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Ph.D. Research Proposal

Doctoral Program in "Department Name"

AI-E2TRLB: Artificial Intelligence based Energy Efficient Task Routing and Load Balancing for SDN based IoT Applications

by

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I. INTRODUCTION / BACKGROUND

Software Defined Network (SDN) is an emerging network paradigm that assists flexible management for networks. When the network size increases, the centralized SDN controller does not meet the increasing demand for packet flow processing. Software Defined Network (SDN) is an emerging network paradigm that assists flexible management for networks. When the network size increases, the centralized SDN controller does not meet the increasing demand for packet flow processing. Hence the promising solution called multi-controller based software defined networking is proposed. A comprehensive survey for multi-controller research in SDN has been discussed in [1]. Hence the promising solution called multi-controller based software defined networking is proposed. A comprehensive survey for multi-controller research in SDN has been discussed in [2]. SDN has gained more attention in Internet of Things (IoT), which is the emerging research field in the future Internet include Industrial IoT, sensor networks and so on [3], [4]. In order to improve the QoS provisioning of SDN control and management, different mechanisms have been proposed such as Routing mechanism, Queuing Model, Scheduling Schemes, Load Balancing Schemes, Traffic Classification Schemes, and so on. However multi-controller can be classified into four major aspects such as consistency, scalability, load balancing, and reliability.

Due to the limited network resources and to satisfy the QoS requirements, load balancing issue that serves to distribute data traffic among multiple resources in order to increase the efficiency and reliability of network resources. However load balancing is accomplished by local information of the network, but SDN controllers have global information of the network and can provide more optimized load balances.

A number of meta –heuristic algorithms have been focused in SDN for load balancing, which are ACO, SA, GA, PSO, and so on. However, optimization algorithms do not handle large communication overhead [6]. With the rate of growth for network devices and its continuous sensing feature, centralized controller cannot handle the network devices. Hence multi-controller

mechanism is introduced currently, which seeks to address the research issues of single controller. In multi-controller SDN, there are two different types of controller mechanism is implemented such as centralized controller with consists of number of local controllers managed by centralized controller and distributed controllers, which are runs itself and taken action for themselves [11]. Switch migration is one of the solutions in multi-controller environment for load balancing. In distributed environment, switch migration is not adequate and it leads to time complexity. Flow rule placement in switches is an emerging research topic in SDN. Recently, it gained more attention among researchers. When flow rules installation need is high, then the flow table of switch might be overloaded, which cause severe issues in QoS provisioning. In addition, when flow rules are installed based on per flow statistics, it cause high computation overhead [9]. In [7] formulate the SDN controller's optimization problem. Then they proposed a routing algorithm Dijkstra-Repeat in SDN nodes which can offer disjoint multipath routing. In order to make it computationally feasible for large scale networks, then developed a new fast fully polynomial time approximation schemes (FPTAS) based lazy routing update. The proposed algorithm minimizes the SDN calculation and obtains lower maximum link utilization. The latency is high while using this routing algorithm. Fast re-routing with load balancing is performed using enhanced method is proposed in software defined networks.

1.1 Research Outline & Scope

QoS provisioning, and control model for SDN is required to design for IoT applications. Optimum load balance path is computed using network topology and minimize new assignments by Best Adaptive Balancing Strategy.

1.2 Research Objectives

- To manage the whole lifecycle of network and maintain a comprehensive view on the network resources when design of IoT applications.
- To improve the QoS performance in Multi-Controller based SDN which provide support for numerous users at a time and solved single node failure (centralized global controller) failure problem by incorporating secondary global controller.

- Our objective function reduces the end-to-end delay by finding the proper path (shortest pat) towards the destination node. This implies low end-to-end delay for high priority packets, high packet delivery ratio, and low packet loss probability for IoT sensitive applications.

II. RESEARCH GAPS

2.1 Common Problem Statement

When a network's coverage increases, a system based on a single SDN controller can experience a severe bottleneck. Using multiple controllers in an SDN may solve the scalability problem. It further induces poor performance in terms of quality of service (QoS). Data collection procedure from IoT and adjustment of global and local loading must be efficient.

2.2 Problem Definition

In [1] authors proposed a load balancing scheme based on genetic algorithm. When the controller is not well balanced, GA performs crossover, selection and mutation to determine the optimal load balancing. Usually, controller load can be estimated by the amount of successfully received messages from the switches, memory usage and the amount of CPU resources and transmission of flow table and network I/O. When the switches generate high complexity packet_in messages, the same performance result can be obtained in the real network.

Problems

- Single node failure can occurs due to the single usage of controller. They have estimated only expression of load for the controller. This is not sufficient for monitoring the network performance.

Proposed Solutions

- Presented a multi-controller in software defined networks. The load of the controller has been evaluated using the following metrics: CPU utilization, Memory utilization, hard disk utilization, Number of flows processing, and number of waiting in buffer.

In [2] authors introduced a software defined networking solution to address Wi-Fi congestion due to an unevenly distributed load among access points. This paper adopts standardized OpenFlow protocol and SDN controller technology to Wi-Fi networks in order to manage the SDN controller and access points. This will helps the controller to estimate the degree of load balancing among access points and choose which load level of the APs can accept association requests without revealing the controller. The load information of the controller can be estimated by three tuples: CPU utilization, memory utilization and the average packet error rate.

Problems

- The traffic congestion is not monitored such as QoS constraints and user priorities are considered during load balancing decisions and also LIFO (Last-In-First-Out) policy to associate the packets to the controller.

Proposed Solutions

- We have mitigated the congestion problem by classifying packets into three types that are: Expedited Forwarding Queue, Assured Forwarding Queue and Best Effort Queue.

In this article [3] authors proposed a RouteGuardian, a reliable security oriented SDN routing scheme which considers the capabilities of SDN switch nodes integrated with a network security virtualization network. This scheme employs the distributed network security devices effectively to ensure analysis of malicious node isolation and abnormal traffic. In addition, RouteGuardian supports dynamic routing reconfiguration based on the latest network status.

Problems

- When routing packets from one switch to another, there occurs Link Spoofing Attack between switches and also link discovery is vulnerable in SDN.

Proposed solutions

- Link spoofing attack is mitigated by estimating the trust value for each switch, whose participate in routing

In this paper [4] addresses research challenges in routing schemes using load balanced routing and machine learning algorithms in SDN. Conventional routing algorithms such as Bellman-Ford algorithm, Link State Algorithm and Dijkstra Algorithm are presented to achieve load balance of routers. These algorithms are time consuming and not effective for load balanced routing. In this paper authors primarily contributions three operations for addressing this issue: (1). Network dimension reduction using Principal Component Analysis (PCA), (2). Queue Utilization (QU) prediction is implemented and (3). Load Balanced Routing using Deep Neural Network (DNN). In this paper software defined routers (SDR) is considered, which are classified into local routers and central router. In local router packets arrived status is monitored and the next hop is selected for transmission, whereas central router is used to detect the QU and traffic rate of all the local routers.

Problems

- Load balance routing for next hop selection is based on QU predicted using DNN, which does not sufficient to achieve load balancing. A task with high priority (real-time) need to be waiting for a longer time. The proposed SDR approach does not suitable for large scale network since central router will leads to serious network burden issue.
- PCA has several drawbacks (does not produce meaningful network patterns, and time consuming task), which does not produce the effective representation of SDR and packet loss rate increases since link quality is a significant metric for extracting network topology.

Solutions Proposed

- Isomoprhism algorithm is proposed for topology management, which effectively determines the link connectivity. We proposed Partially Connected Topology, which

connects based on four criterions: CPU computing resources, node degree, queue utilization, and link quality

- Priority aware energy efficient routing is proposed by GRNN, which considered several metrics for load balanced routing

A new rule placement is a challenging issue [5] due to the limitation of storage constraint of switches. In this paper, a novel approach is proposed for rule placement according to two strategies such as Serial Relationship and Parallel Relationship. For rule placement handling, in this paper a new data structure is proposed which is named as OPTree (Ordered Predicate Tree), which represent the rule and neighbor devices relationship is considered for rules placement and OPTree helps to insertion and search algorithm. Optimum device is computed with the use of OPTree for rule placement.

Problems

- OPTree uses Binary Search algorithm, which height increases as large and time required for insertion and deletion operations is huge for worst case.
- This paper considers the position relationships for neighbor devices, but the number of rule placements is high, which increases computational burden for SDN controller. Employing fat tree or star topology increases the number of rule placement and hence the network topology is important for global network management.

Proposed Solutions

- Proposed Isomorphism Algorithm based Partially Connected Topology for Rule placement in SDN controller.

III. RESEARCH CONTRIBUTIONS

To mitigate the issues illustrated in the problem statement, this research has designed a new model for load balanced routing and traffic classification in SDN-IoT environment. In this work we concentrated on four issues for QoS improvement: Priority Classification, Task Routing, Load Balancing and Rule Placement. This work presented AI based energy efficient

task routing, and load balancing for IoT sensitive and non-sensitive applications. The proposed work consists of distributed controllers such as Global and Local Controllers, Switches, Access Points (AP), IoT devices. There are three layers are incorporated for achieving our objectives that are following:

- IoT Devices and Users
- Data Plane
- Control Plane

In the first layer, IoT devices/users are deployed and sensing is started. The sensed information is acquired and transferred via APs. In AP, traffic is classified into four classes and tasks are put into individual queues:

(1). 1st Queue – handles real-time delay intolerant tasks
(2). 2nd Queue – handles delay tolerant tasks
(3). 3rd Queue – handles real-time mission critical tasks
(4). 4th Queue – handles non real-time and non-mission critical tasks

This priority classification is suited for various application examples. We split the input traffic into four classes using four criterions: (1). Packet Deadline, (2). Packet Size, (3). Protocol Used, and (4). Type of Service Request by SVM classifier.

In Data Plane, firstly construct network topology for number of switches deployed on network. We presented a Partially Connected Topology**.** For routing, we extract topological information. For topology construction, **isomorphism algorithm** is used to analyze the topology connectivity. It defines the each switch connection to neighbor switches via its Nearest Euclidean Neighbors. After network construction, we allow data packets from queue.

Firstly, data packets from 1st queue is handled since that are having absolute priority (delay <5 ms) so we must allow those packets to be processed first. Towards that another tasks are executed concurrently. Based on the delay tolerance for application services, we process the next queue. When data packet is arrived into queue, we must check the flow rule for corresponding packet in a switch. If the flow rule is match in flow table, then the packet is

processed. For that packet, we establish the route. Based on the packet traffic we construct the route. Hence we called it **priority based energy efficient routing**. To find the optimum path, several criterions are taken that are Packet Loss Rate, 1st Queue Packets Queue Utilization Rate, Latency, Bandwidth, Hop Count and Distance between two Switches**.** For traffic aware routing, we proposed **Gated Recurrent Neural Network (GRNN)** which provides better performance than DNN and conventional machine learning methods. GRNN is a combination method, which contain the strengths of CNN and RNN.

In this way, routing is implemented. If the flow rule does not match with the flow table, then switch is requested for the path to that leaf controller. Then controller has given path. With the partial connected topology (parallel and serial relationships to switches), switch has verified that whether the flow rule presented for all switches in the available path. If flow for a data packet is presented in all switches in the available path, then no Rule Placement is required. Otherwise, flow rules are deployed for switches. In this way, rule placement is invoked.

Finally, **adaptive load balancing** is taken into account for SDN-IoT. For offloading, we concentrated on two types:

(1). Packets Offload from Overloaded Switch to the Under loaded Switches (It is called as Optimum Relays Selection) using **Fuzzy AHP** (It is held in Leaf Controller. **Criterions for** packets load balancing: Packet arrival rate, no of packets in buffer, packet loss rate, expected delay, no of flow entries, tot. no of packets processed in history

(2). Switches Offload from Overloaded Leaf Controller to the Under Loaded Controllers (It is called as Switch Migration) using **Deng Entropy function**

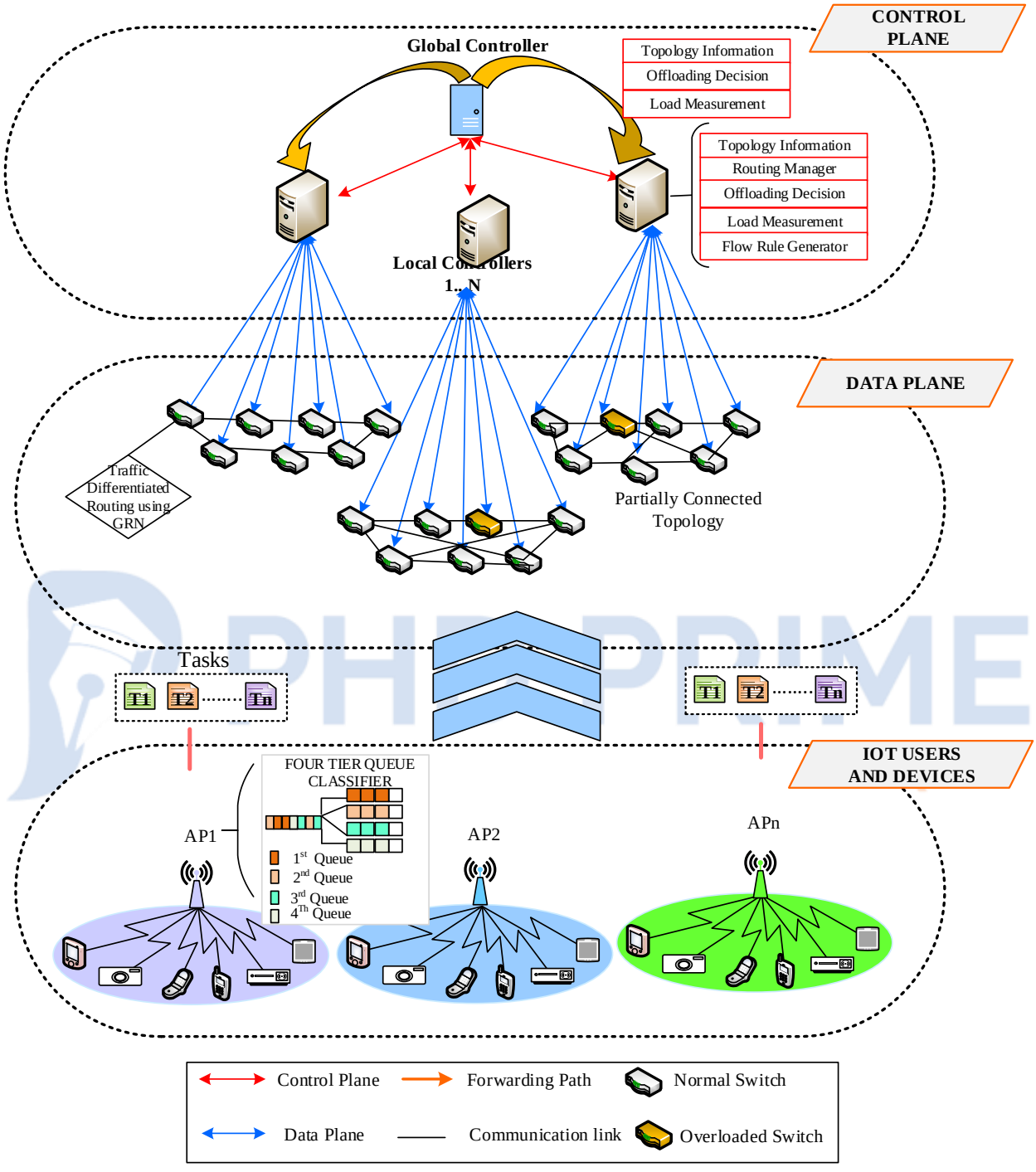
Performance Evaluation

Finally, we compute the performance of our proposed scheme for the following

- Round Trip Time
- Response Time
- Jitter

- Packet Loss Rate
- Migration Time
- Switch Failure Rate
- Controller Failure Rate
- Throughput
- No. of Rules Placed

SYSTEM ARCHITECTURE



IV. RESEARCH NOVELTIES

- We predict the switches utilization and packets migration is implemented when invoke by the controller. We implement packets migration based Ranking based Entropy Function
- We propose switch migration by new HDK-NN algorithm, which is Hassanat Distance based K-Nearest Neighbor Algorithm.
- We implement DANN which finds the optimum path in single iteration, where we do not required k-number of paths and we considered several metrics for balancing the network and packet forwarding.
- Computation of delay between switch and controller is less due to partially connected topology using ISOMAP algorithm and the flow installed for certain switches, which decreases the flow table overloading by installation of new flow rules. Hence the network overhead is decreases.

V. PREVIOUS WORKS & LIMITATIONS

Paper 1

Title: SDN-enabled Traffic Aware load balancing for M2M Networks

Concept – This article proposed a traffic aware load balancing mechanism in M2M (Machine-to-Machine) networks using SDN enabled scheme. In this load balancing scheme, SDN have capability to monitor and control the network by controller and it also satisfy different quality of service (QoS) requirements via traffic identification and rerouting. The simulation results proved that the proposed traffic aware load balancing scheme minimizes service response time up to 50% compared to the non-SDN load balancing scheme.

Problems

- This paper considers service delay and load requirements. This is not sufficient to avoid traffic. Hence the congestion remains the problem. However, malicious packets may increase the traffic because the packets are not classified based on the service type.

- Service response time is high
- Security of the nodes (switches) is not concentrated. This may give the opportunity to attackers to perform any malicious activity in the network.

Proposed Solutions

- We classified the packets based on the priority and we consider service type as a one of the metric for packets classification. This can improve the QoS of the network.
- We compute the trust value for switches during routing.

Paper 2

Title: Detour: Dynamic Task Offloading in Software Defined Fog for IoT Applications

Concept – In this paper, task offloading is initiated and implemented in software defined networking. SDN controller is fully capable to offload tasks in a dynamic and optimum way. Here task execution at the fog nodes and the fog node consists of task queue for processing tasks and optimal fog node is selected for task execution. For queuing M/M/1 queue model is proposed and task offloading is initiated via routing path in data plane towards SDN controller.

Limitations

- End-to-end delay is high for requesting task offloading to SDN controller and high priority tasks must wait for a longer time.

Paper 3

Title: Traffic Load Balancing Software Defined Networking (SDN) Controller as Virtualized Network Function

Concept – Authors have considered load balancing issue by deploying virtual SDN controller (VController). When network traffic is huge, virtual SDN controller is deployed over the network. For this purpose virtual network function (VNF) is used. Authors introduced the concept of the primary and secondary VController, where the load of primary controller gets

increase, and then secondary controller splits the load and process the user requests. The second controller has the copy of primary controller and it balances the load among switches.

Limitations

- Large number of processing load balancing is required, and poor QoS achievement due to virtual controller placement

Paper 4

Title: SDN Enabled Traffic Aware Load Balancing for M2M Networks

Concept – In this paper authors have focused on traffic aware load balancing in SDN assisted IoT (Machine to Machine Communication) networks. Contributions of this paper is following: (1) determine traffic flow at arrived switches with the use of packet header information, (2). Route is considered and the determined traffic flow is forwarded and processed via the route and (3). Flow table is updated if the latency exceeds than the threshold value.

Limitations

- For traffic aware load balancing, delay and type of service is considered which are not sufficient for delay tolerance to providing M2M services

Paper 5

Title: Fragmentation-based Distributed Control System for Software Defined Wireless Sensor Networks

Concept – In this paper, multi-controller distributed SDN mechanism is implemented for WSN applications. Data acquisition and transmission is executed from WSN and controlled in SDN controller. Fragmentation method is introduced in this paper, which contains two different controllers such as local controllers and global controller. Global controller has the global view of local controller's management and control. In software defined WSN, local controller is connected with sink node and it communicates and gathers data from sensor nodes.

Paper 6

Title: Dynamic Load Balancing of Software-Defined Networking Based on Genetic-Ant Colony Optimization

Concept – In this paper, dynamic load balancing is focused by the authors using hybrid genetic and ant colony optimization algorithm. For fast global searching, genetic algorithm is used and to get the optimum solution ACO algorithm is used. In GA, fitness is calculated using Path Length, energy consumption rate for sending and receiving a packet, and Energy status of the entire switches. In ACO, the optimal path is identified and packet is forwarding in that path.

Limitations

- Search speed for path selection is sufficient, but criterions for path selection are insufficient to find the optimum path.

Paper 7

Title: NSAF: An Approach for Ensuring Application-Aware Routing Based on Network QoS of Applications in SDN

Concept – In this paper, network situation aware framework (NSAF) is presented in this paper for handling application routing. Routing is based on QoS requirements and network status changing. This NSAF mechanism comprised of Application Registration, Network Status Monitoring and Violation Detection and Routing Control. For different service classes (Application Type), different serv class is incorporated such as packet loss, delay and jitter.

Limitations

- It does not manage the network changes and control paths when application is change.

Paper 8

Title: An Innovative Approach for Real-Time Network Traffic Classification

Concept – In this paper traffic classification is executed for video streaming applications using machine learning algorithm. Naïve Bayes classification method is proposed for real-time video streaming traffic network classification, which primary intention is to reduce the delay for multimedia service applications requested by the user. Hence in this paper user preference is considered for traffic classification and tolerating delay for sensitive applications.

Limitations

- In this paper, Naïve Bayes Algorithm is proposed for traffic classification, which is a probability based approach, does not suitable for accurate classification.

Paper 9

Title: EASM: Efficiency-aware switch migration for balancing controller loads in software-defined networking

Concept – In this paper distributed multi-controller based switch migration idea is implemented on SDN. Authors proposed the strategy called EASM (Efficiency Aware Switch Migration) for distributed controllers load balancing. The Load Difference Matrix and Trigger Factor to estimate controllers load balancing. The Migration Efficiency problem considered load balancing rate and migration cost for optimal migration of switches.

Limitations

- EASM is not suitable for switch migration in large scale network environment.

Paper 10

Title: FlowStat: Adaptive Flow-Rule Placement for Per-Flow Statistics in SDN

Concept – In this paper authors have proposed three processes: Route Selection, Rule Installation and Rule Redistribution. Authors formulated that Max-Flow-Min-Cost optimization problem for optimal forwarding paths selection. For the computed path, flow rules are installed. AT last, rule redistribution is considered for flow rules traffic congestion at the network, which

decreases the network traffic. It reduces the end-to-end delay for packet forwarding and flow rule installation at data plane.

Limitations

- When the path is frequently selected, installation of flow rules for the particular path is high and it cause flow table overloading in switches. Controller does not considered the metrics for forwarding path selection, which cause severe threats in QoS improvement.

Paper 11

Title: An Improved Mechanism for Flow Rule Installation in In-Band SDN

Concept – In this paper, SDN controller computes and places new flow rules for switches flow table. If a switch receives the data packet, but it does not match with the flow table rules, the switch directly communicate to controller. In this paper, controller place the flow rule for a particular switch and also gives the best path for processing a packet. Then the packet is transmitted to neighbor switches. For flow rule installation, switch controller delay and switch to switch delay is computed for packet transmission via path.

Limitations

- Computation of delay between switch –controller and two switches is relatively high, and traffic overhead is high and flow table of the switch is overloaded within few packets processing.

Paper 12

Title: Topology Preserving Traffic Engineering for Hierarchical Multi-Domain SDN

Concept – Authors of this paper have proposed hierarchical control plane for multi-domain environment. Preserving topology in network traffic is one of the big objectives of this paper. For this purpose, local controller is assigned for each domain (geographical area), and the global controller has the global view to monitor all local controllers in different domains.

Limitations

- Load is imbalanced in the network since when hierarchical structure, the upper layer of controllers is balanced and the bottom layer is very under loaded, which given less priority. It does not update the frequent network changes and global controller is failed to handle failures among local controllers immediately.

Paper 13

Title – A Distributed Decision Mechanism for Controller Load Balancing based on Switch Migration in SDN

Concept – In this paper, distribution decision mechanism is proposed for switch migration in multi-controllers SDN environment. There are three major operations are performed in DDM that are collection of data, switch migration, and synchronization of controller state. Initially, SDN controller gathers information of the whole network since it has global view. In DDM, controllers load status is predicted. Hereby switch migration is implemented according to the probability. The proposed DDM has obtained good performance in load balancing with the aid of effective switch migration process.

Limitations

- Switch migration is executed based on the selection probability, which increases communication overhead between switch and controller. Optimum selection of switch for migration requires optimum solution using heuristic method
- The whole network is imbalanced because DDM supports for controller load balancing only and this paper does not mentioned how to resolve the overload of switches
- This DDM cause large QoS degradation of end users

Paper 14

Title – DSSDN: Demand-Supply based Load Balancing in Software Defined Wide-Area Networks

Concept – This paper resolves the problem of control (packet-in) messages load balancing among distributed SDN controllers in wide area networks. If the controller gets overloaded, OF switches are migrated from the current serving controller to nearest under loaded controller, but this leads to poor QoS among end users. To mitigate such issues, DSSDN is presented which utilizes load status of the SDN controllers. The Karush- Kuhn Tucker (KTT) conditions are promoted for the best controller selection.

Limitations

- The local controller could minimize the processing burden on the WAN controller, but the network performance (throughput) would reduce when the WAN controller was overload or failure, since WAN will acts as an root controller
- The KTT is a non-linear programming theorem in which optimal conditions are estimated. However to derive the sufficient and necessary optimality conditions any optimization technique is required

Paper 15

Title – A Hierarchical Mobility Management Scheme based on Software Defined Networking

Concept – In this paper, hierarchical SDN based mobility management (HMM) mechanism is proposed in control plane, which support intra-domain and inter-domain handovers. The H-SMM is obtained. Experiment results show that the proposed H-SMM is better in terms handover delay and communication overhead and also it is suitable for both intra-domain and inter-domain handovers. The H-SMM model is suitable and more appropriate for sensitive applications.

Limitations

- In control plane, H-SMM model is splits into two layers. In the first layer, global controller (GC) is deployed whereas in second layer, multiple local controllers (LC) are deployed and which are control of GC. It is not suitable for large scale network when all

local controllers overloaded at the same time, GC processing at many times, which increases communication overhead and also traffic load becomes high

- Both handover might cause large delay when GC overloaded.

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