INTERNATIONAL JOURNAL
OF SOFT COMPUTING

MEDWELL PUBLICATIONS SINCE 2000

A Comparative Analysis of QoS in Wired and Wireless SDN Based on Mobile IP

[1]Asma Islam Swapna, [1]Habibur Rahman, [1]Nazrul Islam and [2]Rahamatullah Khondoker
[1]*Department of Information and Communication Technology, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh*
[2]*Fraunhofer Institute for Secure Information Technology (SIT), Rheinstr. 75, Darmstadt, Germany*

Key words: QoS analysis, SDN, SDWN, Micro-mobility, mininet Wi-Fi, Mobile IP

Corresponding Author:
Asma Islam Swapna
Department of Information and Communication Technology, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh

Page No.: 82-89
Volume: 16, Issue 5, 2021
ISSN: 1816-9503
International Journal of Soft Computing

Abstract: Software Defined Networking (SDN) is getting much attention for large network implementation. It provides the programmable feature in the network plane. Demand of wireless networking features is growing simultaneously. Mobility management for large network is an issue in Internet Engineering Task Force (IETF). A large number of solutions are proposed already supporting mobility in the network. Mobile Internet Protocol (MIP) is used in the mobility management. However for SDN platform Mobility adds roaming capability for the mobile nodes in the Software Defined Wireless Network (SDWN). In the wired scenario, SDN has different functionalities to provide network services based on the fixed node. This study provides an analysis in Quality of Service (QoS) in SDN and SDWN. Mininet Wi-Fi as a tool and Ryu as a controller are used for implementing the mobility management API. Random Walk model is applied as the mobility functionality on end nodes. Several QoS measuring matrices are analyzed based on the network topology. Round-Trip Time (RTT), Cumulative Distributed Function (CDF), packet loss and throughput, are analyzed for QoS comparison in SDN and SDWN scenarios based on MIP.

INTRODUCTION

The most emarging network architecture that provides dynamicity, adaptability and cost effectiveness is termed as Software Defined Network (SDN). It is used for complex, heterogeneous networks and vast commercial aspects. SDN allows programmability in the network plane. It decouples the control plane from data forwarding plane[1]. All routing decisions are controlled by centralizing devices called controllers. The decisions are managed by the APIs of the network. The SouthBound API is used to talk with forwarding devices like network switches in both directions. The OpenFlow protocols handles routing decisions from controller to switch maintaining flow rules into the flow table of the switches[2].

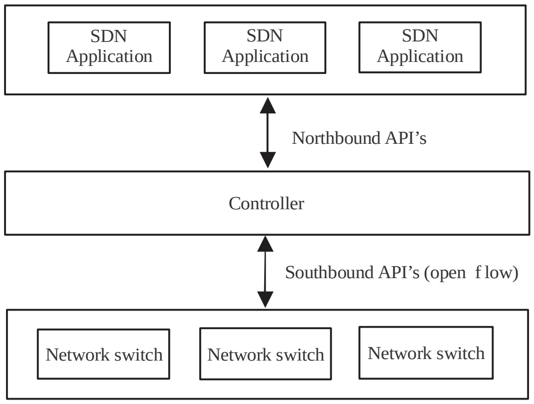

Fig. 1: Software defined network architecture

The network applications using "NorthBound APIs" sit on the controllers. It maintains the communication and provide various on demand network services programmed in the applications. Figure 1 depicts the basic SDN architecture. This SDN analogy is similar to the way the applications are programmed on computer operating systems. The APIs are written to the Network Operating System of the controllers (NOS). This approach facilitates the node's mobility. The mobility development of the Internet, making the mapping function programmable for packet flows[3]. The architecture of SDN enhances the distributing functionality. This centralizes the mobility management for distributed Home Agent[4]. In Software Defined Networking (SDN) scenario, data forwarding network components are connected directly to the central SDN controller. It is connected through physical transmission media. SDN is most suitable for single controller central access to all network entities on a small geographical region (Fig. 1).

Software Defined Wireless Network (SDWN) is the complete SDN solution for Wireless-Personal Area Networks[5]. SDWN supports the flexible definition of SDN controller policies. The mobile nodes can run legacy protocol stack for granted backward and peer compatibility on vast and complex geographical expansion[5]. Hereby, the Quality of Service (QoS) of such SDN composed of mobile nodes are needed. The nodes random mobility, needs appropriate comparative outlook against SDWN to build a flexible, scalable and heterogeneous wireless network.

QoS of the underlying SDN network is defined with the parameters, Round-Trip Time (RTT), throughput, packet in message handling and packet loss ratio etc. Software Defined Wireless Network (SDWN), provides programmability and centralized control outside the wireless access points (APs). SDWN has got emerging research importance soonafter the increased attention of mobile network operator on this technology[6, 7].

Previous studies performed on SDWN includes, OpenRoad proposals to improve robustness during mobility handoff using OpenFlow network[8]. In study[9], CellSDN is proposed for LTE network based operating system for cellular wireless network. Distributed mapping functionality is added for Mobility Management in the network in study[10]. For mobility management both wireless and mobile network has got the researchers' attention where WLAN got most works paid off[8, 11]. No works are done before of SDN for both mobile nodes and use of middle boxes. There is no comparative analysis of SDN and SDWN is performed based on the Quality of Service (QoS) parameters. However, at first, the implementation of SDN for mobile nodes and the uses of middle boxes is needed. Secondly, a performance analysis of the concerned network for both SDN and SDWN is needed. A comparative QoS study is complementary for further network deployment.

This study concerned with the implementation of middle boxes in SDN for mobile nodes. This study presents a Qualitative QoS analysis for wired SDN and SDWN. The research work is performed analyzing the QoS metrics on SDN where nodes have got Mobility. A parallel analysis is performed for SDWN mobile nodes. To cover up the mobility solution, Mobile IP (MIP) is considered in this simulation illustration. It uses a Care-of-Address (CoA) for routing towards a new network. To achieve the goal of this research, Mininet-WiFi network emulator is used to create and observe the QoS metrics for both simulation scenarios based on Mobile IP.

Background and related work: Mobility in wireless network means the change of point of attachment and the IP address for a Mobile Node (MN)[12]. Hence, mobility management of conventional SDN and SDWN is crucial to assume a comprehensive advantage of their perspective deployment. Various research and proposition of several SDN based system is performed for effective mobility management by Yang *et al*.[12].

Handling the mobility for wireless network is difficult task. The mobility architecture of the SDWN is illustrated. Mobile IP functionality is clearly described in paper[13]. Research findings in study[11] demonstrated and evaluated the mobility of an SDN based IP network. Triangle routing is occurred while maintaining the host's mobility in an SDN network. The programmable control plane is used to solve triangle routing. While updating the routing table of the network switches, the control plane controls the routing information. Middle box provides the faster routing facilities. The use of middle boxes provides higher throughput, as well as lower latency, dramatically improving quality of service (QoS)[14]. The essential idea of this study was implementing the middle-box for mapping functionality to multiple locations in the network. In study[15], a solution for IP based Mobility Support in SDNs evaluated for multiple inter-domain communication. However mobility maintenance in the SDWN becomes the essential simulation.

Later on with the emergence use of wireless network several further research conducted in Software Defined Wireless Network (SDWN)[12]. Yang *et al*.[12] interpreted these two technologies, SDWN and Mobile Wireless Network (MWN). The researchers investigate their joint diverse heterogeneous network design with crucial challenge and significant future benefits in a wireless network. They represents the successful implementation of two converged network technologies. It improved the resource utilization, customized services, innovation from network layer to the physical layer and moreover guaranteed QoS. Monitoring the performance of QoS in the SDN the application “MonSamp” is successfully implemented by Raumer *et al*.[16]. The highest quality of service for the business customer in SDN is achieved in study[17]. However, no one is studied the comparative analysis of SDN and SDWN with Mobile IP.

Hens, the above outcome and endless possibilities of SDN in mobility network is analyzed. This paper represents the QoS analysis and comparative performance study on SDN architectures both in wired and wireless scenario. This paper provides the mobility of the hosts in the network architecture on its control plane. However the paper also implements the middle box for better outcomes of Quality of Service (QoS) on its simulation.

MATERIALS AND METHODS

A comparative analysis is performed on wired and wireless SDN network architectures. The performance metrics for Quality of Service of such network architectures are evaluated side by side. This study compares wired and wireless SDNs for data plane’s QoS metrics and mobility management. The mobility functions that are used for the mobile nodes, are based on the Random Direction and Random Walk Model[18]. Among so many network simulation tools including Mininet Wi-Fi [19], OMNET++[20], Network Simulator-2 (NS-2)[21], Network Simulator-3 (NS-3), EstiNet[22], OpenNet[23], Mininet Wi-Fi was chosen. To allow the programmability on the control plane of SDN network using python language Mininet Wi-Fi was chosen. It is used for the system implementation and data collection for evaluation. However, Mininet Wi-Fi has the rich experimentation benefits for both rich APIs and mobile hosts allowing research on SDWN. This study is a comparative analysis of the Wired and Wireless SDN in terms of QoS parameters. Programming in the control plane of the network is performed coding with python (V 3.6.0).

Mininet Wi-Fi is used in this study implementing the SWDN and wired SDN. For the mobility management of the network topology two sets of evaluation is considered; one for wired SDN and another for wireless SDN. The simulation is performed in a virtual machine using VirtualBox with the configuration: Intel’s core-i5 processor with 2 GB memory.

Simulated data were captured using Wireshark, running the ping command between hosts on Mininet Wi-Fi terminal. At the end of each simulation the appropriate QoS parameter values were checked for result analysis. A comparative percentage of the parameters is defined to conclude the study.

Design and implementation: The conducted analysis depicts a Software Defined Network (SDN) topology configured in both wired and wireless in two separate scenarios. These two topology represents the network QoS performance while mobility in nodes is present. Figure 2 depicts the network components and the functionality of the SDN topology. The topology is designed with a single controller, four network domains (A-D) and 10 hosts at each domain. Hosts are connected with APs by wired connection. Open Flow (v 1.4) protocol is used for the packet transmission. Ryu controller controls the mobility for hosts. The hosts follow the Random Walk model for their mobility functionalities.

Figure 3 depicts the configuration of Software Defined Wireless Network (SDWN) topology. The components are placed same as the Software Defined Network (SDN) topology in wireless mannered. The hosts are connected in wireless system. Hosts could move randomly from any position to the other of the access points connectivity region.

The mobility controller Ryu is connected with the mobility management application through northbound API. The access points (APs) are connected with the Ryu controller via southbound API. For the mobility handover session two Correspondence Nodes (CN-1 and CN-2) and two Mobile Nodes (MN-1 and MN-2) are used. The

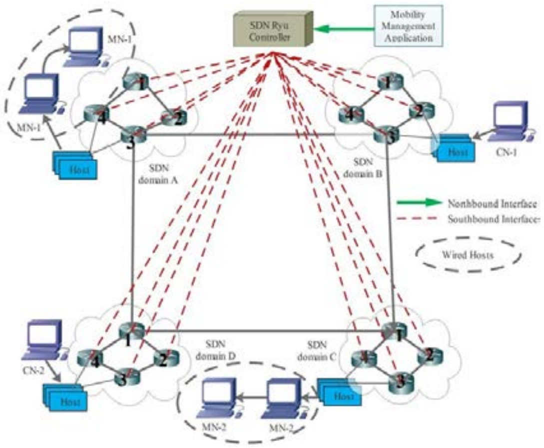

Fig. 2: Wired SDN network topology with fixed stations

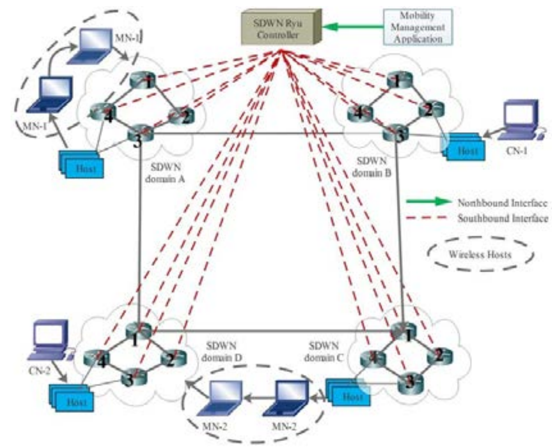

Fig. 3: Wireless SDN network topology with mobile stations

access points are numbered in 1-4. For the continuous flow connection the acces points are connected via a secure chanel. The simulation mechanism is described in the bellow sub-section.

Implementing wired SDN: Flow entry in wired SDN is recorded for each new position of the Mobile Nodes. The MN-1 is connected in the AP-4 in the network domain A (Fig. 2). The mobile node (MN-1) is in the wired connection with the AP-4. Dashed line circle indicates the wired connection. When it moved, the access point 4 is send an acknowledgement to the controller to handover the session to the AP-1. The session is considered in the SDN domain A. A short life time of the entry is managed to minimize the total number of flows for all nodes in the controller. Before running the simulation of the wired SDN topology in Mininet Wi-Fi, flow entry is pre-downloaded in the controller to ensure the reachability of each node in the network. The performance of the topology is measured running Iperf command in the terminal between the hosts. The Wireshark collected the end-to-end performance metrics including TCP secquences, Round Trip Time (RTT) and throughput (Fig. 2).

Implementing wireless SDN: For SDWN context, Mininet Wi-Fi emulator is used. The hosts that connects the APs through WLANx interface is shown in Fig. 3. In this case, a bridge is created among the OpenFlow switch and Wi-Fi interface. When the Mobile Nodes are moved from one acces point to the another, the flow entity is hand overed. Considering the domain C and D in Fig. 3, the MN-2 is connected in the AP-4 in domain C. Whent moved towards the domain D, it sends an acknowledgement to the controller to handover the session to the AP-2. The Ryu controller smartly handel the session and provides the continious flow connection.

For both scenarios packet interval is set 2 seconds and transmitted packet numbers are 100 for each simulation. After simulating the network, the traffic is captured in the Wireshark. The packet detailes are export in the Comma-Separated Values (CSV) file. Then the captured results are ploted in the graph using MATLAB. The results are represented in the result analysis section.

RESULTS AND DISCUSSION

This study illustrates a comparative study and analysis of QoS parameters in two different scenarios of wired SDN and wireless SDN using Mininet Wi-Fi platform. In the topological design the host nodes are fixed in the wired connection. On the other hand, in wireless SDN, the Mobile Nodes (MN) functions mobility in getting detached from current Access Point (AP) and therefore attached to the nearby one. Control Node (CN) updates the flow table based on each new entry forwarded by the switch or APs resultant from mobility functionalities. This mobility model in Mininet Wi-Fi follows Random Way Point (RWP) to move around the MNs in the testbed. MN in the SDWN testbed connects the strongest signal providing AP among other switches in nearby and leaves the previously connected switch.

Implementation follows with two different cenerio with differently organized network topologies. The first topology includes basic LAN based wired network performs on OpenFlow and MIP. The second, inherits with wireless nodes MN, connected with SDN controller via swiching devices called wirelss APs. For both cases, the controller is considered as dynamic and scalable with network size, hence Ryu contrller has been in use. MIP model redirects all the Correspondent Node (CN)-to-Mobile Node (MN) traffic once MN moves to a new switching AP. The traffic handover is performed on strongest signal first basis.

Two sets of analysis are performed based on Mininet Wi-Fi testbed implementation. The first set analyzes the throughput, round-trip time and packet loss ratio for obtained OpenFlow and TCP packet transmission to represent the QoS in both wired SDN and wireless SDN topologies. The later set includes control plane overhead of both the topologies to represent scalability in each scenario.

QOS metrics analysis: Between the hosts sta1 and sta6 Iperf is simulated during the time when sta1 performed two handoffs first from ap1 to ap2 and later from ap2 to ap3. On the opposite way Iperf among sta6 and sta1 is performed through handoffs ap4-to-ap2 and ap2-to-ap1.

Time-sequence graph: Time Sequence graphs show the general activity and events that happen during the lifetime of a controller connection. Collected TCP time sequence of this handoffs in both wired and wireless SDN is depicted graphically in Fig. 4. The Y-axis represents sequence number space and the X-axis represents time, and the slope of this curve gives the throughput over time. This illustration indicates degraded handoff efficiency in wired SDN where retransmission caused some packet loss keeping some space of sequences in between. Movement among the subnets also caused timeouts. The simulation is performed for 10 sec for appropriate analysis in both scenarios. In both scenerios, sequences are captured twice, once during contrller-AP communication and another AP-MN communication. It depicts for all cases, contrller-AP sequence is horizontal and throughput is still. On other hand, throughput increases with time for wireless network than wired SDN. MIP is creating efficient handoff for SDWN inheriting more throughput over time. Wired SDN finds it time consuig to reach the mark because of complexity in handling efficiency on IP based mobility management scenerio (Fig. 4).

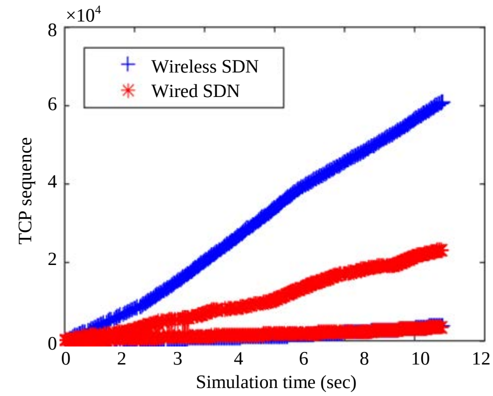

Fig. 4: TCP sequence with respect to time for wired and wireless SDN during handoffs

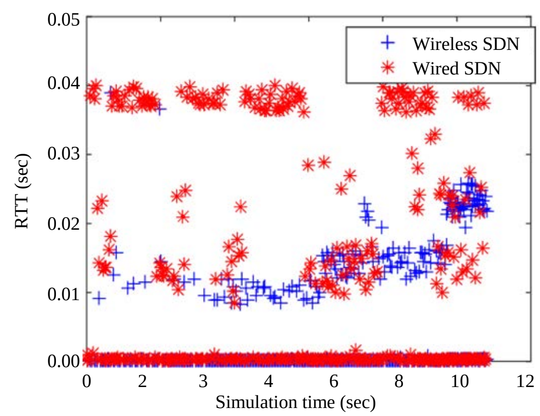

Fig. 5: RTT values of simulation events during handoff situations

RTT graph: With the equal simulation time Fig. 5 shows the RTT in wired and wireless network testbed collected from the Mininet Wi-Fi testbed. The Y-axis represents RTT in seconds and the X-axis represents simulation time in seconds. The red and blue dots represent RTT samples calculated from non-retransmitted segments in wired and wireless SDN. It is vigilant that, RTT levels in both cases rises higher during handoffs. However, wired SDN stays with a higher RTT value than wireless SDN requires for each handoff. This is because, wireless SDN avoids triangle routing choosing the strongest signal providing switches for MIP ensuring optimal forwarding path. Besides, RTT value of wireless SDN increase with handoff number (Fig. 5).

Throughput and packet loss: Throughput and packet loss ratio is also simulated for the both scenario above.

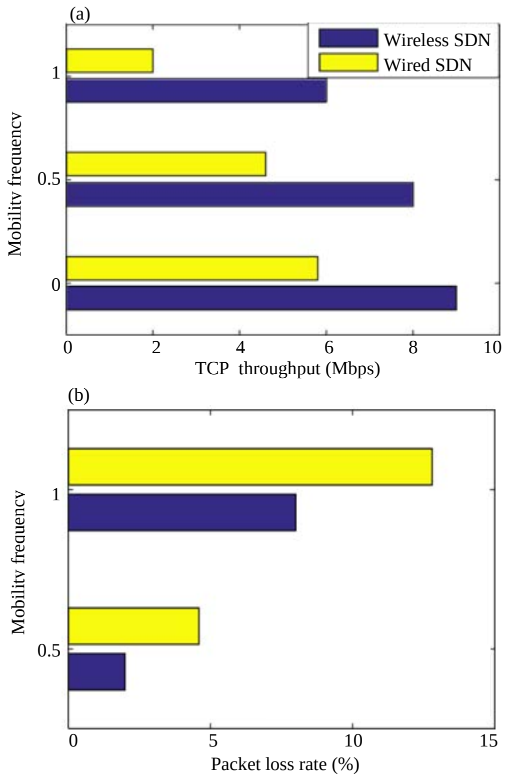

Fig. 6 (a, b) (a) TCP through and (b) UDP packet loss ratio of wired and Wireless SDN with varied mobility frequencies

With different mobility frequency of 0, 0.5 and 1 per second, Iperf is performed between sta1 and sta6 for 10 times taking 1 min each time. This simulation depicts Fig. 6 illustrating higher average throughput in each mobility frequency for SDWN compared with wired SDN. The results also represent in Fig. 6 that SDWN has 40% lower UDP packet loss compared with wired SDN because of handoff efficiency and MIP mobility solution in wireless SDN.

Scalability issues: For scalability analysis, topologies of both wired and wireless consisting of 1 controller, 4 switches and 6 host MNs in each topology is simulated for 10 times with sessions of 10 sec each to generate UDP traffics. During this time number of packet-in messages were captured for 10 simulation times.

CDF result nalysis: In simulation data, the maximum packet-in messages per second turned 35 and average

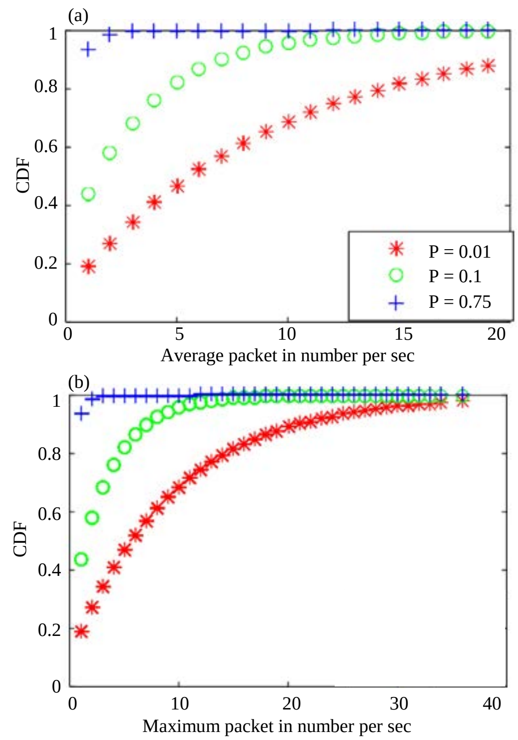

Fig. 7 (a, b): CDF of (a) average packet-in messages and (b) maximum packet-in messages in each controller of both scenarios. Here, p stands for probability of inter-switch movement of host MNs

packet-in messages are 20 got both the scenerios for the simulation duration. These values represents the overhead and mobile scalability of the network. Later Commulative Distributed Function (CDF) of average and maximum packet-in messages are calculated. CDF of average and maximum packet-in messages in handling session handovers by the controller in both wired and wireless SDN is depicted in Fig. 7. The figure depicts similar outcome in simulation results, about 10-13 messages are received by the controller in each scenerio with distinguished interdomain movement probability p (0.01, 0.1, 0.75). This increased CDF in wireless SDN illustrates more scalability than the scalability in wired SDN.

Simulation results demonstrate that probability of inter-domain movement slightly affects average and maximum packet-in messages. In conclusion, largest overhead is the cause of burst packet-in messages which is not prevalent here. The larger the netwoork, the higher the number of packets. More packets transmits throught the controller and it's efficiency deceases. Figure 7a and (b), depicts less scalability options for wired SDN network than SDWN. Hence, the network of compared to wired SDN, SDWN demonstrates scalable performance in packet overhead management.

CONCLUSION

This study is the study of QoS analysis on wired SDN and wireless SDN. It concludes a representation of comparative side-by-side graphical analysis with integration of IP mobility management. The outcomes from Mininet Wi-Fi testbed of these two network types demonstrated a visible state in terms of QoS parameters. Mininet Wi-Fi simulation evaluated that, wired SDN has significantly lower TCP throughput, higher UDP packet loss ratio than the value of wireless SDN. Higher transmission time during handoffs is vigilant in wired SDN compared with wireless SDN's QoS metrics. The reason of such difference is the efficient handoff, MIP based mobility solution for wireless SDN and wired SDN is lag behind in handoff efficiency. MIP mobility model takes less timeout, lower retransmission time in wireless SDN. However, both networks show feasibility and scalability in controller performance. Therefore, the study concludes better adaptively of wireless SDN in complex cellular network.

RECOMMENDATION

In future it will be interesting to prototype the network in real time environment. Security prospects on Transport Layer of SDWN is a potential of research for complex cellular network.

REFERENCES

01. Lo, C.C., P.Y. Wu and Y.H. Kuo, 2015. Flow entry conflict detection scheme for software-defined network. Proceedings of the 2015 International Telecommunication Networks and Applications Conference (ITNAC), November 18-20, 2015, IEEE, Sydney, Australia, pp: 220-225.
02. Shivayogimath, C.N. and N.U. Reddy, 2016. Performance Analysis of a Software Defined Network using Mininet. In: Artificial Intelligence and Evolutionary Computations in Engineering Systems, Dash, S., M. Bhaskar, B. Panigrahi and S. Das (Eds.)., Springer, New Delhi, India, pp: 391-398.
03. Valtulina, L., M. Karimzadeh, G. Karagiannis, G. Heijenk and A. Pras, 2014. Performance evaluation of a SDN/OpenFlow-based Distributed Mobility Management (DMM) approach in virtualized LTE systems. Proceedings of the 2014 IEEE Globecom Workshops (GC Wkshps), December 8-12, 2014, IEEE, Austin, Texas, pp: 18-23.
04. Chan, H., D. Liu, P. Seite, H. Yokota and J. Korhonen, 2014. Requirements for distributed mobility management. Internet Eng. Task Force, 1: 1-24.
05. Costanzo, S., L. Galluccio, G. Morabito and S. Palazzo, 2015. Software Defined Wireless Network (SDWN): An evolvable architecture for W-PANs. Proceedings of the 2015 IEEE 1st International Forum on Research and Technologies for Society and Industry Leveraging a Better Tomorrow (RTSI), September 16-18, 2015, IEEE, Turin, Italy, pp: 23-28.
06. Bernardos, C.J., D.L.A. Oliva, P. Serrano, A. Banchs and L.M. Contreras *et al*., 2014. An architecture for software defined wireless networking. IEEE. Wirel. Commun., 21: 52-61.
07. Sama, M.R., L.M. Contreras, J. Kaippallimalil, I. Akiyoshi, H. Qian and H. Ni, 2015. Software-defined control of the virtualized mobile packet core. IEEE. Commun. Mag., 53: 107-115.
08. Yap, K.K., T.Y. Huang, M. Kobayashi, M. Chan, R. Sherwood, G. Parulkar and N. McKeown, 2009. Lossless handover with n-casting between WiFi-WiMAX on OpenRoads. ACM Mobicom (Demo), 12: 40-52.
09. Li, L.E., Z.M. Mao and J. Rexford, 2012. Toward software-defined cellular networks. Proceedings 2012 European Workshop on Software Defined Networking, October 25-26, 2012, IEEE, Darmstadt, Germany, pp: 7-12.
10. Chan, H.A., H. Yokota, J. Xie, P. Seite and D. Liu, 2011. Distributed and dynamic mobility management in mobile internet: Current approaches and issues. J. Commun., 6: 4-15.
11. Wang, Y., J. Bi and K. Zhang, 2015. Design and implementation of a software-defined mobility architecture for IP networks. Mob. Networks Appl., 20: 40-52.
12. Yang, M., Y. Li, D. Jin, L. Zeng, X. Wu and A.V. Vasilakos, 2015. Software-defined and virtualized future mobile and wireless networks: A survey. Mobile Networks Appl., 20: 4-18.
13. Akyildiz, I.F., J. Xie and S. Mohanty, 2004. A survey of mobility management in Next-generation all-IP-based wireless systems. IEEE Wireless Commun., 11: 16-28.

14. Tu, R., X. Wang, J. Zhao, Y. Yang, L. Shi and T. Wolf, 2015. Design of a load-balancing middlebox based on SDN for data centers. Proceedings of the 2015 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), April 26-May 1, 2015, IEEE, Hong Kong, China, pp: 480-485.
15. Wang, Y. and J. Bi, 2014. A solution for IP mobility support in software defined networks. Proceedings of the 2014 23rd International Conference on Computer Communication and Networks (ICCCN), August 4-7, 2014, IEEE, Shanghai, China, pp: 1-8.
16. Raumer, D., L. Schwaighofer and G. Carle, 2014. Monsamp: A distributed SDN application for QOS monitoring. Proceedings of the 2014 Federated Conference on Computer Science and Information Systems, September 7-10, 2014, IEEE, Warsaw, Poland, pp: 961-968.
17. Sharma, S., D. Staessens, D. Colle, D. Palma and J. Goncalves *et al*., 2014. Demonstrating resilient quality of service in software defined networking. Proceedings of the 2014 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), April 27-May 2, 2014, IEEE, Toronto, Canada, pp: 133-134.
18. Bettstetter, C., H. Hartenstein and X. Perez-Costa, 2004. Stochastic properties of the random waypoint mobility model. Wirel. Networks, 10: 555-567.
19. Fontes, R.R., S. Afzal, S.H. Brito, M.A. Santos and C.E. Rothenberg, 2015. Mininet-WiFi: Emulating software-defined wireless networks. Proceedings of the 2015 11th International Conference on Network and Service Management (CNSM), November 9-13, 2015, IEEE, Barcelona, Spain, pp: 384-389.
21. Issariyakul, T. and E. Hossain, 2011. Introduction to Network Simulator NS2. Springer, Germany.
20. Varga, A., 2010. OMNeT++. In: Modeling and Tools for Network Simulation, Wehrle, K., M. Gunes and J. Gross (Eds.). Springer, New York, USA., pp: 35-59.
22. Wang, S.Y., C.L. Chou and C.M. Yang, 2013. EstiNet openflow network simulator and emulator. IEEE. Commun. Mag., 51: 110-117.
23. Chan, M.C., C. Chen, J.X. Huang, T. Kuo, L.H. Yen and C.C. Tseng, 2014. OpenNet: A simulator for software-defined wireless local area network. Proceedings of the 2014 IEEE Wireless Communications and Networking Conference (WCNC), April 6-9, 2014, IEEE, Istanbul, Turkey, pp: 3332-3336.