Activity Engineering in Software-Defined Networking: Measurement and Management

P. Venkateshwar Rao,
Assistant Professor, Department of CSE,
Malla Reddy Engineering College (Autonomous), Secunderabad, Telangana State

ABSTRACT

As the future generation network architecture, software-defined networking (SDN) has exciting application prospects. Its center idea is to separate the forward layer and control layer of network system, where network operators can program packet forwarding behavior to significantly improve the innovation capability of network applications. Traffic engineering (TE) is an important network application, which studies quantity and managing of network traffic, and designs sensible routing mechanisms to guide network traffic to improve utilization of network resources, and better meet requirements of the network quality of service (QoS). Compared with the traditional networks, the SDN has many advantages to support TE due to it's distinguish characteristics, such as isolation of control and forwarding, global centralized control, and programmability of network behavior. This paper focuses on the traffic engineering technology based on the SDN. First, we propose a reference framework for TE in the SDN, which consists of two parts, traffic quantity and traffic managing. Traffic quantity is responsible for monitoring and analyzing real-time network traffic, as a prerequisite for traffic managing. In the proposed structure, technologies related to traffic quantity include network parameters quantity, a general quantity structure, and traffic analysis and prediction; technologies related to traffic managing include traffic load balancing, QoS-guarantee scheduling, energy-saving scheduling, and traffic managing for the hybrid IP/SDN. Current existing technologies are discussed in detail, and our insights into future growth of TE in the SDN are offered.

Keywords - Software-defined networking (SDN), Traffic Engineering, Network monitoring, Network Quantity, Network Managing.

I. INTRODUCTION

With the consistent improvement and inside and out application of distributed computing and Internet of Things (IoT) [1], [2], the conventional system engineering can't meet the necessities of current industry fields, for example, Cyber- Physical Systems(CPS) [3], 5G remote system [4], and Internet of Vehicle [5]. In this way, a few analysts proposed that Software Defined Network (SDN) will be connected to the industry 4.0 condition, which will build flexibility and development limit of IoT in industrial structure [6][8]. Security and Traffic Engineering (TE) are both research subjects for SDN applications in the fields of modern conditions. In the text [9], we considered security issues of SDN, in this paper, we will most part concentrate on the TE issue of SDN. TE is an imperative application identified with arranges structure, whose principle errand is to examine how to quantify and break down constant system traffic, and outline sensible directing instruments to timetable and guide organize traffic to make strides usage of system assets, or better meet necessities of the system Quality of Service (QoS). Conventional system TE advancements basically incorporate IP-based TE and MPLS based TE. By and large, IP-based TE takes care of the issue of multipath traffic stack adjusts by streamlining the IP steering calculation to dodge organize blockages [11]. For instance, Fortz and Thorup [10] propose an area seek calculation, which depends on interface weights of Open Short Way First (OSPF) to change the steering figuring system, also, finally get different equal most brief ways to accomplish traffic stack adjust. Chen et al. outline a multipath arranging for IoT interactive media detecting [12]. IP-based TE innovation has two clear disadvantages: first, when OSPF connect weights are utilized to control steering of a system, traffic can't be part in an self-assertive extent, prompting powerlessness to make full utilization of arrange assets; second, when joins fall flat, or connection weights of the system topology change, the OSPF convention takes a few time to unite to another system topology, which potentially prompts arrange blockages, parcel misfortunes, delays, and even steering circles.

Keeping in mind the end goal to maintain a strategic distance from these deformities of IP-based TE, scientists proposed another arrangement, in which organize parcels are sent by the Multi-Protocol Label Switching (MPLS) [13], rather than IP headers. Be that as it may, the convention component of the MPLS is excessively mind boggling, and can lead, making it impossible to an elite overhead, so it is difcult to fulfill prerequisites of information focus systems requesting high connection transfer speed use, environmentally friendly power vitality sparing, and high unwavering quality.

To entirety up, control administration and information sending in customary systems are firmly coupled, since the entirety arrange is controlled by dispersed gadgets, where fine-grained control of traffic administration can't be accomplished, furthermore, flexibility and extensibility are difficult to progress. Thusly, it is essentially to build up a system design and relating TE innovation to take care of this issue. Programming Defined Network (SDN) is an imaginative system engineering that was proposed by scientists of Stanford College, and got across the board consideration as of late. Its center thought is to isolate the sending and control planes of a system framework [14], [15], with the goal that system administrators can program bundle sending conduct to significantly move forward the development capacity of system applications. Thought about to the conventional system engineering, SDN has the accompanying recognize attributes.

1) Concentration of control. SDN controller stores the whole system data, including the system topology, dynamic changes of the system status, and worldwide application prerequisites, for example, QoS and security prerequisites.

2) Programmability. A system administrator can progressively program information sending layer gadgets to upgrade the assignment of system assets.

3) Openness. Sending gear has a unified interface to speak with SDN controller, which does not depend on various hardware providers, and the SDN controller can advantageously get arrange status information to plan organize traffic.

The attributes of SDN are helpful for unraveling current issues of system traffic designing, which can be condensed as takes after.

1) Traffic estimation. We can convey adaptable worldwide estimation errands flexibly in the SDN, which can gather continuous system status data, and screen and dissect traffic halfway in the controller.

2) Traffic planning and administration. Traffic application necessities can be thought about all around, with the goal that flexible, granular traffic planning is conceivable.

3) The Open Flow switch has various stream table pipelines, which make flow administration more flexible and efficient.

Nonetheless, despite the fact that SDN gives much help to traffic designing, it has numerous issues that are should have been explained. Right now, there is no examination that would demonstrate that the customary system TE procedure can be completely perfect with the SDN. Another issue is that SDN and customary IP system will exist together for quite a while, and there is pretty much nothing inquires about considering the TE innovation of half breed IP/SDN systems. Consequently, TE advancements in light of SDN is of extraordinary significance for facilitating uses of SDN. Whatever remains of paper is sorted out as takes after. Segment II proposes a system for TE in the SDN, portraying its segments, and connections among them. Segment III talks about traffic estimation issues identified with the SDN in detail. Area IV talks about traffic estimation issues identified with the SDN and IP/SDN in detail. In Section V we examine related open issues of TE in the SDN, and give conclusions.

II. Structure for TE in SDN

Joining the thoughts of TE for conventional systems with qualities of the SDN, we propose a structure for TE in the SDN, as showed in Figure 1.

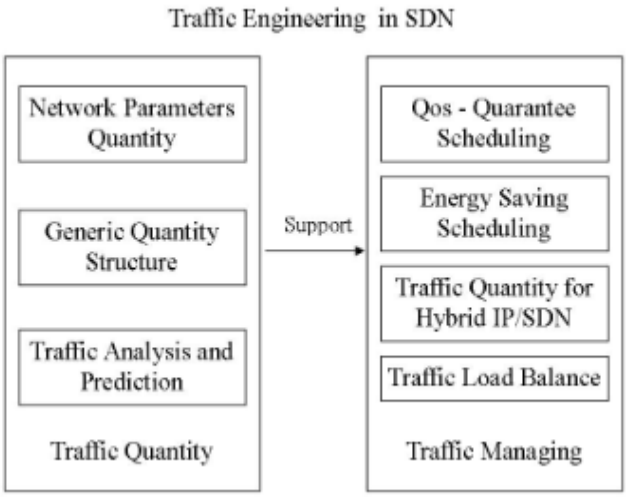

Fig 1: Structure for TE in SDN

The structure incorporates two sections: traffic estimation also, traffic administration. Traffic estimation mostly considers step by step instructions to screen, measure and obtain organize status data in the SDN condition. The system status data incorporates the present topology association status, ports' status (up or down), different sorts of parcel counters, dropped parcel counters, usage proportions of connection transmission capacities, end-to-end arrange inactivity, end-to-end traffic lattices et cetera. In light of the system status data, we can approve whether the present system status is right, and anticipate the future traffic incline by breaking down bundle counters insights, to maintain a strategic distance from organize blockages and enhance organize efficiency. We partition examine take a shot at traffic estimation into three bearings: arrange parameters estimation, a nonexclusive estimation structure, traffic investigation and expectation. Traffic administration primarily contemplates step by step instructions to oversee and plan arrange traffic in light of the organize status data gave by the traffic estimation innovation, to fulfill end client necessities of system applications, for example, QoS. We partition inquires about work on traffic administration into four headings: traffic stack adjusting, QoS-ensure planning, vitality sparing booking, and traffic administration for the half and half IP/SDN. It is worth saying that the half breed IP/SDN exists for quite a while. In this manner, it is important to consider TE in the mixture IP/SDN.

III. TRAFFIC QUANTITY IN SDN

Traffic Quantity is a critical research branch of TE. This segment examines related innovations from the accompanying three perspectives: arrange parameters plan and observing advancements, a widespread structure of flow quantity, traffic investigation and expectation advancements.

A. Network Parameters Quantity

Network parameters are arrangements of records that speak to the current arrange status. Sensible network parameter configuration is a precondition for powerful Network management. Subsequently, arrange parameters configuration is an essential undertaking of network quantity. We surmise that SDN organize quantity parameters for the most part incorporate three sorts: organize topology parameters, organize traffic parameters, and network execution parameters. Network topology parameters allude to the quantity of system hubs, interface data transmissions, association structures and port statuses. As indicated by the Open Flow specification, the SDN controller recognizes the present network topology currently utilizing Link Layer Discovery Protocol (LLDP) , and keeps up worldwide topology data. A mid the procedure of connection disclosure, the controller sends LLDP parcels as Packet-out messages to all switches in the system. At the point when the SDN switch gets a LLDP bundle from the controller, it sends the bundle to all different changes associated with it specifically. Whenever a switch gets a LLDP parcel from another switch, it sends the LLDP parcel to the controller as a Packet-in message for help, in light of the fact that there is no comparing sending principle in the switch' Flow Table. After the SDN controller gets Bundle in messages with LLDP, it can break down which switches are associated straightforwardly to each other, and develop the global topology. The relating working procedure is delineated in Figure 2.

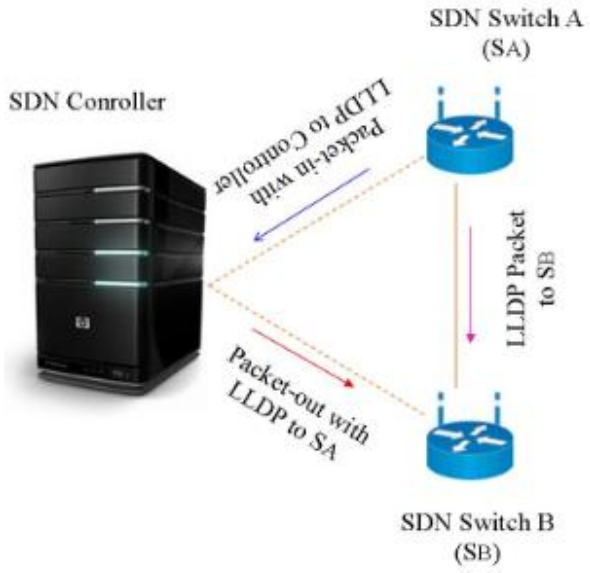

Fig 2: Detection process using LLDP for SDN Topology

Network traffic parameters allude to the number or speed of system parcels that go through network gear or then again a system port, for example, the aggregate number of IP parcels, the quantity of bytes every second et cetera. System traffic parameters are considered as a vital reason for identification of the present system status and examination of system client conduct. In the SDN arrange, there are two sorts of system traffic, control traffic and information traffic. Control traffic is a information flow that is transmitted between the SDN controller and switches, and information traffic is an information flow that is transmitted between switches. Keeping in mind the end goal to decide flow qualities, we should gather factual data on each switch port, counting the quantity of packets, size of packets, and additionally the end-to-end traffic lattice of the whole network, which speaks to the network flow between any two network hubs.

B. Generic Quantity Structure

Network traffic estimation has two commonplace modes, dynamic what's more, detached modes. The dynamic estimation mode produces additional distinguishing traffic, while the latent estimation mode does not, on the grounds that it just screens traffic that goes through SDN switches. Numerous SDN quantity structure embrace traffic observing strategies for conventional IP systems in view of packet testing, in which SDN switches arbitrarily creep nearby bundles to acquire traffic quantity . A famous system for packet sampling and analysis is the Net Flow developed by Cisco [27].The Net Flow identifies flows utilizing five-tuples, where a switch keeps up store record data for each flow. At the point when a flow arrives, the Net Flow thinks about the head of this flow with the data put away in a nearby store record. In the event that they coordinate, it refreshes the packet count; else it includes another passage to the reserve record for this new flow. Other flow examining arrangements incorporate the s Flow and s Flow. They do examining at the passageway of every switch in a certain extent, and afterward send head data of the flow what's more, relating timestamp to the inside authority server. All above estimation techniques suggest a great deal of weight on the SDN focal controller in vast scale systems. Along these lines, they are not reasonable for SDN applications. Keeping in mind the end goal to help an assortment of estimation errands and applications for the SDN successfully, it is important to plan a general SDN estimation system. The PayLess is a flow estimation system with low costs in light of surveying. The PayLess system is planned as a segment of the Open Flow controller, and gives a REST ful style interface for applications. Specifically, the PayLess is mindful for parsing demand summons from the application level of undertakings, and changing these orders into way anticipating some switches. In this manner, the PayLess keeps up a unique perspective of system data for applications; what's more, gives unified programming interfaces to an assortment of system applications. An application defines an errand in JSON organize, where custom segments of clients can be added to the quantity system. exhibit a general, dynamic estimation structure, the Open Sketch, utilizing a product defined technique to gauge traffic. Flow based estimation has imperfections, for example, counter

overhead what's more, estimation mistake, so it can't meet necessities of various clients. Then again, the Open Sketch underpins customization for various clients, and distinctive assignments have diverse prerequisites for equipment, so it is difficult to send different assignments on similar equipment hardware. So as to completely think about adaptability and efficiency, the Open Sketch recommends that estimation control and information layers ought to be isolated, where information layers are outlined as three-stage activities that can be configured powerfully. At the first phase, the Open Sketch offers an assortment of hash calculations that guide bundles into a little measure of quantity information. At the second stage, it stores and pursuit rules utilizing the TCAM and trump card coordinating. At the third stage, it gives flexible tallying utilizing the SRAM. Utilizing this pipeline outline, the Open Sketch abstracts an assortment of measure calculations into a few general advances. At the same time, it gives different quantity modules in the control layer which enables clients to modify any periods of the information layer said above. In any case, it must be noticed that the Open Sketch necessities to upgrade a few sections of equipment, which potentially confines its across the board application. Figure 3 demonstrates the engineering of the Open Sketch.

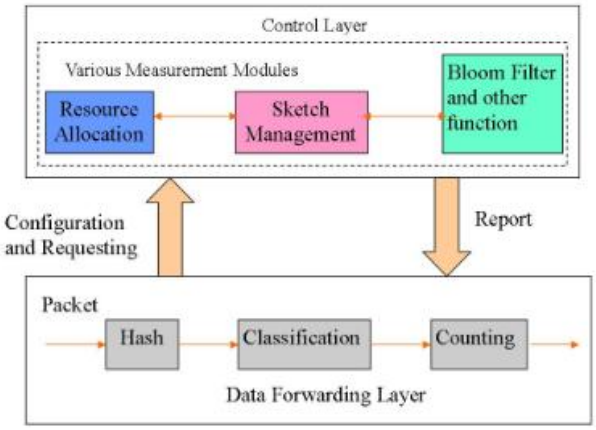

Fig 3: Data Forwarding and Control Layer

Traffic data accumulation and collection are two vital parts of traffic quantity, which require hardware support in the data layer, for example, the TCAM. However the current equipment assets of SDN switches are regularly constrained. What's more, arrange applications have numerous concurrent flow observing errand necessities, rather than supporting than just a single estimation undertaking at a time of time. Accordingly, the subject of how to designate equipment assets sensibly to give precise and compelling flow estimation is additionally imperative. Starting here of view, Moshref et al. propose a versatile administration design for equipment assets, the DREAM, which can successfully balance estimation precision and asset costs. The center thoughts of the design are as per the following.

1) The exactness of a flow quantity task depends upon the equipment assets allocated to the task. With an expansion in the quantity of assets allocated to the errand, there will be a point, after which the capacity of advancing errand exactness ends up noticeably smaller with additionally increment in assets.

2) Resources required by estimation undertakings are extraordinary contingent upon the time and size of the flow, so it is conceivable to alter these assets to raise their usage efficiency.

The DREAM incorporates three levels: the best level is the client layer that is in charge of producing estimation errands, counting sorts of undertaking, specific flow edges, exactness prerequisites and so forth. The center level is the DREAM calculations running on the SDN controller. They get undertakings from clients, at that point make relating undertaking objects, and finally convey these theoretical errands into different switches. Indeed, the arrangement process is additionally the procedure to ask for TCAM assets in the change, and to store estimation rationale in the TCAM. As per the constant input of traffic checking, the DREAM calculations can assess the precision of estimations, also, alter assets designated to each errand, or reuse assets of numerous errands. Then again, the calculations can choose whether to acknowledge another errand concurring to the present circumstance. The base level is SDN sending gadgets that are in charge of measuring stockpiling assets, what's more, return aftereffects of constant flow checking.

C. Traffic Analysis and Prediction

Traffic examination and expectation is a vital piece of system estimation, and one of their objectives is to recognize arrange bizarre traffic, and to break down conceivable possibilities in the system, such system blockages. Along these lines, we can give better information to arrange traffic booking also, administration. Then again, another imperative question is to test whether the present status of the system is right, for example, accuracy of current system hardware configurations, directing circle issues and so on. In this segment, we present related advances regarding SDN traffic examination and expectation. the use of a few conventional irregular traffic recognition techniques to the SDN, what's more, gives a decent down to earth arrangement involvement in SDN abnormal traffic identification. Be that as it may, these techniques are generally straightforward, and appropriate for some specific situations. Propose an online traffic abnormality identification technique, the Open TAD.

To start with, the flow table measurement is gathered from the controller on the web, and the traffic network what's more, example entropy framework are built and amassed. At that point the PCA strategy is utilized to identify anomalous traffic. The Open TAD is straightforward and compelling, and traffic inconsistencies can be confined quickly. This technique is a lightweight online traffic abnormality discovery technique for the SDN. Information sending in systems rely upon a wide range of system gear giving an assortment of capacities, and the process is intricate and defenseless against potential configuration blunders, programming bugs, and different issues, which perhaps cause different system botches, for example, directing circles. The SDN simplifies organize applications, yet it is still difcult to stay away from botches because of many-sided quality of the product itself. In this manner, amend status identification and approval is an essential inquire about errand in the field of traffic estimation for the SDN.

IV. TRAFFIC MANAGING IN SDN

Network administration means to keep up arrange accessibility what's more, enhance arrange execution. Sensible booking of network traffic is an imperative approach to enhance QoS of the network. When all is said in done, there are various ways between the source and goal hub in the SDN, which give probability for traffic planning. The SDN controller keeps up the worldwide perspective of present utilization of every way in the arrange utilizing different network estimation advancements specified above, and we can outline a traffic planning calculation to powerfully design information sending ways to meet clients' prerequisites. In this area, we examine traffic administration advancements in the SDN from the accompanying viewpoints: traffic stack adjusting, QoS-ensure booking, energy saving planning, and traffic administration for the mixture IP/SDN.

A. Traffic Load Balance

In the SDN, there are two sorts of system traffic, information layer traffic and control layer traffic. In this segment, we chiefly talk about the heap adjusting innovation for information layer traffic. Contrasted with the conventional system, the fundamental preferred standpoint of load adjusting in the SDN is that sending choice computations are incorporated and not appropriated, permitting considering numerous discretionary connection usage rates and flow attributes all the more exhaustively, to design the system of stack adjusting better.

The Equality Multipath Directing Innovation (ECMP) in light of a hash calculation is a viable load adjusting arrangement. As indicated by ECMP steering, there might be different sending ways for an objective system. At the point when the bundle lands at a switch or switch, switch or switch extricates the header fields of the parcel to make hash counts, and at that point chooses one of the forward ways as per the hash esteem, which brings about that IP parcels having the same head are sent along a similar way. An unmistakable imperfection of the ECMP is that a considerable measure of expansive flows, called elephant flows, are sent to a similar way, which brings about load irregularity furthermore, transfer speed squander, as represented in Figure 4.

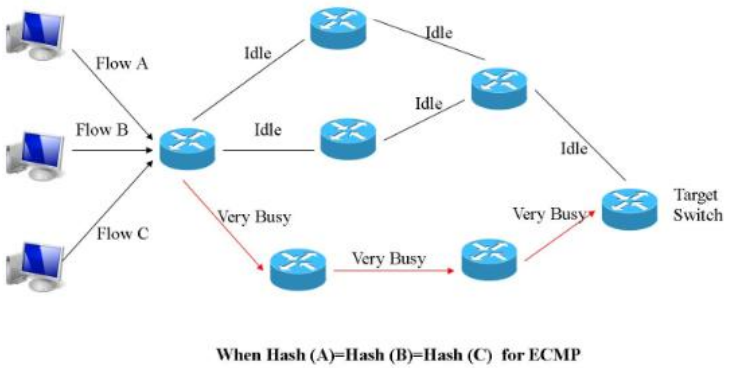

Fig 4: Detection process using LLDP for SDN Topology

A straightforward arrangement is to part traffic from the bundle level, not the flow level. This strategy enormously enhances adequacy of load adjusting, yet it makes reordering issue of the TCP send window more genuine, which causes pointless TCP send window shrinkage. With a specific end goal to tackle the above issue, a few enhanced ECMP plans are proposed. Their principle thought is to recognize elephant flows first, and after that pick the correct way by the controller.

B. QoS-Guarantee Scheduling

In a Network, a considerable measure of ongoing business traffic, for example, voice information, texts et cetera, is touchy to delays also, bundle misfortunes during the time spent transmission. Hence, sensible planning of system assets to give QoS for business is a critical issue of traffic administration. The SDN gives an open control interface to help flexible system traffic planning techniques, which can fulfill QoS necessities of various system applications.

It propose a QoS-ensure arrangement in the SDN, the HiQoS. The HiQoS identifies numerous ways amongst source and goal hubs by lining instruments to ensure QoS for various sorts of traffic. Trial comes about demonstrate that the HiQoS plan can lessen delays furthermore, increment throughput. It merits saying that the HiQoS can recoup from interface disappointment rapidly by rerouting traffic from fizzled ways to other accessible ways.

The Open QoS plot expects to give QoS ensure for mixed media business flows dispersion. Since bundle heads of mixed media business flows are altogether different to other parcel heads, the Open QoS isolates all information traffic into two gatherings, media and information flows, utilizing Open Flow configuration coordinating principles. The Open QoS watches execution of sending ways as far as postponements and parcel misfortunes, what's more, chooses a best way that can fulfill QoS prerequisites. Other information flows are still sent to the first way. However, the Open QoS just enhances interactive media flows booking, also, does not consider business flows having numerous QoS prerequisites.

C. Energy-Saving Scheduling

Because of economy and natural security, decreasing vitality utilization has turned into an imperative issue in late years. Data and correspondence advances are broadly utilized as a part of regular day to day existence. Vitality utilization due to media transmission systems represents 5% of all vitality utilization in created nations, and it is developing at the yearly rate of 10%. Along these lines, the subject of step by step instructions to lessen organize vitality utilization is extremely important. Lately, numerous arrangements in regards to organize vitality sparing were proposed. Since servers are as of now primary buyers of vitality, there is less research to take care of the issue of vitality utilization of server farm systems. Be that as it may, the level of system vitality utilization may even increment to half. Consequently, the SDN ought not just consider interface usage, stack adjusting, and QoS prerequisites, yet in addition vitality utilization necessities during the time spent traffic administration. As is outstanding, organize vitality utilization fundamentally relies upon arrange units, for example, joins, switches and so forth. As of now, there are two sorts of techniques to spare vitality, connect rate versatile and rest models. Connection rate versatile techniques powerfully modify interface rates as indicated by traffic request, on the grounds that the vitality utilization of connections relies upon their information transmission loads, as opposed to use, On the other

hand, the rest demonstrate controls off some system segments, or interprets some non-working segments into rest mode to spare vitality.

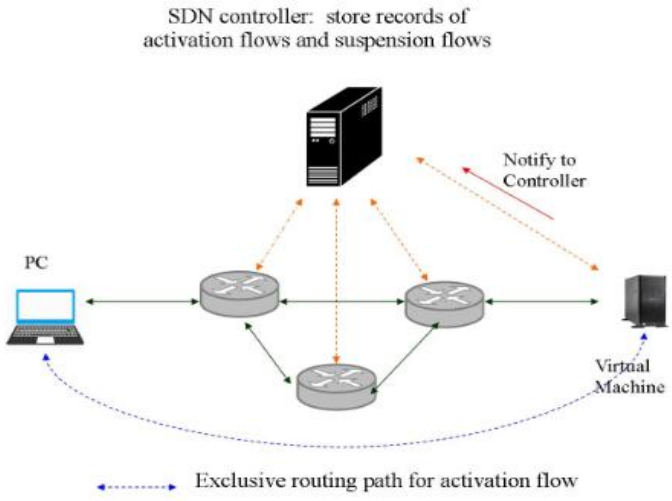

Fig 5: Exclusive routing structure for SDN

D. Traffic Managing For Hybrid IP/SDN

SDN-based TE advances give successful answers for organize advancement. In any case, the procedure to supplant conventional systems for the SDN endures quite a while, so IP/SDN cross breed arrange developed. Only one out of every odd hub of an IP/SDN half breed organize has highlights of a SDN switch, and we just get a precise worldwide perspective of the system somewhat. Contrasted with the unadulterated SDN, traffic administration of the IP/SDN mixture organize is more difficult. Accordingly, the inquiry of how to oversee traffic in the IP/SDN half and half system turns into a test.

It introduce a design of traffic oversee that is appropriate for the IP/SDN half and half system. Specifically, it tries to use the brought together controller to acquire high system usage, and additionally to decrease bundle misfortunes and postponements. To begin with, SDN controller's advancement issues are detailed for traffic designing with fractional organization. At that point the Completely Polynomial Time Approximation Schemes (FPTAS) is intended to take care of these issues. Utilizing these calculations, tests demonstrate that execution picks up are achievable in the IP/SDN half breed arrange condition. investigate traffic building issues in SDN/OSPF half breed systems. It is expected that OSPF weights and flow part proportions of the SDN switch can both be changed, and the controller can part flows coming into the SDN switch self-assertively. Conventional system hubs still run the OSPF. A novel calculation, the SOTE, is proposed to acquire bring down most extreme connection usage. Results demonstrate that at the point when just 30% of SDN hubs are conveyed, close ideal execution is gotten.

Network look for an ideal relocation succession of inheritance switches to SDN-empowered switches, with the goal that we can choose where and what number of switches to move. The creators propose a heuristic calculation to find a relocation arrangement of switches that acquires a large portion of benefits from the point of view of traffic designing. The calculation was assessed by reproductions. The analyses demonstrate that the proposed calculation is quicker than other movement calculations in scanning for a relocation arrangement. On the off chance that system hubs can be legitimately sent, just about 40% of switches prompt a large portion of benefits.

V. CONCLUSION

The improvement of the traffic designing innovation of the SDN is an imperative angle to advance boundless application of the SDN. An effective case is Google B4 arrange. B4 organize takes preferences of attributes of the SDN to actualize the goals of TE necessities that conventional systems can't understand. In this paper, we propose a structure for TE in SD and talk about related advances from two angles: traffic estimation and traffic administration. As to estimation, there are related system parameters in each layer of the system that speak to the status of system. By and large, we screen the parameters of the application layer

and system layer. The traffic lattice is perfect data to reflect the present condition of the system, however anticipating advancements of the traffic framework require additionally examine. Concerning administration, the principle objective is to give sensible traffic planning methodologies as indicated by organize parameters acquired utilizing flow estimation advances to fulfill specific necessities. We talk about four angles, to be specific, traffic stack adjusting, QoS-ensure, vitality sparing booking, and traffic administration of the IP/SDN cross breed organize. Indeed, there are a few issues that are not included, for example, TE in view of the MPLS in the SDN, and execution investigation of TE, which are probably going to wind up noticeably intriguing issues later on.

REFERENCES

[1] J. Wan, C. Zou, K. Zhou, R. Lu, and D. Li. 2014. IoT sensing framework with inter-cloud computing capability in vehicular networking, Electron. Commerce Res., 14(3), 389-416.

[2] J. Wan, D. Zhang, Y. Sun, K. Lin, C. Zou, and H. Cai. 2014. VCMIA: A novel architecture for integrating vehicular cyber-physical systems and mobile cloud computing," Mobile Netw. Appl.,19(2), 153-160.

[3] J. Wan, H. Yan, Q. Liu, K. Zhou, R. Lu, and D. Li, Enabling cyberphysical systems with machine-to-machine technologies," Int. J. Ad Hoc Ubiquitous Comput., Vol. 13, No. 3-4, pp. 187-196, 2013.

[4] K. Lin, W. Wang, X. Wang, W. Ji, and J. Wan. 2015. QoE-driven spectrum assignment for 5G wireless networks using SDR," IEEE Wireless Commun., 22(6), 48-55.

[5] J. Wan, H. Yan, D. Li, K. Zhou, and L. Zeng. 2013. Cyber-physical systems for optimal energy management scheme of autonomous electric vehicle, Comput. J., 56(8), 947-956.

[6] S. Wang, J. Wan, D. Zhang, D. Li, and C. Zhang. 2016. Towards smart factory for industry 4.0: A self-organized multi-agent system with big data based feedback and coordination, Computer Networks, 101, 158-168.

[7] S. Wang, J. Wan, D. Li, and C. Zhang. 2016. Implementing smart factory of industrie 4.0: An outlook," Int. J. Distrib. Sensor Netw., 4, Art. No. 3159805.

[8] J.Wan et al., Software-de_ned industrial internet of things in the context of industry 4.0, IEEE Sensors J., doi: 10.1109/JSEN.2016.2565621.

[9] Z. Shu, J. Wan, D. Li, J. Lin, A. V. Vasilakos, and M. Imran, Security in software-de_ned networking:Threats and countermeasures, Mobile Netw. Appl., doi:10.1007/s11036-016-0676 x.

[10] B. Fortz and M. Thorup. 2000. Internet traf-c engineering by optimizing OSPF weights, in Proc. 19th Annu. Joint Conf. IEEE Comput. Commun. Soc. INFOCOM, 2. 519-528.

[11] G. Han, J. Jiang, N. Bao, L. Wan, and M. Guizani. 2015. Routing protocols for underwater wireless sensor networks, IEEE Commun. Mag., vol. 53, no. 11, pp. 72-78.

[12] M. Chen et al. 2016. Multipath planning based transmissions for IoT multimedia sensing, in Proc. IEEE IWCMC, Paphos, Cyprus, 1-10.

[13] G. Swallow. 2000. MPLS advantages for traf-c engineering," IEEE Commun. Mag., 37(12), 54-57.

[14] Y. Li and M. Chen. 2015. Software-de-ned network function virtualization: A survey, IEEE Access, 3, 2542-2553.

[15] J. Liu, Y. Li, M. Chen, W. Dong, and D. Jin. 2015. Software-de_ned Internet of Things for smart urban sensing, IEEE Commun. Mag., 53(8), pp. 55-63.