Bandwidth Management Service for Group-Based Wireless Devices in Software Defined Networks

Patricia Kaye Caro, Joe Sam Catarata, Charles Kiefer Chong,
Ralph Vincent Guansing and Marnel Peradilla[1*]
Department of Computer Technology, College of Computer Studies, De La Salle University
**Corresponding Author: marnel.peradilla@dlsu.edu.ph*

Abstract: The explosive growth of wireless devices, which are highly dynamic and mobile, creates challenges in managing the network. In particular, to avoid network congestion and maintain quality performance, bandwidth management techniques are essential to meet the demands on the wireless network. Software-Defined Network (SDN) is a new paradigm in network design that brings a lot of advantages for simultaneously controlling and managing networks. This paper utilizes the SDN to manage the devices in multiple wireless local area networks (WLANs). We propose a bandwidth management service for group-based wireless devices that operate in an SDN wireless environment. The proposed bandwidth management service is implemented on a small network topology that consists of three SDN-capable access points connected to an SDN controller and multiple wireless nodes. Each group has its corresponding maximum bandwidth as well as priority. Based on the results of the bandwidth and prioritization tests, the nodes can share the maximum bandwidth allocated to their grouping. The results also show that in the event of network saturation, the solution proves to be successful in maintaining prioritization for the necessary groups.

Key Words: bandwidth management, group-based management, software defined network

1. INTRODUCTION

As time passes by, people are becoming increasingly reliant on technology whether it's for business purposes or for personal use. With the continuous evolution of technology, researchers are seeking to find improvements for efficient network utilization. Network management requires skilled personnel capable of configuring multiple network elements which enable interaction between network devices that becomes more complex as the network gets larger, a systematic-based approach encompassing the elements for simulation is required [1].

The increasing complexity of network management in conventional networks call for a change in network architecture thus leading to the innovation of Software Defined Network. Software-Defined Network (SDN) introduces an architecture that separates the forwarding and control planes, this addresses the limitations toward traditional networks [2, 3 ,4]. SDN allows the network community (research and industry) to create applications for rapid adaptation of the dynamic requirements of the Internet and network devices [5, 6, 7].

Also, the SDN manages the forwarding and control planes with a centralized controller. Instead of having to configure countless of lines in the control plane software running on various legacy devices and allowing them to behave individually, the control plane software on each device is eliminated and now placed in a centralized controller. This manages the network using higher-level policies and provides instructions to the devices which enable them to decide faster on how to deal with incoming packets. The centralized controller provides open interfaces of the controller that allows for an automated control of the network [8, 9].

Another characteristic of SDN is the simplification of devices, since SDN controls the forwarding and control planes with a centralized system running management and control software. Instead of having to configure countless of lines in the control plane software running on various devices and allowing them to behave individually, the control plane software on each device is eliminated and now placed in a centralized controller. This manages the network using higher-level policies and provides instructions to the devices which enable them to decide faster on how to deal with incoming packets. The centralized controller provides open interfaces of the controller that allows for an automated control of the network [7, 10].

As the world becomes more automated and wireless devices become more abundant, SDN is an approach for a dynamic, manageable, as well as cost-effective bandwidth management solution that can control network traffic for group-based wireless nodes. Bandwidth management is the process of controlling and measuring how packets communicate on a network link. It is used for optimizing the bandwidth that carries traffic to ensure that users are getting the best performance of the network. Conventional mechanisms for bandwidth management relies on end-to-end exchange of packets in order to regulate traffic flow. In addition, buffer management and scheduling are functions that guarantee the flow of traffic within the network is monitored [5, 6, 11].

This paper aims to develop a bandwidth management solution for group-based wireless devices in an SDN environment. The proposed bandwidth management service is implemented on a small network topology that consists of three SDN-capable access points connected to an SDN controller and multiple wireless nodes. Each group has its corresponding maximum bandwidth as well as priority. Along with this, the results of the bandwidth and prioritization tests is to be evaluated to determine the accuracy of the implementation of bandwidth management in SDN-wireless environment.

The remainder of the paper is arranged as follows. Section 2 discusses the methodology and how the researchers implemented the experiment. The results of the experiment are presented and analyzed in Section 3. The paper is concluded in the last section where further recommendations are also provided.

2. BACKGROUND OF THE STUDY

SDN arose from a need to separate the control plane and the data plane of a network as this was deemed to be beneficial in maintaining and managing networks. As research of SDN continued, there needed to be a productive instrument for the proposed network to be controlled and analyzed.

This led to the creation of an API for OpenFlow in 2008 [12], after researchers at Stanford continued upon research made by Martin Casado starting 2006. OpenFlow is a protocol that allows developers to access numerous features in a network, particularly the forwarding plane. As OpenFlow matured and eventually became the widely used protocol to create Software Defined Networks, another key component of SDN was then sought for.

A major component of an SDN is the controller. The controller acts as the entire brain of the network. The controller maintains a view of the network, implements policy decisions and controls all the SDN devices present in the network. In an SDN, there can be a single controller or multiple controllers present that are working together.

The SDN devices commonly encountered are switches. These SDN switches contain a flow table that allows them to decide what to do once they encounter a packet. The researchers' aim to implement a bandwidth management solution specifically for group-based wireless devices. Therefore, an SDN switch that doubles as an access point is crucial to the research. The researchers' plan to implement the bandwidth management solution using the Zodiac WX switch [13].

Earlier bandwidth management solutions exist in SDN but the key difference is that these solutions specifically work for individual devices. The paper aims to implement a solution that is targeted for grouped devices. In essence this allows grouping of specific devices and implementing a global configuration for that specific group.

3. SYSTEM DESIGN AND IMPLEMENTATION

Figure 1 shows the proposed bandwidth management module. The following components can be found on either the controller or the switch:

- Controller Module
  - QoS Setting Module
- Switch Modules
  - Translating Module
  - QoS Rule Module
  - Queue Module

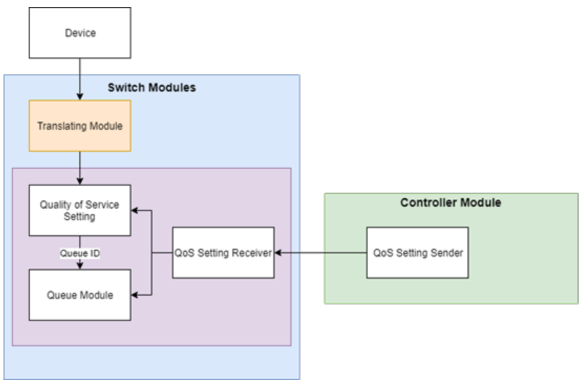

Fig. 1. Group Based Bandwidth Management Module

The group-based bandwidth management module starts by checking the packet sent by a device and then classifies them to group. Next is it checks if it has a Quality of Service (QoS) setting which assigns a queue id to a device. If the device does not have any settings, it will automatically have the queue id for guests. The queue id indicates the bandwidth allocation for a device. The allocations of bandwidth for groups will be dependent on the minimum amount of bandwidth, since this acts as the guaranteed amount of bandwidth a device can accommodate.

The flowchart in Figure 2 begins by assessing incoming packets if it belongs to a group, depending on which device it came from. If it does not belong to any group, it is included in the guest group by default. The MAC address of the packets is then translated to its corresponding group MAC address through the Translating Module which uses a MAC Address Translation Table. Following this, the QoS Rules Module assigns the queue id based on the packet's QoS Setting parameters which uses the Queue Table to determine the minimum bandwidth that will be guaranteed based on the given queue ID.

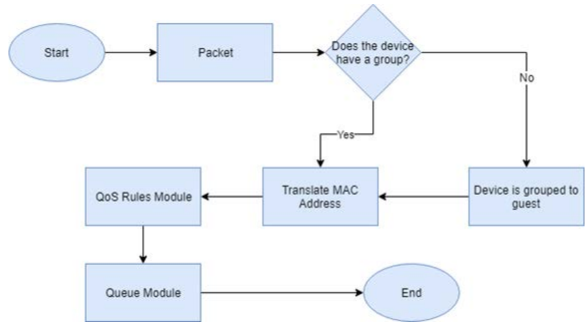

Fig. 2. Flowchart of the Group Based Bandwidth Management Module

Figure 3 shows the testbed's network topology. We deploy three SDN-capable access points (Zodiac WX) distributed among three wireless networks. The settings of all three wireless access points are configured through the SDN controller. In this study, we used Ryu [14] controller as the centralized controller for the SDN-wireless environment. For this implementation, the first two access points have three wireless host devices connected to each network while the last access point has two wireless devices connected.

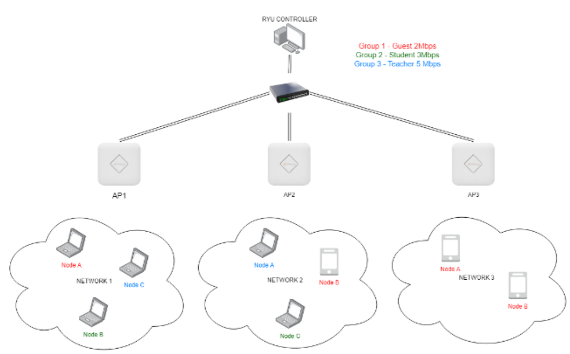

Fig. 3. Network Topology

To set the bandwidth limitations, the meters feature of OpenFlow version 1.3 is used. Meters, handled through meter tables in switches, allow configuration of the maximum bandwidth of flows and not switch ports. The controller then uses the Representational State Transfer (REST) API to send the configuration and updates about the bandwidth settings for each group to the switches.

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The hosts are sorted into three different groups, each with its own corresponding maximum bandwidth, as seen in Table 1. Grp 1 is the default guest group and has an allocated maximum bandwidth of 2 Mbps. Then, Grp 2 has a maximum bandwidth of 3 Mbps. Lastly, Grp 3 has a maximum bandwidth of 5 Mbps. The total bandwidth of each network is 10 Mbps. In wireless network 1 and wireless network 2, each device belongs to a different group. On the other hand, both devices in wireless network 3 belong to Grp 1.

Table 1. Sample Bandwidth Prioritization Table

Total Bandwidth: 10 Mbps	
Group Name	Max Bandwidth
Grp1	2 Mbps
Grp2	3 Mbps
Grp3	5 Mbps

Table 2. Sample Device Grouping Table

Device ID	MAC Address	Group ID
D1	AA:AA:AA:AA:AA:01	*Grp1*
D2	BB:BB:BB:BB:BB:01s	*Grp2*
D3	CC:CC:CC:CC:CC:01	*Grp3*
D4	AA:AA:AA:AA:AA:02	*Grp4*
D5	BB:BB:BB:BB:BB:01	*Grp5*
D6	CC:CC:CC:CC:CC:01	*Grp6*

A list of devices associated with groups are used for the controller to pinpoint the bandwidth limitation to each device. There can be too many devices for an administrator to handle manually, therefore, the controller uses a list of MAC addresses on a csv file which can be modified by the administrator through the use of a program that can update the list. Adding the MAC addresses of the device on the list can ensure that the controller can reuse the list whenever it restarts. Table 2 shows a sample mapping of the devices to their corresponding group based on its MAC address.

4. RESULTS AND ANALYSIS

This section conducts the bandwidth and throughput test in different scenarios. For testing, the web applications used were Speedtest.net and Fast.com. They are similar web applications that check the Internet speed of the device that accesses the site.

The first scenario tests how much throughput is obtained if two nodes of the same group (Grp3) and in the same network are actively consuming bandwidth. The average bandwidth that Node A obtained was 2.39 Mbps and Node B obtained 2.58 Mbps. These results confirmed the assumption that the two nodes share the maximum bandwidth assigned to their group which is 5 Mbps.

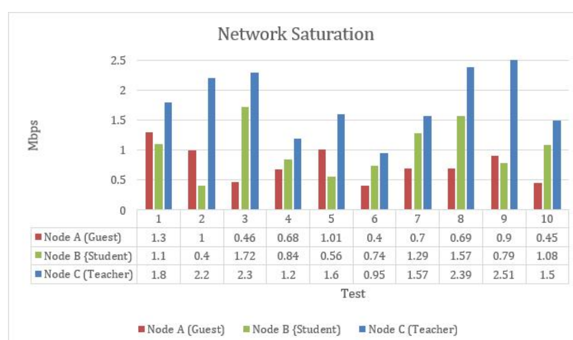

Fig. 4. Network Saturation Results

The second scenario tests the bandwidth obtained by three nodes from different groups in a single network. The average bandwidth acquired by Node A (Grp1) is 2.145 Mbps, Node B (Grp2) got 2.918 Mbps, and Node C (Grp3) got 4.376 Mbps. The results show that the bandwidth of the node belonging to Grp3 is higher than the rest, since this group is allocated a higher maximum bandwidth configuration which is 5 Mbps.

Using the same setup as the second scenario, a sustained bandwidth test was done to test the consistency of the bandwidth obtained by the nodes. All three nodes were set to download the same file. Node A (Grp1) has an average throughput of 1.6055 Mbps. Node B (Grp2) has an average throughput of 2.2813 Mbps. Node C (Grp3) has an average throughput of 4 Mbps. The total network bandwidth for this test is around 8-9 Mbps which is why the values obtained are relatively lower than the other tests where the total bandwidth is 10 Mbps. Nonetheless, the results still prove that the solution is able to limit and prioritize the available bandwidth accordingly.

The third scenario tests the performance during network saturation. Eight nodes are connected in the same network: two nodes from Grp1, three nodes for Grp2, and three nodes for Grp3. The network is saturated through streaming videos. While the videos are being streamed, one node on each group checks for the status of the bandwidth. The average throughput for Grp1 is 0.759 Mbps, Grp2 is 1.009 Mbps and Grp3 is 1.788 Mbps. The results show that Grp3 is still prioritized to acquire more throughput compared to Grp1 and Grp2 since its allocated maximum bandwidth is higher. There are also instances where Grp1 acquires more bandwidth than Grp2 as shown in Figure 4. This occurs because in Grp2 there are two devices actively consuming their allocated bandwidth while Grp1 only has one device streaming the video.

The fourth scenario shows how the bandwidth limitation would work when three nodes assigned to the same group (Grp1) are connected to different access points. Node A, Node B and Node C obtained 1.955 Mbps, 2.05 Mbps and 1.989 Mbps respectively. The average of these three wireless devices is 1.998 Mbps which is approximately the maximum bandwidth assigned to their group. Access points apply the bandwidth limitations separately which is why the nodes did not share their allocated maximum bandwidth.

Figure 5 shows the setup latency for nodes switching between networks. The computation of the setup latency is done when the device disconnects from its present network and moves to a different network. The resulting time will be computed by the controller when the device associates itself with the rules set by it. The average handover latency over 10 reconnections is 4.39 milliseconds, which is the assumed time for a device to acquire its bandwidth rules and settings. Analyzing the results in Figure 5, one can notice that the setup latency largely varies in values. This is partly due to the controller having to deal with the algorithm in which it assigns the settings. The algorithm scans the whole device grouping list until it locates a setting that the device might be assigned to and this usually varies. If it does not find a setting for a device, it will be assigned to the Grp1 settings. This could partly affect the latency, although, there seems to be no clear correlation to this in the experiments.

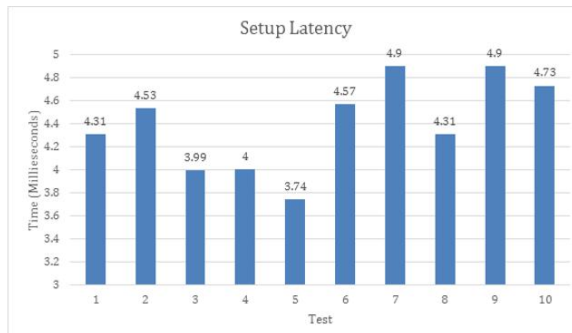

Fig. 5. Setup Latency Results

5. CONCLUSION

This study proposes a bandwidth management solution for group-based wireless devices in an SDN environment in order to efficiently allocate bandwidth for each group while minimizing network congestion. SDN is an emerging network architecture that relies heavily on sufficient bandwidth allocation to provide peak performance; thus, bandwidth management techniques must be carried out to guarantee network stability.

The proposed solution is implemented on a small network with wireless nodes connected to SDN-capable access points and a total network bandwidth of approximately 10 Mbps. The nodes are then divided into three groups based on their physical address and each group is allocated a corresponding maximum bandwidth.

Upon testing, the solution is able to successfully group each node and limit its maximum bandwidth. The nodes connected to the same access point are able to share their bandwidth with other nodes that belong to the same group. When connecting to a network, it takes approximately 4.39 milliseconds for a node to acquire its settings from the controller. In addition, a sustained bandwidth test proved that the bandwidth limitation for each group is maintained even if multiple devices are generating heavy traffic over a period of time. The solution also allows prioritization for the group with the highest maximum bandwidth in the event of network saturation. Overall, the proposed solution proved to be successful in delivering the desired results and improving bandwidth management.

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