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Investigations on vehicles guided by updated road and maps

Abstract *The scope of this paper is to analyze performance of automatic vehicles during data dissemination with the realtime updated road information into the maps followed by the vehicle moments. Both modeling and development of the additional subsystems needed such as communications, reference/sensor systems and mobility are considered. The primary reason is that for solving both traffic congestion and safety problems to save time and fuel. The proposed location based algorithm analyses the features of complete automation of the driving function with suitably equipped road facilities.*

Streszczenie. *W artykule analizowano właściwości pojazdu automatycznego otrzymujące informacje o drodze w czasie rzeczywistym. Rozważano system przesyłu danych, system czujników oraz parametry ruchu przy kryterium oszczędności czasu i paliwa. (**Badania pojazdu automatycznego sterowanego za pośrednictwem mapy otrzymywanej w czasie rzeczywistym**)*

Keywords: VANET, Mobility, Data Propagation, Traffic Regulation.
Słowa kluczowe: pojazd automatyczny, sterowanie, przesył danych

Introduction

Automatic guided vehicles are becoming very common in the manufacturing industry where they have replaced human operated modes. The ideas of using AGV (Automatic Guide Vehicle) for human transportation have been recent attempts to implement. Users also have the added benefit of public transportation that they don't have to share with the public. We are assuming that the most appropriate solutions will involve the integration between the mobility model, clustering, vehicle moment and the roadway. The roadways will be equipped with suitable reference points and communication infrastructure, and that vehicles may also be equipped with devices such as radar. We have therefore not adopted the concept of a fully autonomous vehicle that could travel under automatic control on any road or street. The primary goal is to develop the technology to increase roadway capacity in order to alleviate congestion. As safety will be the dominant factor in the design of any automatic vehicle control system. The approach, therefore, is not to design a system to have no rear-ends collisions, but to design one in which the collisions that do inevitably occur have only minor effects[1].

Spacing Control

The analysis for controlling the spacing between vehicles shows that the significant improvements are obtained when the control system in each vehicle has access to better measurements. Specifically, safe spacing between the vehicles is facilitated when the control system in each vehicle has timely access to the following information's such as distance traveled per unit time, a rate of increase of velocity and interval between the vehicles.

Measurements should be made available within a few hundredths of a second. This delay is roughly in order of magnitude smaller than time constant of the vehicle dynamics, and its obtained by fitting a first-order model to be measured speed and acceleration of a vehicle. The speed and acceleration of each vehicle can be measured by sensors attached to it. Each vehicle measures the distance to its predecessor. Its difficult to use road-based distance measurements during high mobility conditions, made with video cameras or other sensors, which would then be transmitted to the vehicles[1,4]. The speed and acceleration of the preceding vehicle can, in principle, be derived from the previous two sets of acceleration and from the distance to the preceding vehicle. The technology has been chosen based on communication characteristics, effect of motion, and effects of environmental conditions, on the reliability, and on the cost anticipated for high volume production. The minimum amount of information to be transmitted to a vehicle comprises four numbers: speed and acceleration of the first vehicle and of the preceding vehicle. The number of bits required to specify each of these four numbers depends on the desired accuracy.

Radio Transmission

Conventional transmissions, at usual radio frequencies, are not very directional. The implications are that some procedure is required to identify the source of a received signal and different transmitters may compete for a common channel. These multiple access protocols are suitable when each transmitter only needs the channel infrequently and at irregular times to solve the multiple access problems. In our application, the vehicle transmitters must transmit periodically, at regular times, and frequently, by implementing round-robin way of sharing channel [5, 8].

The complexity of radio transmission for the real-time control of vehicles in a platoon, we decided to consider an alternative approach based on infrared transmissions. An infrared communication link uses an optical transmitter, an optical receiver, and the associated electronics. Optical transmitter in the front of each vehicle knows that it is listening to the vehicle in front of it. This essentially eliminates the interference and the multiple access problems. To determine the feasibility of such an optical communication link, one must identify suitable components and determine the characteristics of the transmission under typical operating conditions. We decided to construct a prototype to address those issues. Ultimately, the prototype will be tested on board vehicles.

Vehicle Lateral Dynamics Models

The transmissions take place back-to-back, at the maximum rate. Vehicle to include an indication of the delay it introduces in the propagation of the information. This can be done by using a special counter in the packet. This counter would indicate the number of packet transmission times during which the repeated information has been stored in vehicles. This counter could be incremented by each vehicle. This delay information can be used by vehicles to determine whether the transmission system is working properly. If delays become excessive, then the vehicles could modify their control actions accordingly. The radar provides measurements of the velocity difference between a vehicle and its predecessor and of the spacing between the vehicles. Acceleration is being estimated by differentiation of the velocity signals for the initial round of testing, but if this is found to be excessively noisy the vehicles will be equipped with accelerometers. The control work is focused on the concept of cooperation between the vehicle and the roadway, with an intelligent vehicle receiving much of the information it needs from special elements installed in the roadway [2,3].

Two dynamic models have been developed for the design and analysis of the vehicle lateral controller. A freedom nonlinear model representing the vehicle dynamics as realistically as possible and a linearized model retain only the lateral and dynamics. To verify that the vehicle lateral dynamics are adequately represented by the two models we are using for control design and for simulation of control responses. We also need to verify that the control system works as modeled and simulated when it is operating in the presence of real-world noise, external forces, and imperfections in the placement of the reference points and the road/tire coefficient of friction [8,9]. The speed of the vehicle is controlled by a radio remote control unit, while its steering is controlled using the control logic developed here. Its on-board data acquisition system records the test results for subsequent reduction and analysis.

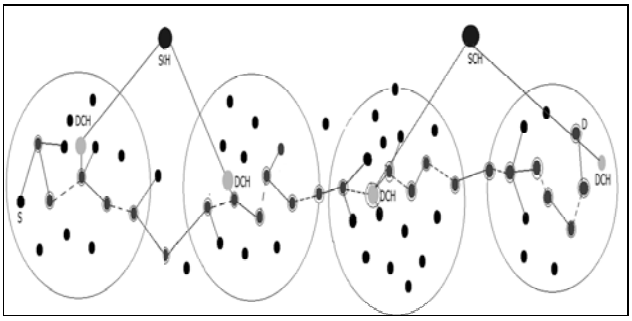

Fig. 1.Data Dissemination Scenario

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The reference information supplied by the road side units of a roadway test section is used to produce the control commands as shown in Fig 1. The driver of the test vehicle retains control by use of the steering wheel in the event the automatic system malfunctions in the tests. Subsequent tests at higher speeds are expected to be conducted on other facilities where additional space makes the higher speeds feasible. The experimental programs are expected to indicate how feasible the road side unit system is for lateral control and to show what performance improvements are possible with use of forward information about road geometry changes.

Unmanned guide vehicle (UGV), is a special vehicle without a human on board. It is controlled either autonomously by computers in the vehicle, or under the remote control or in another vehicle. The term unmanned guided vehicle emphasizes the importance of other elements beyond a vehicle itself. A typical UGV consists of the: Unmanned vehicle, Control system, such as Ground Control Station (GCS), Control link, datalink and support equipments. As the capabilities grow for all types of UGV, nations continue to subsidize their research and development leading to further advances enabling them to perform a multitude of missions. To distinguish UGVs from other vehicles, a UGV is defined as a vehicle that does not carry a human operator, can run autonomously and can carry a large amount of information database.

System Model

Each node is identified by a MAC address as well as a node identifier (NID). The NID is chosen by each node at random, included in the header of each packet transmitted on channel c_0, and changed if the node detects that its ID is already in use by another node [5]. Time is partitioned to frames consisting of a constant number of fixed duration time slots. The number of time slots per frame on channel c_m is denoted by s_m, m = 0,1.2 . . , M, and a time slot on channel c_m is identified by the index of this time slot within a frame on channel c_m is 3. On channel c_0, each frame is partitioned into three sets of time slots: L, R, and F. The F set is associated with RSUs, while the L and R sets are associated with vehicles moving in left and right directions respectively [13]. Every node is equipped with a global positioning system (GPS) receiver and can accurately determine its position and moving direction using GPS. The current position of each node is included in the header of each packet transmitted on channel c_0, and synchronization among nodes is performed using the 1PPS signal provided by any GPS receiver.

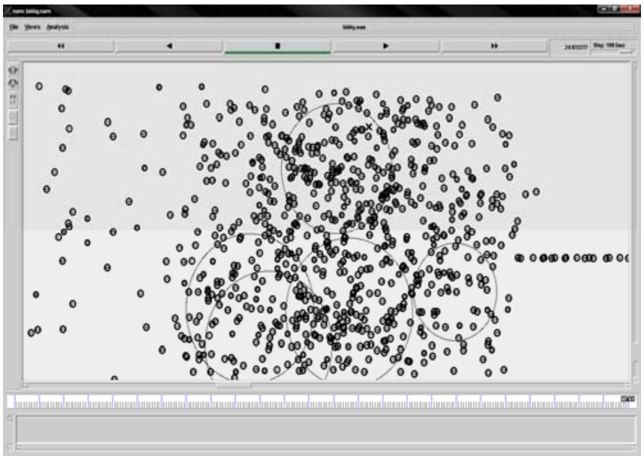

Fig. 2. Ns-2 Implementation of Real-time Scenario

Experimentation

These tests were used to validate the behaviors that been developed and tested in simulation as shown in Fig.2. Different behaviors were tested such as location searching, searching of road networks, searching of densely clustered areas. The test location was a large, relatively flat, unencumbered field approximately 500 meters by 1000 meters. The small building facsimiles were constructed in a small 50-meter by 50-meter portion of the field as shown in Fig 3. First two separate areas were defined in which a target might be located. One area consists of immediate vicinity of the buildings; a second larger area consisted of a larger rectangular area. Simultaneously a third objective was defined; the protection of a building central to the town. The vehicles responded to these objectives by first searching through the town for objects [14]. Data can then be forwarded between nodes according to the values in the routing table entries. When a vehicle wants to transmit data to multiple destinations, the intermediate 2-hop nodes select relay nodes based on the prediction of nodes that travel towards the destination.

Novel Routing Protocol

Parameters

BV - *Border Vehicle*
CID - *Cluster_ID*
CMID - *Cluster member_ID*
DCH - *Dynamic Clusterhead*
DVID - *Destination Vehicle_ID*
LID - *Location_ID*
MV - *Master Vehicle(bus)*
NV - *Neighbour Vehicle*
SCH - *Static Clusterhead*
SVID - *Source Vehicle_ID*
VCID - *Virtual cluster_ID*
VID - *Vehicle_ID*

```
VANET( LID,VID, States)
        Partition the geographic area into clusters
        Each location have LID
        Mount SCH at selected locations
  1. if  VID = CMID
        {
           a. unclustered member(CMID)
                    + timestamp.
           b. set state = 'undecided'
           c. static clusterhead  <-  entry(CMID)
        }
  2. if VID = new(MV)
        {
           DCH  <-  MV
           SCH   <-  entry (DCH)
        }
  3. if CID  <-  unclustered VID
        {
         if timestamp  >  threshold time
           {
             flood hello messages to all its NVs
             &  form virtual  cluster with unique VCID
                SCH  <-  entry(VCID)
           }
        }
```

This type of routing strategy leads to data load spreading across the network according to the estimated quality of the paths. When a path is damaged, it will be avoided, and congestion will be relieved. However other paths will be overloaded, leading to higher congestion, which will make their end-to-end delay increase. However the relay nodes try to spread the data load evenly over the network by flooding. During data transmission, the source node sends out proactive beacons. Initially they are normally unicast from source choosing its 2-hop neighbors according to the table values. In this way they serve two purposes. If a forward beacon reaches the destination in a single broadcast it simply validates an existing route. It gathers updates and quality estimates of this path and updates the source routing table values. The beacons broadcast at any point will update only the new routes. It is possible that in 2-hop neighbors the information of further vehicles pointing towards the destination may be missing. In such a case broadcast is triggered again. The beacons will then quickly grow and flood the network, like reactive routing. To avoid iterative flooding a limit is set for flooding, it may be maximum value of five. In order to guide the data packets, hello messages are used.

These messages are broadcast every *'t'* seconds by the nodes. If a vehicle receives a hello message from any other new vehicle, it will add it as a destination in its routing table. After that it expects to receive a next hello from that node after every *'t'* seconds. Using these messages, each vehicle knows about their immediate and intermediate neighbours and its routing table is updated with routing information of those neighbours.

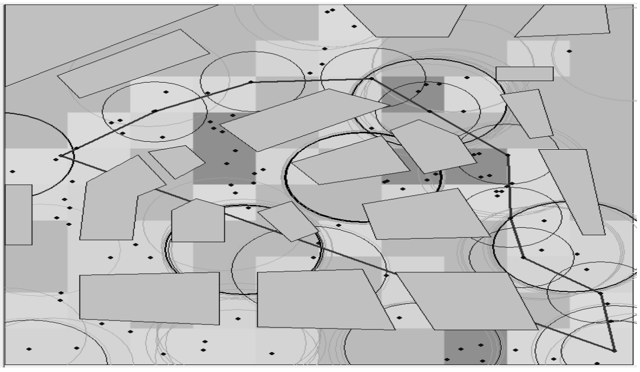

Fig. 3. Realtime network formation in city scenario with buildings

Protocol Overview

Static and dynamic clusterheads maintains a routing table that records all the *vehicle_id* of its neighbour clusterheads. Vehicles exchange information using flooding followed by multicasting approach, i.e., every source should flood the beacon message regularly and each of its 2-hop will choose the direction towards the destination and do the multicast operation. If any node wants to send data to the destination it will immediately check the routing tables of neighbour nodes for a path to destination. In a high mobility situation the links are broken because for each vehicle the former clusterhead moves away or a cluster member does not receive beacon packets continuously from its clusterhead. Thus, a vehicle after entering a new cluster area will choose either a static or dynamic clusterhead as its new clusterhead. After distributing beacon packet in a new cluster, the clusterhead is informed that a new member has joined its transmission range. After receiving beacon packets from the clusterhead, communication is established between member and clusterhead.

The omnidirectional antennas in each vehicles aid the sender to reach the destination nodes located at different distances, by adjusting the transmission power level. Each node in a cluster maintains the multicast forwarding state for L2MF. A *type_flag* in each vehicle indicates if this node is a source, receiver, or forwarder or both a receiver and a forwarder. Within the cluster the directed path from the source to the destination will be established through the clusterhead. It shall be seen later that this information is used to avoid loops in the multicast process. Each node should contain neighbor node entries in its routing table that are within its maximum transmission range. Each entry in the table includes a past history of routing. Each node periodically transmits beacon signals to the maximum transmission range such that the distance information between any two nodes can be found out. If Global Positioning System (GPS) is available, such distance information can also be obtained by exchanging coordinates included in the beacon. During data distribution, the source will periodically initiate flood at a low frequency by sending beacon messages. Beacon message contains the source address, neighbor node addresses, sequence number and flags.

The beacon messages are propagated to keep each vehicle in the cluster to be updated with messages of forwarding state. The beacon messages propagating with the maximum transmission power allow neighboring nodes to exploit the information in a multicast fashion to perform the operations of link maintenance and lifetime enhancement. Traditional VANET multicast algorithms use the same transmission power for data delivery. L2MF algorithm, on the other hand, uses the hierarchical clustering algorithm to group the vehicles, monitor the mobility of vehicles and adjusts its transmission range. When a vehicle receives a multicast packet, it checks the *type_flag*. If it is a relay node, it should forward the packet to all its 2-hop by a single transmission. If it is a destination, it passes the packet up to the protocol stack to allow the packet to be processed.

The possibility of destination choosing the same route to acknowledge the reception of packets is very less due to dynamic mobility nature. Before starting the backward propagation, destination node starts to propagate parameters, like speed, direction and deviation. The intermediate nodes also record the information from destination to source but do not broadcast it. Thus, more than one route will be discovered between source and destination and vice versa. After the source node receives the beacon messages from the destination, it sets up multiple paths from source node to destination node. According to the number of intermediate nodes, delay and bandwidth included in the path, they are classified into optimal path, shortest path and so on. Each path is weighed based on the number of hops, delay of transmission and bandwidth included in the route table. Large packets are fragmented into smaller ones to solve the unreliability of the network. According to the weight, L2MF distributes the fragmented packets over the available paths. The data load is distributed over multiple paths in order to minimize packet drop rate, achieve load balancing, and reduce end-to-end delay.

Simulation considering AODV, DSDV AND L2MF

The L2MF algorithm is evaluated in a number of simulation tests. Ns-2 simulator is used for the comparison of the performance of AODV, DSDV and L2MF. Ns-2 traces files are analyzed using tracegraph [12]. Simulation considering the number of vehicles ranges from 50 to 500 are placed randomly in an area of 2500m × 2500m. Each experiment is run for 2000 seconds. Data traffic is generated by 25 constant bit rate (CBR) sources. The sources send one 512-byte packet per second. Each CBR source starts sending at a random time between 0 and 180 seconds after the start of the simulation, and keeps sending till the end. At the physical layer a two-ray signal propagation model is used.

Table 1. Simulation parameters for L2MF

Parameter	Values
Simulation time	2000s
Simulation area	2500m × 2500m
Communication range	250m
Vehicle speed	[10-120] km/h
Bandwidth	11Mbps
Number of vehicles	50-500
MAC type	IEEE 802.11
Mobility model	RWP and RPGM
Routing protocol	AODV, DSDV and L2MF
Packet size	512 bytes

The radio propagation range of the nodes is 250m. For the different experiments in this setting, the mobility patterns of the nodes were varied. The tests with random waypoint mobility model were done to know the variations of the vehicle speed and the pause time. In Group Mobility Model, analysis is based on its location and speed. The mobility movements were generated with the BonnMotion software and the simulation parameters for L2MF are shown in Table 1.

Impact of Vehicle Density

Data packet delivery ratio is considered as the metric for measuring the performance at various vehicle densities. Fig. 4 shows the impact of vehicle density on data packet delivery ratio. The L2MF achieves a better delivery ratio at the time of less vehicle count because of its flooding nature. In high vehicle density, overhead increases resulting in delivery ratio decrease. Compared to AODV and DSDV, L2MF performs better because of data distribution throughout the network. AODV can perform a local repair to the source node using routing tables. AODV uses sequence numbers maintained at each destination to prevent routing loops.

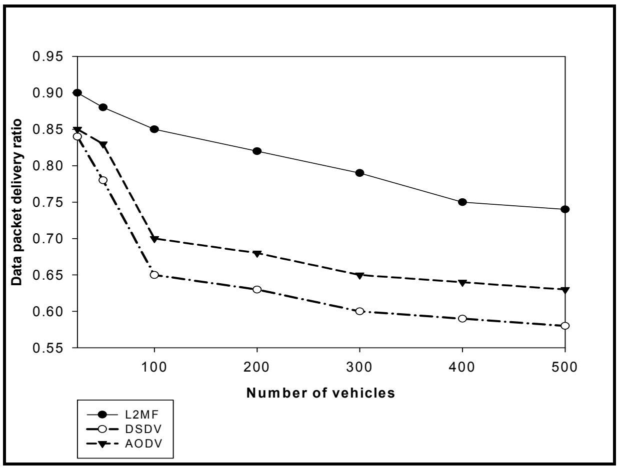

Fig. 4. Data packet delivery ratio at various vehicle densities

The on-demand nature at high vehicle density results in decrease in the delivery ratio because of increasing delay. DSDV avoids loops by tagging route information for each destination with a sequence number originated by the destination. It also prevents routing fluctuations by delaying advertisements of possibly unstable routes. DSDV uses hop distance to bind the scope for routing message update. It computes the shortest path routes either by using topological information of the whole network resulting in increase in overhead and decrease in delivery ratio at high vehicle density.

Fig. 5 shows the delay of transmission during different vehicle density situations. At low-density conditions, L2MF reduces delay. In high-density conditions, node dispersion increases delay. In AODV, delay increases because of hop-by-hop search process. In L2MF, when the retransmission and acknowledgement mechanism detects that the link is broken, the detecting node returns a *route_error* packet to the source of the packet immediately. The node will then search its route cache to find if there is an alternative route to the destination. Whenever *route_error* packet is received, the link in error is removed from the local route cache to avoid further delay. However in AODV, a source node needs to send a packet to a destination node for which it has no routing information in its table. Each node remembers only the next hop and not the entire route, as in source routing. Once the next hop becomes unreachable it will wait until it finds the new route resulting in increase in the delay. In DSDV, the searching process in the table entries increases the delay of transmission. It includes all possible delays caused by queuing; retransmission at the

MAC, propagation, and transfer time, DSDV performs better than AODV at high-density condition.

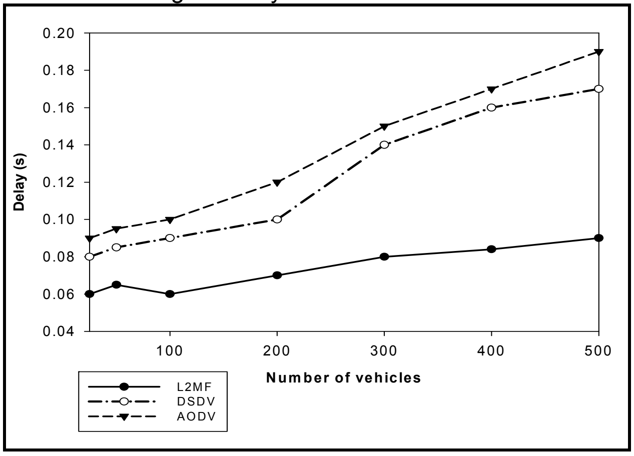

Fig. 5. Delays of transmission at various vehicle densities

Analysis of L2MF during Mobility

Data packet delivery ratios in random waypoint scenario at different vehicle speeds are shown in Fig.6. There is no additional overhead observed at low mobility. L2MF, uses ocal repair mechanisms, hence data packet delivery ratio decreases slightly when the mobility level is high. The hierarchical clustering of L2MF tends to locate the farthest node quickly, resulting in an improved delivery ratio than AODV and DSDV.

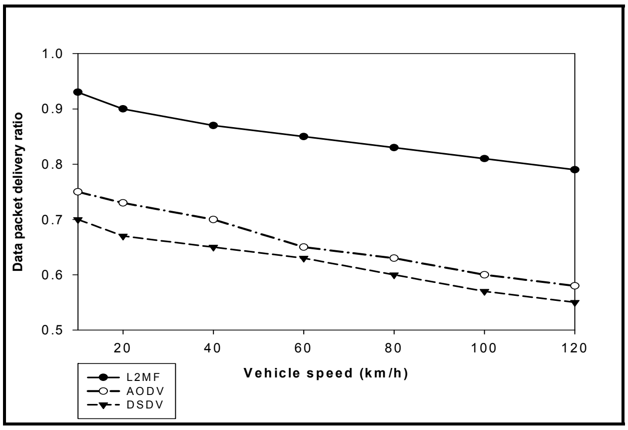

Fig. 6. Data packet delivery ratio at various vehicle speeds under RWP scenario

L2MF is an adaptive one in which vehicles uses continuous learning to update paths, and use these to search for new paths. AODV on the other hand is a reactive algorithm; it will restart from its original state after every route failure. In a large-scale environment, AODV generates routing overhead only when there is data traffic to send, and thus has been traditionally considered more suitable for adhoc wireless networks and it tends to cause heavy overhead due to the large-scale flood search triggered by motion. AODV generates more routing overhead than the number of data delivered.

DSDV relies on periodic exchanges of routing information. They do not scale well because they propagate routing information of all nodes throughout the network. With random mobility, frequent updates are required to keep the information up-to-date, thus producing a large amount of control overhead resulting in decrease in the data packet delivery ratio.

Conclusion

The technologies of automatic vehicle control are sufficiently challenging that we expect numerous iterations of design and testing to follow from the work we have initiated before the AGV systems are in the possession of everyday drivers. Many years of effort will be required to refine system designs, and especially to incorporate the needed safety and reliability capabilities. In the absence of such facilities, progress on these technologies will soon stall because we will have reached the limits of what we can learn using the presently available facilities.

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