Using Service Delay for Facilitating Access Point Selection in VANETs

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***Abstract*—With the rapid development of wireless mobile networks, VANET (vehicular *ad hoc networks*) that adopt transportation tools as mobile platforms have received great attention. Integrating VANETs with wireless infrastructure to provide high-quality transmission services also has become one of the important research topics. Because terminal devices in vehicular environments are highly mobile, a MN (*mobile node*) will encounter frequent handoffs while accessing wireless network services. However, supposing the chosen handoff AP (*access point*) presents too long service delay, the quality of the Internet, especially real-time services, like VoIP and multimedia streaming, will be greatly influenced. Therefore, by using the packet scheduling architecture for classified service at APs, this paper proposes a handoff scheme based on service delay prediction. According to the scheduling scheme, we can estimate the load and service delay of different access categories of the regional APs. Our proposed scheme allows the MN requesting real-time services to be allocated to the AP with the lower service delay and the chosen AP thus can reduce the service delay for users.**

Keywords- VANET; Wireless network switch; AP selection

I. INTRODUCTION

In recent years, wireless network has been extensively deployed in the environment for users to access network services. Wireless communication, consequently, becomes more and more important in our daily life because users at any locations are able to use wireless network via APs during the moving process. Because of the emergence of abundant real-time network services, the QoS (*quality of service*) of wireless network also becomes significant. By integrating wireless network with telematics, VANETs (*vehicular ad hoc networks*) provide more and more services for vehicles on the roads. Nevertheless, owing to the high mobility of terminal devices in VANETs, handoffs occur frequently while users access wireless network services [1][2]. If the handoff latency is too high, the quality of network services, like VoIP and multimedia streaming, will be greatly influenced [3]. Previous VANET researches mainly focused on the reduction of scan delay during the handoff procedure, but did not consider the delay resulted from the load of the target AP. For example, not only the processing speed of different service types but also the load of different service types in an AP varies. Thus, the existing methods cannot select the most suitable AP to decrease the service delay. For this reason, this paper presents a scheduling scheme to estimate the load and service delay of different service types for the APs in the area and select the optimal AP for each service type for handoff. Our proposed scheme allows the MN requesting real-time services to be allocated to the AP with the lower service delay.

The rest of this paper is structured as follows. Section II introduces the background and related works. Section III explains our proposed scheme, including system architecture, scheduling architecture of APs for different service types, load estimation for APs, service delay prediction for APs, service-oriented plus service delay prediction-based regional load balance, and AP selection flowchart. Section IV uses the simulation to prove that our proposed scheme decreases the service delay for users. Finally, the conclusion and future objective is given in Section V.

II. RELATED WORKS

Every AP on a wireless network is responsible for a specific coverage area. When a MN is leaving the coverage area of the current AP, the MN has to search for the surrounding APs and handoff to the next suitable one. The complete handoff procedure includes scanning, authentication, and re-association. Through the selection mechanism, the MN can determine the most suitable AP, perform the authentication and re-associate with the AP to finish the handoff. All existing handoff mechanisms choose the best AP to handoff based on the RSSI (*received signal strength indicator*) but such mechanisms are not suitable for highly mobile VANETs since the time for a MN to stay with an AP is short and handoffs thus frequently occur. Because MNs choose the target APs by themselves and most of them connect to the network via several specific APs, the service delay increases greatly and consequently affects the quality of network transmissions, especially real-time network services.

Therefore, traditional mobility management mechanisms for Internet and MANET (*mobile ad hoc network*) cannot satisfy the needs of vehicular networks and the performance degrades severely owing to the unique features of vehicular networks [4]. In this paper, we mainly focus on the communication between vehicles and infrastructure of RSU (*roadside unit*) with the attempt to satisfy users' requirements by improving the handoff according to the characteristics of VANETs.

Up to now, many AP selection schemes have been proposed to determine the best AP to handoff by different load metrics and we will introduce several existing AP selection schemes next. The load metric proposed in [5] is the Maximizing Local Throughput, which is based on the number of MNs connected by each AP and the PER (*packet error rate*). However, the number of MNs only roughly implies the load of each AP because the degree of network utilization of each AP differs and the states of different traffic types alter with the time. In addition, this mechanism depends on the PER very much. When the PER is very low, the load balance cannot be improved efficiently. Another AP selection mechanism presented in [6] chooses the AP in light of the signal strength of APs, the number of MNs and the bit rate. By considering the bit rate between APs and MNs and the number of MNs connected to each AP, [7] estimates the throughput between APs and MNs at the higher rate. In [8], on account of queue congestion that might occur when the network is overloaded, the authors use the frame dropping rates of the current AP as the load metric and regulate the received signal strength from each AP to adjust the coverage area of each AP with the aim of achieving load balancing. Based on the measurements of delay incurred by 802.11 beacon frames, [9] selects the AP with the maximal potential throughput or bandwidth. Due to QoS considerations, [10] proposes the iLB (*integrated Load Balancing*) scheme, which chooses the AP with the lower packet delay and defines a handoff threshold value based on the packet loss rate. The iLB scheme establishes an APC (*AP controller*) to gather related information for the APs periodically and broadcast the information of the adjacent APs to the MNs by beacon frames. For QoS management and congestion control for wireless APS, Tartarelli et al. [11] proposes to establish a Policy Server to differentiate QoS guarantees for different traffic types and users, and to reduce network congestion by traffic distribution. Tüysüz et al. [12] present a novel AP selection algorithm, which uses E-model conversational audio quality factor R to estimate the perceived voice quality as the criterion in selecting the most suitable AP to handoff.

III. Proposed Load Balance Scheme

In VANETs, MNs connect to APs to access wireless services, but MNs may encounter different levels of service delay because of frequent handoffs. According to the scheduling, we propose to quantize the load of different ACs (*access categories*) in each AP and present the Service Delay Prediction scheme, a service delay-based AP selection mechanism. After the scheme quantizes the service delays of different ACs in each AP, users can select the handoff APs with the lower service delay based on the current services. Such a classified selection scheme distributes the load efficiently in case the throughput is degraded and some APs are overloaded due to load imbalance. Previous AP selection methods chiefly select the best AP to handoff based on various load metrics after the affiliation of MNs. In this paper, we classify the network services, use the service delay of different ACs in each AP as the load metric, and select the most suitable AP that meets the requirements of the MN to decrease the service delay.

A. System Deployment and AP Control Architecture

Based on the AP architecture proposed in [14], this paper divides the vehicular environment into several service areas and APs in each area offer services for local MNs. When several MNs are leaving the current service area, APs in the forward area will provide wireless services to MNs. To guarantee QoS and distribute the load, our scheme gathers users' statuses and APs' load in the forward area to estimate the load of the next handoff AP for MNs to select a suitable AP. As shown in Figure 1, an AP controller is established to periodically gather the area information. Every AP in the area regularly uploads its own information and the conditions of the current MNs in the area to the APC. AP information includes the current channel, location and data amount of each AC that is waiting to be processed. MN information records the traffic flow of all ACs that users are accessing in the area. Supposing a MN is accessing several kinds of services simultaneously, the AC with the highest use frequency is regarded as the representative category. According to the information, the APC estimates the loading states and waiting delay of each AC in APs in the forward area and sends the computed result to the MNs in the current area through the current APs.

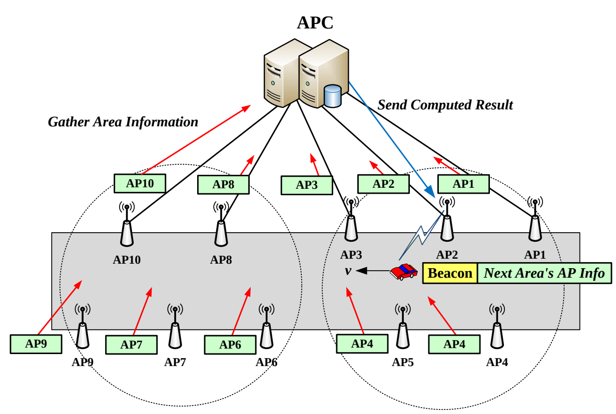

Figure 1. System architecture.

B. QoS for Service Classification

For APs to support QoS-guaranteed service classification, when packets of various traffic types arrive at APs in the vehicular network, the classifier of each AP maps the packets to the ends of the corresponding FIFO (*First In First Out*) queues and the packets in the queues wait to be delivered. Packets in the output queue of each category will be scheduled by the packet scheduler. By the weighted round robin module, the scheduler transmits the packets from the high-priority queues first. Queues of different ACs have different priority values and thus the number of packets will be different in each round- robin cycle. In every round-robin cycle, the packet number of every queue is fixed and proportional to the weight. As defined in IEEE 802.11e, packets in vehicular environment include four access categories: AC_0=AC_VO, AC_1=AC_VI, AC_2= AC_BE, AC_3= AC_BK and each AP has four output queues to store the packets of VO (*Voice*), VI (*Video*), BE (*Best Effort*) and BK (*Background*). In this paper, the packet size of the four categories is the same and the time for an AP to deliver packets is set to T (Delivery Time Unit). Every AC has its own weight: W_{VO},W_{VI},W_{BE} and W_{BK}, which means the packet number that can be delivered in each round-robin cycle. Packets are sent in order from the highest-priority VO, VI, BE to BK. The total deliver time of packets from four queues in every complete round-robin cycle can be denoted by Equation 1:

$$\sum_{i=0}^{3} W_{AC_i} \times T \qquad (1)$$

Queues with the higher weights can deliver more packets in each round-robin cycle and the processing speed for different queues differs. The scheduler transmits the data of four ACs in order in each round-robin cycle until the packets of each AC are fully delivered.

C. Load Estimation for APs

In the previous section, we have introduced the service-classified packet scheduling architecture for APs. The packet number of each AC that is waiting to be delivered in the AP is set to NNN. Based on the parameters of priority scheduling for the router in [15], we set the weight values of four ACs (W_{VO},W_{VI},W_{BE},W_{BK}) to (8,4,2,1). MU_{AC_i} means the number of round-robin cycles for all the packets in the queues waiting to be transmitted completely and to serve the MNs. Supposing the number of round-robin cycles of two ACs at an AP is the same, the waiting delay for users who access the two ACs will be similar, which implies the loading states of the two ACs are the same. On the contrary, the bigger difference between the numbers of round-robin cycles refers to not only different loading states of the two ACs but also their waiting delay. The number of round-robin cycles displays the comparative busyness of the ACs and the number of rounds that users have to wait.

$$\mu = \frac{\sum_{n=1}^{n} MU_n}{n} = \frac{\sum_{I=0}^{3} MU_{AC_i}}{4} \qquad (2)$$

Equation 2 uses μ to represent MU_{AC_i}, the average number of round-robin cycles of each AC at an AP. In this paper, the value of μ is regarded as the load of an AP. The higher value of μ means the larger average number of round-robin cycles of the ACs at an AP. Therefore, the data that waits to be delivered must be processed by more rounds and the load of the AP is comparatively heavy.

D. Service Delay Prediction for Different Access Categories

Because we use a round-robin algorithm to schedule packets from several output queues, the amount of time needed to process one queue is directly influenced by the amount of data in the other queues. The packet scheduler transmits the packets in the queues in order. When a MN chooses the ACs on an AP, different amount of data in the queues results in different levels of service delay. Figure 2 displays the flowchart for computing service delay of different ACs.

Several basic parameters are defined as follows:

- N_{AC_i} : number of the AC packets waiting for transmission at an AP
- $Total$: AP's service delay caused by the cumulative number of packets sent before serving users
- W_{AC_i} : number of the AC packets that can be transmitted during a round-robin cycle
- MU_{AC_i} : number of round-robin cycles for the AC queue to wait for processing the MN's data
- T : delivery time unit for the AP to transmit packets
- I : serial number of the target AC { 0=VO , 1=VI , 2=BE , 3=BK }

Through the APC, we know the states of the four AC queues in the APs in the forward area, estimate the service delay of the AC queues, and obtains the service delay of each AC while the MN determines the best AP to handoff. Different levels of service delay is required for different service types. Compared with previous load estimation methods, our proposed scheme measures the service delay that users may encounter after choosing the target AP and thus reveals the loading states that users actually experience more. The APC gathers the information of the forward area and obtains μ, the current loading states of the APs, and service delay of each AC according to N_{AC_i}, the data amount of the ACs.

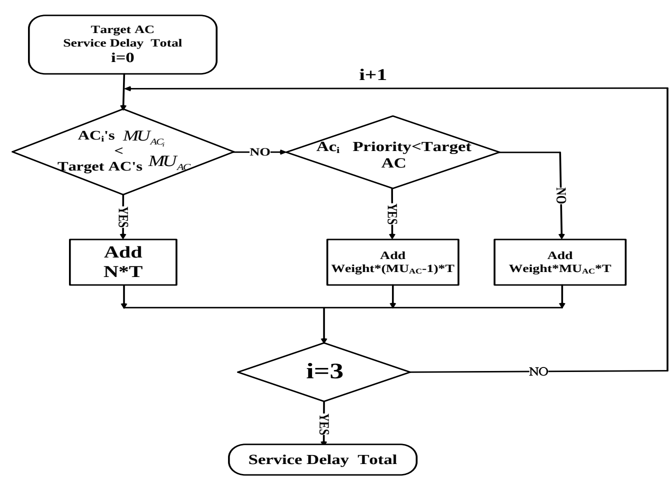

Figure 2. Flowchart for the computation of service delay.

E. Service-oriented plus Service Delay Prediction-based Regional Load Balance

This paper presents a service-oriented scheme, which selects the best AP to handoff according to the service delay of all APs. As shown in Figure 3, the vehicle MN1 can choose AP1 or AP2 for the handoff. Because different ACs have different advantages, the processing speed of the four AC queues in each AP is also different and so are the queue lengths. Thus, before MN1 makes the decision, several considerations must be made. As for the simple circumstance, MN1 demands VI service currently, keeps uploading a fixed number of packets to its designated AP, and will choose the best candidate AP to handoff. Figure 3 shows that AP2 is lighter loaded than AP1 but the number of VI packets to be delivered in AP2 is more than AP1. Different queue lengths of the four ACs influence the service delay. For this reason, our proposed scheme considers both the service delay of each AC and the loading states of the APs to guarantee the QoS of each AC and to achieve the regional load balancing. We aim to select an AP with the lower service delay of a specific AC and the less average round level for the handoff.

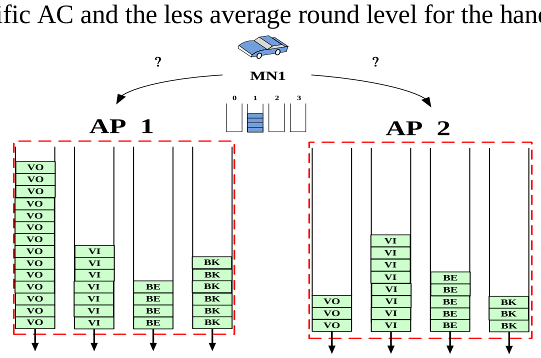

Figure 3. Service-oriented AP selection.

By our scheme, we can get the service delay of each AC on each AP in the forward area. Since AC VO clients cannot endure too long delay, service delay is significant to AC VO and an AP with the lower service delay will be necessary for the handoff procedure. Also, AC VO traffic has low bandwidth requirement. On the other hand, with the design of the buffer, AC VI often can endure longer delay than AC VO, but the data generation rate of AC VI is higher and thus demands higher bandwidth requirement than AC VO. According to ITU-T, G.1010 [13], based on users' tolerance of real-time services, we set the threshold values for service delay, Th_1 and Th_2, and classify the service delay of the ACs on each AP into three levels, as displayed in Table 1.

TABLE I. SERVICE DELAY LEVELS

Service Delay Level	
Level 1	**Service Delay<Th$_1$**
Level 2	**Th1<Service Delay<Th$_2$**
Level 3	**Th$_2$<Service Delay**

In the APC, each AC has a table of service delay levels to level the APs and APs in the forward area are divided into three levels according to the table. Level 1 means the service delay that is lower than Th_1 and is imperceptible to users. Level 2 means the service delay ranging between Th_1~Th_2 that is perceptible but tolerable to users. The service delay that is higher than Th_2 and intolerable to users is leveled as Level 3. Therefore, four ACs are leveled into different service delay levels based on the same thresholds.

F. Service Delay Prediction AP Selection Scheme

The APC gathers the states of each AP in each area, calculates the service delay of each AP, and lists each AP in the target AC's service delay level table. After the APs broadcast the service delay level table of the APs in the forward area, users can examine the table of the target AC and select the AP with the minimum service delay level and the least average round level for the handoff. By the load estimation, our service delay prediction scheme allows the MNs to select the APs that satisfy the service delay of the target AC and choose the handoff AP with the minimum service delay level and the minimum average round level. Instead of choosing the AP with the minimum waiting time, we choose the AP with the lightest load so that the MN can distribute the load efficiently while selecting the AP to handoff. To satisfy QoS guarantee and achieve load balancing, our scheme maps users to different ACs, considers the APs with the minimum service delay level first, and selects the AP with the minimum average round level.

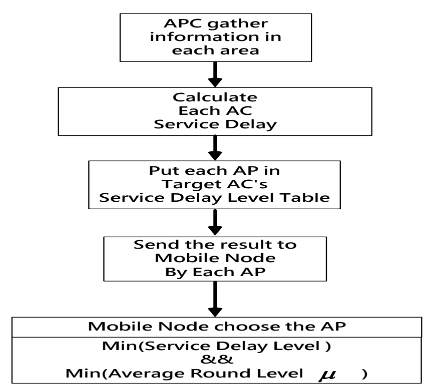

Figure 4. Mobile Node Handoff Architecture.

IV. PERFORMANCE ANALYSIS

This section will simulate and analyze our proposed scheme. Section 4.1 investigates the average service delay variation of four ACs under different traffic flow. Matlab is used as the simulation tool and related steps and parameters are described in the following.

By referring to [14], we group the APs in the areas and choose the best APs to handoff when MNs move from one area to the other. Figure 5 presents the simulation scenario, in which each area is constructed by a fixed number of APs. The overlapping range of the two areas is assumed to be

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50M. The average data generation rate of each AC is set based on ITU-T, G.1010[13] and the weight values of the four ACs are set to (8,4,2,1). Compared with (4,3,2,1), our assumed setting conforms to the service delay of the four ACs more under the same load. To choose the most suitable APs to handoff, we predict the service delay that MNs might encounter while moving into the next area. Moreover, to avoid too long service delay affecting the QoS of real-time services and to maintain the load balancing of the next area, we classify the APs and MNs according to the service types and use the average round level and service delay as the load metrics. In the following simulation, with 5 APs in the forward area, we examine the service delay variation of the four ACs when the amount of data increases. The rest parameters are listed in Table 2.

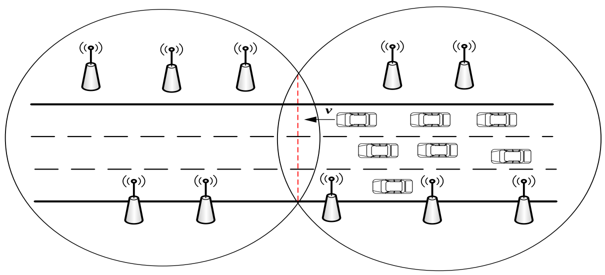

Figure 5. Simulation Scenario.

TABLE II. SIMULATION PARAMETERS

Parameters	Value
Packet Size	1024 bytes
AP Service Rate	100MBps
AP transmission Radius	500m
Overlap range	50m
Mobile Node Speed	100 Km/h
Access Category	VO,VI,BE,BK
(W_{VO},W_{VI},W_{BE},W_{BK})	(8,4,2,1)
Service Upload Rate	8~50 packets/sec
Offered Load(MB)	5MB~30MB
Th_1	150ms
Th_2	400ms

4.1 Analysis of Service Delay

In the scenario, there are 5 APs in the forward area. When the MNs' load during the handoff procedure increases, we use different load metrics and compare the average delay variation of the four ACs under different traffic flow conditions. The results are shown in Figure 6~8. The load metrics include: (1) service delay, proposed in this paper that calculates the service delay of four ACs in each AP and classifies the APs, (2) load balance, proposed in [10] that selects the best AP to handoff according to the packet delay metric, and (3) RSSI. Because Service Delay Prediction scheme levels the APs in the forward area based on service delay, Figure 6 reveals that our method allows the MNs requesting real-time services to have lower service delay. Compared with the packet delay-based scheme presented in [10] and the RSSI-based scheme, considering that different ACs require different service delay, our Service Delay Prediction scheme classifies the APs according to the services to the MNs, classifies the MNs, and chooses the AP with the lowest service delay levels for the handoff.

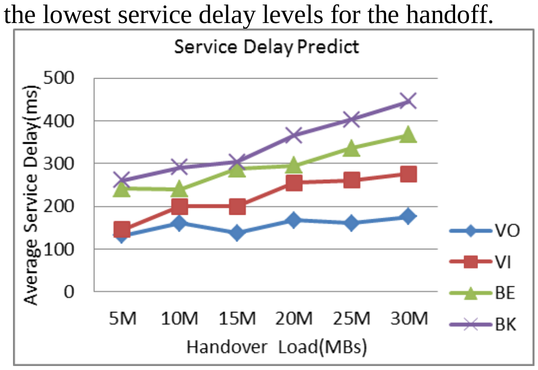

Figure 6. Simulation Scenario. Average delay variation of four access categories (Service Delay Prediction).

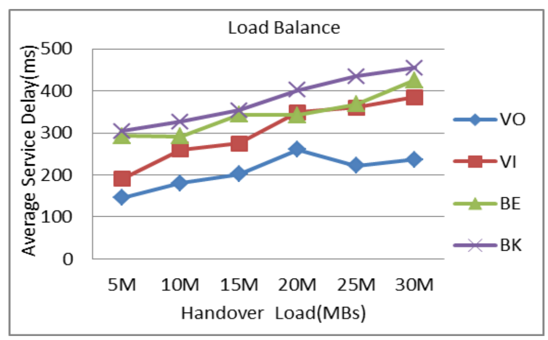

Figure 7. Average delay variation of four access categories (Load Balance).

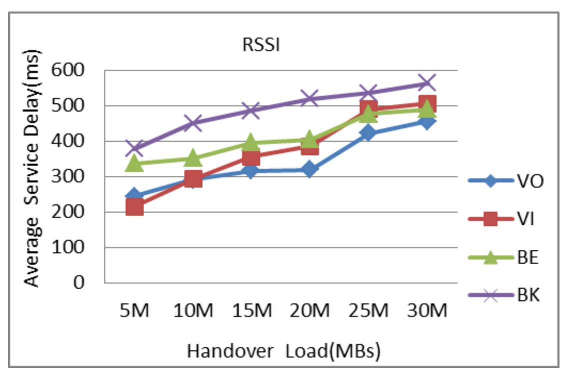

Figure 8. Average delay variation of four access categories (RSSI).

To satisfy QoS guarantee and achieve load balancing, the AP with the minimum average round level is chosen for the handoff. Figure 7 shows that the packet delay-based AP selection scheme proposed in [10] does not consider service delay caused by different busyness of different ACs in each AP and thus the MNs accessing real-time services cannot have the lower service delay. To select the handoff AP based on the RSSI, Figure 8 reveals that the handoff APs chosen by the MNs will be closer to the previous area and cannot satisfy the service delay for the ACs. Therefore, the service delay of the four ACs is obviously longer than the other two schemes.

4.2 Analysis of AP Load Balance in the Area

μ , the average number of round-robin cycles of APs, is taken as the balance index in our proposed method, as shown in Equation (3):

$$\beta(x) = \frac{(\sum \mu)^2}{N \times \sum \mu^2} \quad (3)$$

To compare packet delay-based load balancing scheme [10], RSSI-based scheme and our Service Delay Prediction scheme, we simulate two situations, in which there are 4 and 5 APs in the area, respectively, to examine the load distribution of different ACs by each scheme in different handover load when the MNs are in the overlapping area. The simulation results displayed in Figure 9 and 10 reveal that by using our Service Delay Prediction scheme, the load balancing method in [14] enables the system to reach load balance, which is very close to 1. As for the RSSI-based scheme, the balance index is low and becomes unstable with the increase of handover load. Because of the RSSI, some APs nearer the previous area are easily selected by the MNs without considering the current load of the APs and the load thus cannot be distributed to the regional APs. The load balancing method presented in [14] chooses the handover AP according to the busyness of AP and thus performs better than the RSSI-based scheme in load distribution. Nevertheless, the load of different ACs in each AP is not considered and therefore the general load dispersion is below the Service Delay Prediction scheme. Our Service Delay Prediction scheme chooses the suitable AP for the MNs moving to the forward area according to the service delay of different ACs in the APs, thus making good use of resources of each APs in the forward area.

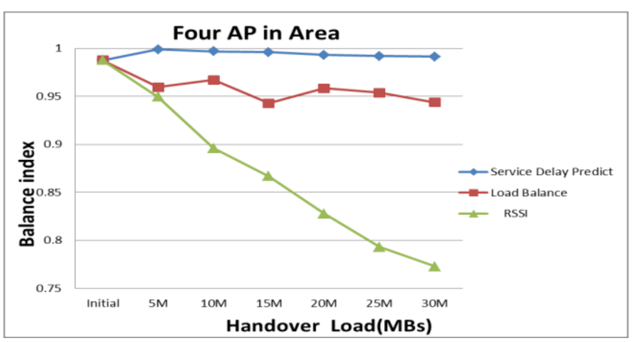

Figure 9. Load Balance Analysis (Four APs in the area)

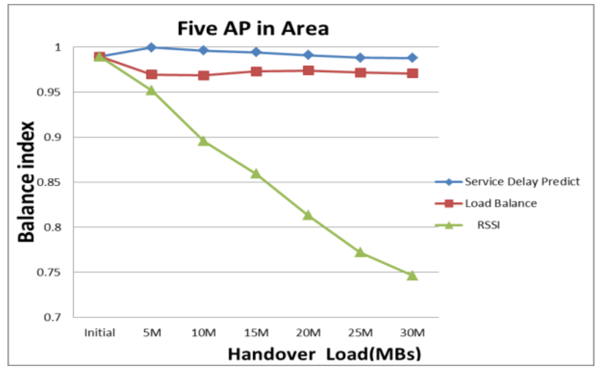

Figure 10. Load Balance Analysis (Five APs in the area)

V. CONCLUSION

Based on the service delay of the APs in the forward area, this paper proposes an access point selection scheme for VANETs, in which an APC (Access Point controller) is established to gather the information of APs and users in each area and compute the service delay of the APs in the forward area. The computed result is sent to MNs by the regional APs. A QoS-guaranteed handoff AP not only reduces the service delay of real-time services in each AP but also maintains the load balancing among the regional APs and the simulation result proves that our proposed method achieves the above-mentioned goals. In the future, we aim to include users statuses under frequent handoffs during long-term movement to enhance the regional load-balancing capacity in the area. Also, to classify the services for further discussions will be more pertinent to actual utilization.

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