A Survey and Comparative Study of Vehicular Traffic Control System (VTCS)

V. B. Vaghela
Associate Professor (EC)
SankalchandPatelCollege of Engineering,
Visnagar, Gujarat, India

D. J. Shah
Principal
L. C. Institute of Technology
Bhandu, Gujarat, India

ABSTRACT
This paper presents a survey on vehicular traffic control systems over wireless networks. A brief outline is given for vehicular traffic control systems then they are compared with various parameters. The challenges in designing the essential functional components and the corresponding protocols (for radio link control, routing, congestion control, security and privacy, and application development) are discussed and the related works in the literature are reviewed. The open research challenges and several avenues for future research on vehicular traffic control over heterogeneous wireless access networks are also outlined.

General Terms
Vehicular traffic control system

Keywords
Agent, Mobile Ad-hoc Network, Vehicular Ad-hoc network.

1. INTRODUCTION
There is a growing need for the improvement of the efficiency of urban traffic in order to ensure the sustainability of modern cities. It is now recognized that this objective requires not only the improvement of traffic monitoring and management schemes in traffic control centres but also the provision of information services for ordinary road users. With the advent of increasingly sophisticated traffic management systems, such as those incorporating dynamic traffic assignments, more stringent demands are being placed upon the available real time traffic data. With the existing vehicular traffic control systems following transportation needs or issues are identified:

- Lack of real-time traffic information.
- Lack of access to travel information and 24 hour real-time alternate route information.
- Better alternate route guidance.
- Peak time freeway congestion and reversible lanes for evacuation routes.
- Lack of readily available transit information to increase ridership.
- Dedicated lanes for emergency services, police, public transport, etc.

1.1 Mobile Ad hoc Network (MANET)
- MANET is an infrastructure-less network, that means there is no existence of any infrastructure like router, base station, etc. Nodes in MANET, themselves have to work to discover the network topology and also work as a router to route the packets. Since all the nodes are not in range, nodes use intermediate node(s) as a router (or hop) to route the packets. More details about MANET are available in [1], [2].
- Some important features of MANETs are:
- Host is no longer just an end-system; it also acts as a router.
- Every node can be mobile; hence network topology may change over time.
- The mobile nodes have a limited power capacity.
- There is limited wireless bandwidth for communication.
- The channel quality is varying.
- There is no centralized entity, i.e., the network is distributed.

1.2 Vehicular Ad hoc Network (VANET)
A Vehicular Ad hoc Network (VANET) is a subclass of Mobile Ad hoc Networks (MANETs), to provide communications among nearby vehicles and between vehicles and nearby fixed equipment, usually described as roadside equipment. These networks have no fixed infrastructure and instead rely on the vehicles themselves to provide network functionality. However, due to mobility constraints, driver behavior, and high mobility, VANETs exhibit characteristics that are dramatically different, from many generic MANETs. These characteristics have important implications for design decisions in these networks. These characteristics are as follows [3]:

- Rapid changes in the VANETs topology are difficult to manage. Due to high relative speed between vehicles network's topology changes very fast.
- The VANET is subject to frequent fragmentation, even at a high rate of deployment.
- The VANET has small effective network diameter. Rapid changes in link's connectivity cause many paths to disconnect before they can be utilized.
- No significant power constraints, unlike sensor and other types of mobile networks where limited battery life is a major concern.
- Potentially large-scale: In a city center or highways at the entrance of big cities the network could be quite large scale.

Variable Network density: The network's density depends on vehicular density which is highly variable. In traffic jam situations the network can be categorized in very dense networks whilst in suburban traffics it could be a sparse network. The topology of the network could be affected by driver's behavior due to his/her reaction to the messages. In other words the content of messages can change network's topology.

Various parameters are compared in the following Table 1.

Table 1. Comparison of MANET with VANET

Sr.No.	Parameters	MANET	VANET
1	Cost of production	Cheap	Expensive
2	Change in n/w topology	Slow	Frequent and very fast
3	Mobility	Low	High
4	Node density	Sparse	Dense and frequently variable
5	Data rate	Few Hundred kbps	Few Thousand kbps
6	Range	Upto 100m	Upto 500m
7	Node Lifetime	Depends on power resource	Depend on lifetime of vehicle
8	Multihop routing	Available	Weakly available
9	Reliability	Medium	High
10	Moving pattern of nodes	Random	Regular
11	Addressing scheme	Attribute based	Location based
12	Position acquisition	Using ultrasonic	Using GPS,RADAR

The rest of the paper is organized as follows; section II presents the research work carried out in the field of vehicular traffic control using various approaches, section III gives discussion and suggestions and finally section IV draw conclusion.

2. VEHICULAR TRAFFIC CONTROL SYSTEMS

In this section, some of the Vehicular Traffic Control Systems (VTCS) developed using conventional database approaches and other approaches are discussed.

2.1 VTCS with database approach:

Some of the Vehicular Traffic Control Systems (VTCS) developed using conventional database approach is discussed here.

CarNet [4] is an application for a large ad hoc mobile network system that scales well without requiring a fixed network infrastructure to route messages. CarNet places radio nodes in cars, which communicate using Grid, a novel scalable routing system. Grid uses geographic forwarding and a scalable distributed location service to route packets from car to car without flooding the network. CarNet will support IP connectivity as well as applications such as cooperative highway congestion monitoring, fleet tracking, and discovery of nearby points of interest.

In [5], authors presented Traffic View that is a device that can be embedded in the vehicles to provide the drivers with a real-time view of the road traffic far beyond what they can physically see. The vehicles equipped with Traffic-View devices disseminate traffic information using short-range wireless communication. Traffic-View devices construct an ad hoc network on-the-fly, which changes dynamically to reflect the current traffic situation. Traffic-View defines a framework to disseminate and gather information about the vehicles on the road. Using such a system, a vehicle driver will be aware of the road traffic, which helps driving in situations like foggy weather or finding an optimal route in a trip several miles long.

The work discussed in [6] presents the concept of distributed databases in traffic event detection and management. Authors presented various issues related to the development of integrated software architecture for a traffic incident monitoring, mitigation, and analysis system. The set of distributed databases are used for distributed coordination of sensing, control, and analysis algorithms. The semantic event/activity database in the integrated architecture is used to provide high level abstractions to model traffic incidents and traffic behaviors. In distributed architecture, every functional component of the architecture is logically distributed. The logical distribution of functions is mapped to a physical configuration of sensor and actuator clusters and to clusters of workstations. An important function of the architecture is to provide interfaces for incorporation of algorithms for the analysis of the monitored environment. These analysis algorithms are typically distributed and use the distributed database query interfaces. Typical functions provided by analysis algorithms are classification of objects, clustering of usual traffic related events and behaviors, etc. These databases can be broadly divided into two classes of world and system databases. The world databases deal with the abstracted state of the monitored environment, whereas the system databases deal with the abstracted state of the monitoring system.

In [7], a knowledge based traffic control architecture proposed. Authors proposed the two basic ways of controlling traffic by controlling traffic lights are signal plan modification, and signal plan selection, where the former changes the signal plans dynamically according to the traffic in one junction, and the latter chooses the best out of a predefined set of signal plans either for the traffic environment as a whole, or in one singular junction. The proposed system architecture consists of a centralized database and agents based architecture. The central database consists of a traffic model coupled with functionality for construction and maintenance of this model. The traffic model is a representation of the actual traffic in the modelled environment. The database is used as a blackboard in the way that all the agents operate on and communicate through it. The agents use this traffic model in their problem solving procedures. Agents perform the actual reasoning in the system. The agents are divided into different functional groups like: Data collection and completion agent which disseminates the available detector information to all objects in the traffic model; The Data Analysis agent interprets the disseminated detector information and tries to recognize known traffic situations and possible causes of congestion; The Traffic prediction agent predicts future traffic loads on the basis of the given qualitative and quantitative traffic information; The traffic control agent performs the signal plan selection process.

A concept of estimation of vehicle trip table in real time is described in [8]. The method uses traffic cookies placed on in-vehicle computers to maintain the state (current trip) of vehicles moving through the system. These cookies are persistent from day to day; they form a complete travel history for a traveler or vehicle. The method leverages the vehicles themselves to store their own travel data, and then physically carry that data around the network. This paper describes an approach to solving the problems like: how to uniquely identify a vehicle, track that vehicle as it moves through the system, store the collected data, process the data for use in traffic management applications, transmit the collected data and/or the processing results to local control hardware, and address privacy concerns - by making the traveler a partner in the process of traffic monitoring and control.

The concept of map database for navigation and driver assistance is proposed in [9]. Here, author proposed use of map database for creating driver assistance and as a reference for other data sources that enable dynamic route guidance. In [10], authors developed the distributed shared memory system to provide real time traffic data and the range of information services for distributed traffic monitoring. The developed structure is a Distributed Memory Environment (DIME) that manages the data from a number of sources (Traffic Control Centre, public transport company and the user).

The work [11] presents a framework to model the potential benefits from dynamic vehicle on-line routing in a distributed traffic information system based upon a vehicle-to-vehicle information-sharing architecture. Within this framework, based on real-time and historical traffic information, vehicles independently optimize their routes, forming a self-organizing traffic information overlay to the existing vehicular roadway network. Authors proposed a model for in-trip rerouting decisions arising from drivers' interactions according both to a rational-boundary model and to a binary-logic model under the assumption that each driver is a rational entity.

2.2 VTCS with other approaches:

There are several approaches reported to vehicular traffic control. Some of the existing works which use approaches like multi-agent technology, information transfer protocol, and traffic cookies are discussed.

Multi-agent system based vehicular information ad-hoc networks presented in [12]. This describes the some of the most promising applications of the VANETs like traffic control and safety information, location-dependent services and access to fixed infrastructure.

Vehicular Information Transfer Protocol (VITP), an application-layer communication protocol, proposed in [13] is designed to support the establishment of a distributed, ad-hoc service infrastructure over VANET. The VITP infrastructure can be used to provide location based traffic-oriented services to drivers, using information retrieved from vehicular sensors and taking advantage of onboard GPS navigation systems. Authors introduced the VITP, specifying the syntax and the semantics of messages between VITP peers. A VITP peer runs on the computing device of a vehicle, uses its IVC (Inter-Vehicle Communication) capabilities, and accesses the vehicle's sensors to retrieve useful information. VITP peers establish on-demand dynamic, ad-hoc groups, which collect, communicate, and combine information from the on-board sensors of different vehicles in order to resolve incoming requests.

A test bed for multi-agent [14] control systems in road traffic management is described in [15]. The work describes how the activities of the agents that comprise the multi-agent system should be coordinated with managing different levels of complexity, a diversity of policy goals, and different forms of traffic problems such as vehicle oriented and road oriented traffic problems. The decentralized traffic control concepts are proposed by authors with the multi-agent system for hierarchical control, intra controller, and inter controller coordination.

Sentient future competition the vision of cooperating vehicles that help to keep roads free of traffic congestion is presented in [16]. This vision explores the concept of dynamic-time-space corridor (virtual slot) that can be negotiated between cooperating vehicles to guarantee congestion-free journeys from departure to arrival. In the proposed technique, cooperating vehicles that can sense their environment will be able to implement virtual slot system. These vehicles will be able to determine their position, speed, and direction and then successfully negotiate access to a virtual slot. Once a slot is assigned to the vehicle, the vehicle must not stray from the slot and thus speed and direction must be controlled.

In [17], traffic congestion discovery and dissemination techniques in VANET presented. The work uses combination of clustering and epidemic communication for traffic information discovery and dissemination by use of standard GPS driving aid and peer-peer wireless communication.

In [18], concept of artificial intelligence is integrated with VANET to create driver aid that helps in combating traffic congestion as well as embedding safety awareness by dynamically rerouting traffic depending on road conditions.

3. DISCUSSION AND SUGGESTION

Intelligent Transport System (ITS) applications can be supported through vehicle-to-roadside (V2R) and vehicle-to-vehicle (V2V) communications. V2R communications involvevehicular nodes and road side base stations. IEEE 802.11 (WiFi) [19], IEEE 802.16 (WiMAX) [20], and Dedicated Short Range Communications (DSRC) [21] technologies can be used in this model of communication. In particular, with the DSRC standard, onboard units placed at each vehicle can send or receive data to or from roadside units. However, if a vehicle cannot directly send its data to a road side unit, it can relay its data to other vehicles until the data reach the road side units using a multi-hop transmission strategy [22]. There are several applications for this communication model such as electronic toll collection, infotainment services, safety message dissemination, and web browsing. Besides the on-board computer and communication interface, on board units are typically equipped with a Global Positioning System (GPS), which provides information on vehicle position in real-time, and an event data recorder, which stores relevant data that, in case of an accident, can be used in forensic analysis. Road side units act as base stations or access points, and are connected to application servers.

Three general types of applications are anticipated to be developed over vehicular networks. Safety applications are the first type of applications that improve the safety of the passengers on the roads by notifying the vehicles about any dangerous situation in their neighbourhood. Well-known examples are collision warnings such as notifications about a chain car accident, warnings about road conditions such as slippery road, approaching emergency vehicle warning, etc. The main concern here is finding low-latency, reliable, and efficient methods for disseminating safety data among neighbouring vehicles. A large number of data dissemination mechanisms were proposed in the literature. While many of these works rely on repeaters and (or) access points (APs) for disseminating the safety data [23], [24], some other works suggest that infrastructure-independent fully ad-hoc communications suffice [25], [26].

Another type of applications is traffic applications that call for the deployment of Traffic Information Systems (TISs), which carry out traffic management and provide drivers with the traffic situation and road information. The drivers use this information to avoid congestion and to find the route with minimum delay to their destinations. In other words, TISs aim at balancing the vehicular traffic on streets in order to use the capacity of streets and junctions efficiently and consequently save the lives and reduce the travel time and waste of energy. One of the seminal TISs is self-organizing traffic information system (SOTIS) [27], in which each road is divided into several segments, and vehicles send the average velocities of the segments periodically. All these studies, however, are fully ad-hoc TISs and suffer from large delays at far distances and not having a reliable mechanism to make sure that every vehicle is provided with all the traffic information it needs. The coexistence of intelligent agents and ubiquitous database could overcome this problem. This review includes the concepts considered and analyzed in existing collections of papers obtained as the outcome of some recent and ongoing research projects [28–37].

4. CONCLUSION

We have performed extensive survey VTCS applications. VANETs have increased popularity in researchers and generated an interest to develop more realistic and accurate model for it. The vast majority of VANET research has focused on road vehicles and safety, examining applications that include mobile Internet, intersection collision avoidance, and automated conveying. We hope this survey will be useful to the researchers who are hungry to do research in this area.

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