Hierarchical IP Distribution Strategy for VANET

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***Abstract*—Vehicular Ad Hoc Network (VANET) is a special type of application in wireless communication, different from the traditional Mobile Ad Hoc Network (MANET), it has the characteristics of high speed and unlimited power supply in data transmission. Issues on addressing always play critical roles in wired and wireless networks, source nodes can transmit data correctly according to the addresses of the destination nodes. A number of researches on addressing in VANET are proposed, there are mainly two types of addressing mechanisms, which are centralized and distributed mechanisms respectively, these researches on addressing claim high efficient IP configuration, effective duplicate IP detection and the duration of possessing an IP can be continuously extended by vehicles, but the mechanisms of IP recycling and the method to surrender an IP are not discussed clearly, the issues mentioned above are related to the problems of IP reuse. In light of the aforementioned problems, we propose a mechanism for high efficient hierarchical IP distribution system, the basic idea is to endow each AP with the ability to distribute IPs, and these APs are all connected to a server in a hierarchical form for available IP synchronization in order to avoid duplicate IPs and detect unused IPs. Aside from emphasizing the high efficient IP assignment, the additional action for duplicate IP detection is unneeded, and the strategy to recycle IPs surrendered from vehicles for IP reuse and an effective method for recycled IP management are also presented. Furthermore, there is a probability that an AP could malfunction, and the available IPs in this AP will be invalid, the problem is also properly solved in this paper.**

***Index Terms*—vehicle ad hoc network (VANET), IP recycling, available IP synchronization.**

I. INTRODUCTION

In these years, Vehicular Ad-Hoc Network (VANET) plays an important role in human life, a lot of advanced communication equipments are installed on vehicles to assistant drivers, such as sensors which can sense emergency messages to inform driver to avoid any dangerous condition, and the transceivers which can receive or transmit a number of practical information for entertainment or other objectives. Different from the traditional Mobile Ad-hoc Networks (MANET), speed of moving for nodes in VANET is usually higher than that in MANET, so the type of communication must be modified moderately for VANET. The protocol for radio communication usually used in VANET is Dedicated Short Range Communication (DSRC) [1], Access Point (AP) and vehicle act as Road Side Unit (RSU) and On Board Unit (OBU) respectively to communicate with each other. This protocol is allotted two spectrums, one is 915 MHz with a communication range of 30 m, and the other is 5.9 GHz with a communication range of 1000 m. The former is used only for Electronic Toll Collection (ETC) or other short range applications, and the latter is used either for ETC or general Internet access, and also employed by many researches on VANET. Aside from DSRC, IEEE 802.11b [2] is also commonly used in VANET, the frequency band for this protocol is 2.4 GHz with a communication range of 100 – 300 m.

Addressing is the most important issue in transmitting data between nodes, because source node must know the destination node`s address so that it can correctly send packets to the destination. Many researches on VANET usually omit the issue on addressing, IP is always assumed to have been successfully assigned to each vehicle, but addressing is also a critical issue which cannot be neglected in data-transmitting. When users drive their cars, they would like to access a variety of useful information, such as neighboring gas station, supermarket, shopping mall and other stores for commodities, or play online games. The aforementioned applications all need address to achieve any connection to the destination or obtain practical information on the Internet.

Dynamic Host Configuration Protocol (DHCP) [3] can automatically allocate IP to each node, decreasing the burden for the network administrator. DHCP can assign either the dynamic IP to any node or a static IP to one node according to the MAC address of the specific node recorded in its MAC address/IP address table. Private IP is usually used in the local area network, a node which has obtained an IP can access to Internet through NAT, and the function for NAT [4] is converting the private IP to a public one. When a node obtains an address from DHCP, the address must pass the authentication by Remote Authentication Dial-In User Service (RADIUS) [5] in order to acquire the access to Internet through NAT. Efficient IP distribution to each node is more important in VANET than that in MANET. Due to the high speed, vehicles will pass through a communication range of an AP in a few seconds, so the number of handoffs can be considerable, a mechanism for IP assignment and recycling must be dealt with efficiently. In this paper, a mechanism for hierarchical address configuration using DHCP will be proposed to implement an efficient IP assignment and recycling system for VANET, with the proposed strategies, how the IP is assigned and recycled is handled efficiently.

The rest of this paper is organized as follows. The related work on IP configuration in VANET will be discussed in section II. Section III mainly focuses on the proposed mechanism for IP distribution and recycling. The future work about the subsequent plan of simulation, performance evaluation and the conclusion will be described in section IV.

II. Related Work

The general way for implementing wireless communication in VANET is utilizing the infrastructures known as AP or Internet Gateway (IG). APs are usually installed along the highway or in the urban for vehicles to access to Internet. AP can act as both a gateway for access to Internet and a DHCP to assign an IP to a vehicle, vehicles under the communication coverage of the current AP can obtain an address from the AP so as to access to Internet. Suppose there are two cars which are vehicle A and vehicle B respectively, IP which has been assigned to vehicle A can be reassigned to vehicle B when vehicle A moves away from the current AP, which means an address is unique only within the communication range of the current AP, in other words, if vehicle A possesses the IP and keep moving to the communication coverage of the next AP, it could meet another vehicle with an identical IP, so it must return the IP back to the current AP before going away from the communication range of the current AP, according to the aforementioned situations, the number of handoffs for each vehicle could be considerable. Furthermore, every DHCP server built on the AP has the probability to produce an identical IP, in light of this problem, there must be an efficient available IP synchronization mechanism implemented between these APs. With the synchronization mechanism, DHCP servers can dynamically assign IPs through the detection of identical IPs without the concern of duplicate IPs under the same communication coverage of an AP.

Vehicular Address Configuration (VAC) protocol [6] is a representative distributed mechanism for IP management utilizing a distributed DHCP protocol to assign IPs, the scenario for VAC is depicted in Fig. 1. Each vehicle is equipped with a DHCP server so as to have the ability to distribute IPs. Vehicles in VAC are characterized as Leader car and Normal car respectively, Normal cars would send a request for an IP when entering the network, and Leader cars can assign IPs to Normal cars. Leader car has a *SCOPE* of which size is the number of hops for other Leader cars away from it, in this scenario, the size of a Leader car is one hop. A Leader Chain will be formed by utilizing the linked border of communication range for each Leader car. An address distributed by a Leader car (Leader A) can be unique until a Normal car with this address moves out of the *SCOPE* of Leader A, and then it must transmit a request for a new IP to another Leader car (Leader B). The roles of Normal car and Leader car can be exchangeable according to the relative distance, if the distance between two Leader cars is smaller than the threshold *TH_min*, then one of the two Leader cars will become a Normal car, or if the distance exceeds the threshold *TH_max*, then one Normal car between the two Leader cars will become a Leader.

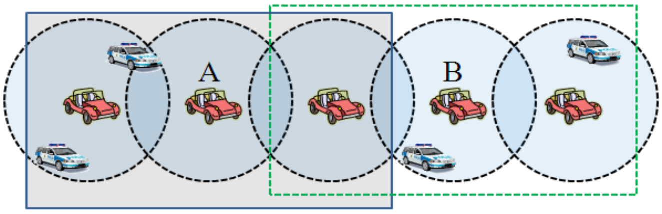

Fig. 1. The scenario for Vehicle Address Configuration protocol.

The available addresses could be divided into a number of sections named *addrSet*, every Leader car has its own *addrSet* from which it can select one address to distribute to a Normal car. Leader cars could periodically send a *Hello* packet in broadcast with an interval of 800 ms, which contains the information on available address pool it can assign and the list of Leader cars in its *SCOPE*, other Leader cars within the same *SCOPE* will update their available address pools and the lists containing Leader cars within their own *SCOPE* when receiving the *Hello* packet. A Normal car entering the network will listen to the *Hello* packets transmitted by Leader cars for a few seconds, then it selects one Leader car to request an address, the selected Leader car is usually the nearest Leader. Duplicate Address Detection (DAD) is employed by VAC. Normally, Normal cars could periodically receive the *Hello* packets sent by Leader cars to perceive that if it has exceeded the *SCOPE* of the current Leader, if so, it would perform the DAD procedure, in other words, again to listen to the *Hello* packet for a while to send another Leader a request for a new IP.

In the researches on IP configuration in VANET, how to obtain an address immediately for a vehicle is a critical issue, in VAC each vehicle entering the network has to listen to the *Hello* packets transmitted by Leaders for a specified time and then send a request to the nearest Leader for an address. With the interval for transmitting *Hello* packets by Leaders, vehicles certainly cannot obtain an address immediately, the overhead for obtaining an address must be considerable. Because of the implementation for distributed DHCP protocol, No matter if a vehicle is the Leader or not, each vehicle must be equipped with a DHCP server, increasing the burden for them, and drivers may be reluctant to play the role for assigning the IPs.

The problem with duplicate addresses still exists throughout the network because vehicles have to perform the DAD procedure to keep listening to the *Hello* packets and detect if it has exceeded the *SCOPE* of the current Leader, then decide whether to change the possessed IP or not, so the number of reconfigurations is considerable for Normal cars. Furthermore, according to the Leader-based strategy proposed in VAC, when a Normal car becomes a Leader, it must change its own IP to another one, so the number of configuration for Leaders should be at least two, in other words, the number of Leaders significantly affects the number of configurations. Because of the different relative velocity between vehicles, Leader Chain may be unstable, transition from a Leader to a Normal car or from a Normal car to a Leader depends on the distance between Leaders which maintains the Leader Chain, significantly affecting the total number of configurations in the entire network.

In light of the aforementioned drawbacks for VAC, a mechanism for centralized address configuration [7] was proposed to provide a more stable and efficient mechanism for IP assignment. The authors presented a centralized IP assignment system using a centralized DHCP server, and a number of RSUs are connected to a DHCP server, the scenario is depicted in Fig. 2.

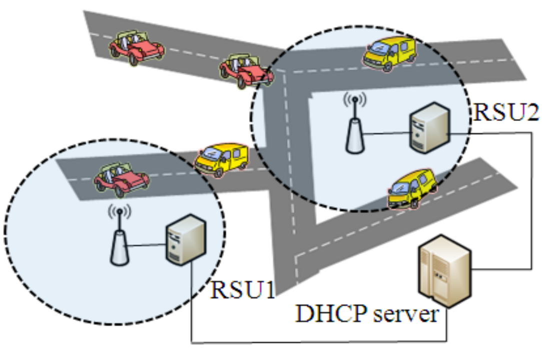

Fig. 2. The scenario for centralized address configuration.

Each RSU is equipped with an AP to provide a delimited communication range, and RSUs take responsibility for relaying the request for an address by a vehicle. Normally, when a vehicle enters the specific area, it would send a request for an address in broadcast, then more than one AP will receive the request, according to the operation for DHCP operation, these APs would send a DHCP OFFER message to the vehicle, and then the vehicle will choose one AP for configuration by broadcasting a DHCP REQUEST message, according to the operation mentioned above, the RSU with an AP plays an critical role in relaying the request for an address to a DHCP server. Furthermore, because only one DHCP server is used, the problem with duplicated IPs will not exist in this scenario.

The centralized mechanism for IP assignment claims high efficient IP configuration, each vehicle entering the network can immediately obtain an IP through the operation of DHCP protocol. Furthermore, the lease for an IP can last for a long time through the operation for extending the IP lifetime. Basically, a vehicle doesn`t need to extend the lease for an IP within the current AP, it can keep moving to another communication range of another AP to extend the lease for its own IP, in other words, the lease in this scenario is unlimited.

There are some factors which must be considered, like queuing delay and processing delay, these factors are neglected by the authors. Because a number of RSUs are connected to a DHCP server for relay, and they are installed in the different entrances respectively in the network, there could be a considerable load for central DHCP server. Suppose there are two RSUs connected to a DHCP server and two groups of vehicles entering the network from two different entrances respectively to request an IP simultaneously, the central DHCP server may not deal with the tremendous number of requests at the same time so the efficiency of IP distribution will be decreased, and it is unclear that whether the operation for the central DHCP server used in this scenario employs the mechanism of multithreading or not. Furthermore, the scheme does not consider the resolution of handling the IP which is no longer needed by a vehicle moving out of the network.

III. HIERARCHICAL IP DISTRIBUTION

This section describes the contribution of the proposed scheme on IP configuration using a hierarchical strategy. The main idea is to endow all APs with the ability to assign IPs, that is, to equip APs with a DHCP server. These APs are connected to a central server which is responsible for synchronization of different available IP pools owned by APs and load balance in distributing IPs, the central server is named Balance Server (BS) in this paper. This infrastructure operates in the urban, APs are installed in the high traffic entrances or other high traffic areas of the urban for distributing and recycling addresses. Suppose that the urban is Taipei city of which area is about 271.7997 km^2, APs are mainly deployed in the high traffic entrances such as bridges, normal roads or highways connected to Taipei city from other cities, these APs are named Border AP, and there are other APs installed inside the urban, which are named Inner AP. All APs are connected together in a hierarchical form so as to communicate with each other, and there are not any overlaps for communication range among all APs, vehicles can access to Internet by ad-hoc or direct way through APs. The snapshot for the scenario of the proposed Hierarchical IP Distribution (HID) is depicted in Fig. 3, in this scenario, AP 1 is Inner AP, and the others are Border APs.

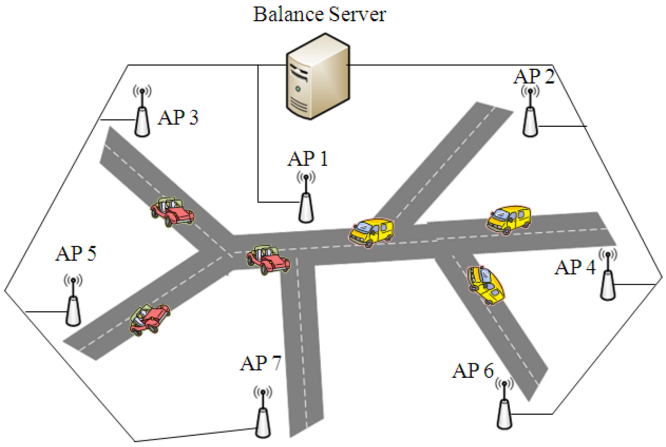

Fig. 3. The scenario for Hierarchical IP Distribution (HID).

APs are all numbered, the AP with a smaller number means a higher level AP, and APs usually send related information periodically to the higher ones by one level. For example, AP 5 is higher than AP 7 by one level, so AP 7 usually sends request messages to AP 5 periodically, and the higher level node than AP 1 is BS, so BS is the highest level node namely the root node. The efficiency for IP assignment plays a critical role in VANET than that in traditional MANET, APs in this paper can directly assign IPs without the need to ask BS, increasing the efficiency, and vehicles entering the urban can immediately obtain a unique IP from the nearest Border AP or surrender an IP to Border AP by direct or ad-hoc way. Because the beacons transmitted by Border AP and Inner AP are different, vehicles can decide when it should request or surrender an IP by receiving the specific beacons.

BS can perform the function for IP synchronization, so the problem with duplicate IPs will be resolved in the urban, so the mechanism of duplicate address detection which is an additional burden for AP is not needed. Behind the scenario, there must be a well-designed IP management system which can immediately produce unique IPs to each vehicle, recycle IPs and deal with the load balance in distributing IPs. At first, a number of available IP segments must be defined definitely, and then distributed to each AP for IP assignment. Furthermore, once the number of an AP`s available IPs are not sufficient to be assigned or an AP recycles too many IPs, there must be some related solutions to these critical problems, it is the so-called load balance in IP assignment. On the other hand, there could be a probability that an AP may break down so as not to distribute IPs anymore, so the available IPs not assigned yet in this AP must be recycled for reuse, but the situation for the malfunction of BS is not considered. About the problems mentioned above, related solutions will be presented in this paper, the operation of IP assignment for proposed HID is showed as a flowchart in Fig. 4. A protocol known as 802.11p standard with a spectrum of 5 GHz and a communication range of up to 1000 m is also employed as the standard radio communication in this proposed scenario. According to the standard operation for DHCP protocol, assigned IPs all have a lease, when an IP`s lease expires, the vehicle which possesses this IP will send a request to the current AP which assigned the IP to extend the IP`s lease, if it fails to do this, the vehicle can ask other APs to complete the procedure, so the lease can last for a long time. The way for DHCP server to assign IPs will be moderately modified for the correspondence to the proposed strategy which will be discussed in the subsequent paragraphs.

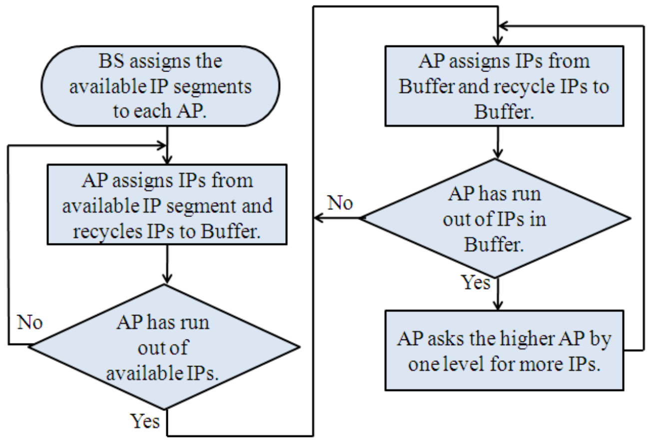

Fig. 4. The operation of IP assignment for proposed HID.

A. Deployment for APs

The communication range for an AP, the traffic and the cost for AP deployment must be all considered in deploying APs for IP distribution. An example is presented to explain the concept for AP deployment in this paper and it is depicted in Fig. 5.

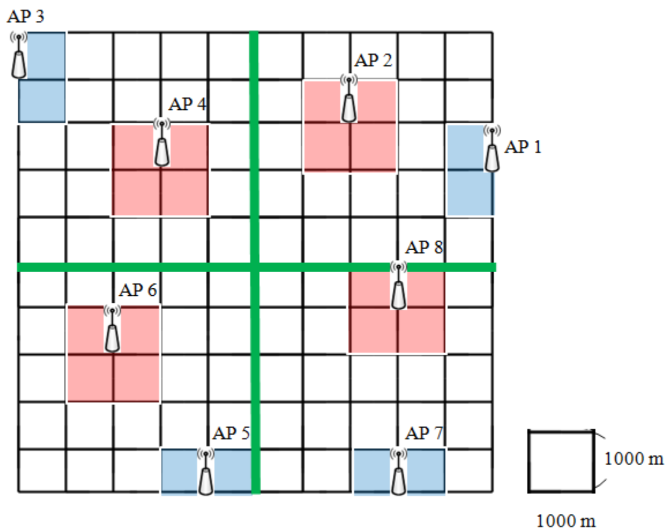

Fig. 5. The concept for AP deployment.

There are 100 squares with the area of 1000×1000 m^2 combined together to form a

10×10 grid, the grid is seen as an urban namely Taipei city and each cross is depicted as an intersection. In order to achieve the objective of equivalent deployment, the network is divided into four quadrants, and each quadrant is just equipped with two APs, which are Border AP and Inner AP respectively; there is no overlap among the communication coverage of all APs so each vehicle must communicate with each other by ad-hoc way. There are two types of rectangles inside this grid, which are colored blue and red respectively, the blue one stands for the high traffic entrance to this urban, which is known as a freeway connected to this urban, and the red one stands for an intersection with high traffic where a significant landmark stands; each high traffic entrance must be equipped with an AP namely Border AP to assign IPs to the entering vehicles. Considering the cost of AP deployment, the number of the deployed APs must be limited, so the Inner APs must be deployed only at the high traffic intersections inside the urban for IP distribution or access to Internet. In this example, AP 2, AP 4, AP 6 and AP 8 are just deployed in the high traffic areas such as hot spots; AP 1, AP 3, AP 5 and AP 7 are just installed respectively in the high traffic entrances to the urban which are known as freeways connected to the urban. Each AP is endowed with different probability to assign IPs referring to the statistics of Traffic Engineering Office in Taipei City [8].

B. Distribution of initial available IP segments

The scenario in this paper can be referred to as a wireless local area network, the private IPs are usually used in this type of network. Three segments used for private IPs are showed in Table 1, and they are all utilized in this paper for performance evaluation.

Table 1. Private addresses used in the wired/wireless local area network.

Category for IP	Private IP segment
Class A	10.0.0.0 – 10.255.255.255
Class B	172.16.0.0 – 172.31.255.255
Class C	192.168.0.0 – 192.168.255.255

The first segment 10.0.0.0 – 10.255.255.255 will be used as an example for available IP segment division. The standard IP format for IPv4 contains four sections and is divided into two types of bits, which are network bits and host bits respectively, in this example, the first section is used for network bits, and the other three sections are used for host bits, the format of IPv4 is depicted in Fig. 6.

The number in section 1 for 10 . X . X . X is used for network bits, so the section 2 will be divided for use. The available size for section 2 is 256, and it will be divided into a number of subsections to be distributed evenly to each AP for IP assignment respectively, and one of these subsections is reserved by BS.

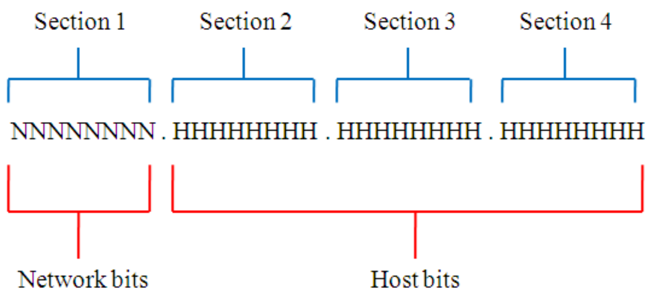

Fig. 6. The format of IPv4.

Initially, BS provides each AP with an available IP segment from which APs can select an address to assign to a vehicle, and each AP has its own number. Let available IP segment be *AIS*, the size of section 2 of which number is 256 in this example be *SOS*, the number of APs be *NOA*, and AP number be *AN*. BS is endowed with the smallest AP number for calculation, the method used by BS for distributing the available IP segments to APs is showed as follows：

$$AIS = \frac{SOS}{NOA + 1} \tag{1}$$

$$HEAD = AN \times AIS \tag{2}$$

$$TAIL = (AN + 1) \times AIS - 1 \tag{3}$$

In section 2 of available IP segment owned by AP, the biggest number is named *HEAD*, and the smallest number is named *TAIL*, the two numbers can be obtained with equations (2) and (3) respectively. For example, there are 7 APs installed around the border and in the interior respectively of an urban plus a preservation IP segment owned by BS, each AP`s *AN* is set from 1 to 7 respectively, and BS`s *AN* is set to 0, the size of section 2 must be evenly divided into 8 available IP segments, the result calculated with equations from (1) to (3) is showed in Table 2.

The biggest number and the smallest number for section 3 are set to 0 and 255 respectively, and the same as the section 4. For example, in table 2, the biggest number and the smallest number in section 2 of available IP segment for AP 1 are 32 and 63 respectively. The size of section 2 for each AP is 32, so the number of available IPs for each AP to distribute is 2,097,152, we assume that the addresses 10.0.0.0 and 10.255.255.255 can be assigned. Furthermore, the first addresses in the available IP segments will be as the addresses of AP and BS, so these addresses cannot be assigned to vehicles, for example, in table 2, the address 10.32.0.0 is the address of AP 1, so AP 1 begins to assign IPs from address 10.32.0.1. After completing the assignment procedure of available IP segment for each AP, APs can begin to assign IPs to vehicles with a specific algorithm which will be presented in the next session.

Table 2. Available IP segments assigned to APs.

Owner	Available IP segment
Preservation	10.0.0.0 – 10.31.255.255
AP 1	10.32.0.0 – 10.63.255.255
AP 2	10.64.0.0 – 10.95.255.255
AP 3	10.96.0.0 – 10.127.255.255
AP 4	10.128.0.0 – 10.159.255.255
AP 5	10.160.0.0 – 10.191.255.255
AP 6	10.192.0.0 – 10.223.255.255
AP 7	10.224.0.0 – 10.255.255.255

C. IP assignment and recycling

With an onboard DHCP server, APs have the ability to distribute and recycle IPs, and some policies of IP distribution are employed by DHCP server. Static allocation utilizes a table with MAC address/IP address pairs to assign specific IPs to vehicles recorded in this table, and automatic allocation also uses a table recording the specific nodes which can be assigned fixed IPs. The two policies mentioned above are not suitable for VANET, because vehicles entering and moving out of the network are constantly changeable. There is another method called dynamic allocation, it must find a free address in the available IP pool to assign to a requesting node when it asks for an IP. It implies that a table must be maintained to record an available IP pool, and the action of search must be performed by DHCP server in order to assign an available IP, so it may take a lot of time in searching for free IPs before assignment.

In this paragraph, a modified method for assigning IPs using DHCP without the need to detect duplicate IPs and to maintain a table is presented; an algorithm for IP assignment performed by APs is showed in Fig. 7.

```
IP-ASSIGNMENT()
 if y < 255
   then assign the address 10.HEAD.x.y
        y ← y + 1
 else if y == 255 and x < 255
   then assign the address 10.HEAD.x.y
        y ← 0
        x ← x + 1
 else if y == 255 and x == 255 and HEAD < TAIL
   then assign the address 10.HEAD.x.y
        y ← 0
        x ← 0
        HEAD ← HEAD + 1
 else take one IP from the Buffer for assignment
```

Fig. 7. Algorithm for IP assignment used by APs.

At first, each available IP segment of which size is 2,097,152 for each AP is calculated by BS and then assigned to APs for IP distribution. In fact, each BA only knows the biggest number and the smallest number in section 2 namely *HEAD* and *TAIL*, when APs receive the DHCP DISCOVER from vehicles entering the urban, they can refer to the *HEAD* and *TAIL* and use the proposed IP assignment algorithm before sending DHCP OFFER message to generate available IPs in order and assign them without maintaining a table and searching for available IPs. With the IP assignment algorithm used by each AP, efficient IP assignment can be achieved completely. Let the IP format 10 . X . X . X be 10 . $HEAD$. x . y, and the initial value for both x and y is 0.

In additional, each AP has a Buffer which is designed as a circular queue to store the recycled IPs for reuse on the exhaustion of the available IPs initially assigned by BS. The behaviors for AP 1 to recycle and distribute IPs using Buffer are depicted in Fig. 8 and Fig. 9 respectively.

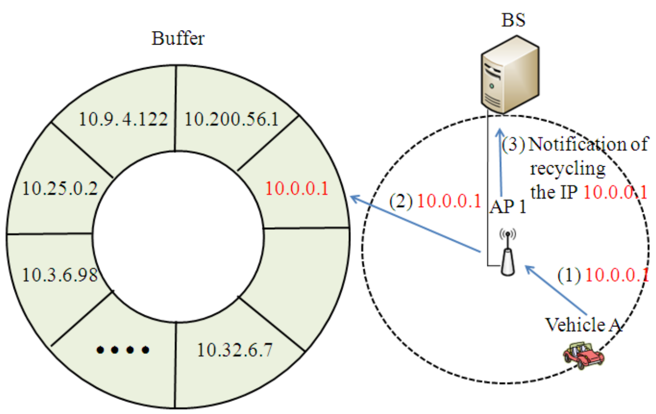

Fig. 8. The operation of buffer in recycling IPs.

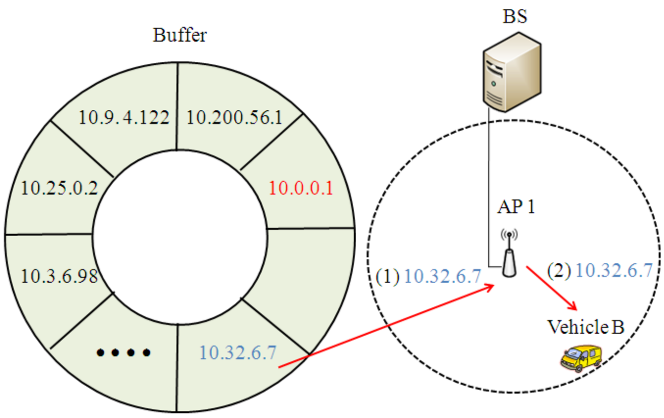

Fig. 9. The operation of buffer in assigning IPs.

When a vehicle surrenders an address to an AP, the AP will put this address into the top of its Buffer and send a notification message to BS for available IP synchronization, it means that the AP tells BS not to distribute this IP to other APs when this IP`s active time has not been updated for a long time, exceeding the threshold which is recorded in BS. If the number of IPs in the Buffer exceeds the specified maximum namely the queue is full, the AP will send the recycled IP to the higher AP by one level. APs begin to use the IPs in the Buffer only when the available addresses initially assigned by BS are exhausted. In the worst case, once the IPs in the Buffer is exhausted, AP will ask the higher AP by one level for more available IPs, which can avoid the problem with insufficient IPs.

If the size of Buffer is too small, AP cannot deal with a large number of recycled IPs released by vehicles leaving the urban, so it must frequently ask the higher AP by one level to recycle the surplus IPs, which will increase the overhead. Reversely, a very large Buffer may cause a waste of the space. In order to moderately specify the size of each AP`s Buffer, we refer to the statistics of Traffic Engineering Office in Taipei City. Basically, the size of Buffer for each AP is different referring to the real traffic statistics. An example is proposed to present the scenario where an AP is installed at the intersection of JingMao 2nd Rd and SanChong Rd in Taipei as a Border AP to recycle IPs released by leaving vehicles, the scenario is depicted in Fig. 10. Letters A, B, C and D represent four different directions for vehicles to enter the urban, and it is assumed that vehicles which means bus and car moving in the directions A, B and D respectively will eventually move in the direction A to leave the urban and the AP installed on the JingMao 2nd Rd can recycle IPs surrendered by leaving vehicles, so the size of this AP`s Buffer will be set to the sum of entering vehicles in the directions A, B and D. The number of entering vehicles including buses and cars from 07:00 to 19:00 in a day in the direction A on JingMao 2nd Rd is showed in Fig. 11.

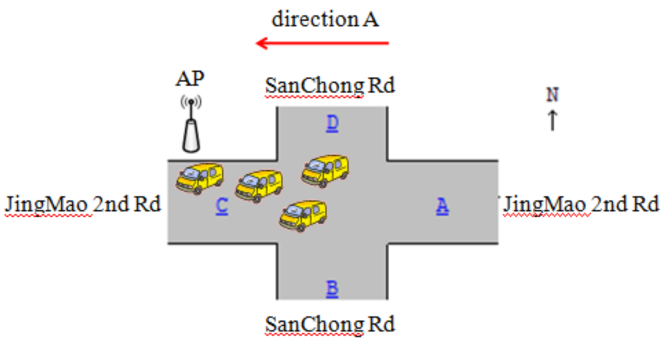

Fig. 10. The situation for IP distribution using Buffer.

The mechanism of IP recycling and reuse is used for the situation in which the source of IPs is insufficient, so the private IPs from Class A to Class C must be tested in order to decide which Class is the most suitable one to be utilized in this scenario, a simulation is performed to present the situation of IP consumptions for Class A, Class B and Class C respectively, and the rate of unassigned IPs to the number of assigned IPs will be observed for reference. Available IPs for Class A are almost unlimited for an AP to distribute, that of Class B are exhausted when the number of assigned IPs reaches 1,200,000, and that of Class C are exhausted when the number of assigned IPs reaches 200,000, through the simulation result, Class B and Class C both need a mechanism for IP recycling and reuse. The simulation result for Class B and Class C are showed in Fig. 12.

(The traffics of the nearest roads and the gateways)

			Left				Forward		
Direction	Time		Bus	Car	Motorcycle (1)	(2)	Bus	Car	Motorcycle
A	07:00	07:15	0	0	0	0	6	158	121
	07:15	07:30	0	0	0	0	14	351	274
	07:30	07:45	0	0	0	0	29	574	420
	07:45	08:00	0	0	0	0	46	810	594
	08:00	08:15	0	0	0	0	63	982	743
	08:15	08:30	0	0	0	0	82	1166	868
	08:30	08:45	0	0	0	0	93	1333	980
	08:45	09:00	0	0	0	0	111	1508	1083
	17:00	17:15	0	0	0	0	8	192	106
	17:15	17:30	0	0	0	0	17	377	203
	17:30	17:45	0	0	0	0	24	547	292
	17:45	18:00	0	0	0	0	31	689	355
	18:00	18:15	0	0	0	0	40	887	472
	18:15	18:30	0	0	0	0	44	1089	581
	18:30	18:45	0	0	0	0	48	1245	670
	18:45	19:00	0	0	0	0	50	1369	743

Fig. 11. The traffic statistics from 07:00 to 19:00 in a day in the direction A on JingMao 2nd Rd.

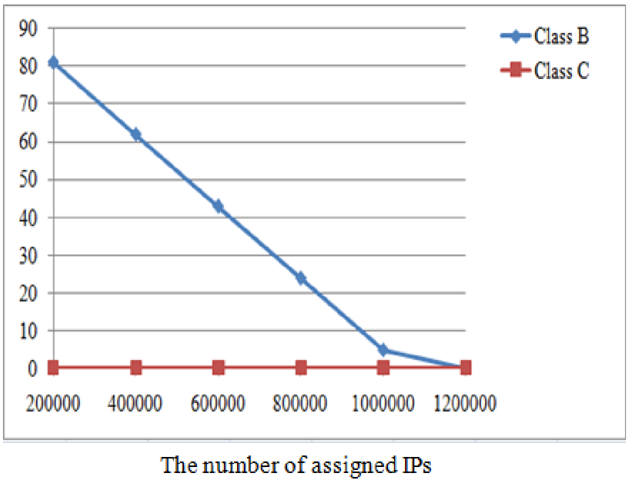

Fig. 12. The rate of unassigned IPs to the number of assigned IPs.

There is another simulation result for Class B and Class C showed in Fig 13, 7 APs are installed in the high traffic intersections and entrances to the urban respectively for IP assignment, all APs assign IPs until the total number of assigned IPs reaches the statistics of registered vehicles in Taipei city [9]. Simulation result shows that the number of unassigned IPs for Class A is tremendous close to 2,000,000 for each AP, and that of Class B and Class C are relatively small, especially for Class C, the rate of the rest IPs is close to 0 % for each AP. Through the simulation results, Class A does not need a Buffer to recycle IPs for reuse due to the nearly unlimited number of available IPs, and it may cause a waste of the source of IPs because an urban does not need so many IPs, the number of available IPs used in this scenario must be decided moderately, so Class B and Class C are more suitable than Class A for the proposed strategy of IP recycling and reuse.

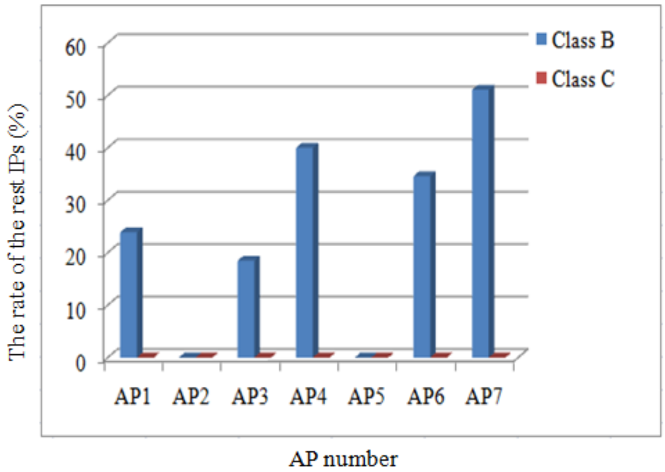

Fig. 13. The rate of the rest IPs for each AP.

Each deployed AP has different probability in assigning IPs because of the different traffic, and the probability must be set properly, in order to prove the correctness of setting the probability, a simulation is performed to observe the load of each AP in assigning IPs, Fig. 14 shows the rate of assigned IPs for each AP; there are two kinds of bars which stand for Class B and Class C respectively. Same as the simulation result showed in Fig 13, all APs assign IPs until the total number of assigned IPs reaches the statistics of registered vehicles in Taipei city. It is hoped that the rate of assigned IPs by each AP can reach or exceed 50 % in order to prove that each AP is correctly deployed in the high traffic areas. The simulation result shows that AP 2 has the lowest load but its IP assignment rate is still close to 50 %. The effectiveness of IP deployment in the high traffic areas or entrances can be proved through this simulation.

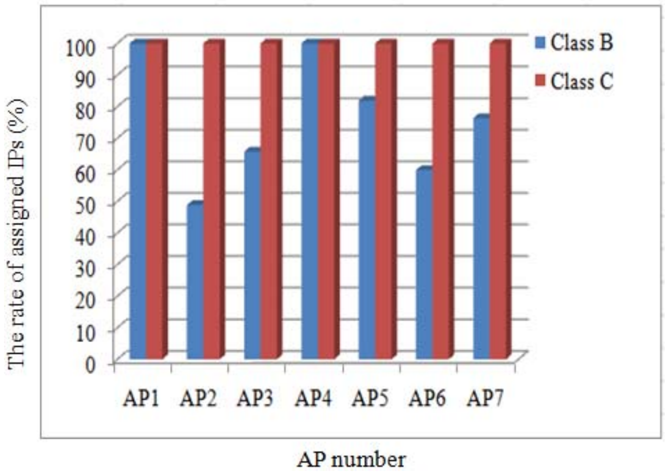

Fig. 14. The rate of assigned IPs by each AP.

D. Synchronization for available IPs

In order to achieve the objective for efficient IP assignment without the concern of duplicate IPs, AP plays an important role in solving the above problems. BS maintains a form which is named IP Active Time Form (IATF). IATF records all IPs used in this scenario and other related information, including the status of IP, IP active time and the current owner of an IP. The format of IATF is showed in Fig. 15.

Address	Status	Active time	Owner
10.0.0.0	*available*	—	BS
10.0.0.1	*assigned*	10：05：31	—
10.0.0.2	*assigned*	10：01：34	—
10.0.0.3	*recycled*	—	AP 4
10.0.0.4	*assigned*	10：08：00	—
⋮	⋮	⋮	⋮
10.255.255.253	*assigned*	09：59：28	—
10.255.255.254	*recycled*	—	AP 2
10.255.255.255	*available*	—	AP 7

Fig. 15. IP Active Time Form maintained by BS.

There are three statuses for IPs, which are *available*, *assigned* and *recycled* respectively. Status *available* means that the IP is now available for assignment, status *assigned* means that the IP is now possessed by some vehicle and status *recycled* means that the IP has been recycled by an AP and put in this AP`s Buffer.

Once an IP is assigned, the current time will be recorded in the relative Active time column and the value in relative Owner column will be marked "—", because this IP no longer belongs to any APs or BS. Vehicle which has obtained an address will periodically transmit a packet with the information about its own IP by ad-hoc way to the nearest vehicle through the aid of GPS and the periodically broadcasted *Hello* packets by vehicles; finally, this packet will be relayed to an AP, when an AP receives this packet, it will forward the packet to BS for the update of the time recorded in the relative Active time column, if the time in the Active time column for an assigned IP has not been updated for a long time and exceeds the specified threshold, the IP will be recycled by BS namely the value in the relative Status column will be marked *available* and the relative Owner column will be set to "BS" namely the current owner of this IP is BS, and then the time in relative Active time column will be marked "—" because only the assigned IPs have the active time. Suppose AP 4 recycles an IP, it will immediately send a notification packet to inform BS that this IP has been recycled, and then BS will set the value in relative Owner column to "AP 4", only an IP which is not possessed by a vehicle has a value in relative Owner column. Once a vehicle parks, it`s IP will become invalid, APs certainly cannot recycle this IP, and then this IP`s active time will have not be updated for a long time, exceeding the threshold because this vehicle no longer transmits packets, in this situation, BS will perceive that the time in Active time column for this IP is overdue, so the values in relative Status column and Owner column will be marked *available* and "BS" respectively for reuse, once the vehicle starts again, it can either ask the nearest AP for a new IP or directly move to the exit. The operation of IP recycling is depicted as a flow chart in Fig. 16.

If an AP`s Buffer is full, it will send the newly recycled IP to the higher AP by one level, and then this higher level AP will tell BS to mark the value *recycled* in this IP`s Status column, and the value in relative Owner column will be marked the AP`s number which recycled this IP. Reversely, If the number of available IPs in an AP`s Buffer is exhausted, the AP will ask the higher AP by one level for more available IPs, and then the higher level AP will take some IPs from its Buffer to the requesting lower level AP, and then this higher level AP will tell BS that the value in Owner column for distributed IPs must be all set to the requesting lower level AP`s number, it means that these IPs can be used by this requesting AP.

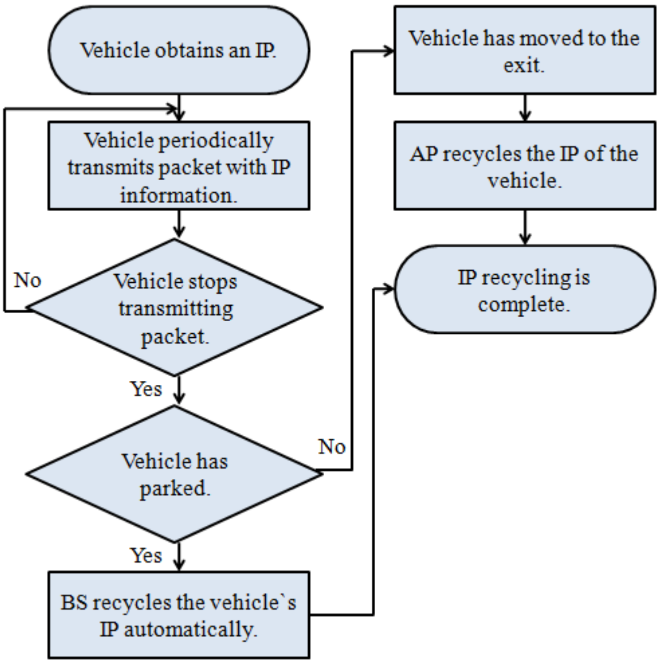

Fig. 16. The operation of IP recycling for proposed HID.

Through the methods mentioned above, the load balance for IP assignment can be completely solved, APs don`t worry about the insufficiency for available IPs. APs don`t need to maintain a table from which they must search for available IPs for assignment as long as the proposed IP assignment algorithm is utilized to assign IP directly, which can increase the efficiency for IP assignment, and the table maintained by BS can also effectively avoid duplicate IPs without an additional mechanism for duplicate address detection.

E. Detection for malfunction of APs

AP could send a packet to the higher AP by one level periodically, and then the higher level AP can update the related information including the available IPs for the lower AP by one level, the objective is to detect the current status for APs because there is a probability that an AP may break down and IPs owned by this AP will become invalid. This periodically sent packet is the same as the packet which when the IPs in the Buffer are insufficient AP will send, in other words, there is a column recording the status of the Buffer in the periodically sent packet. When the number of available IPs in the Buffer is insufficient, AP will add a specific value in this column to tell the higher AP by one level that more available IPs are needed.

If the higher level AP has not received a packet sent by the lower level AP for a long time, exceeding the specified threshold, it will assume that this lower level AP has malfunctioned, and then the higher level AP will recycle the available IPs which haven`t been assigned by the lower level AP. The mechanism mentioned above means that the higher level AP is the supervisor of the lower level AP so as to monitor the status of the lower level AP.

IV. CONCLUSION

In this paper, a mechanism named Hierarchical IP Distribution (HID) is presented, DHCP is installed in the AP and an efficient algorithm for IP assignment is proposed, so APs can directly assign IPs without any overhead, and a method for IP recycling is proposed to achieve the objective for IP reuse. Furthermore, BS taking charge of managing the IATF can effectively avoid duplicate IPs and the malfunctioning AP can be detected through the hierarchical mechanism. The available IPs owned by APs can be always sufficient to be assigned through the functionality of hierarchical architecture using the dynamic allocation to complete the load balance for IP distribution. A complete simulation platform will be built in the future to simulate the performance of HID compared with other researches on IP assignments [6][7], we will use JAVA on the Eclipse platform of which version is 3.4.2 to simulate the proposed strategies and get related statistics to prove the effectiveness of the proposed mechanism for IP assignment and recycling.

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