

# Estimation of the ABW for Mobile Broadband over SDN using SFC-Constrained Shortest Path Algorithm

Pucha Venkata Subbarama Sarma, P. Bala Krishna Prasad

**Abstract:-** Software-Defined Networking (SDN) is an evolving algorithm which is depended upon the computer network transformation. In SDN, Bandwidth Utilization is a critical aspect to enhance network performance. To obtain the accessible bandwidth for the Mobile Broadband over SDN and in sequence enhance the accessible Mobile Broadband is the main objective. A significant characteristic is ABW (ABW), having a robust influence on a wide range of applications. However, this metric is very complex to estimate using traditional or conventional methodologies. The Traditional Bandwidth Estimation Technique has limited accuracy along with huge convergence time. The Estimation Time cannot be predicted as it depends on the existence of appropriate traffic produced through any third-party applications. 50% of Systematic Errors are not uncommon. In order to overcome the above-mentioned issues, in this paper, a novel approach is introduced for the estimation of ABW over SDN using three different scenarios. In which, SFC constraint shortest distance algorithm is employed for solving the classical max-flow issue that occurs in multiple scenarios while evaluating the ABW. The experiment result is carried out using Mininet testbed for network emulation and Floodlight as an SDN controller. Some of the interesting cases are considered, and the ABW is measured for the proposed software-defined network and compared with the existing traditional network and existing software-defined network.

**Keywords:** Software Defined Network, ABW, Mobile Broadband, Network Management, Max-Flow Problem, Shortest Distance Algorithm.

## I. INTRODUCTION

These days a mobile terminal is a complicated system containing multiple network applications, where each application various requirements of QoS like video, audio traffic, or background OS-related control traffic. Additionally, MBB enables networks are frequently shared between diverse tools through multi-access mobile tools that achieve routing and NAT for a network of wireless-connected tools towards an uplink cellular data connection. The Mobile Broadband (MBB) accessible networks are extensively used worldwide along with the increase in the tools used to access them, such as mobile hotspots, smartphones vehicular infotainment systems in terms of quantity and complexity. This high energetic environment scenario requires constant monitoring and network measurement, particularly the cross-layer management of network applications.

With recent changes in network management, SDN is a significant device to control these advancing situations defined using the conditions due to data plans, HW, and virtualization. Over the most recent couple of years, SDN is the most alluring construction for improving network performance. With SDN, network administrators could program network progressively and monitor the direction of the system through extrication of the control plane from the forwarding plane [15, 21].

SDN paradigm developed according to the restrictions of traditional networking architectures. The central global network preview, programmability, and segregation of data and control planes are the rewards. This detachment gives network operators through effective utilization of network resources and flexible to resource provisioning. Hence, SDN makes programmability flexible to alter attributes of complete networks. This capacity simplifies the administration of the network subsequently, decoupled from the data plane. So, network administrators could simply and rapidly control, construct, and enhance network resources having energetic, automatic, and proprietary-free curriculums done through itself in SDN construction [1, 2]. Techniques for estimating QOS metrics like bandwidth utilization, packet loss, and delay are currently presented in the literature for SDN-aided circumstances, however consistently different approaches are required concerning to the traditional network environment by facing novel challenges and exploiting novel chances. A significant characteristic is ABW having a robust influence on a wide range of applications. However, this metric is very complex to estimate using traditional or conventional methodologies. The Traditional Bandwidth Estimation Technique has limited accuracy along with huge convergence time. The Estimation Time cannot be predicted as it depends on the existence of appropriate traffic produced through any third-party appliances. 50% of Systematic Errors are not uncommon. With the end goal to conquer the previously mentioned issues, in this paper, a novel approach is introduced for the estimation of ABW over SDN using three different scenarios. In which, SFC constraint shortest distance algorithm is employed for solving the classical max-flow issue that occurs in multiple scenarios while evaluating the ABW.

### 1.1 Organization of the Chapter

A brief introduction to the SDN and motivation for the paper is given in this section. A short review of the existing survey and approaches that employed SDN is given in section 2.

The proposed approaches of estimating ABW over SDN is briefly explained in section 3. The experimental results and its analysis are briefly defined in section 4. The conclusion and references are specified in section 5 and section 6, respectively.

## II. LITERATURE SURVEY

There have been a few proposals in the ongoing years, for controlling SDNs. FlowSense authors [3] offer to employ required OpenFlow messages to regulate bandwidth utilization on the network. While the methodology provides bandwidth regulation with zero additional weight to network, it demonstrated to operate erroneously beneath energetic traffic circumstances [4]. The rest of the article suggests employing FlowStatsReq message in OpenFlow to poll outline and flow counters in switches for bandwidth measurement [4–6]. Additionally, MonSamp [5] and PayLess [4] provides adaptive sampling approaches that could adjust for present network load. Yet, methods are differing subsequently. PayLess proposes increasing sampling frequency whenever the traffic load is more. However, MonSamp proposes decreasing sampling frequency underneath the higher weight. To control per flow measures, for example, packet loss, delay, and throughput amongst source and destination, OpenNetMon [7] is a current approach in SDN that monitors the performance measures for every flow distinctly and not for specifies a location. The suggested methodology evaluated the accessible bandwidth link wise and constituted on-demand to discover the endwise accessible bandwidth for the specified location. In [8], scholar evaluates endwise ABW amongst any two end-hosts employing SDN measurements. However, its effort agrees link capability be known prior. In [20], the process of estimating end-to-end ABW and path loss rate in the dynamic evaluation approach is defined [20]. The initial phase is to investigate network path. This is accomplished by inserting a group of probe packets using pre-determined segregations or dissemination. The circulation is inversely proportional to the inquiry rate estimated in bits per second. Therefore, lesser is distribution amongst probe packets; more will be probe rate. In [9], SOMETIME research project is presented that objectives at improving active measurements leveraging the features provided by SDN technologies. Numerous platforms and tools are being accessible to investigate MBB and SDN separately. A reference testbed known as MONROE platform, a system offering in-the-field MBB experimenting

facilities, is considered. MONROE is a utilization case that features the significant issues and difficulties raised by the SOMETIME vision, examining the attainability of SDN-based dynamic estimations for MBB. The impact of SDN is surveyed on the working of dynamic estimations, to be specific (ABW) estimation, an end-to-end network organize metric describing the space capacity on a path. The starter results affirm the expected challenges in ABW estimation over MBB yet additionally approve the possibility of SDN-based methodologies and recommend future bearings for SDN-based improvement of ABW estimation. The applicable work specifies a difference in Precise Time Protocol, known as ReversePTP [19], and meant for allocating appropriate time to SDN switches, letting corresponding functions. In addition to OpenFlow protocol is projected in [11] to accumulate guidance for Synchronized Ethernet in SDN. Based on the calculation of statistical traffic distribution, another approach is presented in [12], but focusing on delay for providing bounds. In [13], two contributions are made, i.e. suggesting and authenticating a methodology to guess end-to-end ABW on some random way through making link wise ABWs, suggested an approach to evaluate link capacity employing OpenFlow protocol. The outcomes are compared with the ones attained by the Existing Survey bandwidth measurement tool, Yaz.

## III. PROPOSED ABW ESTIMATION APPROACH USING SFC CONSTRAINT SHORTEST PATH

In Fig. 1, the architecture of SDNs is given, which communicates using switch through the southbound API, where the utmost employed framework is OpenFlow. For NOS platform, numerous accessible open software are there like Ryu [16], Floodlight [15], NOX [14], POX [14] etc. Also, there are constant industrialized association's assignments for regulators platforms focused on data centers; for instance, ONOS [18] or OpenDayLight [17]. SDN could process the network by northbound API of NOS. But these APIs are precise to regulators; therefore, maximum currently present SDN applications are merely capable of functioning on one NOS platform. The northbound interfaces employ either an exact programing language or REST aided API. In SDN atmospheres, the circumstance is highly distinct from conventional ones. The central control plane offers fascinating chances for evaluating ABW that are unanticipated in conventional environments.

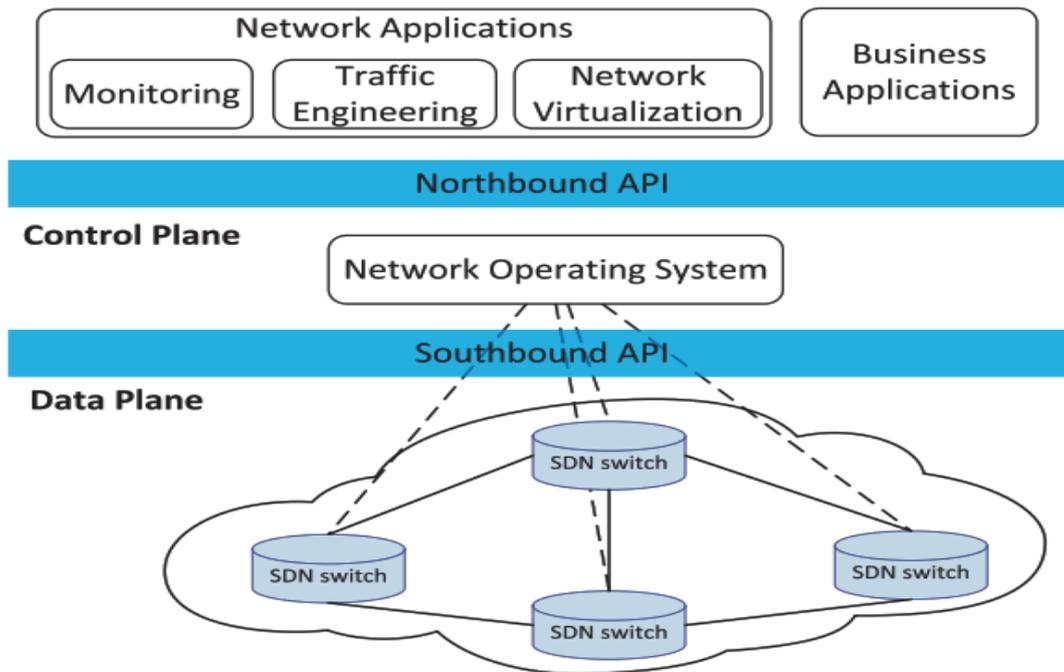


Fig 1: Architecture of SDN

In the architecture of SDN, the usage of the passive approach for ABW evaluation takes the gain of NOS. Northbound API is utilized to find the topology of the network and to screen bandwidth usage of links. At any given time, with this data, the ABW calculates for any path in the network. The topology generalization of the network is queried, which is a compulsory characteristic in each SDN controller [10] using the northbound API of NOS. Initially, the application employs the information to develop the topology graph  $G(V, E)$ , having node  $V$ , which refers to switches, and edge  $E$  refer to links. Pertaining to topology generalization tools the capacity  $c_i$  of each link is likewise known in network. The application is likewise ready for quantifying the current load  $b_i$  of each link. Using the PortStatsReq OpenFlow message, the counters are intermittently polling in the SDN switches. This approach is now proved to be efficient in SDN, and it offers a flexible outcome for determining the bandwidth usage for the whole system. Further progression, the accessible bandwidth  $a_i$  on each link in the network is calculated. Depending on  $a_i$  values ABW on the specified path  $P$  using the below equation

$$AWP_p = \min_{e_i \in P} a_i \quad (1)$$

According to them, this method can differentiate amongst three diverse situations and evaluates the ABW. They are:

1. ABW on static paths: The routing policies are static in this scenario. Therefore, for specified flow, initially need to discover the paths on the network, and further evaluate the ABW by means of (1).
2. Best available path. Need to discover path  $P$  amongst two points in the network; in this case, the accessible bandwidth is highest using the below equation this can be done:

$$ABW_{A \rightarrow B} = \max_{P \in P_{A \rightarrow B}} \min_{e_i \in P} a_i \quad (2)$$

An improved Dijkstra algorithm is hired for resolving this equation, where measurement of the path is not evaluated using the summation of edge distances however through (1) and by this algorithm it similarly provides the finest probable path for finest AWB in  $O(|E| + |V| \log |V|)$  same as typical shortest-path Dijkstra approach.

3. Multiple path state. The multiple paths can be employed amongst two points in the network. As SDN framework could simply facilitate outcomes for multipath routing, so it is an important scenario. The traditional max-flow issue on the topology graph  $G(V, E)$  to be overcome using the SFC-constrained shortest path methodology.

SFC is the capacity to determine an arrangement of network functions and, additionally, execution order for each flow [19]. Based on call flows for precise facilities, the packets ought to move over an orderly group of network functions, either physical or virtual known as Service Function Chains (SFC) prior to reaching the destination. The flow which is essential to fulfilling the SFC constraint is denoted as:  $(v_s, \varphi_1, \dots, \varphi_r, v_d)$ , where  $v_s$  and  $v_d$  are the source and destination, correspondingly, and  $(\varphi_1, \dots, \varphi_r)$  signifies a series of network functions through which entire packets of flow should be handled prior to reach  $v_d$ . A novel solution is presented cleverly via changing the graph,  $G$ , to the novel graph,  $\bar{G}$ , where the shortest path would be figured and plotted to the path in  $G$  as given in algorithm 1.

**SFC-constrained shortest path Approach**

Input:  $G = (V, E)$ , and  $SFC = (v_s, \varphi_1, \dots, \varphi_r, v_d)$ .

Output: the Shortest path from  $v_s$  to  $v_d$  which fulfils SFC constraint.

# Estimation of the ABW for Mobile Broadband over SDN using SFC-Constrained Shortest Path Algorithm

//Preliminary Building of  $\bar{G} = (\bar{V}, \bar{E})$

- for each  $v_k$  in  $V$  do
  - Generate  $r + 1$  virtual vertices  $v_0^k, \dots, v_r^k$ , and accumulate to  $\bar{V}$ .
- end for
- for each edge  $(v_l, v_k)$  in  $\bar{E}$  do
  - for each  $v_l^i$ , in  $\bar{V}_{v_l}$  do
    - Pick  $v_k^{j^*}$  in  $\bar{V}_{v_k}$  such that
      - $j^* = \max\{j : \{\varphi_{i+1}, \dots, \varphi_j\} \subseteq \Phi_{v_k}, j \geq i\}$  (1)
    - Add edge  $(v_l^i, v_k^{j^*})$  to  $\bar{E}$ .
  - end for
- end for

// Pruning  $\bar{G}$

- though there is vertex  $v$  in  $\bar{V}$  without any arriving or departing edge(s), excluding source and destination do
  - Eliminate  $v$  and edges which link to  $v$ .
- end while

// evaluating the shortest path

- Describe  $t$  as the initial network functions of SFC which are accessible to the source
- Plot the source  $v_s \in V$  to  $v_s^t \in \bar{V}$
- Plot the destination  $v_d \in V$  to  $v_d^r \in \bar{V}$
- Employ Dijkstra's shortest path algorithm to evaluate the shortest path  $\bar{p}$  from  $v_s^t$  to  $v_d^r$  in  $\bar{G}$ .
- Plot  $\bar{p} = (v_s^t, \dots, v_k^{t+1}, \dots, v_d^r)$  to path  $p = (v_s, \dots, v_k, \dots, v_d)$  in  $G$ .

## IV. EXPERIMENTAL RESULTS AND ITS ANALYSIS

In Fig 2, the SDN controller is used as a testbed for the Mininet for network emulation and Floodlight [10]. Using Virtual Box, Mininet is processing within the virtual machine1 on the host server. The Floodlight is run straightforwardly in the host server. Meanwhile, load issues are frequently confronted while running within the virtual machine. As a first step, the experiment is showed to measure the Mininet environment utilizing a wide variety of polling rates and immediately, therefore compete with an ideal case. Table 2 refers to the comparison of Bandwidth Measures Values using different switch counts for Traditional Network, SDN based Network, and Proposed SDN based Network.

In Table 3, the initial first row refers to the mean and standard deviation of measured error values. This signifies errors inherent to the measurement system. Subsequently, it isn't conceivable to distinguish the timestamp of counters through switches in the present OpenFlow spec. But, it is seen that the mean error rate having 0.5-sec polling is underneath 1%, and the error rate is more falling with the rise of the polling period. This recommends variance of delay has a more significant effect on measurement error.

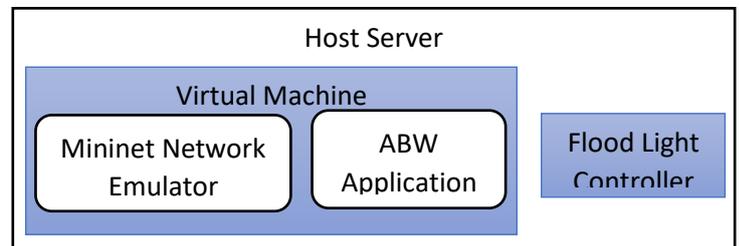


Fig 2: The Test Configuration for the Proposed Approach

Table 2: Comparison of ABW using Traditional and SDN

Use Cases	Traditional Network		SDN		Proposed SDN	
	Switch Count	Bandwidth Measured	Switch Count	Bandwidth Measured	Switch Count	Bandwidth Measured
1	1	108 Mbits/sec	1	1.07 Gbits/sec	1	2.01 Gbits/sec
2	10	15.2 Mbits/sec	10	457 Mbits/sec	10	1.11 Gbits/sec
3	20	7.80 Mbits/sec	20	287 Mbits/sec	20	564 Mbits/sec
4	40	3.60 Mbits/sec	40	153 Mbits/sec	40	376 Mbits/sec
5	60	2.40 Mbits/sec	60	105 Mbits/sec	60	207 Mbits/sec
6	80	1.60 Mbits/sec	80	81.2 Mbits/sec	80	98.4 Mbits/sec
7	100	1.38 Mbits/sec	100	64.7 Mbits/sec	100	79.4 Mbits/sec

Table 3: Comparison of an Error rate of ABW measurements employing the real traffic

Switches → NOS Delay	0.5		2		5		10	
	$\mu$	$\sigma$	$\mu$	$\sigma$	$\mu$	$\sigma$	$\mu$	$\sigma$
No Delay	0.72%	0.94%	0.19%	0.23%	0.09%	0.11%	0.03%	0.06%
$\mu = 5ms$	1.34%	1.67%	0.36%	0.45%	0.19%	0.28%	0.07%	0.09%
$\sigma = 10ms$								



$\mu = 25ms$								
$\sigma = 10ms$	2.50%	3.11%	0.62%	0.78%	0.24%	0.29%	0.14%	0.19%
$\mu = 100ms$								
$\sigma = 25ms$	5.60%	7.04%	1.47%	1.85%	0.54%	0.66%	0.30%	0.37%

### V. CONCLUSIONS

In this paper, a novel approach for estimating ABW for Mobile Broadband over SDN is introduced. Firstly, the application customizes the information to develop the system topology graph  $G(V, E)$ , having node-set  $V$  refers to switches and edges  $E$  relates to links. Pertaining to topology generalization tool the capacity  $c_i$  of each link is likewise recognized in the network. This strategy can recognize three extraordinary scenarios and calculate the ABW. In which, SFC constraint shortest distance algorithm is employed for solving the classical max-flow issue that occurs in multiple scenarios while evaluating the ABW. The experiment result is carried out using Mininet testbed for network emulation and Floodlight as an SDN controller. Some of the exciting cases are considered, and the ABW is measured for the proposed SDN and compared with the existing traditional network and existing SDN.

### REFERENCES

1. S. Sezer, S. Scott-Hayward, P. Chouhan, B. Fraser, D. Lake, J. Finnegan, N. Viljoen, M. Miller, N. Rao, Are we ready for sdn? implementation challenges for software-defined networks, Communications Magazine, IEEE 51 (7) (2013) 36-43. DOI:10.1109/MCOM.2013.6553676.
2. K. Bakshi, Considerations for software-defined networking Sdn): Approaches and use cases, in Aerospace Conference, 2013 IEEE, 2013, pp. 1-9. DOI:10.1109/AERO.2013.6496914.
3. C. Yu, C. Lumezanu, Y. Zhang, V. Singh, G. Jiang, and H. Madhyastha. Flowsense: Monitoring network utilization with zero measurement cost. In Passive and Active Measurement, volume 7799 of Lecture Notes in Computer Science, pages 31–41. 2013.
4. S. Chowdhury, M. Bari, R. Ahmed, and R. Boutaba. Payless: A low-cost network monitoring framework for software-defined networks. In-Network Operations and Management Symposium pages 1–9, May 2014.
5. D. Raumer, L. Schwaighofer, and G. Carle. Monsamp: A distributed sdn application for QoS monitoring. In Federated Conference on Computer Science and Information Systems (FedCSIS), Sept. 2014.
6. N. van Adrichem, C. Doerr, and F. Kuipers. Opennetmon: Network monitoring in OpenFlow software-defined networks. In-Network Operations and Management Symposium (NOMS), 2014 IEEE, pages 1–8, May 2014.
7. B. Lantz et al. A network in a laptop: Rapid prototyping for software-defined networks. In Proceedings of the 9th ACM SIGCOMM Workshop on Hot Topics in Networks, pages 19:1–19:6, 2010.
8. Floodlight. retrieved: Sept. 2015.
9. Giuseppe Aceto, Valerio Persico, Antonio Pescapé, Giorgio Ventre, "SOMETIME: Software defined network-based ABW Measurement In MONROE," 2017 Network Traffic Measurement and Analysis Conference (TMA).
10. T. Mizrahi, Y. Moses, Using reverse ptp to distribute time in software-defined networks, in Precision Clock Synchronization for Measurement, Control, and Communication (ISPCS), 2014 IEEE International Symposium on, IEEE, 2014, pp. 112–117.
11. R. Surez, D. Rincn, S. Sallent, Extending OpenFlow for sdn-enabled synchronous ethernet networks, in Network Softwarization (NetSoft), 2015 1st IEEE Conference on, 2015, pp. 1–6, DOI: 10.1109/NETSOFT.2015.7116183.
12. Z. Bozakov, A. Rizk, D. Bhat, M. Zink, Measurement-based flow characterization in centrally controlled networks (2016).
13. Manmeet Singh, Nitin Varyani, Jobanpreet Singh, and K Haribabu, "Estimation of End-to-End ABW and Link Capacity in SDN," Ubiquitous Communications and Network Computing pp 130-141, 2017.
14. NOX and POX SDN Controllers, [Online]. Available: <http://www.noxrepo.org/>.
15. Floodlight, Available: <http://www.projectfloodlight.org/>.
16. RYU Network Operating System, [Online]. Available: <http://osrg.github.com/ryu/>.
17. The OpenDayLight Project, Available: <http://www.opendaylight.org>.
18. The Open Network Operating System (ONOS), [Online]. Available: [HTTP:// onosproject.org/](http://onosproject.org/).
19. A. Sinha and E. Modiano. Optimal Control for Generalized Network Flow Problems. IEEE INFOCOM 2017, Atlanta, GA, May 2017.
20. ConstantinosDovrolis, Parameswaran Ramanathan, and David Moore. Packet distribution techniques and capacity estimation. In IEEE/ACM Transactions on Networking, December 2004.