing links underutilized by the shortest path next, and the next path in the direction of the maximal binding utility.
They pose an IP formulation for problems sensitive routing traffic and energy, based on link utility information, and evaluate algorithms using real traces of low traffic volumes, medium, high and topologies network.
In [14] the proposed algorithm allows the controller to configure routes and remote service rates by updating the flow table of network devices and setting the port rates. This algorithm solves approximately the following SDN routing problem: given the network topology, a set of data flows and their traffic demands, discrete operating rates available for each link, it can search the way Full routing data stream and the operating rate of all the links of the network power consumption is minimized.

Two key points can be drawn from this first class of energy-saving approaches:

- Disabling too many links can result in significant link load and higher total power consumption than when multiple links are active.
- Traffic is relatively concentrated after energy savings, which makes the network vulnerable in the event of link failure and sudden burst of traffic. However, there has been no research on energy savings given the reliability of the network at the same time until now

3.2 Tcam Management

According to our classification, approaches involving the TCAM is divided into two parts:

(i) Rule placement:
This technique focuses on how to place the rules in transfer switches, since the controller has the capacity to convert high-level strategies understandable rules of the switch.
The technique pallet distribution [15] is a replacement of the rules by breaking a large table in smaller table and distribute them afterwards, this approach balances the size of the tables on the network and reduce the total number entries by sharing resources between the different connections, and its implementation is based on graph theory formulation of algorithms and heuristics.
One big switch [16] is another technique at the placement rules, it is to see all the forwarding area as a single switch, it models the SDN controller into three components: endpoint strategy, routing strategy and investment strategy rule. The authors present effective rules placement algorithms that divide transfer policies on SDN general networks while managing the constraints of space rules, and explain how to handle the dynamic update and incremental policies, They demonstrate that the Palette technique cannot handle the case where the switches have a non-uniform rule capacity and a path length greater than 2 and more Palette cannot handle the case where the switches have a non-uniform rule of capacity.
In the approach of Giroire [17] the routing decision of an Open Flow switch is based on flow tables implemented with TCAM. Each entry in the flow table defines a matching rule and is associated with an action. When receiving a packet, the switch identifies the highest priority rule with a corresponding predicate and executes the corresponding action: A packet that does not match

any rule is processed using the default rule takes priority Lowest that the default rule is' forward packets to a default port. In this work they clearly identify the meaning of a rule and formalizes an ILP algorithm for the entire network.

(ii) Compression of the Tcam:
This approach is designed to compress either the rules or the content of the TCAM so as not to waste too much memory.
COMPACT TCAM [18] which uses shorter labels to identify the flow that the original number of bits used to store feed entries for SDN switches.
They show that the size of stream 15 fields defined in the SDN (15 fields stored in 356 bits) can be effectively reduced to 16 bits, a compact input compared to the 356 original bits. By reducing the number to 16 bits, their experiences can save about 80% of the power loss and optimize costs by increasing the number of streams that can now be stored in the same tables' flows.
The technique of "Weaving bit" [19] uses a compression scheme without prefix and is based on the observation of TCAM entries that have the same decision, but whose predicates differ by a single bit which can be merged into a single entry replacing the one bit with *. The "Weaving bit" uses two new approaches, exchange bits and merging bits. The Key advantages of this technique are timeliness, efficiency, and perhaps complementary to other TCAM optimization methods as routine pre / post processing.
TCAM Razor [20] proposes a solution in four steps to compress the packet classifier. First, it converts a packet classifier given a reduced flow chart. Second, for each non-leaf node of the decision tree, it minimizes the number of prefixes associated with its outgoing edges using dynamic programming. Third, it generates rules from decision logic. Finally, it removes redundant rules.
RCAS is the most recent work in the field of eco-energy SDN using EAR energy aware routing and compression tables of OpenFlow rules, while respecting the capacity constraints of the bonds and constraints space rules on routers.
The authors in [21] announced that in addition to capacity constraints, the rules of space is also important because they can change the routing solution and affect the quality of service. By offering solutions using compression transmission table they define the problem of energy efficient routing with compression (RCAS) for SDN networks. Eventually managing to model the problem using integer linear programming, even for a complex compression to which a stream can be routed according to two packet header fields, they provide effective heuristic algorithms for large networks. Using this intelligent allocation rule space, it is possible to save almost as much power consumption than the conventional approach EAR.

To conclude this second class of energy-saving approaches we can say that:

- For TCAM compacting solutions, information stored in the TCAM cannot be compressed after a certain threshold.
- The rule placement affects both investment performance and routing since the routing and the final host of network policies, it is necessary to have a formal and effective means to represent the rules.
- Almost all energy efficient approaches using optimization algorithms, on average, the heuristics can give a near optimal solution with a feasible time. But in a dynamic environment, the problem becomes even more difficult.

3.3 Virtualization: final host

The Datacenter jobs can be split into two parts, distribution or placement of virtual machines and the routing of flows, among these there are similar approaches already discussed studies, but applied to the topologies of DCNs.
"Honeyguide" [22] is a virtual machine migration topology for energy efficiency in the data center networks where two techniques are combined: optimizing the placement of virtual machines (VMs) and consolidation of traffic.
The solution EQVMP [23] proposes an investment-efficient virtual machines and energy that meets the QoS requirements for data centers SDN.
The system uses the energy profile of network devices and power consumption switchport different link speeds. By adding energy network profiles to optimize processes and routing topology, energy-efficient method based on the energy profile also allows the system to operate flexibly with heterogeneous devices from different vendors.
The scheme optimizes the network topology and routes traffic based energy profiles of network devices
In [24], the authors propose an overbooking strategy: optimizing the dynamic occupancy rates, which jointly operates virtualization capabilities and SDN, for consolidating virtual machines and traffic. With the workload changes dynamically, the proposed strategy allocates a specific amount of resources to virtual machines and trafficking. This strategy can increase the overbooking in a host and a network while providing enough resources to minimize violations of SLA: service level agreements. This technique calculates the ratio of allocation of resources based historical monitoring data from the online analysis of the use of host and network without any prior knowledge of workloads. It has been implemented in a simulation environment to scale Wikipedia. This technique allows to save energy in the

data center while reducing the ALS rates compared to baseline.
Therefore the majority of energy optimization strategies for Datacenter affecting traffic can be applied at this level, there is just one particularity in the virtualization part where the final host approach is implemented, this approach that directly affects machine virtualization and energy-saving placement.

4. Comparative Analysis

At this level we have classified the different energy efficient techniques using the new SDN paradigm, each uses a network parameter to save the energy consumed by the different network elements, we discussed and listed the advantages and disadvantages different energy-saving approaches, but an important point to discuss is the implementation and the support of QOS and security through this energy-saving techniques.
For most of the above mentioned techniques, the authors announce an approach to better energy saving and high efficiency, but do not take into account the security setting that makes the network vulnerable to various risk attacks, particularly traffic management, which makes these techniques incomplete even if they are energy efficient. The Table Tab1 represents the support or not of the quality of service and security by the studied techniques.

Table 1: Table of energy saved techniques which supports or no QOS and security

Approches	Subclasses of approches	references	Energy saved	security	Quality of service
Trafic management	LS	[7]	67%	--	--
		[8]	-------	--	--
		[9]	60%	--	--
		[10]	33,33%	--	√
		[13]	37%	--	√
		[12]	70%	--	--
	ALR	[11]	47%	--	√
		[14]	54%	--	--
TCAM management	Rule placement	[15]	------	--	--
		[16]	------	--	--
	TCAM compression	[17]	37%	--	√
		[18]	80%	--	--
		[19]	70%	--	--
		[20]	54%	--	--
		[21]	52%	--	√
Virtualization : Final host		[22]	69%	--	--
		[23]	25%	--	√
		[24]	50%	--	√

Quality of Service (QOS) is supported by a number of techniques in the form of load balancing [10] and algorithmic use to maintain acceptable network performance [13] [17] [23]. We can say that it is present but under certain constraints: Quality of service support influences the rate of energy saved. According to the histogram of Fig.3, it is very clear that the more energy saving is important for a given technique, the more it does not take into account either the security or the quality of service, so that these techniques are not too beneficial for the network, which opens a very important line of research: how to make the network energy efficient taking into account the constraints of security and quality of service, and it is this optimal solution that we are studying and which will be published in future works.
A problem to be solved is to minimize energy consumption while maintaining an acceptable performance; an important research question is this: how to make the energy consumption of a network proportional to the volume of traffic.
To conclude, we cannot favor one technique over another. Each has its advantages and disadvantages and it differs according to the field of application.

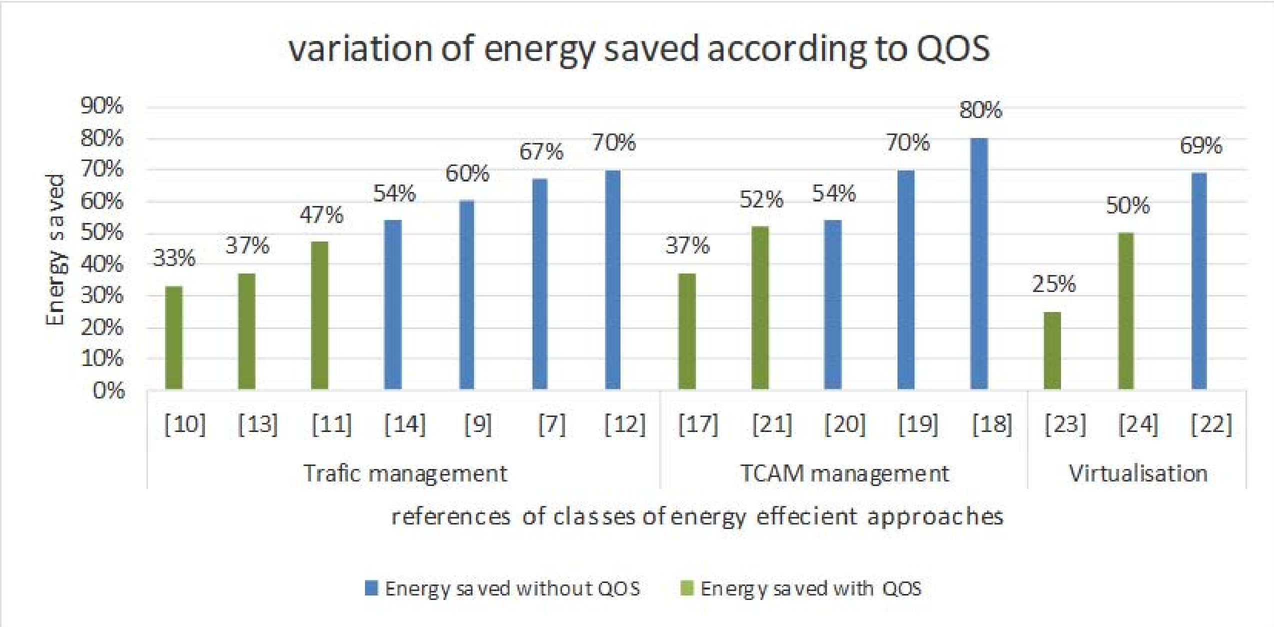

Fig. 3 Variation of the percentage of energy consumed for the different techniques according to the existence or not of the QOS

4. Conclusion

In this paper, we were able to classify different approaches and techniques in energy efficient SDN networks, which is a new paradigm more dynamic and flexible networks. This classification has an update on three important classes: traffic management, the management of the TCAM and virtualization with SDN. These techniques affect the hardware of the SDN namely switches or elements of the relay, and also the software part, which focuses on the controller: the brain of such networks.

As prospects and future work, we will focus on a contribution in energy-efficient technologies which will touch one of the following points: 1) Consider a model of energy consumption in which the rate of energy consumption of the links is proportional to their use, 2) Eliminate redundancies in packets transmitted over the network by turning off more links and limiting the number of routing rules in SDN routers, 3) design an energy efficient model that supports QOS.

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