

highway traffic conditions (jams, accidents, etc.) based on collected data can be viewed as a pattern recognition problem. In the literature several attempts have been made to analyze the traffic problem as a pattern recognition problem under different assumptions. In the problem of network-level traffic detection has been addressed as a two-class problem for simulated data on the freeway. The data is collected from fixed freeway and therefore suffers from the limitation of required infrastructure. In a similar problem is presented with a wavelet energy approach applied to data collected from the FSP I-880 project. In MANET-based traffic condition detection is presented, but the solution methodology is based on group formation with issues regarding leader and follower being resolved before any traffic conditions are considered. There have been many other attempts in the literature to address the problem of traffic condition detection, but the solutions presented are specific for network communication protocol.

II. METHODS AND MATERIAL

I. Pattern Recognition Formulation

The problem of traffic condition monitoring helps form the basis for the application of MANETs in vehicular transportation systems. Apart from the issues involved in communication protocols for ad hoc networks of vehicles, this problem can be considered as a pattern recognition problem. In ad hoc networks of vehicles, the vehicles communicate with each other and can gather information regarding traffic conditions of the individual participating nodes in the ad hoc network. This traffic information as gathered by any individual node can be arranged as a pattern of traffic flow condition around the node in real time. From the point of view of that particular node the pattern may now be classified into traffic condition classes, such as free flow or jam, by utilizing proper pattern recognition techniques. To demonstrate the idea we restrict our traffic flow to single-direction traffic on a freeway. Since MANETs have the capability to communicate within a certain range with each other,

the node of interest is the most recent node joining the group. We analyze the problem from the point of view of the node most recently join.

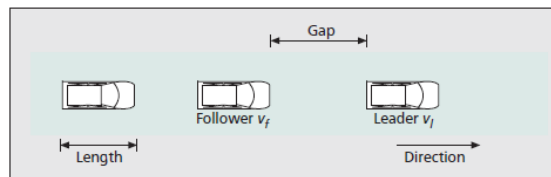


Figure 1. Traffic Model Parameter

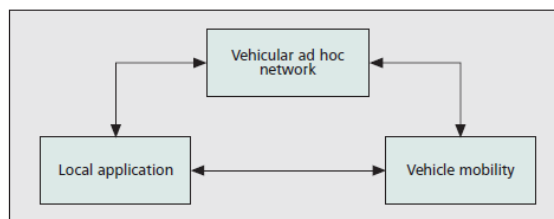


Figure 2. Simulation System Overview

II. Distributed Traffic Information Acquisition Based On IVC

In recent years, distributed traffic information acquisition based on wireless communication technology is attracted more and more attentions from traffic researchers, engineers and managers. Here, the traffic information acquisition system is consisted of the following three parts.

- 1) Vehicles Equipped with Communication Module.
- 2) Road-side Stations.
- 3) Traffic Management Center.

A prototype of this traffic information acquisition system is illustrated in Fig. 3. Vehicles with wireless communication modules form the vehicular ad-hoc network.

And they are not only traffic information sensors that detect their own traffic states such as position, velocity, acceleration etc., but also network nodes that can communicate with each other through wireless network sharing information. The road-side stations are responsible for collecting traffic information from vehicles in their service ranges and transferring to superior traffic management center just as a local access point or a hub. The network traffic management center gathers all the

information of whole traffic network, analyzing the traffic situation and making traffic control or guidance policies.

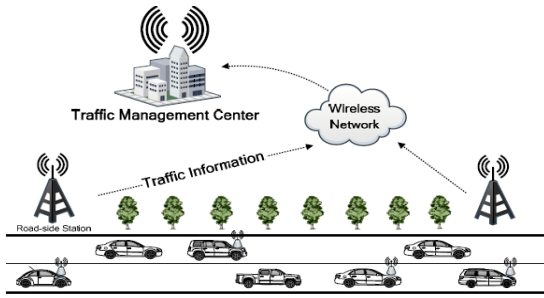


Figure 3: wireless communication modules

III. Adaptive Traffic Beacon (ATB)

The main objective of ATB is to exchange information in knowledge bases by sending beacons as frequently as possible, but to maintain a congestion-free wireless channel. ATB achieves this by employing two different metrics, the channel quality C and the message utility P , to calculate the beacon interval I with which to disseminate messages. The benefits that adapting beacon intervals can bring to beaconing schemes are obvious: increasing the TIS performance of static beaconing schemes to a level comparable with that of adaptive beaconing schemes causes packet collisions to rise to intolerably high values. In fact, channel load can be up to several orders of magnitude higher, as illustrated in Fig. 1. In the following, we briefly introduce the different metrics ATB uses to assess channel quality and message utility. Each metric is derived by considering one particular measure of either channel quality or message utility and calculating its value relative to a fixed maximum value. We further illustrate how the metrics work together to adapt the beacon interval and present how nodes manage their local knowledge bases.

Channel quality C : The channel quality is estimated by means of three metrics, which are indicative of network conditions in the past, present, and future, respectively. First, a node observes the number of collisions on the channel, deriving a value K which is a measure of past channel

conditions. We made our protocol very sensitive to this metric to prevent overload situations. Secondly, a node continuously measures the Signal to Noise Ratio (SNR) on the channel to derive S , which reflects current channel use. Obviously, this is only an indicator for the channel quality. If the car is far away, thus, the SNR being small, we anticipate a larger beacon interval, hoping to see other cars beaconing first. This is in line with findings published for example in [2]. Lastly, a node observes other nodes' beacons, deriving a measure for the number of neighbours N and thus enabling it to factor in, to a certain degree, the outcome of channel access in the near future.

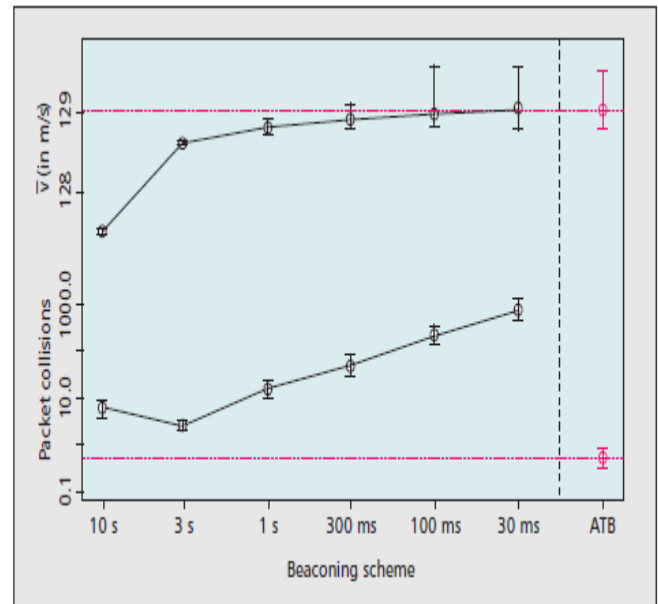


Figure 4: TIS performance of static beaconing

Based on these metrics, which capture the quality of the channel in the past, present, and future, a node is able to derive a metric of the overall channel quality C , which is a linear combination of K , S , and N , ranging in the interval $[0; 1]$ (lower values describing a better channel quality). In order to tune the reactivity of the protocol, flexible weight should be given to the estimation of future channel use N , while equal weight should be given to the more immediate metrics K and S .

Message utility P : The message utility P is derived from two metrics: First, a node accounts for the distance of a vehicle to an event as D_e , which is the

most direct indication of message utility. Second, it accounts for message age A , thus allowing newer information to spread faster. Both De and A are of equal value for determining the compound utility metric P . As part of ongoing research on RSU supported operation of VANETs, we are aiming to further expand the calculation of P to take into account how useful a particular message might be in the presence of RSUs, as well as its utility to nearby RSUs. Similar to C , the value of P can also range from 0 to 1, lower values describing a higher priority messages.

Beacon interval calculation: Based on the two aforementioned metrics, C and P , ATB continuously adapts the beacon interval in a range from I_{min} to I_{max} . As the channel quality metric C in turn depends on the value of I that was chosen by nearby vehicles, ATB exhibits some properties of a self-organizing system on a macroscopic scale, vehicles participating in the VANET will independently arrive at beacon intervals that enable them to use the shared channel commensurate to their own and other nodes' needs. Hence, proper rules at the local level (car level) lead to emergent behavior at the global level. ATB adjusts I such that it becomes minimal only for the highest message utility and the best channel quality. In all other cases, channel use is reduced drastically, allowing uninterrupted use of the channel by other applications. In addition, the relative impact of both parameters wI is designed to be configurable (e.g., in order to calibrate ATB for different MAC protocols).

In our experiments, we used $wI = 0.75$, that is, weighting the channel quality higher than the message priority. That means that the beacon interval is very sensitive to the conditions of the radio channel. As described in a more detailed technical report already a few collisions will cause ATB to backoff in order to efficiently use the remaining capacity of the wireless channel. This also means that ATB inherently can co-exist with other applications using the same channel. In our

implementation this is achieved by reevaluating C and P and deriving a new beacon interval I after each beacon sent or received, according to the following equation — please note that I is thus in the range $[I_{min}, I_{max}]$: $I = I_{min} + (I_{max} - I_{min})(wIC^2 + (1 - wI)P^2)$. That is, if both C and P are low, i.e. the channel is free and there are high priority messages, the resulting beacon interval I is low. If either C or P is high, then the result is somewhere in

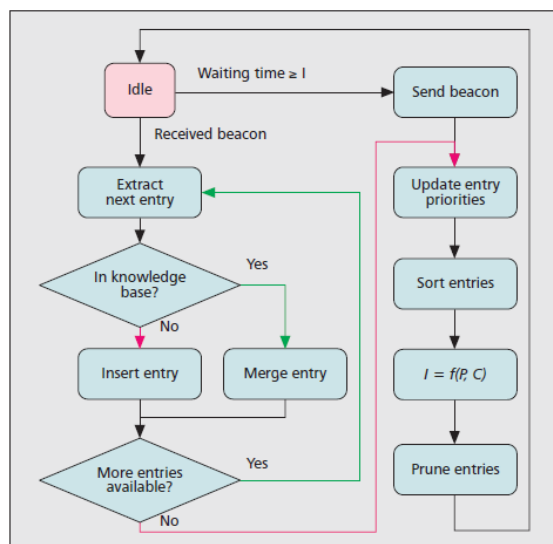


Figure 5: Core functionality of ATB protocol

The middle; and if both are high, the resulting beacon interval is close to I_{max} (i.e., it is high). We also use a higher weight for C compared to P as the channel quality is clearly more important. The quadratic form is used to make ATB very sensitive in “bad” situations (e.g., channel overload), whereas to only slightly adapt I in the “best” case scenarios. A detailed sensitivity analysis of all these parameters is presented in [7].

Knowledge base management: In order to maintain the scalability of the TIS, the transmission of irrelevant information needs to be suppressed and each knowledge base needs to contain all received traffic information in aggregated form [12]. The operation of ATB, however, is independent from the scheme used for the selection of knowledge base entries and their aggregation, so any of the numerous approaches in the relevant literature can be used in an implementation. As a

baseline for our evaluation of the message dissemination characteristics, we implemented a simplistic scheme: The knowledge base stores only the most recent information for each route segment; that is, each new event either updates an existing record or it is appended to the knowledge base. A garbage collection process continuously expunges entries that are older than a configurable timeout. Each node prioritizes available information according to the age of an entry, as well as the distance to the event. Using the calculated priorities, a node can then generate beacon messages by selecting as many entries as there is room in a single link layer frame from the top of the list, i.e., those with the highest priority. The most important message is used to calculate the message priority for the beacon interval. This way, the frame size is optimally used, and problems with state full handling of messages split into multiple frames are inherently avoided. Nodes that receive these beacons can then in turn update their knowledge bases and beacon intervals according to the algorithm illustrated in Fig. 5. Clearly, the presented handling of the knowledge base is not yet optimal — the key aspect of ATB is the efficient use to the available capacity of the wireless channel.

IV. Overload Tolerant TDMA Mechanism

The OLT-TDMA mechanism is a dynamic TDMA protocol which tolerates the oversaturated situation where the number of vehicles exceeds the number of the limited reserved time slots in the coverage of a RSU. In this protocol, a vehicle will always find the most appropriate time slot to transmit its own beacons based on the current traffic conditions. The selection procedures, including RSU selection and time slot selection, will be conducted on every vehicle. RSU is responsible for collecting all the vehicles' information and re-broadcast them after simple processing. Details of this mechanism will be specified in this section.

A. TDMA Frame Structure

We define the time duration parameters according to the U.S. standards within IEEE. Where the packet size $B=300$ bytes, the transmission rate $R=6\text{Mbit/s}$ and $T=100\text{ s}$ guard given in [12]. So a single slot reserved for a vehicle is 0.5ms . In our work, we divide the whole frame into two segments: the RSU segment and the vehicles segment. As illustrated in Figure 6, the first part of the frame is reserved for RSU broadcast. This duration lasts for 50ms . The next duration, also 50ms long, is further divided into 100 fixed slots for at most 100 vehicles. Each interval lasts for 0.5ms and is repeated periodically along with the vehicles segment. This ensures a vehicle to deliver its beacons to RSU in every 100ms period once it gains a time slot. In such a way, all the vehicles with a selected time slot will broadcast their own status periodically.

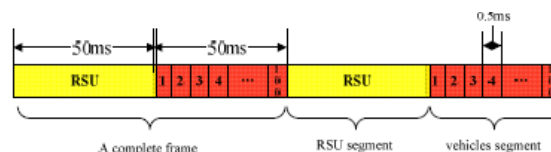


Figure 6. TDMA frame structure

B. Specifications of RSU Segment

Within an urban road scenario, we assume that a vehicle is always in the coverage of one or more RSUs in which they could communicate mutually. OBUs scan for RSU beacon. If more than one RSU respond, it means the OBU is in the intersection region of these RSUs. Then OBU will select the best one based on RSSI (Received Signal Strength Indication) and put the other RSUs in the candidates list ranked by their RSSI. If the selected RSSI deteriorates to the minimum reliable transmission threshold, RSU that ranked first in the candidates list will be used. Note that the ranking is dynamic. It ensures the OBU can find the best RSU all the time.

1) Safety Related Information

After a vehicle selects a RSU, it will first listen to the channel for a complete frame especially for the RSU segment. In the RSU segment, which is also the downlink transmission, it will broadcast all the safety related beacons sent to it in the last frame to vehicles after processing. Thus a vehicle can be aware of all other vehicles' driving status within the same RSU coverage. Though a specific vehicle may not put direct threats to all the others, its driving status is still broadcast to all to ensure a more secure driving condition. Note that the transmission range between vehicles is actually enlarged by RSU as a "relay" node. As the transmission power of a vehicle is rather limited, it may not be able to send messages to faraway vehicles. However, with a RSU as a relay, this is possible.

2) Time division topology map

RSU will broadcast the "time division topology map" as well. i) If there are packets received in a particular time slot, it will mark this slot as occupied and attach its user information (e.g. Vehicle ID) to it on the topology map. ii) In case of an anomaly, in which a vehicle fails to send its beacons in its time slot while it is still in the RSU coverage, we impose another rule to RSU: if no packet is received in a time slot for three consecutive frames, mark the slot as available. According to these rules, RSU is able to complete the time division topology map, hence give guidance to new joining vehicles about which slots are free and which are still in use.

3) Collision map

A vehicle trying to gain a slot will thus be aware of the entire time slots availability after listening for a complete frame. It thus makes a decision on which one to take. If there is more than one free slot, the vehicle will pick one randomly. In our design, RSU is also responsible for the completion of a "collision map" for all the slots. If more than one vehicle chooses the same time slot simultaneously, they

cannot detect this collision. But this can be supervised by RSU. Then RSU marks this slot in the "collision map" and send this map to all the vehicles in the next frame. In this way, vehicles will be able to determine if collisions have happened and choose other free slots in the next frame to avoid further collisions.

C. Specifications of OBU Segment

A vehicle with a chosen slot will first synchronize its clock with RSU based on the position and time information from its GPS. Then it will send beacons which contain the vehicle's ID number, current position, velocity, acceleration and all the other safety related information to it. As there are no acknowledgements with broadcast mode from RSU or other vehicles, the transmission of these beacon records should also be considered carefully. Here we choose the stable and high-speed 3G\ communication network as the data uplink path instead of IEEE 802.11p.

D. Slot selection mechanism in vehicles

1) Light-loaded traffic

A light-loaded traffic means that the time slots are sufficient for the vehicles to use. A vehicle will randomly pick one free slot to start transmission. "Collision map" mentioned above will be taken into consideration to prevent collisions.

2) Heavy-loaded traffic

In an overloaded scenario where all the available time slots have been used up, as shown in Figure 7, a new joining vehicle will first listen for a complete frame and then start the LIF (Least Interference Factor) algorithm to help it find its optimum slot.

3) Remaining residence

This is time for a new joining vehicle to share the channel with. All the variables needed to calculate a LIF will be obtained from the RSU segment in last frame. LIF algorithm is repeated for N (the total number of vehicles) times until we pick up the

largest LIF after comparison. The details of the procedure are below.

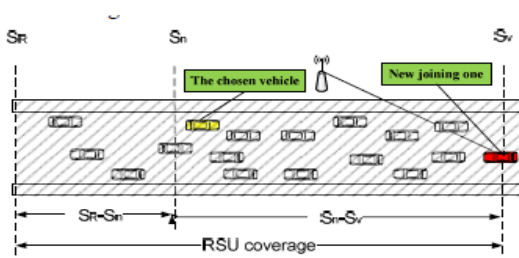


Figure 7. The road architecture in overload situation. The red vehicle is a new joining one. It obtains the traffic load information from RSU and it will share the same slot with the chosen vehicle whose LIF is the largest.

V. Mobility Patterns

In this section, we briefly review the general characteristics of our mobility scenario. First, we consider a region comprised of several streets and intersections such as in Fig. 8. It is assumed that vehicles arrive at each entrance according to a Poisson process. We also assume that each vehicle is destined to one of the streets in the region. In this paper, we focus on situations when the streets are not very crowded such that an independent mobility pattern for each vehicle can be considered. Another important feature of the mobility pattern is how the vehicles make a decision at intersections. When a vehicle arrives at an intersection it can go straightforward, turn left, or turn right. Based on the information given to the drivers as well as their destination, the drivers select their next street at each intersection differently. So, in this paper, we consider two vehicle routing algorithms called as TLI and TLD algorithms. In the first one, the decision-making is carried out based on the current intersection as well as the location of the destination. However, in the second one, the traffic load status of the streets is the extra information, given to the drivers. So, the drivers are able to make a more reasonable decision.

A. TLI Algorithm

In this simple algorithm, going toward the destination through the shortest possible path is the main principle for the drivers to choose their

direction at intersections. In fact, every vehicle faces three streets at each intersection, but only one or two of these streets make the vehicle nearer to its destination. We call these streets as suitable streets for that vehicle at that intersection (see Fig. 9). In this algorithm, at each intersection the vehicles choose between their suitable streets with equal probabilities and they do not take the traffic load of the streets into consideration.

B. TLD Algorithm

In the TLD algorithm, traffic load of the streets play a key role in decision-making process at intersections. In this paper, we consider the average number of vehicles (ANV) in a street as the indicating factor of its traffic load. In this algorithm, according to each destination street, we categorize all the intersections into three groups. Group 1 contains the two intersections at both sides of the destination street, i.e., terminal intersections of the destination street. Group 2 contains the intersections at the same row or column of the terminal intersections with a distance equal to one street (see Fig. 10). Group 3 contains the other intersections which are not included in the two previous groups. In considering TLD algorithm, the traffic status of different streets is the information appeared at the electronic billboards at the intersections. So, it is reasonable that the drivers make their decisions at each intersection considering both traffic load of the streets and location of their destination. Although different algorithms may be considered in the decision-making process, we assume that the behavior of the vehicles is matched with the electric current flowing at different electric paths. In this case, according to Ohm's law, the current intensity at different paths is proportional to the conductivity (inverse of resistivity) of the paths. In the TLD algorithm considered in this paper, ANV plays the role of resistivity. However, we include the distance to the destination street as another factor in decision-making process. Therefore, when a vehicle arrives at an intersection, first the intersection's

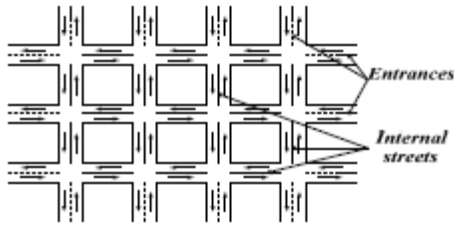


Figure 8: Typical region in this paper.

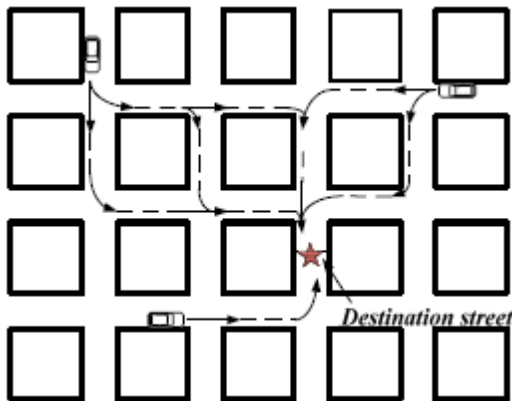


Figure 9: Suitable streets (solid arrows) and shortest paths (dashed lines) for the vehicles at different intersections in the TLI algorithm.

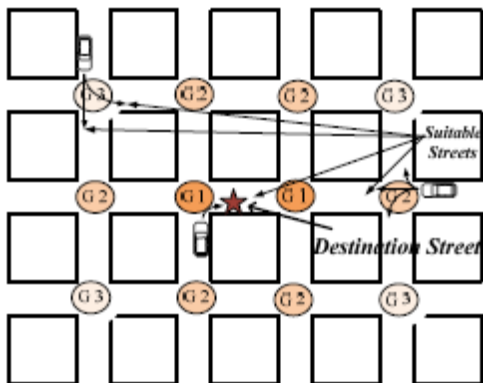


Figure 10: Categorization of the intersections and the vehicles' behavior at each type of intersections in the TLD algorithm. (With respect to the vehicle's destination street) should be considered.

It is due to the fact that the behavior of the drivers at intersections near to destination is reasonably different from their behavior at farther intersections. Thus, according to the intersection's group, the vehicle follows different manners to select its path. On the other hand, the information on electronic billboards contains the traffic load status of the local streets. Regarding the above two facts, TLD algorithm is described as in the following. If the intersection is of group 1, the vehicle goes to its destination street directly. If the intersection is of group 2, the vehicle chooses among all three streets

of the intersections, with the probabilities dependent on the traffic load of the streets. Among the three streets that the vehicle faces at this group of intersections, only one leads the vehicle to the shortest path toward its destination. This street is recognized as the suitable street for the vehicle at this intersection by the TLD algorithm (see Fig.10). To specify the probability of routing to each street, we attribute an interest factor to each street. The interest factor for the suitable street equals twice the inverse of ANV of that street and the interest factor for any of the other two streets equals the inverse of the ANV of that street. The interest factor indicates a tradeoff between weights assigned to the distance to intersection and the crowdedness of the streets in the decision-making process. Then, the probability that the vehicle selects a street is proportional to the interest factor of that street. Furthermore, if the vehicle arrives at an intersection of group 3, only the suitable streets for the vehicle at that intersection (such as in the TLI algorithm) are considered. There are two suitable streets for the vehicles at this group of intersections (see Fig.10). Then, we attribute an interest factor to each suitable street which equals the inverse of ANV of that street. Then, the probability of routing to each suitable street is proportional to its interest factor.

III. CONCLUSION

The Traffic Pattern in Vehicular ad hoc network are various in all situation so up to now the vehicle to vehicle traffic scheduling was done but we can take Road side unit in this scenario for adjusting the broadcasting time. First we put the RSU in Training phase than through that we consider the time slot in which the traffic will sparse, dense, and regular and then road side unit will automatically adjust the broadcasting time period.

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