Intelligent Traffic Management in SDN

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***Abstract*—Nowadays, most of the traffic is produced on the Internet by applications such as video streaming, P2P and web surfing. With the vast extension of portable applications that offer on-demand access to services, the capacity to track end-users' perceived service quality has transformed into a significant viewpoint for future frameworks. Software defined networking and network functions virtualization in the versatile core offer amazing flexibility for traffic steering, leading to advanced levels of quality-of-service control. Idea is to utilize the SDN concept to dynamically control network traffic over wide area networks (WANs) from edge nodes of wireless networks depending on changing network conditions and application types. SDN-based application aware routing system allows mobile network operators to achieve better efficiency of the networks, service providers to enhance customer satisfaction, and end-users to encounter desirable service quality for various network applications.**

Keywords—Software-defined Networking (SDN), Network Functions Virtualization (NFV), Quality-of-Service (QoS) in LTE)

I. INTRODUCTION

Today's service providers take advantage of distributed networks to speed up the delivery to clients. SDN purpose is to assign a client to a geographically close delivery node. Once the connection is established, however, it is hard to closely monitor the end-user's perceived quality-of-experience (QoE) and pinpoint a bottleneck in a network while content is delivered to the client. To provide an worthy level of QoE to the end users, it is necessary to understand a tight cooperation between network operators and content providers, so as to a) have full access and visibility into end-to-end connectivity across all network segments, including content server side networks, transit Internet service providers (ISPs) and network of clients ,b) dynamically control traffic flows based on network conditions, and c) monitor end-user's QoE in real time.

To guarantee enhancement in software-based networking SDN application have been proposed for more portable and innovative networks that can enhance the present delivery services. In this paper, SDN platform is proposed to provide end-to-end QoS from the perspective of LTE network operators, where they have full control over the portable networks but limited access to the SDN controllers that are connected to the SDN-enabled WAN routers are limited in the Internet.

It is assumed that each WAN service provider operates its own SDN platform, and the SDN controllers are interconnected and exchange information about their respective domain. As shown in Figure 1, the WAN-SDN platform is already deployed in the Internet. The proposed SDN application runs on top of Gateway is designed to enforce the following two objectives:

1) *Monitoring end-to-end network conditions:*
To guarantee end-to-end network conditions, network gateway enables getting the outside data in the system from the SDN controllers, using an existing SDN protocol , for example, OpenFlow. Limited LTE network information such as LTE QoS parameters and Enhanced Packet System (EPS) bearer status with the SDN controller can be shared.

2) *Performing dynamic end-to-end flow control:*
Packet information of network can progressively control routing flows and perform adaptable resource allocation at the remote according to the end-to-end network conditions via SDN. When a quality degradation is expected based on the end-to-end network conditions provisioned via the SDN controllers, the SDN application in gateway is intended to send queries to the controllers. At that point the controllers examine the associated SDN enabled WAN routers to monitor network states of the traffic flow, to pinpoint the bottleneck interfaces in the system. To determine the blockage, the SDN controller initially chooses the QoS budget e.g., packet delay budget per network segment under each of the SDN managed zone. Such criteria are utilized by the SDN controllers to decide if any routing alteration is required or not. Further, the controller can dynamically a) update inbound routing ways among WAN routers in a network, b) change outbound routing paths by switching border routers in a network, or c) invoke a signal to redirect the client to another node with higher performance.

The challenges of implementing intelligent service delivery on existing WAN-SDN and wireless access systems such as LTE and Wi-Fi are addressed. As per the SDN concept, a novel application is proposed which unifies the control plane end-to-end, over the Internet (e.g., LTE /Wi-Fi)and mobile core network, to progressively control traffic flows based on changing network conditions and service types in real time.

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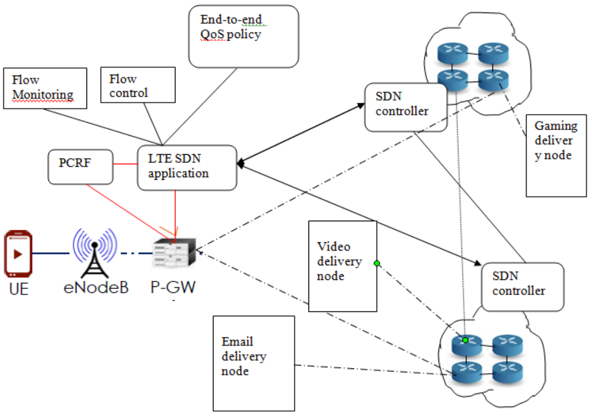

Figure 1: Intelligent traffic management using SDN

II. RELATED WORK

With the approach of SDN/NFV, many researchers have been researching about the application-awareness and WAN routing controls in SDN, and the separation of control and data planes in mobile networks.

Application-awareness in SDN propose a machine learning (ML) based application awareness that uses a crowd-sourcing approach to conduct traffic classification in SDN. Deep packet inspection (DPI) is used by an application awareness in SDN-enabled networks track YouTube video streaming traffic, and progressively modify the directing paths while a video content is conveyed to the customer using SDN also addressed the role of DPI in SDN.A multi-protocol label switching traffic engineering (MPLS-TE) innovation has gained more consideration in WAN-SDN. It demonstrates the feasibility of how MPLS-TE can be basically executed over an SDN-enabled network. Networking application utilizes OpenFlow capacities to ensure application-aware accumulation and TE among WAN-routers in SDN. A centralized traffic engineering using OpenFlow is implemented, where the Internet backbone traffic is transferred among data centers that are geographically distributed over the world. SDN can be simply applied to cellular data networks, and elaborate the challenges of providing scalability and QoS-based dynamic flow control in SDN-enabled mobile networks.

III. BACKGROUND

In this segment, the difficulties of SDN/NFV for providing end-to-end QoS, and the current QoS mechanisms in LTE are addressed.

A. *Challenges of providing end-to-end QoS in SDN/NFV*

Key function of SDN and NFV is the different planes of control and data-forwarding. Control plane between service applications and network devices makes for more flexible and agile network service environments. Service providers can easily introduce new applications which dynamically obtain network information from the control plane, and immediately control traffic flows for their needs. In order to provide end-to-end QoS, however, there are constraints that need to be addressed.

1) *Confinement on application-awareness*: Such recognized applications has become critical for enhancing QoS policy based flow control and security. The existing OpenFlow mainly focuses on conducting inspection, lack of application awareness of higher layers .DPI has been proposed as one of available solutions, but it needs edge node devices with high performance and also leads to high computation cost in terms of latency, especially for high bandwidth applications.

2) *Lack of access to wireless networks*: WAN-SDN has been proposed to guarantee flexible control traffic flows among WAN routers in the Internet, so as to provide QoS based services. However, it has overall control of the WAN routers, it has limited access to mobile networks such as 3G and 4G. Since most congestion of mobile Internet traffic is likely to occur in radio access networks
(less likely on the fixed parts of the network such as transit networks and servers), the SDN controllers cannot fully provide the end-to-end network conditions without the support of the wireless core networks.

B. Challenges of QoS in LTE

An LTE framework gives a comprehensive QoS, policy control structure and charging system, with respect to the client-profiles and application service types to enhance service quality.

1) *Mechanisms of QoS in LTE*: A subscriber requests QoS-enabled services such as an online gaming and VoIP, a traffic flow template (TFT) including a set of QoS policies for policy and charging control enforcement. Typically, QoS parameters are utilized for the wireless resource allocation at transport nodes when network encounters bottleneck.

- QCI (QoS Class Identifier): The QCI determines IP packet forwarding treatment such as scheduling weights, queue managements in transport nodes in LTE and link layer protocol configuration. Nine QCI values altogether standardized in terms of resource type, priority, packet delay budget and error loss rate of packet, relies on application service types.
- ARP (Allocation and Retention Priority):When an LTE network is loaded with requests, the gateway and nodes take account of the ARP. Then, it decides to remove some existing bearers or accept / refuse a new bearer in the network.
- GBR (Guaranteed Bitrate) and MBR (Maximum Bitrate):The bearer consists of two types, GBR and Non-GBR. In a GBR mode, the bandwidth of the bearer is ensured. MBR indicates the maximum bitrate allowed in the LTE network. Bearer with Non-GBR is typically used for the services such as downloading of file and web surfing. When the network experiences congestion, it has a lower priority.

2) *No access to WANs in the Internet*: However LTE provides QoS services, but unable to ensure the network conditions between the gateway and the nodes in the Internet.

IV. TRAFFIC MANAGEMENT IN SDN

An SDN northbound application is implemented
On packet data network gateway in LTE that communicates with the SDN controllers. An existing LTE system advantage is combined with the strength of next generation SDN/NFV networks to deliver unprecedented QoE to the end users.

1) *Building an application-awareness*: In an LTE network, different QoS parameters such as QCI, ARP, GBR and MBR are utilized to classify application types (e.g., video, voice, gaming and email) and provide the required QoS. Solution key point is to distribute QoS parameters of LTE with SDN controllers that face difficulties in implementing the application- awareness. Latest research suggests various approaches with the use of machine learning and crowdsourcing to distinguish applications depending on traffic characteristics. Although techniques used for implementation is verified practically in an SDN network. SDN controller provides more accurate and consistent end-to-end QoS, with the defined parameters in LTE which leads to a truly agile application-aware network.

2) *Real time monitoring of end-user's QoE*: To ensure end-to-end QoS, it is required to track end-user's perceived quality while delivering contents to the clients. This is challenging since there is no method to accurately estimate the QoE from the point of network operators that have limited access to client applications and server side networks. The QoS and QoE factors can also be measured using DPI. With the help of DPI, gateway enables executing inspection that gives context-awareness along with extracting metadata attributes (e.g., URL, file name, browser type, cookies, DNS queries, video codec, and operating system) and to calculate networking performance statistics (e.g., delay, jitter and application response time) for each flow other data is required.

3) *Performing a dynamic end-to-end flow control from P-GW*: The flow paths of the SDN controller is dynamically changed in the real-time network conditions periodically reported from P-GW and SDN-enabled WAN routers. The advantage of the outside network information obtained from the SDN controller is utilized by gateway in LTE network, to enforce end-to-end QoS.

- Efficient server selection: Gateway sends queries to the SDN controller(s) to obtain network conditions on each path between the gateway and each node. To select the best available server for the applications on clients' devices the above information can be used.
- Rapid end-to-end connection control: Gateway directly sends signals to the SDN controller to dynamically add / remove a flow in advance via SDN application.
- Flexible resource allocation at the wireless access node: Depending on outside network information

received from the SDN controller, gateway can
modify the QCI values of some traffic flows, if it is accepted by the corresponding applications, to flexibly reallocate wireless resources among subscribers. For an example, an LTE user is experiencing the slow Internet speed. If there is traffic flood from the outside network in the Internet and no alternative paths or content delivery nodes available at the moment, this signifies that there is no way to determine the clog either inside the LTE networks or through the external networks in the Internet. In this case, P-GW may degrade the QCI value, so other competing flows attached to the same nodes can have more chance use the network resource.

A. *Building an SDN Application on P-GW*

SDN application is designed to take the account of information of various flow that can be retrieved from gateway and is distributed with the SDN controllers in the Internet.

1) *P-GW and PCRF (Policy and Charging Rules Function):*
The gateway is the interconnection between the packet core and the external IP networks. Primary roles of a packet data network gateway are to conduct QoS policy enforcement for the service data flows (SDFs), packet filtering using DPI and charging support. Policy and Charging Enforcement Function (PCEF) in gateway communicates with the PCRF that is responsible of policy control decision-making and flow-based charging functionalities. PCE Policy and Charging Control (PCC) rules are given by PCRF which also includes SDF identification, policy control, and flow based charging rules for each SDF. Additional network elements from the Application Function (AF) are obtained for applications that need dynamic policy and charging control. PCEF manages the traffic events, according to the PCC rules for each SDF.

2) *SDN application*: SDN application can be deployed in the same machine where the P-GW is running on.
Else, it can be built in other machines and communicate with the gateway via the interface that is used for charging and policy control between P-GW and PCRF. Thus, SDN application is designed to distribute the traffic information related to QoS enforcement with the SDN controllers using existing northbound APIs such as Representational state transfer (REST). To dynamically control traffic flows in SDN and LTE, design of simple decision tree, as shown in Figure 2.

V. IMPLEMENTATION

On Linux machine, a mininet network is implemented with a physical networking interface attached to the virtual network. Connected interface (eth1) is extended to the 802.11g wireless access point. Only the real Wi-Fi clients are allowed to access any hosts in the Mininet network by the system. To periodically update network statistics to the monitoring services, a mininet is designed in the SDN application. Visualization of the traffic in the network is provided by the monitoring system over the Internet in real time.

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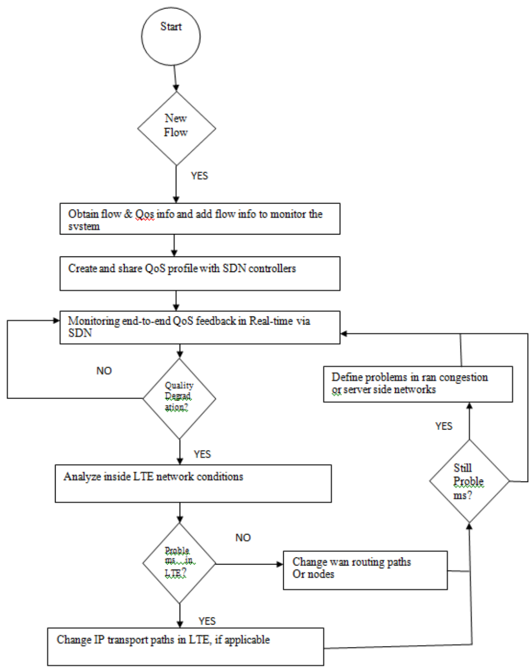

Figure 2: Flow chart of QoS-based flow control

- Creating WANs in Mininet: Various subnet networks are implemented where virtual routers and switches are used to forward IP network traffic among the hosts in the network.
- Examining network conditions on links: Many links are implemented in the virtual network such that an assumption is made that each WAN link has 100 Mb/s bandwidth capacity. For a realistic setup, background is emulated for traffic on the links based on recent mobile traffic statistics.
- Addition of 802.11g network to Mininet: An 802.11g network is attached to the virtual network. Wi-Fi client is attached to the access point which enables communication between the clients and the servers in the Mininet network as shown in figure 3.
- Deploying an SDN controller over the network:
  As discussed , QoS enabled application runs on the top of the SDN controller . It is designed to communicate with the open virtual switches using OpenFlow to get network statistics and control routing paths according to the QoS policy rules. The updates of network information are periodically sent monitoring server.
- A database flow: Assume that the edge devices of last mile networks dynamically access and update the flow database in the WAN SDN controllers. Traffic information for each traffic flow is included in the database. For example, the database may contain client identification, application types(e.g., video, voice chat and emails), priority, and necessary network conditions in terms of bandwidth and latency. According to the provisioned network condition, SDN controller refers to the database for dynamic flow control in the network.
- Building a monitoring server: Main function of the monitoring systems is to provide the network status in real time to the clients over the Internet.

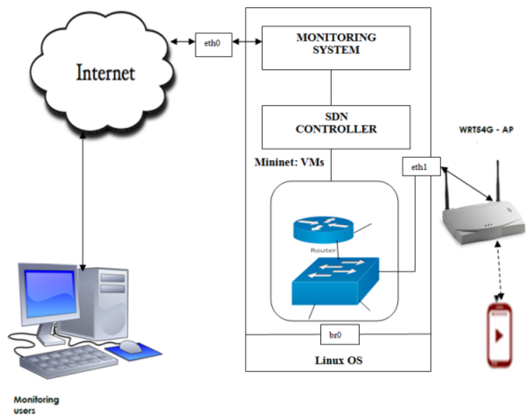

Figure 3: Architecture of Testbed

VI. CONCLUSION

The feasibility of an intelligent traffic management system in SDN is achieved. The unified control plane end-to-end across the web access and mobile core network on which novel application relies dynamically control traffic flows according to network adaptive conditions and service types in real time. The idea of feasibility emulates multiple WAN nodes and adds real Wi-Fi clients in the Mininet's virtual network. Therefore, the solutions of SDN-based QoS enables in attaining dynamic flow control based on adapting network conditions and application types, leading to enhance end-user's perceived service quality.

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