Prioritizing Mice Flows in Software Defined Networks for Enhanced Monetization and User Experience
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Software-defined networking (SDN) has emerged as a new trend for dynamic and flexible network traffic optimization and shaping. SDN helps decouple the control and data plane, and provides a programmable interface to the network, reducing complexity and enabling network managers to holistically manage the network from a central location. As SDN continues to evolve, applications such as bandwidth calendaring, traffic re-engineering, and subscriber aware route optimization will come into play to enable effective network monetization.

This paper presents an approach for flow optimization that factors in user demand for a better Quality of Experience (QoE). The SDN Controller helps meet this demand by configuring the network dynamically based on the type of application, user services, and traffic flow at runtime to achieve high performance. The proposed approach discusses prioritization of important flows leveraging monitoring tools like nDPI and sFlow; this will enable Over-the-top (OTT) players and network operators achieve better utilization and monetization through more adaptable and responsive control over network traffic. The paper also presents the next steps in enabling a more effective design by leveraging the SDN Controller Service Function Chaining (SFC) feature.
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The impact of mice flows on quality of experience and monetization

Network data flows are usually categorized as either elephant (long lived) or mice (short lived) flows based on the applicable thresholds set by operators. Flows that are over the specified threshold are categorized as elephant while those below the threshold are categorized as mice flows. The coexistence of elephant and mice flows impacts mice flows in terms of latency sensitivity, delay jitter and congestion, affecting the quality of experience (QoE) delivered.

A majority of mice flows are generated by network applications (like banking, surfing, chatting) and largely govern the QoE of the end user. Prioritizing applications within mice flows as well as mice flows over elephant flows can thus help deliver better QoE and enable effective monetization. For example: if a user is performing an important transaction like banking (classified:mice) or placing order on amazon (classified:mice) while concurrently downloading a large media (ISO/Torrent) file (classified:elephant), following this approach can help the network operator deliver higher QoE.

Alternatively, consider a scenario where two users browse web pages on Amazon, watch videos on YouTube, text or video chat through WhatsApp, and download movies on Torrent simultaneously. The first three instances generate mice flows while the last one generates elephant flows in the network.

The rate of flow of the application traffic across the network determines the QoE. In this case, the QoE is likely to be impacted as all the links share the same network bandwidth. If the first user has subscribed for better QoE on a per-application basis, the network needs additional intelligence to ensure that the user’s applications are given priority.

Prioritization of mice flows

Network visibility in terms of application recognition and flow characterization are critical components for prioritizing important mice flows. Currently, SDN supports policy implementation for layers two to four (L2-4) of the network but does not address the same in higher level layers (level 7 or L7), which is important to ensure an application-specific QoE to the end user.

To enable mice flow prioritization, or the prioritization of applications within mice flows, the network needs application-level intelligence. There are two approaches to achieve this:

- **Deep Packet Inspection (DPI):** This approach leverages third party or open source DPI ecosystem along with flow monitoring to extract meta-data for application level visibility. This helps identify important mice flows after factoring in user subscribed services and reengineer the traffic flow patterns through SDN Controller (OpenDayLight). DPI also gives operators greater control over networks that carry traffic for a wide range of services and applications, and supports intelligent decision making.

- **Packet sampling:** This approach leverages open-source bandwidth monitoring tools such as Sflow and Netflow. These tools also provide L2-L4 information about the type of packet and classify them as elephant or mice flows based on threshold alerts.
Technical architecture for SDN application

In order to implement the discussed approach, it is necessary to design viable architecture for the SDN application, as shown in Figure 1. For the purpose of explanation, we assume there are two users, emulated as two virtual machines, connected to the internet through a hybrid OpenVSwitch (OVS) which is part of the SDN. Network monitoring tools such as sFlow and nDPI continuously monitor the network and are integrated (via east-west adaptor interfaces) to the SDN application deployed on the OpenDaylight SDN Controller.

The functional units of the SDN application are:

1. **DPI engines**: This module gathers dynamic and intelligent network information from sFlow and nDPI, including application level details. Network applications are uniquely mapped to an application ID, as shown in figure 2. nDPI provides the metadata corresponding to each application ID. For example, the application ID 126 corresponds to packets going to google.com.

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[1] nDPI refers to a DPI library based on OpenDPI and currently maintained by ntop. This is an open-source library. [http://www.ntop.org/products/deep-packet-inspection/ndpi/](http://www.ntop.org/products/deep-packet-inspection/ndpi/)
2. **DPI monitor:** While the DPI engine is being probed on the network nodes, the DPI monitor qualifies the abstract output. This helps validate that the information is appropriate and can be sent to the QoE manager for flow optimization.

3. **Presentation tier:** The presentation tier enables the network operator to set the policies and rules corresponding to the users and applications that they want to prioritize. The data is saved as a JavaScript Object Notation (JSON) file and undergoes verification while matching the metadata of incoming packets.

4. **User services manager:** This module serves as the mediator between the User Interface (UI) and the QoE manager. It records the configuration set by the network operator and allows the QoE manager to implement the preference for a specific user and application, enabling the prioritization of important applications.

5. **QoE manager:** The QoE manager is a key component of the SDN application. With the dynamic creation of priority queues on a network node, this module matches the data from the DPI engines and user services manager. It then writes corresponding flows to the controller, which enables prioritization of important mice flows.

6. **Application flow programmer:** Using an OpenDayLight flow programmer API, this unit writes corresponding flows to the controller that enable prioritization of important mice flows.

To better understand the SDN application, let’s consider a mice scenario on one virtual machine where the user is surfing the web. The second user is downloading a file on the other virtual machine, generating elephant flows. The DPI engine and sFlow get the application metadata dynamically from OVS, depending on the type of application on the network. If the metadata matches all the policies set by the operator, specific rules are written to the network to shape the traffic effectively using a switch queue mechanism.

The logical flow of a typical scenario when the packets come into the network is described in figure 3. It consists of the following steps:
The DPI monitor analyzes the application traffic and sends the information to the QoE manager. The QoE manager then checks the metadata from the DPI along with user configured data, as shown in the boxes marked 1, 2 and 8.

The user policies are configured in the presentation layer, as shown in the boxes marked 5, 6 and 7. In the presentation layer, the operator can configure the user service category as gold or silver (based on user subscription) along with the applications that the user wants to prioritize. The user services manager records this configuration as a JSON file.

In case no match is found, rules are not written by the application and all the traffic goes from the default queue (Queue0) as depicted by the path marked 3.

If the QoE manager finds the silver user’s data on the network, corresponding flows are written to the underlying network. All the silver user’s elephant traffic then moves from another queue (Queue3), as indicated by paths marked 9 and 10.

If the QoE manager finds the gold user’s data on the network, then the corresponding application IDs from the DPI monitor and user configuration are matched, as depicted by path 11.

If a match is found, corresponding flows are written to the underlying network. As a result, each application traffic is segregated into different queues. For example, YouTube data for the gold user goes from Queue1 and the Amazon traffic moves from Queue2. This provides a dedicated congestion free link to the end user’s priority network application, as represented by paths 12, 13, 14, and 15.
Use cases for network monetization through application-aware SDN applications

This approach can be leveraged by the underlying network in three ways depending on the type of user subscriptions and applications accessed. In the scenario described earlier, the users have been classified as gold and silver based on their service category. Using the same categories, the following use cases outline how an application-aware SDN application can deliver differentiated data flows based on user subscriptions:

1. **Default users:** In this scenario, no application is monitoring the network. This means that all the users are default users of the network, all packets move from the default queue, and every user on the network gets the same QoE. As illustrated in figure 4, all the packets move through Queue0 and the average volume of data on the queue is very high.

2. **With silver users:** Configuring a silver user in the network requires the segregation of all elephant traffic on the silver user’s link to a different queue. Queue4 becomes active and all elephant flows move to this queue, as shown in figure 5. The average number of packets on the default queue (Queue0) go down making it free from large flows and thereby delivering better QoE for silver user.
3. **With a gold user:** Network operators can specify certain network applications that need better QoE irrespective of congestion in the underlying network. Consider a scenario where the gold user is browsing Amazon and watching YouTube videos. Out of all the network applications, the traffic generated by these classified applications move from the default queue to the dedicated queues. As illustrated in figure 6, Queue1 becomes active for the user’s Amazon traffic and Queue2 for the YouTube traffic. This ensures that the gold user’s applications receive dedicated bandwidth, providing better application level QoE. The average volume of data on the default Queue0 also reduces, ensuring more bandwidth for other applications.
In summary, whenever packets are routed through a network they are sampled for size and application meta-data, which is then forwarded to the SDN application. The application checks if the network operator has specified policies regarding the packets. The SDN application then writes the rules to the network to segregate that particular traffic and ensure better Quality of Service (QoS) through better utilization of the underlying network resources.

Moving forward: Leveraging SFC to meet growing network traffic requirements

Though the described approach works well on small to mid range networks, for scaling to larger networks there is increasing interest in evaluating the use of service function chaining (SFC) features in OpenDayLight, as shown in figure 7. Using this feature, the SFC classifier receives the policies from the presentation tier of the SDN application. The SFC classifier then writes flows that sends all packets from the underlying network to a DPI-based service function in an overlay network. Using the information from the packets in the overlay, the SDN application writes traffic rules to the networking elements.
Using this approach, the underlay network remains the same while the overlay network becomes responsible for traffic steering or shaping. Coupled with SFC, DPI becomes a shared function across different networks that can be automatically scaled depending on the users and network traffic. There are different ways to steer traffic with SFC. The switch queue mechanism for the network or Differentiated Services Code Point (DSCP) marking on each packet help provide better QoS across the network fabric.

Responding to growing user demand with SDN

An application-aware SDN application enabling prioritization of L2-L7 traffic is the next step forward to enable network monetization. This paper has highlighted one possible use case that service providers and Over-The-Top (OTT) players can leverage to extend differentiated services on a software-defined network. In addition, they can fulfill such requests without making changes to the existing infrastructure. Implementing an agile SDN ecosystem helps OTT players and network operators respond to growing user demands and manage network traffic congestion efficiently, thereby enhancing user experience and satisfaction, an important differentiator in today’s competitive environment.
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