

國立交通大學

網路工程研究所

碩士論文

點對點即時路況導航系統

P2P Real-Time Road Traffic Navigation System

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中華民國九十六年九月

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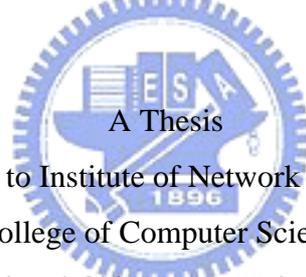
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隨著道路狀況日益複雜以及車輛日漸普及，為了增加駕駛人行車的便利性，於是就出現了集中式的路況導航系統。此系統雖然能提供即時路況資訊，幫助駕駛人做最佳路徑的選擇，然而卻需要相當昂貴的建置及維護費用。於是有文獻提出了非集中式的路況導航系統，在此系統中，車輛直接透過車間通訊互相交換彼此觀察到的路況，省卻了路況中心的建置費用。然而此系統在交通密度低的情況下路況交換較為困難，車輛要獲得遠離道路資訊會受到較長時間的延遲。因此我們提出了結合車間通訊及無線網路(WiFi, WiMAX, or 3G)的非集中式點對點路況導航系統。本系統採取了階層式的架構，我們利用點對點網路將車間通訊網路可能離散的部份接起來，讓路況資訊的交換不再受到車間通訊傳輸半徑及車流密度的限制。本系統的目標在於讓駕駛人能夠迅速的獲得正確且即

時的道路資訊。在本篇論文的最後，我們會透過實驗數據說明本系統的確能幫助駕駛人作有效率的路況查詢。



P2P Real-Time Road Traffic Navigation System

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Abstract

The logo of National Chiao Tung University is a circular emblem. It features a gear-like outer border. Inside the circle, there is a stylized building with the letters 'ES' on it. Below the building, the year '1896' is inscribed. The entire logo is rendered in a light blue color.

Existing centralized real-time traffic information systems provide excellent road guidance. However, the cost for constructing and maintaining the traffic center is expensive. Recently, several decentralized ad-hoc based traffic information systems are proposed. Vehicles in this kind of system detect traffic conditions with GPS devices and exchange observed traffic conditions with each other through inter-vehicle communication. However, ad-hoc based traffic information system has problem to efficiently disseminated traffic condition in large scale places when the penetration rate is low. For this reason, we propose a combined IVC and infrastructure-based decentralized P2P real-time road traffic information system. The system aims at providing accurate traffic reports and supporting efficient traffic report lookup. The system is organized as a two-layer hierarchical architecture. All vehicles participate in the

ad-hoc network and broadcast observed traffic condition through IVC. Parts of vehicles are elected as super nodes and they form a P2P overlay atop ad-hoc network to support traffic report lookup through infrastructure-based wireless network interfaces. Simulation results demonstrate that the proposed system dose provide efficient traffic report lookup.



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本論文得以順利完成，首先要感謝指導教授 曹孝櫟 博士的教誨，老師在專業能力上面給予了我們紮實的訓練，從如何發現問題，如何針對問題找出解決方法，到如何邏輯性的闡述我們的想法，以及最後將我們的想法轉化成流暢的文章，都是老師所重視的，進入實驗室的這兩年著實獲益良多。同時也要感謝口試委員 鄭瑞光 教授，彭文志教授和 曾建超 教授，給予了許多寶貴的意見，使本論文更趨完整。

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Chapter 1. Introduction

With the development of road network and the increase of vehicles, traffic situation becomes more and more complex. In recent years, people pay a lot of attentions on ways to increase their driving convenience. Today, it is fairly common that people equip their vehicles with Global Positioning System (GPS) devices for driving path guidance. Unfortunately, GPS navigation system provides only one-way location information. Real-time road traffic information is not available for drivers to make optimized route path selection.

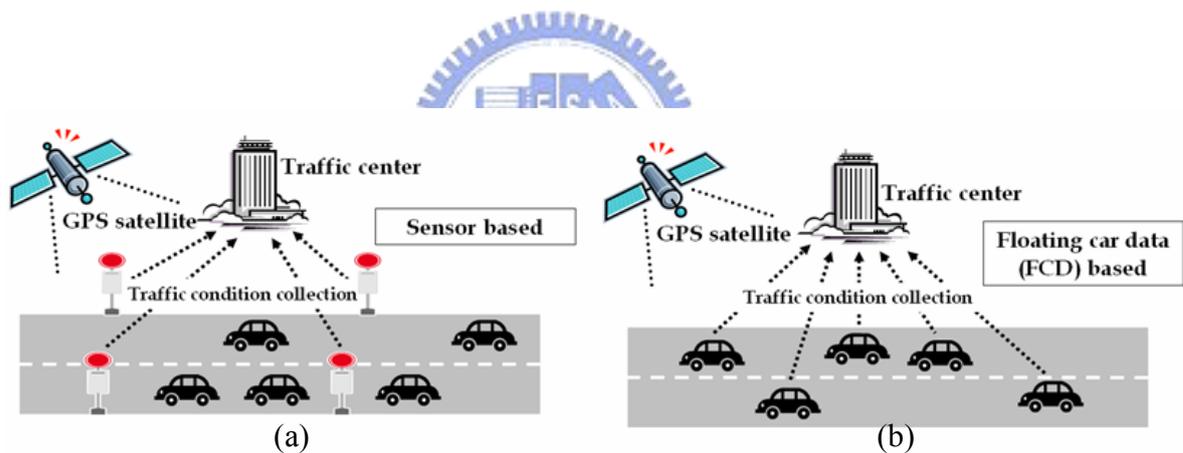


Figure 1. Centralized traffic information system: (a) sensor based (b) FCD based

One possible solution is to construct a centralized real-time traffic information center such as Intrix[3], EFCD[4], TaxiFCD [5] TrafficMaster [6]. The center is responsible for collecting traffic conditions from different kinds of sources such as roadside sensors, or floating cars. In the sensor-based method, as illustrated in Figure 1 (a), a large number of sensors have to be

deployed along the roadway to monitor traffic conditions. As to the floating car data (FCD) method, as showed in Figure 1 (b), vehicles in this system are equipped with GPS receivers and act as mobile sensors to detect traffic condition of the road they currently traverse on. Traffic conditions measured from sensors or floating cars are periodically transmitted back to the center. Traffic center performs traffic condition filtering and aggregation to generate traffic report of each road. Drivers can retrieve traffic reports that they are interested in directly from traffic center through webpage interface or short message service (SMS). With real-time traffic reposts, drivers can easily make good route selections. However, construction and maintenance costs of the traffic information center are fairly expensive.

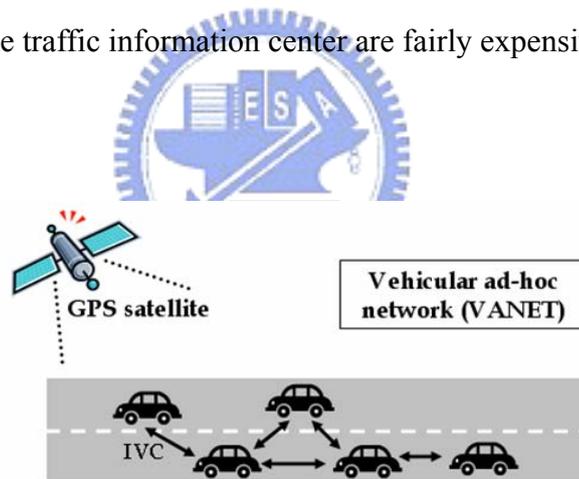


Figure 2. Decentralized ad-hoc based traffic information systems

For this reason, decentralized ad-hoc based traffic information systems, as illustrated in Figure 2, are proposed. Vehicles in this system are equipped with GPS devices and digital radios. The way how traffic conditions are detected are exactly the same as the FCD-based method in the centralized traffic information system. However, the way drivers retrieve traffic

reports is totally different because of the absence of centralized traffic center. With aid of digital radios, vehicles can communicate with each other through inter-vehicle communication (IVC) [2]. Vehicles periodically broadcast observed traffic conditions to other vehicles within their one-hop transmission range. Once receiving broadcast packets from others, vehicles update their traffic condition database and include newly observed information in next broadcast packets. In this way, traffic report can be gradually disseminated.

Decentralized ad-hoc based system does eliminate the construction and maintenance cost of traffic information center. However, under the situation where traffic density or penetration¹ rate is low, vehicles have problem to encounter communication buddies to exchange traffic conditions with. In this case, traffic conditions can not be efficiently disseminated to large-scale places; therefore the latency for retrieving distant traffic conditions is long.

In this paper, we aim at providing solutions to construct a traffic information system which eliminate the construction and maintenance cost of traffic center and support efficient traffic reports lookup. We propose a two-layer hierarchical decentralized P2P real-time road traffic information system. The system architecture is illustrated in Figure 3. It is assumed that each vehicle has two wireless network interfaces: IVC and infrastructure-based wireless interface

¹ The percentage of vehicles participates in the traffic information system.

(such as WiFi, WiMAX, or 3G). All vehicles participate in the ad-hoc network and broadcast observed traffic condition through IVC. Parts of vehicles are elected as super nodes and they are responsible for traffic condition collection and traffic report generation. Moreover, these super nodes turn on infrastructure-based wireless network interfaces and form a P2P overlay to support traffic report lookup. The P2P overlay is organized in an unstructured fashion, and we add the unstructured overlay with small world property by considering geographical characteristics of vehicles. The feature of the overlay is that geographically close super nodes are highly clustered, and short cuts can be found between distant super nodes. Through small world P2P overlay, vehicles can perform traffic report lookup to search traffic report.

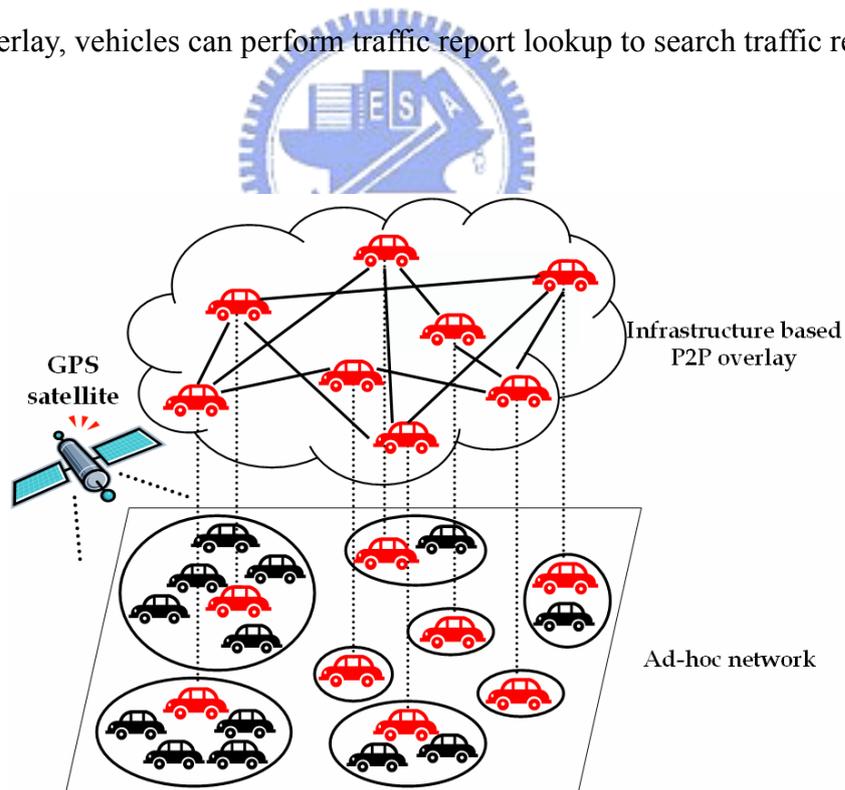


Figure 3. Hybrid decentralized road traffic information system architecture

We define two metrics to evaluate if our design supports efficient traffic report lookup: (1)

lookup latency, (2) lookup message overhead. Simulation results show that the two-layer hierarchical traffic information system does provide efficient traffic report lookup.

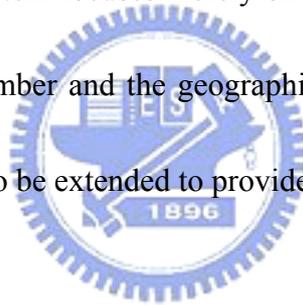
The rest of the paper is organized as follows: We discuss related works and describe the shortcomings of each design in Chapter II. In Chapter III, a brief overview of P2P overlay is introduced. Details about system design are described in Chapter IV. In Chapter V, performance of our design is evaluated according to simulation results. Finally we present our conclusion and future works in Chapter V.



Chapter 2. Related Work

For these reason, Decentralized ad-hoc based traffic information systems such as [7], TrafficView[8], SOTIS[9][10], are proposed.

[7] is a traffic system which proposes zone-based organization methodologies to dynamically group vehicles together for group members to collect information that is relevant to their driving safety. Because this system focuses merely on safety information, the population of a group is limited to a small number and the geographical distribution of members is usually local. Therefore, it can hardly to be extended to provide large scale traffic information.

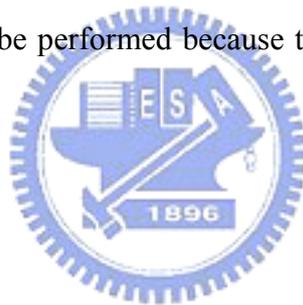


TrafficView[8] takes the diffusion mechanism for vehicles to gather and disseminate traffic information and road conditions in front of them. Also, data aggregation techniques are proposed to include more information in a packet while the accuracy of distant traffic information may be sacrificed.

SOTIS[9][10] presents segment-oriented data abstraction and dissemination (SODAD) for traffic information distribution. Moreover, vehicles can dynamically adapt broadcast interval through observing two kinds of events: provocation and mollification to avoid overload

conditions and to favor the propagation of significant information changes.

Generally speaking, ad-hoc based traffic information system can be rapidly constructed at low cost. However, under the situation where the penetration is low, the whole network is likely to be separated into several disjoint parts. The network disjoint phenomenon causes two serious problems. First, traffic information has problems to be disseminated to distant places. Even though it can reach distant place, traffic information is likely to be outdated. Outdated information is useless for vehicles to determine current situation. Second, active traffic information search can hardly be performed because the disjoint network may result in high search failure rate.



Chapter 3. Background

In this chapter, we first provide an overview about decentralized P2P overlay networks. Then, we introduce two categories of decentralized P2P overlay networks. In the end of this chapter, we make a conclusion on what kind of overlay is more suitable for a traffic information system.

In a decentralized P2P overlay, there is no central server to handle resource query, but rather peers cooperatively process resource query over the P2P overlay to locate resources they are interested in. To construct a P2P overlay, each peer maintains a small set of peers as its neighbors and establishes logically links with them. The neighbor relationship determines the topology of the P2P overlay. Decentralized P2P overlay network can be classified into two categories: structured and unstructured, according to how peers make neighbor selection.

In structured P2P overlay networks such as Chord[11], Pastry[12], Tapestry[13], and CAN[14], rules for neighbor selection and resource index management are fairly strict. Peers construct neighbor table based on distributed hash table (DHT). Also, peers publish indexes of resources that they own to certain peer according to DHT. To lookup a resource, peers consult their neighbor table and forward the query to the neighbor who is logically closest to the peer

who maintains the index of the target resource. In Figure 4, we use Chord as an example to illustrate how key management, finger table² construction, and resource lookup are performed in a structured P2P overlay network.

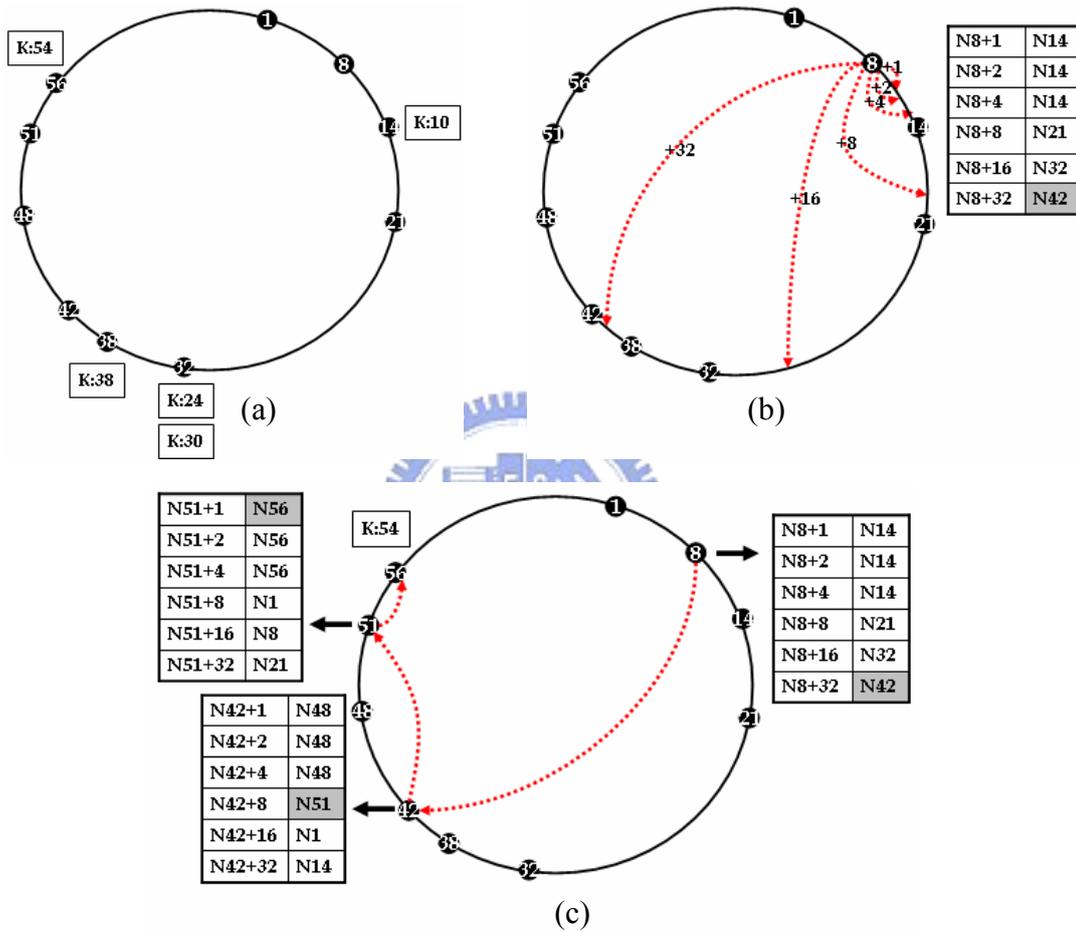


Figure 4. Chord: (a) peer identifier and key management (b) finger table of peer 8 (c) peer 8 lookup resource 54

With neighbor strictly selected and index rigidly placed, structured P2P overlay networks provide efficient resource lookup. However, in the face of an environment with high churn rate, peers have to make great effort on keeping neighbor relationship and index placement

² In Chord, index of a resource is called as key, and neighbor table is called as finger table.

correct to guarantee successful resource lookups. Peers may be overwhelmed by handling such a large number of maintenance messages to reconstruct the overlay.

In an unstructured P2P overlay network such as Gnutella [15], neighbor links are randomly established. Peers just take care of their own resources and index of resource is not published to other peers. Peers have no knowledge about the mapping between resources and their owners; therefore they perform scoped flooding to locate resources. Each peer forwards lookup message to its neighbors and this process repeats until a predefined hop bound is reached. Each intermediate peer examines its resource database and replies a hit message if it has the target resource. Lookup message forwarding in Gnutella is illustrated in Figure 5.

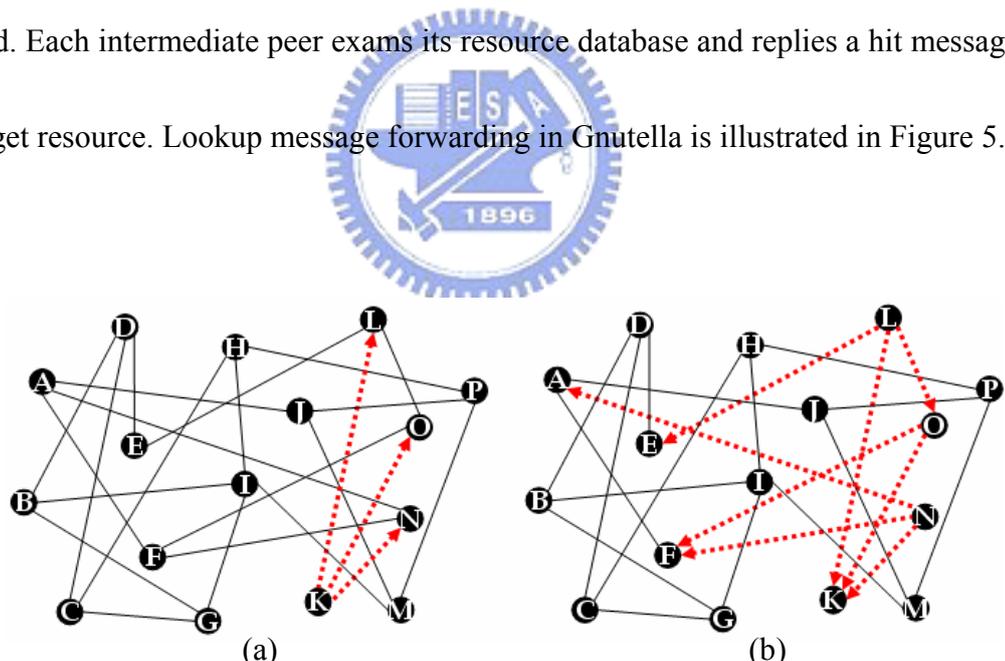


Figure 5. Gnutella: peer K initiate a resource lookup
 (a) lookup message proceeds one hop (b) lookup messages proceed two hop

Unstructured P2P overlay networks have some disadvantages. Scoped flooding may result in a large amount of lookup messages. A lookup may fail because the lookup scoped is restricted

by hop bound. However, unstructured P2P overlay is less invulnerable to churn because failed neighbor links can easily be replaced and index publishing is eliminated.

Based on above discussion and the research done by [16], we find that it is more suitable to organize peers into an unstructured P2P overlay network in an environment with high churn rate. Therefore, in our system design, the P2P overlay network atop ad-hoc network will be organized in an unstructured fashion. Details about how the overlay is constructed and how ad-hoc network and infrastructure-based overlay work together are described in next chapter.



Chapter 4. System Design

The system we proposed is a two-layer hierarchical decentralized P2P real-time road traffic information system. In the lower layer, vehicles broadcast observed traffic condition through IVC. However, under the situation where traffic density or penetration rate is low, vehicles have problem to encounter communication buddies to exchange traffic conditions with. In this case, traffic conditions can not be efficiently disseminated to large-scale places and the latency for retrieving distant traffic conditions is long. Therefore, we build a P2P overlay atop to bridge possible disjoint parts in the lower layer. Each vehicle makes super node selection to determine if it shall become a super node. Afterwards, super nodes turn on their infrastructure-based wireless network interfaces and form a P2P overlay. In the way, efficient traffic report lookup can be performed.

In this chapter, we first introduce the system assumption that we made. Then, we describe how we make super node selection. Next, we present the construction of P2P overlay network. In the next, we talk about traffic condition collection and traffic report generation. Finally, we explain how peers perform traffic report lookup.

4.1. Assumption

- 1) Vehicles should be equipped with GPS receivers and digital maps. Combined with GPS receivers and maps, vehicles are able to link their geographic coordinates to their locations on maps. Roads on the digital map are divided into segments. Each segment is assigned with a Segment ID (SID) and has a well defined start and end points pair, direction, number of lanes, and a speed limit profile. The way how segments are defined is illustrated in Figure 6 (a) (b).

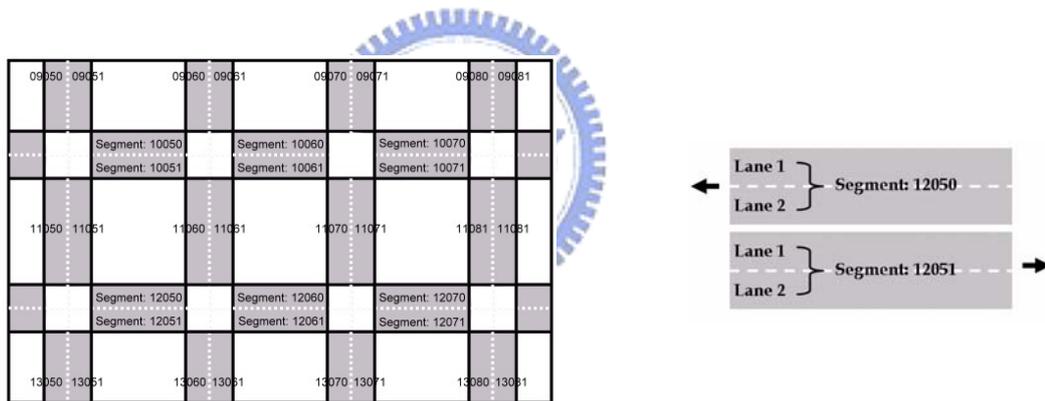


Figure 6. Road segment and Segment ID

- 2) Vehicles must have two network interfaces. Each vehicle should be equipped with a digital radio for inter-vehicle communication and has infrastructure-based wireless network accessibility for P2P overlay network communication. Vehicles should always turn on inter-vehicle communication interface to broadcast traffic condition they observe. While they turn on the infrastructure-based network interface only when it is elected as

super node.

4.2. Super node selection

Vehicles communicate through IVC can be viewed as a mobile ad-hoc network. A wireless ad-hoc network can be modeled as a unit disk graph (UDG) $G = (V, E)$ in which $V, |V| = n$, is the set of peers and there is an edge (u, v) in $E, |E| = m$, if and only if u and v are within each other's one-hop transmission range. Figure 7 illustrates a mobile ad-hoc network of eighteen nodes modeled by UDG.

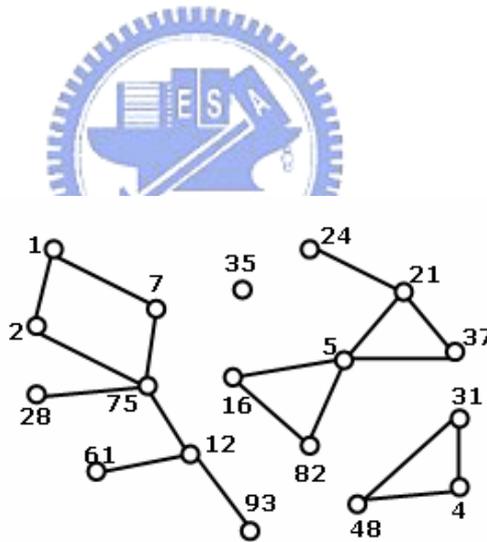


Figure 7. UDG of a network of 18 nodes

We apply max-min d-cluster formation [17] for super node³ selection. Max-min d-cluster formation can be divided into four phases⁴: initial phase, floodmax phase, floodmin phase, and

³ Super nodes here are originally called as clusterhead in [17].

⁴ In our system, we just need to select super node; therefore, operations for gateway nodes selection are omitted.

super node selection phase. After the first three phases, each node will get a log as illustrated in Table 1. Based on analyzing this log, each peer determines if it should become a super node. After the complete the entire max-min d-cluster formation process, each node is either a super node or at most d hops away from a super node where parameter d can be dynamically adjusted according to traffic density. Figure 8 illustrate a mobile ad-hoc network of eighteen nodes after max-min d-cluster formation.

	1	2	28	61	7	75	12	93	35	16	82	5	48	24	21	37	31	4
Flood Max 1	7	75	75	61	75	75	93	93	35	82	82	82	48	24	37	37	48	48
Flood Max 2	75	75	75	93	75	93	93	93	35	82	82	82	48	37	82	82	48	48
Flood Max 3	75	93	93	93	93	93	93	93	35	82	82	82	48	82	82	82	48	48
Flood Min 1	75	75	93	93	75	93	93	93	35	82	82	82	48	82	82	82	48	48
Flood Min 2	75	75	93	93	75	75	93	93	35	82	82	82	48	82	82	82	48	48
Flood Min 3	75	75	75	93	75	75	75	93	35	82	82	82	48	82	82	82	48	48
SN	75	75	75	93	75	75	93	93	35	82	82	82	48	82	82	82	48	48

Table 1. WINNER log of 3-hop cluster formation in a network of 18 nodes

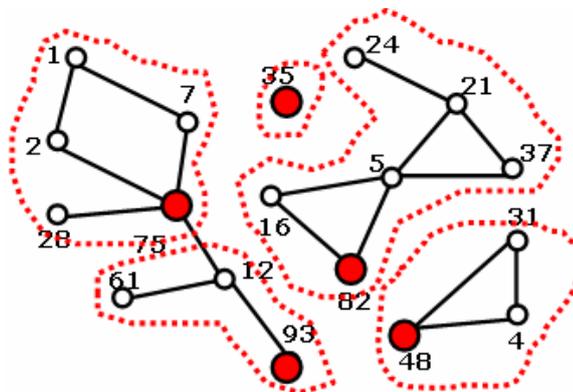


Figure 8. Maxmin d-hop clustering

Due to the mobility of nodes in an ad-hoc network, nodes may move away from the super node they originally selected. Therefore, nodes must be continuously reselected in a timely fashion.

4.3. P2P overlay construction

As mentioned in Chapter 3, it is more suitable to organize super nodes in vehicular network as an unstructured P2P overlay. After considering the geographical characteristic of traffic conditions and their owner⁵, we design the overlay as a small world network [18] [19], a special case of random network. Each node in a small world graph keeps both regular and random links. Small-world networks have two important features: (1) shortest characteristic path length as random network and (2) high cluster coefficient as well-ordered network.

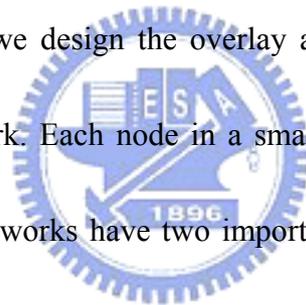


Figure 9 illustrated a example of small world graph with random probability $\alpha = 0.2$.

In our system, we use geographical relation as the measure of link selections. We define *regular links* as links between geographically nearby super peers. *Random links* are selected randomly. Each node in a small world graph keeps both geographically nearby links and random links. Based on the link selection mechanism, geographically nearby super peers are highly clustered. In addition, the overlay can be guaranteed to be connected because it also

⁵ Traffic condition of certain road segment is observed by vehicles currently traverse on this road segment.

has the property of random network.

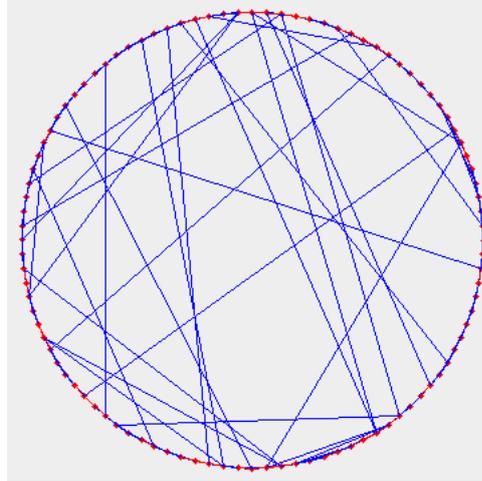


Figure 9. A small world graph



To construct an unstructured overlay with small world property, the most important thing is that how nodes make neighbor selection. To construct neighbor table, peers need to first keep a candidate list. Nodes in candidate list are candidates for neighbor table. Candidates can be super nodes which a node previously contacts or can be obtained from traffic condition packets it receives. If candidates are all failed (become normal nodes or exit the system), this node can retrieve super node information through well-known bootstrap nodes.

After obtaining candidates, super peers can start building neighbor table. First, neighbor table size is set to k which means each peer keeps k neighbors. Then, we set random probability p which indicates the percentage of random neighbor links. Random probability p ranges from 0

to 1. Therefore, each peer keeps $k(l-p)$ nearby links and k_p random links. After finishing the neighbor table construction, peers accomplish the overlay join procedure. During the lifetime (period peers participate in the overlay) of peers, they can obtain new candidate information through the interaction between different super peers. An update period T_u is set to schedule periodically neighbor table update.

4.4. Traffic report generation

Each peer periodically broadcasts traffic condition of the road segment it currently observes its super node through IVC. We define the broadcasting period as T_b . Each super node may receive traffic condition of different segments from different vehicles. Different traffic conditions from different peer of the same segment should be aggregate into single traffic reports.

If peer P_i receive N traffic conditions $C(V_1, S_i)$, $C(V_2, S_i)$, ..., $C(V_N, S_i)$ from vehicles V_1 , V_2 , ..., V_N about segment S_i at time T_k . Here, we use traveling speed of a vehicle to represent the traffic condition it observes. The average traffic condition can be computed by applying aggregation function $R(S_i, T_k)$.

$$R(S_i, T_k) = \text{Avg}(C(V_1, S_i), C(V_2, S_i), \dots, C(V_N, S_i)) = \frac{\sum_{k=1}^N C(V_k, S_i)}{N}$$

The average traffic condition is then mapped to traffic level of service (LOS). A traffic report of a road segment consists of a LOS value to indicate its average traffic condition and a timestamp to record when this traffic report is generated. Table 2 lists traffic LOS range in Urban and Highway environment.

LOS	Urban	Highway
A	61 ~ km/hr	81 km/hr
B	41~60 km/hr	61~80 km/hr
C	21~40 km/hr	41~60 km/hr
D	0~20 km/hr	0~40 km/hr

Table 2. Level of Service table

Each peer keeps a traffic report database to maintain all traffic reports it generates or receives from other peers. To guarantee the correctness of traffic reports, a lifetime $\Delta\tau$ is defined to bound the valid period of traffic reports. Traffic reports exceeds lifetime $\Delta\tau$ should be discarded because it may not be fresh enough to reflect current traffic condition.

4.5. Traffic report lookup

Traffic report lookup is a procedure which peers search traffic reports that they are interested in. The lookup procedure is performed mainly through P2P overlay. A successful lookup requires the lookup message to reach one of the super nodes who manage the traffic report of target segment or any other super peers who holds a cache.

In our design, lookup messages are forwarded using location based routing [20][21] instead of scoped flooding which traditional unstructured P2P overlay network usually applies. Location based routing are routing protocols which use positional information for next hop selection to reduce lookup message overheads. Super nodes know the location of the target segment because the geographical coordinate of each segment is recorded on the map. Also, they have knowledge about their own positions and the position of their neighbors. Based on the location information of nodes and segments, each super node can make local choice for next hop selection.

When a super node wants to lookup a traffic report, it forwards the lookup message to the neighbor whose location is closest to location of target segment (destination). The neighbor who receives the message continues the message forwarding. After each hop, the message gets closer and closer toward the destination. The forwarding stops until a traffic report cache is found or the message reaches the super node who manages the traffic report of target

segment. Once the target traffic report is found, the message is directly returned to the super node who initiates the lookup.

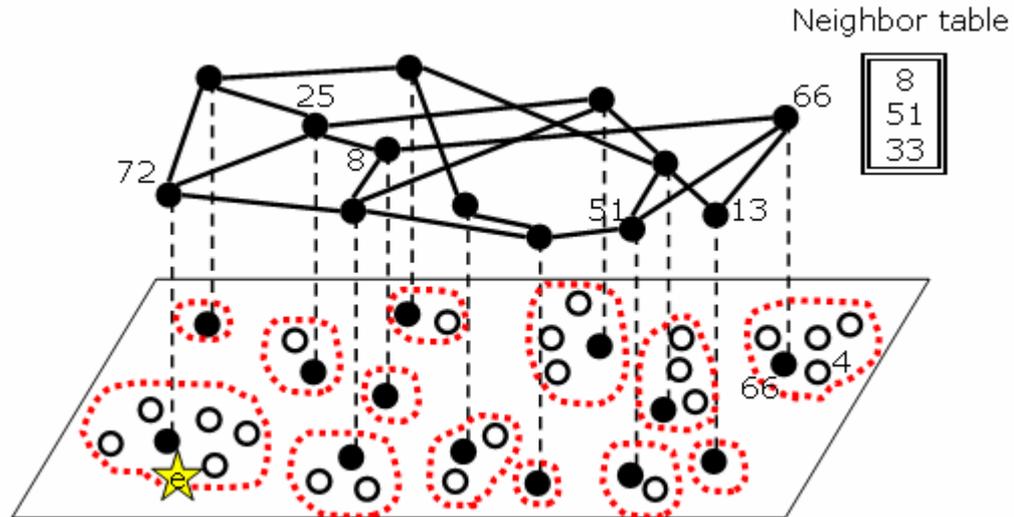
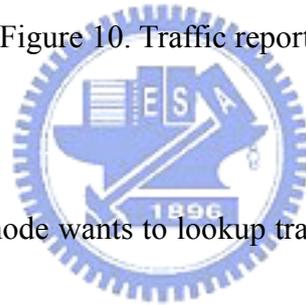


Figure 10. Traffic report lookup



In a situation where a normal node wants to lookup traffic reports, it needs to forward lookup message to its super node through IVC. Then, the super peer acts as this normal peer's agent to complete the rest of the lookup process. When the target traffic report is found, it is first returned back to the agent. Later the agent transmit the target traffic report to this normal node though IVC.

Figure 10 illustrates how a traffic report lookup is performed. Node 4 is a normal node and it is managed by super node 66. When node 4 initiates a lookup to locate traffic report e, it forwards the lookup message to super node 66. Then super node consults it neighbor table and

select the node which is closet to the destination. The neighbor it forwards the lookup message to is super node 8. The lookup message is then forwarded to super node 25 and 72. Finally the target traffic report is found on super node 72. Super node 72 returns the target directly to super node 66, and super node 66 transmits the target to normal node 4 who initiates the lookup.

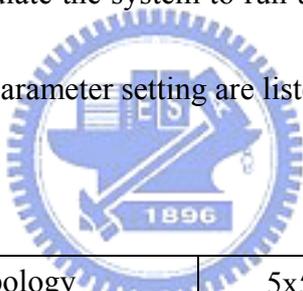


Chapter 5. Simulation

5.1. Simulation setting

The simulation process can be divided into two phases. In the first phase, we generate vehicle trace log file using micro-scope traffic simulator SUMO [22]. The simulation road topology is a 5x5 grid road network. Each road segment is defined as 500 m. The traveling speed of each vehicle is gradually changed according to local traffic condition. The maximum speed is not exceeded over 20 m/s. We simulate the system to run under different levels of traffic density.

Details about traffic simulator parameter setting are listed in Table 3.



Road topology	5x5 km^2 grid topology
Segment length	500m
Number of lanes	2 lanes per direction
Deceleration probability	$2.6 m / s^2$
Acceleration probability	$4.5 m / s^2$
Vehicle length	5m
Maximum velocity	20 m/s
Traffic Density	{1, 2,4} vehicle/km

Table 3. SUMO traffic simulator parameter setting

The second phase is to use the vehicle log file as input and write our own simulation program.

The radio communication range of each node is set to one kilometer. Two nodes are said to have direct wireless link between if they are within each other's communication range. The neighbor table size is six and the small world random probability is set to 0.25. We simulate the system to run using different d-hop cluster formation. Details about system parameter setting are listed in Table 4.

IVC transmission range	1 km
Neighbor table size	6
Random probability	0.25
Super node selection period	2 seconds
Traffic condition broadcast period	2 seconds
Neighbor table update period	1 seconds
Traffic report lookup period	30 seconds
Traffic report lifetime	3 minutes
d-hop cluster formation	[1, 2, 3]

Table 4. System parameter setting

We use the famous unstructured P2P overlay, Gnutella, as benchmark to examine the performance of our system. The simulation focuses on the traffic report lookup efficiency. We define two metrics to evaluate if our design supports efficient traffic report lookup: (1) lookup latency, (2) lookup message overhead. Simulation results show that the two-layer hierarchical

traffic information system does provide efficient traffic report lookup.

5.2. Simulation result

In Figure 11 and Figure 13, we study the performance of lookup latency in Gnutella and in our system design. The x-axis denotes the distance between the node who initiates traffic report lookup and the target road segment. The y-axis denotes the P2P overlay hop count per lookup. The phenomenon we observe is that in Gnutella the lookup hop count is not affected by distance between initiator and target location. In our design, the lookup hop count is larger than that in Gnutella; however, the difference is fairly small.

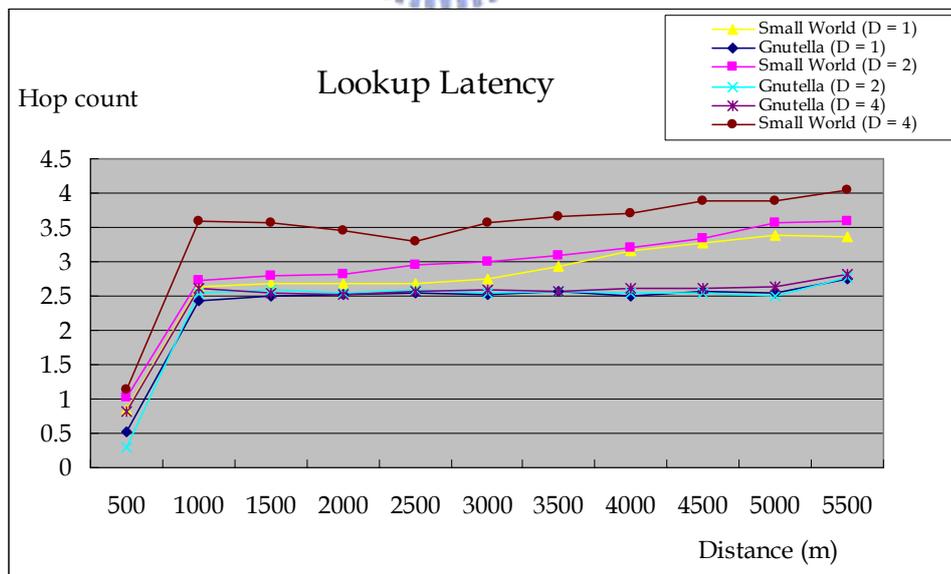
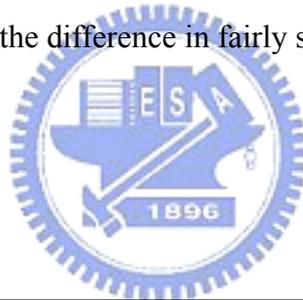


Figure 11. Lookup latency in Small World overlay and Gnutella overlay under different traffic density

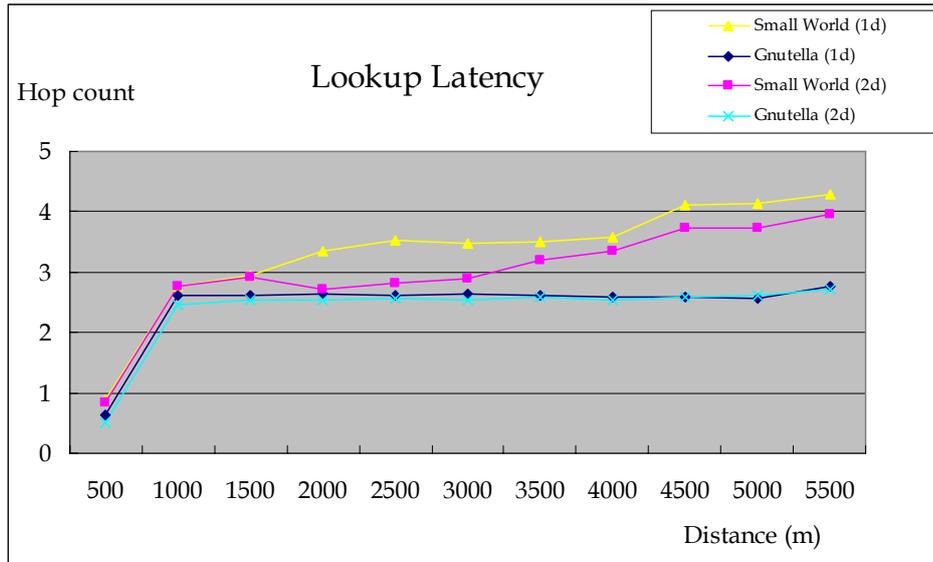


Figure 12. Lookup latency in Small World overlay and Gnutella overlay under different d-hop cluster



In Figure 12 and Figure 14, we study the performance of lookup message overhead in Gnutella and in our system design. The x-axis denotes the distance between the node who initiates traffic report lookup and the target road segment. The y-axis denotes the P2P layer message overhead per lookup. The phenomenon we observe is that our system largely reduced message overhead because we rely on location based forwarding rather than scoped flooding for traffic report lookup.

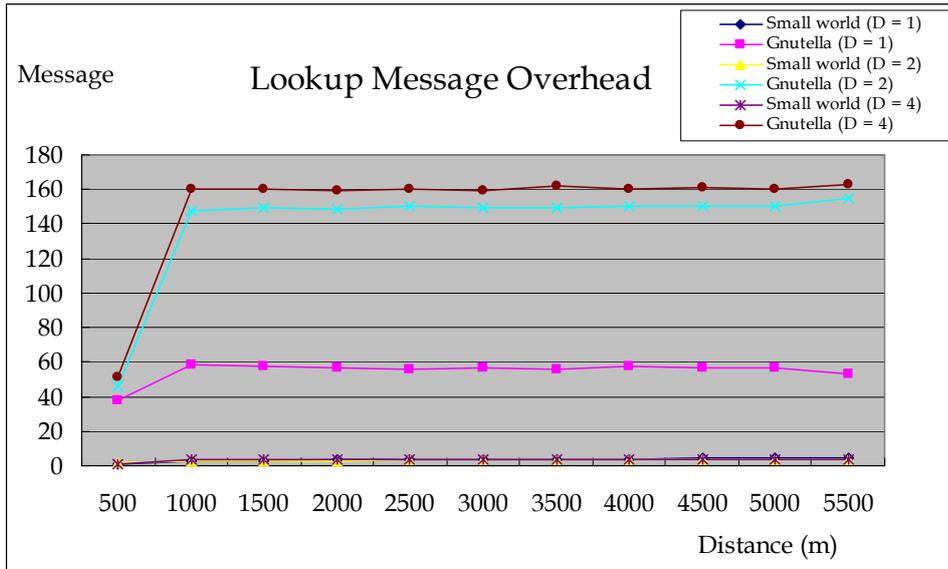


Figure 13. Lookup message overhead in Small World overlay and Gnutella overlay under different traffic density

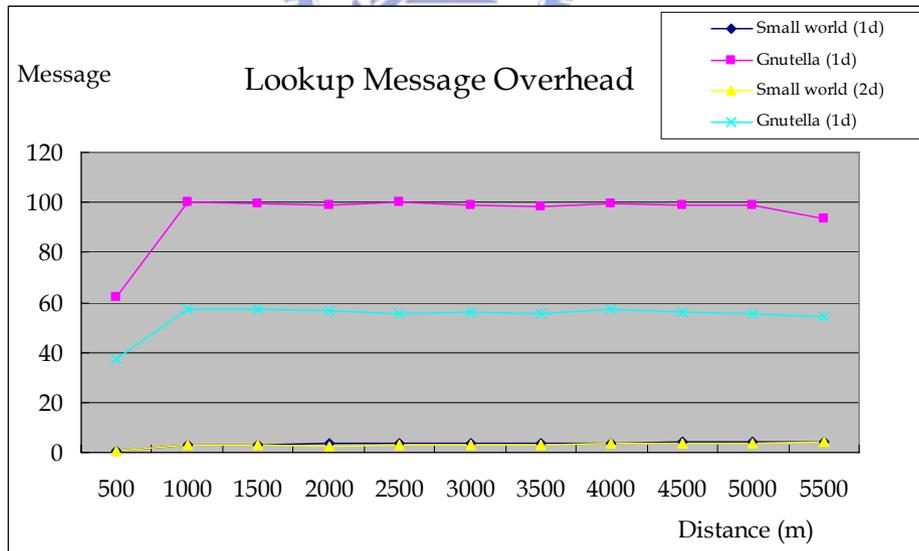


Figure 14. Lookup message overhead in Small World overlay and Gnutella overlay under different d-hop cluster

Chapter 6. Conclusion

In this paper, we propose a two-layer hierarchical decentralized P2P real-time road traffic information system which combines IVC and infrastructure-based wireless network. The system aims at providing accurate traffic reports and supporting efficient traffic report lookup.

All vehicles share their capability and broadcast observed traffic condition through IVC. We take max-min d-cluster formation to select certain number of nodes as super nodes. These super nodes form a P2P overlay atop ad-hoc network to support traffic report lookup through infrastructure-based wireless network. With this overlay, lookup can be efficiently performed for drivers to retrieve real-time traffic reports.



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