Energy Optimization at Cloud Data Centre using SDN

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Abstract*— Rapid growth and demand for cloud computing technology has led to the creation of large-scale data centres consuming enormous amounts of power. Improving the efficiency of data centres, with a focus on optimization of power consumption and carbon emission, is major research work. The objective of this project is to design and implement a computing technique that improves energy efficiency at the Cloud Data Centre. An algorithmic-based approach is proposed to minimize the energy consumption at the Data Centre. The proposed approach utilizes one of the most promising technologies in the areas of server virtualization research area, namely Software Defined Networking (SDN) using OpenFlow technology. This newly emerging technology, not only allows flexible control of network devices, but also brings a new opportunity towards DCN energy optimization.*

Keywords*—* **Cloud Data Centre (CDC), Software Defined Networking (SDN), Energy-efficiency, TCAM,**

OpenFlow, Mininet

I. INTRODUCTION

Cloud computing is known for bringing speed to innovation, rapid scalability and agility, and a lower total cost of ownership to business organizations. It has gained significant space as a successful model by promising economy, ease of use and flexibility in control on how resources are used, anytime and anywhere, to provide users with required computational power, but the increasing demand for Cloud Computing has led to the high energy consumption at Cloud Data Centres.

Natural Resources Defence Council [1] pointed out that in 2013 US data centres consumed 91 billion kilowatt-hours, which are enough to power all the households in New York City over twice and are on-track to reach 140 billion kilowatt-hours by 2020.

CISCO global cloud index [2] predicts that by the end of 2017, cloud traffic will represent 69% of data center traffic. Furthermore, recent business insights into data center network evolution also forecast an unprecedented growth in data center traffic with 76% of the aggregate traffic not exiting the data center.

The Global e-Sustainability Initiative (GeSI) [5] estimated that in 2010, network energy requirement in European telecom operators was about 21.4 terawatt-hours (TWh) and forecasted a figure of 35.8 TWh in 2020 if no power saving initiatives are adopted.

The increasing migration of applications to the cloud, and the increase in the number of users and the number of distributed applications, is probably the major driver of this trend. This trend will ultimately lead to increase in the amount of energy consumption at the Cloud Data

Center. Hence, Data Center energy consumption optimization is the main aim of this paper.

In a typical data center, energy consumption is mainly caused by two parts: servers and network devices (e.g., switches). Optimizing the amount of energy consumption can be done by efficient utilization of network resources. In order to do so we are using Software Defined Networks (SDN) technology.

II. SDN FOR CLOUD COMPUTING

Software Defined Networking (SDN) is an approach (a framework) to use open protocols, such as OpenFlow[3], to manage networks and to access network devices such as switches and routers without having to physically set up them[4].

As we have discussed above, in the introduction, that network devices are one of the main contributors for energy consumption at the Data Centre, SDN based solutions can be used to tackle the energy consumed by these devices.

Any network device consists of two planes:

1. Control plane: it determines where the traffic is sent
2. Data plane: it forwards traffic based on what the control plane tells it to do.

By using SDN, the control plane and the data plane can be separated and a software interface can be used to manipulate the network devices. This separation makes network virtualization possible because the commands are no longer executed on the hardware.

The data plane remains with the network hardware (eg. network switches) but the control plane that makes decisions about where traffic will be sent is now executed through software. This software interface gives the network admin an opportunity to make their network device adjustments through a Centralized Control Console (CCC) and access the network devices.

SDN provides opportunities to extend the service provisioning model of IaaS beyond computing and storage resources to include a rich set of accompanying network services for more flexible and efficient cloud computing.

III. RELATED WORK

Several approaches have been proposed for addressing the challenge of cloud energy consumption in Cloud Data Centres through virtualization, server consolidation, and intelligent cooling systems.

Abts et al. [6] dynamically adjust the link rate according to the predicted bandwidth requirement to save energy consumption. Want et al. [7] invent a correlation-aware power optimization (CARPO) algorithm that dynamically consolidates correlated data flows onto a subset of links and switches in a Data Centre Network (DCN) and shuts down under-utilized network devices for energy savings.

Ad hoc On-demand Distant Vector (AODV) [8] was proposed in 1999, and became an IETE standard. It is a routing algorithm in consideration of the distance between the nodes. Its quick adaption to link conditions, low memory usage and low network utilization make the ADOV algorithm popular.

Most approaches, as discussed above, mainly focus on exploring the SDN technology to manipulate the network devices in DCNs to reduce energy consumption. However, the inherent characteristics of SDN such as the TCAM size limitation and the multi-path routing in DCNs are usually overlooked.

So, we focus to explore these two characteristics of SDN and develop an energy-efficient technique by using them.

IV. TCAM AND MULTI-PATH ROUTING IN SDN

TCAM (Ternary Content-Addressable Memory): It is a specialized type of high-speed memory that stores forwarding rules and searches its entire contents in a single clock cycle [9]. The term “ternary” refers to the memory's ability to store and query data using three different inputs: 0, 1 and X.

The “X” input, which is often referred to as a “don’t care” or “wildcard” state, enables

TCAM to perform broader searches based on pattern matching, as opposed to binary CAM, which performs exact-match searches using only 0s and 1s.

TCAM is commonly found in networking equipment, such as high-

performance routers and switches, to increase the speed of route look-up, packet classification, packet forwarding

and access control-list-based commands.

According to the SDN rule policy, for any given flow going through a switch, there must be one forwarding rule in the TCAM to describe the flow handling action. However, the number of rules that can be put in a switch is constrained by its TCAM size as TCAMs are usually expensive and thus it is very important that we make complete use of it or no use at all. Our approach is based on this line.

Multi-path routing:

Multipath routing is the routing technique of using multiple alternative paths through a network topology [10]. Mininet [11] is an emulator that emulates the data plane of devices (such as routers and switches) and Software Defined network controllers and thus creates a virtual network topology composed of virtual hosts, switches, and a controller.

The OpenFlow [3] component which is the fundamental element in the SDN architecture gives secure access to the data plane of devices such as routers or switches from remote controller over the network. Once the network is emulated and referenced to the controller, a FlowTable can be abstracted and then that table can be used on the physical network of OpenFlow switches. The switches and controller communicate via the defined OpenFlow protocol messages such as packet-received, send-packet-out, modify-forwarding table, and get-stats.

SDN abstracts the network control functionality to a logically centralized controller. The routing decisions are then made by the controller and pushed to network nodes through a well-defined Application Programming Interface (API) such as OpenFlow.

V. PROPOSED APPROACH

Our approach is to minimize the switch energy consumption, by selectively deactivating those switches that are not in use. But the question that comes up is, which switches should be deactivated and how to route flows in the sub-topology such that minimum number of switches are used.

Each switch *s* is allotted with some TCAM size *t*. The flow-demand matrix *F* is loaded with the possible flows amongst the hosts *h* that are connected to the switches. Fig.1 below shows a topology created with 4 switches and 4 hosts and the links between them that show the possible flows between the hosts.

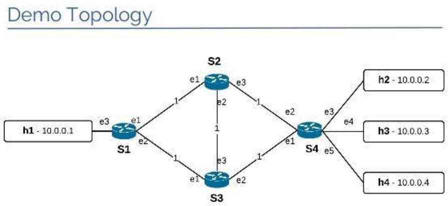

Fig. 1 A demo topology consisting of 4 switches and 4 hosts

The source and destination hosts are selected randomly and the possible flows are recorded in Table 1 that would be loaded in the flow-demand matrix F.

Source	Destination	Possible flows
h1	h2	h1□ s1□ s2□ s4□ h2 h1□ s1□ s3□ s4□ h2 h1□ s1□ s2□ s3□ s4□ h2 h1□ s1□ s3□ s2□ s4□ h2
h1	h3	h1□ s1□ s2□ s4□ h3 h1□ s1□ s3□ s4□ h3 h1□ s1□ s2□ s3□ s4□ h3 h1□ s1□ s3□ s2□ s4□ h3
h1	h4	h1□ s1□ s2□ s4□ h4 h1□ s1□ s3□ s4□ h4 h1□ s1□ s2□ s3□ s4□ h4 h1□ s1□ s3□ s2□ s4□ h4

Table 1: The possible flows between the hosts

We already know that, according to the SDN rule policy, for any given flow going through a switch, there must be one forwarding rule in the TCAM to describe the flow handling action. So, TCAMs on activated switches are always fully explored by using the SDN OpenFlow controller before selecting that particular flow.

Once a switch is activated, the aim of the SDN controller is to ensure that the TCAM utilization goes up to 100% or at least close it and contrarily the switches whose TCAM utilization is 0 are deactivated.

SDN OpenFlow controller [3] is intelligent enough to globally manage the flows' states and explicitly notifies the virtual switches to permit or suspend a flow. The idea is to aggregate network flows into a subset of switches/links and uses as few switches/links as possible to carry the flows. In this way, the active switches can carry more traffic and the idle switches can be put into sleep mode for energy saving.

VI. ALGORITHM

Algorithm: TCAM capacity based switch activation and deactivation

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Input: DCN graph $G$ consisting of hosts $h$ and switches $s$, TCAM size of each switch $t$, flow-demand matrix $F$
Construct the flows and load them in the TCAM $t$
Activate switch $si$ based on the flow
while incoming messages not equal to zero
    if(TCAM capacity $t$ of switch $si$ >0 and <= 100%)
        if(flow exists between source hi and destination hj in $F$)
            keep the switch $si$ active
            continue
        end if
    end if
    else if(TCAM capacity $t$ of switch $si$==0)
        deactivate the switch $si$
        update flow-demand matrix $F$
end while
Output: Activated switch set $SW$
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Number of switches	Number of hosts	Number of flows	TCAM size	Number of activated switches
4	4	12	350	3 out of 4
4	4	12	750	2 out of 4
6	20	140	350	5 out of 6
6	20	140	750	3 out of 6

Table 2: **Energy calculation**

From Table 2, it is evident that by varying the TCAM capacity for each combination of hosts and switches, the number of activated switches are been reduced thereby minimizing the overall energy consumption.

VII. CONCLUSION

In this era of computation and Big Data, the number of applications and the data driven by them is increasing tremendously and so should be the network capabilities. One more factor that is growing exponentially is the energy cost at the Data Centre. SDN comes as a strategic advantage to design and implement energy-efficient based approaches in order to optimize the energy consumption at the Cloud Data Centre. It is due to its key characteristics that enable an administrator to manage the entire network as if it were a single device and adjust existing configurations much quicker. In this paper, we propose a TCAM size based multi-path routing approach to optimize the energy consumption at the Cloud Data Centre, thereby reducing the Operational Cost and towards a sustained growth.

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