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INTELLIGENT INFORMATION DISSEMINATION IN VEHICULAR AD HOC NETWORKS

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ABSTRACT

Vehicular Ad hoc Networks (VANETs) are a compelling application of ad hoc networks, because of the potential to access specific context information (e.g. traffic conditions, service updates, route planning) and deliver multimedia services (VOIP, in-car entertainment, instant messaging, etc.). In this paper, we propose an agent based intelligent information dissemination model for VANETs. Safety information like cooperative driving, accident, road condition warnings, etc. play a major role for applications of VANET. Safety information dissemination poses a major challenge of delay-sensitive nature. This paper proposes an agent based model for intelligent information dissemination in VANETs. Proposed model uses cognitive agent concept for realizing intelligent information dissemination. To test the efficiency of the model, proposed scheme is simulated using NS-2 simulator. Some of the performance parameters analyzed are bandwidth utilized, push latency and push/pull decision latency.

KEYWORDS

Vehicular ad hoc networks, Cognitive agents, Push-pull concept

1. INTRODUCTION

A Mobile Ad-hoc Network (MANET) is comprised of a group of mobile nodes, which have the capability of self-organization in a decentralized fashion and without fixed infrastructure. VANETs are special case of MANETs. The key differences as compared to MANET environment are following: 1) Restricted mobility constraints 2) Extremely high mobility and time-varying vehicle traffic density 3) Most of the vehicles provide sufficient computational and power resources, thus eliminating the need for introducing complicated energy-aware algorithms. 4) Vehicles will not be affected by the addition of extra weight for antennas and additional hardware. Some parameters that have to be mainly concentrated in VANETs for protocol design are extremely high mobility, restricted movements, fast topology changes and time varying vehicle traffic density.

VANET raises several interesting issues with regard to Media access control (MAC), Mobility management, Data aggregation, Data validation, Data dissemination, Routing, Network Congestion, Performance analysis, Privacy and Security [1].

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- *Mobility management:* Since vehicles are highly mobile and change their point of network attachment frequently while accessing Internet services through gateways, it is advisable to have some mobility management schemes that take care of vehicle mobility and provide seamless communication. Mobility management has to meet the following requirements: seamless mobility (communication must be possible irrespective of vehicle position), low handoff latency, support IP V6 and scalable overheads.

- *Data aggregation:* The vehicles have to pass on the data sent by the neighbors to other neighbors of its coverage area. This increases the number of packets to be sent by a vehicle. Therefore, data aggregation techniques are applied to reduce such overheads. Data aggregation is an interesting approach, which reduces the number of packets transmitted drastically by combining several messages related to the same event into one aggregate message. For example, the records about two vehicles can be replaced by a single record with little error, if the vehicles are very close to each other and move with relatively the same speed.

- *Data validation:* A vehicle may send the data it has observed directly (assuming that a vehicle always trusts the data it has gathered itself) to its neighbors. Sometimes malicious vehicles may send the incorrect information to confuse the users. For example, a malicious node may send the false accident information and divert all the vehicles on other roads, which may some times lead to traffic congestion. In such situation data validation techniques must be applied before passing on the received information to other nodes.

- *Data dissemination:* Data dissemination can be defined as broadcasting information about itself and the other vehicles it knows about. Each time a vehicle receives information broadcasted by another vehicle, it updates its stored information accordingly, and defers forwarding the information to the next broadcast period, at which time it broadcasts its updated information. The dissemination mechanism should be scalable, since the number of broadcast messages is limited, and they do not flood the network. VANET characteristics like high-speed node movement, frequent topology change, and short connection lifetime especially with multi-hop paths needs some typical data dissemination models for VANETs.

- *Routing:* Since the topology of the network is constantly changing, the issue of routing packets between any pair of nodes becomes a challenging task. Most protocols should be based on reactive routing instead of proactive. Multicast routing is another challenge because the multicast tree is no longer static due to the random movement of nodes within the network.

- *Network congestion:* Congestion control in VANETs is a challenging issue. The Internet is based on an end-to-end paradigm, where the transport protocol (e.g. TCP) instances at the endpoints detect overload conditions at intermediate nodes. In case of congestion, the source reduces its data rate. However, in VANETs the topology changes within seconds and a congested node used for forwarding a few seconds ago might not be used at all at the point in time when the source reacts to the congestion.

Some of the important applications of VANETs are message and file delivery, location-dependent services, Internet connectivity, information and warning functions, co-operative assistance systems, safety services (like emergency breaking, accidents, passing assistance, security distance warning, etc.) traffic monitoring, etc.

2. RELATED WORKS

Several works reported in the literature deals with ad hoc networks and their applicability in VANETs. Some of the works are as follows. The work given in [2] describes a system called as Ad Hoc City, which is a multi tier wireless ad hoc network routing architecture for general-purpose wide-area communication. The backbone network in this architecture is itself also a mobile multihop network, composed of wireless devices mounted on mobile fleets such as city buses or delivery vehicles.

The work given in [3] addresses the issues pertaining to medium access control schemes in highly dynamic automotive networks that reduce latency and perform reliable communication. It also describes a distributed positioning algorithm, called the kernel algorithm, suited for asynchronous ad hoc wireless networks under complexity constraints. Traffic congestion avoidance by disseminating traffic information through peer-to-peer networks based on WiFi technology is studied in [4].

A mixed mode wireless LAN comprising of infrastructure and ad hoc mode operations is presented in [5] where MANETs are connected through several base stations. The work given in [6] presents an autonomous, self-organizing and decentralized configuration and management system for a group of base stations in wireless networks. The individual base stations aggregate and share network information. A distributed algorithm computes a local configuration at each base station based on the shared information.

A dynamic clustering solution, which is distributed in nature, handles the cluster management by taking into account practicalities like packet losses etc., and integrates with a routing module, is presented in [7]. A security concept based on a distributed certification facility is described in [8]. A network is divided into clusters with one cluster head node for each cluster. These cluster head nodes execute administrative functions and hold shares of a network key used for certification. The work given in [9] introduces a scalable service discovery protocol for MANETs, which is based on the homogeneous and dynamic deployment of cooperating directories within the network. A congestion control method with dynamic clustering for variable topology and link qualities is discussed in [10].

Autonomous and cooperative collection of traffic jam statistics to estimate arrival time to destination for each car using inter-vehicle communication is proposed in [11]. Optimal next-hop selection in a route between two vehicles for a simple scenario of VANETs on a highway is necessary to enhance the route lifetime [12]. In [13], problem of low-latency content distribution (multicast streaming) to a dense vehicular highway network from roadside info-stations, using efficient multi-hop vehicle-to-vehicle collaboration is explained. A model to predict parking lot occupancy based on information exchanged among vehicles is discussed in [14]. A data-gathering scheme for wireless sensor networks based on agent's cooperation to deal with the importance of the information is discussed in [15]. Agent cooperation aims to reduce an important amount of the information communicated over the network by eliminating the unimportant information and the inter-sensor-nodes redundancy. A priority-scheduling scheme to increase the Quality of Service in VANETs is proposed in [16].

The problem addressed in the paper is information dissemination using software agents including static cognitive and mobile agents. Vehicles autonomously collect, classify and disseminate critical information with assistance of cognitive software agent. Rest of the paper is organized as follows. Brief explanation of software agents is given in section 3. Proposed intelligent information dissemination is presented in section 4. Simulation and the result analysis are presented in section 5. Finally, section 6 concludes paper and explains future work.

3. SOFTWARE AGENTS

The traditional programming paradigm uses functions, procedures, structures and objects to develop software for performing a given task. This paradigm does not support development of flexible, intelligent and adaptable software and also does not facilitate all the requirements of Component Based Software Engineering (CBSE). In recent developments, agent technology is making its way as a new paradigm in the areas of artificial intelligence and computing which facilitates sophisticated software development with features like flexibility, scalability and CBSE requirements [17].
Agents are the autonomous programs activated on an agent platform of a host. The agents use their own knowledge base to achieve the specified goals without disturbing the activities of the host. They have two special properties: mandatory and orthogonal which make them different from the standard programs. Mandatory properties are: autonomy, reactive, proactive and temporally continuous. The orthogonal properties are: communicative, mobile, learning and believable [18]. There are four different types of agents used in problem solving: local or user interface agents, network agents, distributed AI (Artificial Intelligence) agents and mobile agents. The network agents and user interface agents are single agent systems whereas others are multiagent systems. Agents of single agent systems never cooperate or communicate with each other but they can interact with the local or remote resources of the specified host.

Mobile agent is an itinerant agent consisting of program, data and execution state information, migrates from one host to another host in a heterogeneous network and executes at a remote host until it completes a given task [19]. By nature, mobile agents are flexible modular entities, which can be created, deployed and deleted in real-time. The mobile code should be platform independent, so that, it can execute at any remote host in a heterogeneous network environment. Inter-agent communication can be achieved by message passing, RPC (Remote Procedure Call) or common knowledge base (blackboard). A mobile agent platform comprises of agents, agent server, interpreter and transport mechanisms. An agent server is responsible for receiving mobile agents and sending it for execution by local interpreter.

Agents can be written in Java, Tcl, Perl and XML languages. An agent interpreter depends on the type of agent script/ language used. An agent platform offers the following services: creation of static and mobile agents, transport for mobile agents, security, communication messaging and persistence. Some of the Java based agent platforms are: Aglets, Grasshopper, Concordia, Voyager and Odyssey [20]. The agent based schemes comprising of static or mobile agents offer several advantages as compared to traditional approaches: overcomes latency; reduces network traffic; encapsulates protocols; flexibility; adaptability; software reusability and maintainability; and facilitates creation of customized dynamic software architectures. The multi-agent architecture of context-aware system and the learning scenarios within ubiquitous learning environments is presented in [21]. This architecture is based on the system for sharing public interest information and knowledge, which is accessible through always-on, context-aware services.

A cognitive agent may be defined as a software entity, which functions continuously and autonomously in a particular environment. Cognitive agent carries out activities in a flexible and intelligent manner. It is responsive to changes in the environment. It learns from the experience and can communicate and co-operate with other agents. It is proactive, exhibits opportunistic, goal-oriented behaviour and takes the initiative when appropriate.

In agent systems, the basis for ascribing beliefs and intentions to their actions is not just sentimental. Even though computational agents are pieces of machinery, their designs must be specified and behaviours commanded by humans. And because humans think and speak using cognitive terms such as beliefs, knowledge, desires and intentions, it is natural to use the same cognitive concepts when constructing agents and assigning the tasks to them. An agent operates in a physical or a computational environment. Some combination of the agent's data structures and program must reflect the information it has about its environment, so that the agent can work properly according to the changing environment. Because this information would reflect the state of the environment according to the agent, it can be termed its *knowledge* or a set of its *beliefs*. *Desires* are the state of the environment the agent prefers. *Intentions* correspond to the state of the environment the agent is trying to achieve, which should be a consistent subset of the agent's desires and should be directly connected to the agent's actions.

4. INTELLIGENT INFORMATION DISSEMINATION IN VANETS

In this section, we describe network environment and cognitive agency for intelligent information dissemination in VANETs.

4.1. Network environment

In this section, we introduce network environment used in the analysis of scheme for critical information gathering and dissemination in VANETs. We consider a VANET in which N numbers of vehicles are separated by the safety distance (between consecutive vehicles) S_d. Proposed VANET is purely based on vehicle-to-vehicle (V2V) architecture, where both the collection and the restitution of information are done within the VANET. We assume that vehicles move in an urban road scenario as shown in figure 1. All vehicles are equipped with General Positioning Systems (GPS) and on-board communication devices for communication. Each vehicle is loaded with location digital map and is concerned about road information ahead of it on its direction. Each vehicle communicates with other vehicle within its communication range R. If the neighbor vehicle is not within communication range R, the vehicle delivers critical data to the data center "D", which may be associated with traffic light at cross junction. All vehicles are assumed to have several sensors. Safety information in vehicle is determined by particular set of sensors. For example, tyre pressure and vehicle speed sensors are responsible for safety speed driving. Traffic density sensor, accident sensor (body pressure sensor) and vehicle speed sensor together sense the occurrence of accident, which will be disseminated for further decisions for driving.

4.2. Cognitive agency

Proposed agent framework for critical information gathering and dissemination is based on push-pull concept. For critical events, proposed scheme takes appropriate decisions (push or pull) as and when required. Using push approach, we can efficiently use bandwidth by broadcasting only the critical events that are detected (like accidents, heavy rain, fog, etc.) to the vehicles in VANET. In pull approach, noncritical applications (like road conditions, vehicle speed, etc.,) can be stored within vehicle itself.

The framework comprises of cognitive information agency. Components of agency and their interactions are depicted in figure 2. Agency consists of knowledge base (consists of critical information details and running application(s) details), static agents and mobile agents. Static agent is Vehicle Manager Agent (VMA). Mobile agents are Critical Information Push Agent (CIPSA) and Critical Information Pull Agent (CIPLA).

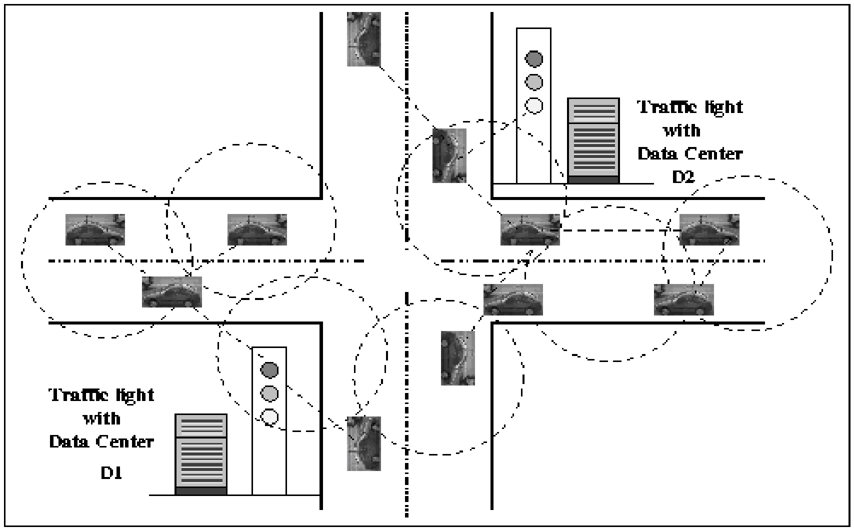

Figure 1. Network Environment

- *Knowledge Base (KB):* It comprises of information of node ID, neighbors list, available bandwidth for communication, node status (connected/disconnected to network), total number of critical information available, information status (old/new) and push/pull event of past and present critical information. KB is read or updated by VMA, CIPSA and CIPLA.

- *Vehicle Manager Agent:* It is a static cognitive agent based on BDI model that runs in a node, creates agents and knowledge base, controls and coordinates activities of cognitive agency. This agent triggers CIPSA for pushing critical information, and CIPLA for delivering pulled information to vehicles in network. Belief set, desire and intention generation are part of VMA functions.

  Belief set generation: VMA updates its beliefs according to sensed values from sensors and also updates knowledge base. We assumed that sensor has two states: LOW and HIGH. If sensor reading is greater than or equal to threshold value (assuming that threshold value is decided by VMA), then sensor state is treated as HIGH, otherwise it is LOW. VMA observes individual sensor states for a fixed time window T (where T represents time duration from tx to tx' where $tx' > tx$). During this time window, out of total transitions (T_{lh}), VMA counts number of LOW transitions (T_l) and HIGH transitions (T_h). Finally, VMA computes sensor state as either HIGH or LOW.

  Desire and Intention generation: Desire and intention generation for an event is core part of cognition capabilities of VMA. A determined desire (either push or pull) for current captured sensor status is generated using belief, if and only if all conditions leading to its generation are satisfied

  Extraction of nearest matching event belief sets is as follows: If an event has been happened, which is having ambiguity to match with contents in the belief. Extraction of nearest matching event belief sets is done by comparing sensor states with sensor states of previous values. From extracted event belief sets, segregate them based on actions with push or pull. From knowledge base, reorganize segregated event belief sets for push and pull actions, respectively. Joint density function for push and Pull is computed. Based on these functions desire is generated for maximum value of push and pull. Generated beliefs and desire are updated in knowledge base.

- *Critical Information Push Agent (CIPSA):* It is a mobile agent, employed to push critical information to other vehicles in network. It is triggered by VMA that travels around network by creating its clones (a clone is a similar copy of agent with different destination addresses) and disseminates critical information. For each visited vehicle, it updates KB in coordination with VMA of vehicle. It is assumed that all vehicles have GPS facility and loaded with digital road map. VMA in each vehicle has knowledge of road length, road width, and number of lanes and current position of the vehicle.
  Operation sequences of CIPSA are as follows.
  1. Whenever critical information is detected source vehicle VMA identifies it's location based on the GPS.
  2. VMA classifies the critical information dissemination area into four quadrants.
  3. VMA considers dissemination area as a pair of quadrant considering source vehicle position and direction of travel.
  4. VMA triggers CIPSA to move in any one of the quadrant (dissemination area).
  5. CIPSA delivers critical information to all vehicles in the dissemination area. While delivering critical information to a vehicle, CIPSA also encapsulates available critical information in visited vehicle for delivery to other vehicles.
  6. Encapsulated critical information is delivered to all vehicles on the way.
  7. Once the CIPSA finds boundary vehicle of dissemination area (assuming vehicle has a mechanism to detect boundary of VANET based on GPS coordinates with respect to source vehicle), CIPSA queries for data centers. Data centers are usually attached with traffic lights, mobile towers etc.
  8. CIPSA pours critical information to data centers and destroys itself.

- *Critical Information Pull Agent (CIPLA):* VMA triggers CIPLA when vehicle is interested to retrieve latest information like fog, weather condition, etc. available in other vehicles of a network. VMA knows relative positions of neighbor vehicles using stored road maps, by mapping vehicle's latitude and longitude coordinates to points on road in which vehicle is driving.
  Operation sequences of CIPLA are as follows.
  1. VMA triggers CIPLA by mentioning required information and destination.
  2. With the help of GPS, VMA gives its upfront neighbors list to CIPLA (source vehicle is interested in information available in forward direction).
  3. From source vehicle, CIPLA moves in forward direction towards its required destination hopping from one vehicle to another.
  4. At each visited vehicle, CIPLA interacts with VMA.
  5. If required information or nearest matching information is available in visited vehicle, CIPLA sends back information to source vehicle. Otherwise, it updates itself and moves forward by using vehicle positioning information (based on GPS) till it reaches destination (based on GPS and Road maps). In this way CIPLA roams around network.
  6. Once CIPLA reaches a vehicle at destination, it traces back to source with information picked at visited vehicles.
  7. If CIPLA does not find a vehicle to reach vehicles at destination, it sends available information to source and keeps waiting for certain duration around place until finds a vehicle moving towards required destination. Similarly, it performs waiting operation when moving towards source.

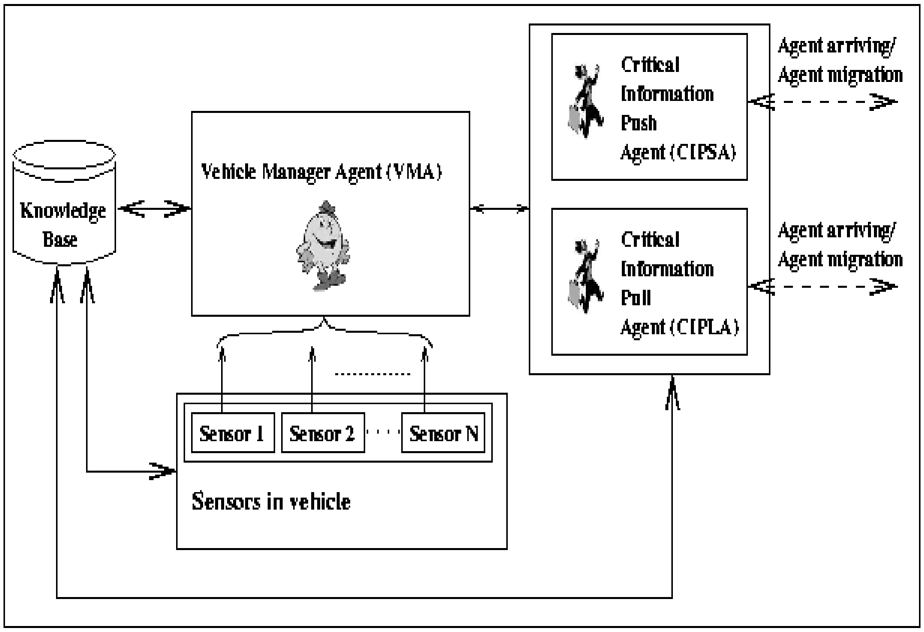

Figure 2. Cognitive agency

5. SIMULATION

5.1. Simulation Model

We have simulated proposed model by considering a Bangalore city map. The simulation is carried out using NS-2.28 to test the performance and effectiveness of approach. We consider “N” number of vehicles moving in a fixed region of length “A” Km. and breadth “B” Km. We consider vehicles to move in number of lanes “L”. Communication coverage area for each vehicle is considered as a “V_{com}” meters.

At the beginning of the simulation, vehicles are uniformly distributed in lanes. This setting holds under assumption that there is a free flow movement of vehicles, i.e. we do not account for congestion that may arise in roads. It is assumed that all vehicles are equipped with a communication device and knows start position, start time of vehicle, route that it selects, and speed at which it travels.

Safety distance of “R” meters is maintained from preceding vehicle for a certain tolerance time, and then change lane if possible. Changing lane allows vehicle to move to an adjacent lane if there is space (safety distance) in that lane. At every intersection, we assume that each vehicle can choose to make either a left or right (if not a one-way road) or no turn. Mobility factor for each node is in between the range of “I” to “J” Kmph (Kilometers per hour). Border effect of bounded simulation region on vehicle mobility is accounted for by making vehicle reappear in the region.

5.2. Simulation Procedure

Simulation inputs are as follows: A= 5000m, B= 5000m, N= 50, V_{com} = 300m, I= 10 Kmph, J= 100 Kmph, L= 2, R = 4 mts. Simulation procedure for proposed cognitive agent model is as follows.

Begin

Generate VANET in given road length by placing vehicles uniformly.
Maintain a data structure at each vehicle to store information as specified by scheme.
Apply mobility to nodes.
Generate cognitive agency (agents are implemented as objects).
Compute performance of system.

End

5.3. Performance metrics

Some of performance metrics evaluated are Bandwidth utilized, Packet delivery ratio, Push latency, Push/Pull decision latency.

- Bandwidth utilized: It is defined as the amount of bandwidth utilized out of the total bandwidth available. It is expressed in terms of Mbps.
- Push Latency: It is total time taken by source vehicle to disseminate critical event information to all vehicles in VANET. It is expressed in terms of milli seconds.
- Push/Pull decision latency: It is the total time taken by vehicle to decide the generated event as Push or Pull. It is expressed in terms of microseconds.

5.4. Result Analysis

As shown in figure 3, for different mobility values like 40 Kmph, 60 Kmph, 80 Kmph and 100 Kmph, as the number of vehicles increase, the bandwidth utilization increases linearly. Bandwidth utilization remains constant if VANET has constant number of vehicles on the road. Push latency for the mobility values of 40 Kmph, 60 Kmph, 80 Kmph and 100 Kmph with varying number of vehicles is depicted in figure 4.
As shown in figure 5, as the number of sensors increase, Push/Pull decision latency increases linearly. For large number of sensors, Push/Pull decision latency remains constant. This is because of the efficiency of VMA in computation to decide the generated event as either critical or non-critical.

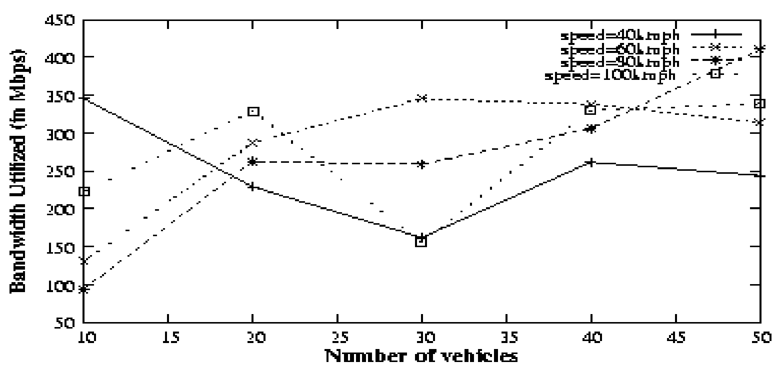

Figure 3. Bandwidth utilized Vs. Number of Vehicles

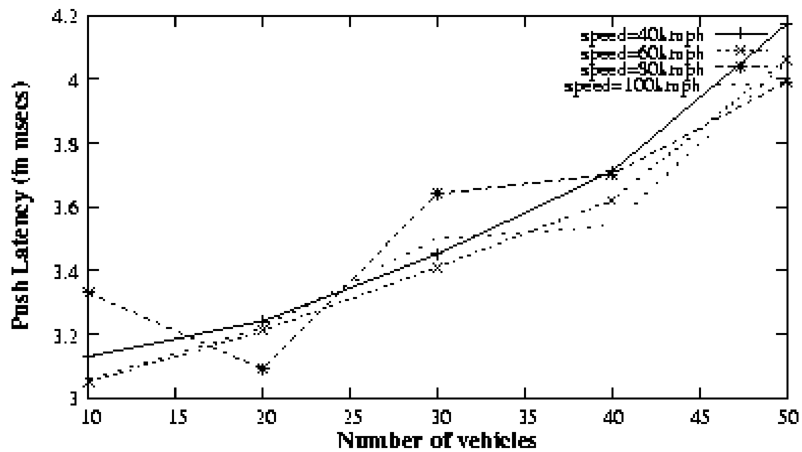

Figure 4. Push Latency Vs. Number of Vehicles

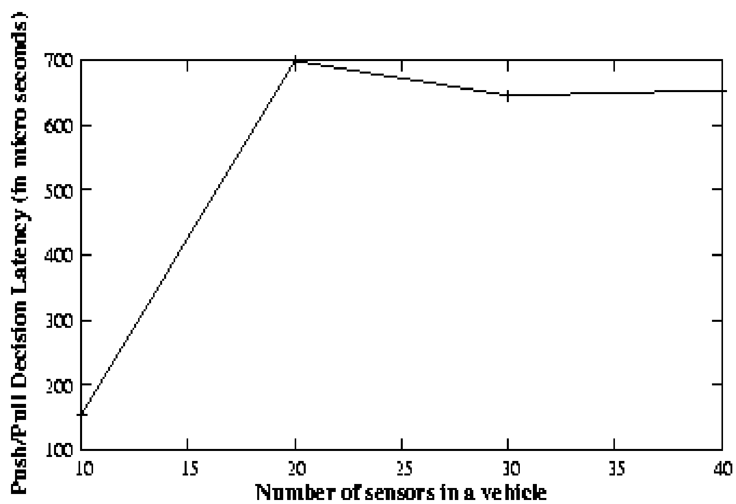

Figure 5. Push/Pull Decision Latency Vs. Number of Vehicles

6. CONCLUSIONS

There is a good future for applications of VANET, ranging from diagnostic, safety tools, information services, and traffic monitoring and management to in-car digital entertainment and business services. However, for these applications to become everyday reality, an array of technological challenges needs to be addressed. In this paper, we have developed an agent-based intelligent information dissemination in VANETs. Some of the issues like evaluation of the cognitive agent based model overheads including memory, computational and communication overhead, consideration of more number of lanes per road, etc., may considered for future work.

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