SDN architecture on fog devices for realtime traffic management: A case study

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Abstract. Software Defined Network has become one of the most important technology to manage the large scale networks.The separation of the control plane from the data plane in networking devices is the main idea of SDN. Currently, Open Flow is the popular SDN standard, which has a set of functionalities.In the emerging cloud scenario smart devices plays an important role. But they are facing latency and intermittent connectivity. For this fog devices are placing in-between cloud and smart devices.Fog computing is currently applying on connected vehicles, sensor network etc. This article looks into the vehicular network area as a case study where SDN architecture can apply on fog devices for enhancement of the performance and betterment of traffic management and QoS on distribution of real time data.

Keywords: Fog computing, SDN, Vehicular Network, Openflow, DSRC

1 Introduction

Today's data is tremendously dispersed and delivered continuously, in large volumes and to a large number of users with different devices.Fog devices provide data, storage, computation and application services to the end-users at a distributed level. Thus, the idea of fog computing is to distribute all data and place it nearer to the user, which will remove network delays and jitter associated with data transfer [1],[7],[10]. When many users are simultaneously streaming the same content in a given cell in a cellular network, each user gets his own video stream and consumes his own portion of the cellular capacity. This unicast model and video's intensive bandwidth demands can cause frequent network congestion. Again, the initial establishment of cellular connection takes several seconds and the end-to-end latency is comparatively high [2]. DSRC(Dedicated Short Range Communication),also called 802.11P [4] is an alternate to cellular network, a short range communication services that supports in v2v environment [3]. Software Defined Network(SDN) is an emerging paradigm that makes the behavior of the network devices (such as routers/ switches) programmable and allows them to be controlled by a central element, thus offering advanced customizability of network control and forwarding behaviors [9].
The rest of the paper is organized as follows. Section 2 describes the related work on content distribution. Section 3 discussed on proposed algorithm. Section 4 result analysis followed by future work and conclusion in section 5.

2 Preliminaries

For large amount of content distribution, V2V model is the wiser option than V2I model. In the first SDN concept of vehicular networks and centralized control over V2V [5], RSU can serve as fog devices.By leveraging the control plane in SDN, the system can effectively collect and maintain individual vehicle states in a logically centralized way also control and optimize V2V/V2I multi-hop routing/switching. Basically, in this paper, we formulate the characteristics of the system is like this: Transmission of content can be done in two phases. In the first phase of the content server to RSUs and in the second phase Content will transfer from RSUs to vehicles. In Fig.1, the core switches and aggregation switches will only route the content to the edge switches and edge switches are responsible to forward the content to RSUs. Then after control flooding is accomplished. RSUs will record all subscribers of a particular content service request. Each time the updates (a part of the content) will be broadcast to the subscribers.The more subscribers, the better efficiency can be achieved. Because of the intrinsic nature of the wireless communication, in a close environment the vehicles may suffer in transmission collision. Only one mode is active at a time i.e V2V or I2V, for the above reason[12].

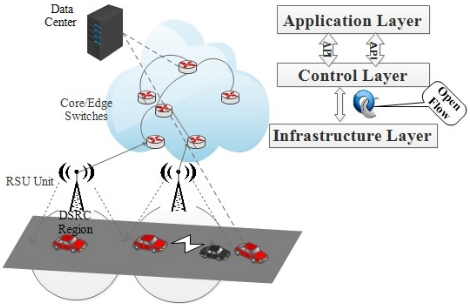

Fig. 1. DSRC and cellular link for content distribution along with SDN logic.

2.1 Intelligent capabilities in SDN

There are two types of entities in the SDN/OpenFlow network switches and controllers. The controller directs the switches to forward the flows. We are adding the third one, i.e. a analyzing server, to store the application information and perform traffic patterns analysis and prediction and classify the pattern which could improve the intelligence in SDN. To identify flows and detect applications, used Machine Learning (ML) techniques, which are based on statistical features. ML algorithms apply on true data set to train a classifier to classify flows, e.g. Support Vector Machine (SVM), Naive Bayes, neural networks etc.[6]. These techniques assume that the application typically sends data in some sort of pattern; these patterns can be used as a means of identification which would allow the connection to be classified by traffic class.Both supervised and unsupervised learning technique for the Internet traffic classification problem can be used. The unsupervised clustering technique use an Exception Maximization (EM) algorithm which classifies unlabeled training data into groups based on similarity[11].

3 Related Work

In [14] shows the CDS(Content Distribution Scheduling) is a NP-hard problem. CDS is a novel approach where each vehicle notify the current neighboring list to the RSU , then RSU select the sender and receiver vehicles and communicate either by using V2V or I2V channel. In this paper, we have used Type Based Content Distribution (TBCD) method [2] along with add more intelligent capabilities in SDN while forwarding the packets. The goal of our paper is to provide a content distribution model in a vehicular environment, which will provide high scalability, communication reliability under limited bandwidth using SDN paradigm.

Table 1. notations used in the algorithm.

Notation	Description
$D = \{d_1, d_2, .._n\}$	Set of data items
RSU_n	Road Side Unit
SW_{Ci}	Core Switches
$V_I(t)$	Set of vehicles in I2V mode
$V_V(t)$	set of vehicles in V2V mode
$RQ_{Vi}(t)$	set of request submitted by V_i
Rq_i^j	jth request of i
SQR_{Vi}	Set of satisfied request of V_i
URQ_{Vi}	set of unsatisfied request of V_i
N_{Vi}	Set of neighbor of V_i
$DSRC_i$	i^th DSRC region1

4 System model and Problem analysis

For a clear understanding we discuss the notation used in the Table I. The total number of data items D requested by a subscriber is denoted by $\{d_1, d_2, ...d_n\}$. The set of RSU in a city is denoted by $RSU = \{RSU_1, RSU_2, ...RSU_n\}$ The set of vehicles $V(t) = \{V_1, V_2, ...V_V(t)\}$,where $V_V(t)$ is the total number of vehicles at time t. The total number of vehicles can be grouped into either V2V or V2I mode; these two sets are denoted by $V_I(t)$ and $V_V(t)$ respectvely. One vehicle has to be stay in one mode at a time ; i.e $V_I(t) \cap V_V(t) = \emptyset$ and $V_I(t) \cup V_V(t) = V(t)$.Each vehicle is having a set of request i.e $RQ_V i(t) = \{RQ_i^1, RQ_i^2, ...RQ_i^n\}$ where n is the total number of request send by the vehicle V_i at time t. Set of services again may be divided into satisfied request and unsatisfied request or pending request, they are denoted as $SRQ_V i$ and $URQ_V i$. So $SRQ_V i \cap URQ_V i = \emptyset$ and $SRQ \cup URQ = Q_V i(t)$. Any vehicle V_i has a set of neighbor vehicles in V2V mode, they denoted by $N_{Vi}(t)$. V_{RSU} is the set of vehicles in the RSU region.To facilitate the above scenario the following set of conditions has to satisfy.

$$\{V_i | V_i \in V_{RSU} \wedge V_i \in V_I(t) \wedge d_I(t) \in URQ_{Vi}(t)\} \tag{1}$$

It tells that V_i must be in RSU region V_i is in I2V mode and $d_I(t)$ has not yet been serviced. In V2V mode the set of vehicles $SV(t) = \{SV_1, SV_2, ...SV_n\}$ are the designated sender vehicles. Set of data items to be transmitted by the set of vehicles is denoted by $D(SV(t)) = \{d(SV_1), d(SV_2), ...d(SV_n)\}$. Because of broadcast of packets, multiple data items may reach to the receiver, which may cause collision. Given a set of sender vehicles SV(t), for any V_c in the V2V mode, SV_a and SV_b are the neighbors. So both must be in SV(t) i.e $SV_a, SV_b \in SV(t)$.The data collision might be occur in the following situation.

$$\{V_c | V_c \in V_{vt} \wedge V_c \in N_{SVa}(t) \wedge V_c \in N_{SVb}(t)\} \tag{2}$$

Keeping in eye the dynamic nature of the traffic and heavy demand of the data services, it is required to enhance QoS via cooperative data exchange. So one of the objective is maximization of vehicle that either I2V or V2V mode during communication and simultaneously minimization of the packet transmission from server to the vehicle through RSUs.

5 Proposed Algorithm

When a vehicle sends a request to the server, the SDN agents keep track of vehicles' information in the cache. Then the server begins to push the content to the designated RSUs through switches. All these initial actions carried out between RSU and SDN agent is described in the algorithms 1.

Algorithm 1 Initial action

```
$V_{RSU}(t) \leftarrow \phi$
for each $V_i \in V(t)$ do
    if RSU receives the updates periodically from $V_i$ then
        $V_{RSU}(t) \leftarrow V_{RSU}(t) \cup V_i$
    end if
end for
for each $V_j \in V_{RSU}(t)$ do
    for each $q^m_{vj} \in RQ_{Vj}(t)$ do
        Push the content request to the server
    end for
end for
```

Core switches send the data packet to the other switches whereas edge switches determine the updated copies and send the packets to the RSUs according to the current location of the vehicle. If the vehicle is in the DSRC region of an RSU, then it receive immediately, otherwise wait for update come from other vehicles in V2V mode. When a vehicle received a new update, it waits for a time interval W_s. It can be represented by

$$w_s = 1/d_s \tag{3}$$

where d_s is the distance from RSU. If the vehicle receives the same content during this period it will prohibits from rebroadcast. Otherwise the vehicle rebroadcast the packets to the others after W_s interval. The next action among RSU, vehicles and V2V are described in the algorithm 2.

Algorithm 2 Content transmission from Switch to RSU and RSU to vehicle

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for do$SQR_{Vi}(t) \subset RQ_{Vi}$
    if $SW_i \in SW_c$ then
        $SW_k \leftarrow SQR_{Vi}(t)$ (where $SW_k \notin SW_c$)
    else
        $RSU_i \leftarrow SQR_{Vi}(t)$ (where $SW_k \in SW_e$)
    end if
    if $V_{RSUi} \in DSRC_i$ then
        $V_{RSUi} \leftarrow SQR_{Vi}(t)$
    else
        wait for V2V mode
    end if
end for
```

6 Simulation Result

With a limited functionalities we have simulated this architecture using the Mininet simulator. The traffic characteristics are simulated based on Greenshield's model. This model is widely used in simulating macroscopic traffic scenario[13]. Using SDN technology in the said algorithms the total number of packet transmission from content server to the subscriber reduced drastically.

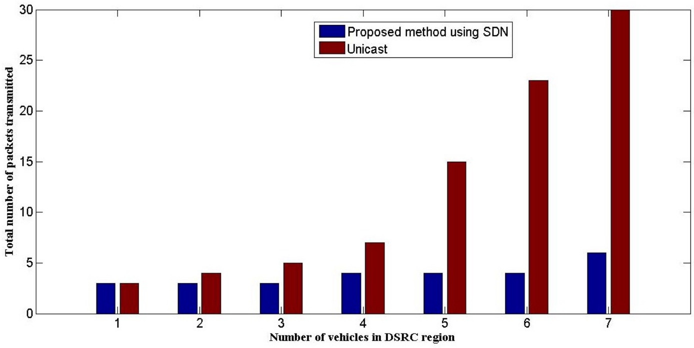

Fig. 2. Number of packets transmissions

Since the real time information is flowing from the content server, then would go to core switches and then to edge switches, to a RSU and finally reaches to the subscriber. So the packet is forwarded once in each hop. The graph obtained from the simulation shows that the packet is forwarded once for each hub, so the total number of packets transmitted is nearly equal in each time for content transmission which is depicted in fig 2. On the contrary, each subscriber,in the on-demand unicast method will retransmit once from the server. So the total number of packet transmission grows linearly with the number of subscribers increases.

7 Conclusion

For our work we have used Type-Based Content Distribution (TBCD) method[2], along with we have theoretically added ML classifier to classify the flow to support large scale real time content distribution in vehicular net-works. Theoretically, we have modeled ML classifier in our approach which our future research work. In future we will focus on the content delivery based on both ML classifier and DPI classifier. To extend this work, we will investigate the innovative approach to capture, aggregate, and analyses the fine grained real-time traffic to enhance the QoS in SDN architecture. Also current RSU model does not support multi hop V2V transmission, which is one of our future work.

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