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VANETs-A Platform for the Future Intelligent Transport System (ITS)

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Abstract: VANET is a type of ad hoc network in which moving cars are considered as the nodes. These nodes can communicate with each other and forms an Intelligent Transport System (ITS). This will be useful in a wide range of applications that include driver safety, entertainment related and improved navigation. A lot of research has been done in VANETs considering different problem areas that include routing protocols, architecture, security, protocols for physical layer and link layer, clock synchronization, vehicle mobility, etc. In this study, researchers give a detailed review on VANETs, its applications, its prospective research areas and the tools useful for research. This study will be very helpful for researchers working in this area and will be a complete guide survey, comparison and reference.

Key words: Vehicular Ad hoc Networks (VANETs), Intelligent Transport System (ITS), vehicular communications, protocol, security

INTRODUCTION

In today's world driving is becoming an indispensible part of everyone's life. The number of drivers on the road has been steadily increasing over the years. There are more vehicles on the road than ever before. This traffic congestion is sure to keep increasing over the years. With this the need for driving safety has become very important. There are many preliminary precautions currently being used like seat belts and air bags. However, there are problem due to the drivers inability to foresee certain situations, e.g., speed of other vehicles, sudden braking, animal on the road, etc. The average time taken for a person to perceive and react to a certain incident is 1.5 sec. This time is sometimes not sufficient enough to prevent accidents. It will be helpful if some sensors can detect the situation and transmit alert messages through wireless communication to the drivers at fixed intervals. This could buy some extra time for the drivers to react to a situation and thus eliminate or limit the risk of potential accidents. One promising technology of the future that focuses on this is VANETS.

Background: There has been a lot of advancement in hardware, software and communication technologies over the last years. This has also led to the development and design of different types of networks that are deployed in varied environments. One such interesting field in which networks and communication have crept into is the vehicles on road. It is an area with tremendous potential of growth (Chandrasekaran, 2007). Communication between vehicles using communication technologies (e.g., cellular networks, Bluetooth) has become very common. However, direct communication between two vehicles has been under research in the past decade. Communication using optical laser or infrared laser has been proposed by Fujii *et al.* (1995), Sasaki *et al.* (1994) and Mizui *et al.* (1994). In this each vehicle can communicate with the vehicle directly in front of it and the one directly behind it in the same lane. This system has the drawback that each vehicle can communicate with only two vehicles at a time. The communication is also very sensitive to the alignment of the vehicles and weather conditions like rain, fog or snow. Another method proposed is communication using Radio Frequency (RF) (Kremer *et al.*, 1993; Valade, 1995). Here, the vehicle can broadcast to all the vehicles in its range. VANET is a mobile network with the moving cars as the nodes. These nodes communicate with each other as well as with the roadside equipments. The communication can take place between car to car or between car and roadside units within short ranges of 100-300 m. VANETs are self-organizing and decentralized systems. These days cars are equipped with devices to sense the surrounding environment. Researchers are working hard to develop Intelligent Transport Systems (ITS) in which the vehicles can communicate with each other as well as with roadside infrastructure. This will pave the way for development of smarter communication technologies that will be helpful for many applications that are currently under research.

Practical applications: Here are some practical examples where VANETSs could aid in improving driving safety, prevent accidents and delay.

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Roaming animals: Sometimes animals keep roaming on the roads causing accidents (Sourour and Nakagawa, 2008). In US, in the year 2000 out of 6.1 million crashes, 247,000 crashes were deer-vehicle collisions. This lead to about 200 human deaths, many deer deaths and property damage of about $1.1 billion. Using VANETs, any vehicle that spots this can pass on the information to the approaching vehicles thus helping the drivers to drive cautiously.

Poor visibility: In hilly places fogs often cover the roads affecting visibility. The visibility can be reduced to 10-20 m. The visibility is also reduced at night times and during heavy rain or snow. In such cases if vehicles can communicate with each other about their position, speed, etc; it will be useful in avoiding accidents.

Unfavorable road conditions: This includes a wide range of unexpected emergency situations like an accident in the road, slippery roads due to heavy rains or a fallen tree that is blocking the road. An alert message by one vehicle can prevent chain accidents by helping the approaching drivers to take timely decisions. Similarly, whenever a route is occluded due to traffic jam if the approaching vehicles can be notified, they can take alternate route and avoid the traffic. A curvy or steep road ahead can be cautioned to the following vehicles by the front vehicle. This way the approaching vehicles can take precautionary steps or take an alternate route.

Unexpected vehicle failure: Anything can go wrong with the vehicles at the most unexpected time. It can be brake failure, driver fatigue or some other vehicle repair. If the sudden applying of brakes can be communicated to the following vehicles, it can help prevent collisions.

VANET

Characteristics of VANETs: Some of the major characteristics that distinguish VANETs from other mobile ad hoc networks are:

- VANET nodes: the nodes in a VANET are vehicle nodes and the roadside units. All the nodes act as transmitters and receivers
- Topology: vehicles keep moving continuously which results in rapid topology change
- Mobility: vehicles run on pre built highways and roads. Hence, the motion pattern of the vehicles can be predicted based on the road topology and layout
- Speed: the nodes in a VANET move at a very high average speed compared to MANETs
- Node density: the number of nodes in a VANET can be very high in busy highways and very sparse in remote highways. Similarly in a particular place, the traffic may be at peak during busy office hours and minimum during midnight hours. Hence, any protocol designed should take into consideration both scenarios (Dotzer, 2006)
- Frequent disconnections: since vehicles are constantly moving, the communication links between them are constantly established and broken. In remote highways where the vehicle density is low, existing links can break before the new links are formed. This may lead to temporary disconnections of the network
- No energy constraints: since the nodes in a VANET are vehicles, they have constantly recharging batteries. Due to this abundant resource, vehicles can be equipped with GPS or other devices
- No infrastructure: the communication between nodes in VANET is direct and does not rely on any underlying infrastructure. However, it can be connected with the infrastructure too
- Unbounded network size: VANETs are highly scalable as it can span through regions of one city or several cities
- Better security: VANET nodes are more secure than nodes of other wireless networks

Applications of VANETs: The wireless technology has become cheaper and permeating in the last decades. This promises many innovative vehicular applications in the future that include.

Safe smart driving: These applications focuses on giving timely alerts to the drivers about collisions, poor road conditions, traffic jams, etc. They also include providing real time guidance to drivers while merging, driving uphill/downhill or in curvy roads.

Post accident investigation: The roadside devices can store information about accidents that can be used later. This will be helpful for investigators in forensic reconstruction and for insurance companies.

Media applications: This includes web browsing, accessing emails, video streaming, etc. The time that would otherwise be wasted in travel, traffic jams, toll gate queues can be used productively for personal or official work if connected to the internet. With the help of VANETs, one can check mails, use Skype or watch a movie while on the road (http://en.wikipedia.org/wiki/Vehicular_ad-hoc_network).

Research in VANETs: There has been quite a few works in the area of VANETs. The Car 2 Car Consortium (http://www.car-to-car.org/) is a non-profit organization in Europe. Its main aim was to improve road safety using V2I and V2V communications. In 2008 the European Union reserved a radio frequency for vehicle applications. In 2009, the dash driver network was started in Sunny Valley, CA that allows drivers to broadcast their location and speed. A central collecting entity collects the broadcasted information from all the vehicles, compiles it and transmits the updated traffic information to all the vehicles. A project by Google called the Google Driverless Car involves developing the technology for autonomous cars or "self driving" car (http://en.wikipedia.org/wiki/Google_driverless_car). The system combines the information gathered from Google Street View along with the artificial intelligence software and the input from the video cameras inside the car. A LIDAR sensor on top of the vehicle, radar sensors on the front of the vehicle and a GPS position sensor attached to one of the rear wheels helps to locate the position of the car on the map. Google anticipates that this automated driving system could help reduce road accidents and also use the space on roadways more efficiently. Some of the other ongoing research in the area of VANETs includes:

- Vehicle mobility: as researchers discussed earlier, vehicles move in pre defined roads. However, the mobility still depends on many factors like traffic density, weather conditions, unexpected incidents, etc. There is research focused on this topology change and routing
- Vehicle count: the number of vehicular nodes in a VANET varies drastically. In remote roads there may be just 1-2 vehicles whereas in busy highways there may be heavy traffic
- Security: VANETs are public networks. Most of the applications of VANETs are related to driving safety, accident avoidance, etc. that related to life or death situations. It is very crucial that an attacker is not able to modify the data or insert unwanted data. In the recent years research is done on different security issues like encryption, different attacks-its detection and prevention, etc
- Channel utilization: the available bandwidth for wireless communication is scarce. Some applications that broadcast packets demand high bandwidth usage
- Cost optimization: VANETs have not been implemented much in real time due to the cost involved. There have been various ideas proposed to optimize cost by including road side sensor nodes in the network, reducing power consumption, etc.

ARCHITECTURE

The communication in VANETS can be of three types:

- Vehicle to vehicle communication
- Vehicle to roadside communication
- Roadside to roadside communication

The first type of communication is between the vehicular nodes. The second type is the communication of messages from the vehicular nodes to the road side units. The final type is the communication between any two roadside infrastructures. This could be RSU to RSU communication or message transfer between RSU and base station for communication with the internet. These are represented in Fig. 1. The main challenge in the communication between vehicles is the connectivity problem. The vehicular node movement pattern is constraint but they move with different velocities. Due to this the connections between the vehicles may become weak or get lost.

STANDARDS AND PROTOCOLS

Physical layer: The standard used for wireless communication is IEEE 802.11 in 5 and 2.4 GHz spectrum band (Wi-Fi). The Federal Communications Commission (FCC) in US has allotted 75 MHz of frequency spectrum at 5.850-5.925 GHz for Dedicated Short Range Communication (DSRC). DSRC uses this for many private and public applications like safety, real time traffic management, real time road information, in car entertainment, email access, voice chat, etc. In Europe, the band allotted for Car 2 Car Communication is between 5.885-5.905 GHz.

IEEE 802.11p is an approved amendment to the IEEE 802.11 standard to add Wireless Access in Vehicular Environments (WAVE) (IEEE 802.11p). This is also a cost-efficient solution that can be applied in VANETs for both ON Board Units (OBUs) and Road Side Units (RSUs). It uses the licensed ITS band of 5.9 GHz (5.85-5.925 GHz). The basic data rate for this standard is 3 Mbps for a 10 MHz channel.

MAC layer: Developing a reliable and efficient medium access control protocol is one of the current research areas in VANETs. Medium sharing is particularly challenging in VANETs due to high mobility and fast topology changes. The two approaches developed for the C2C-CC radio system are IEEE 802.11p and IEEE P1609.4. The MAC algorithm adopted for this is CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance).

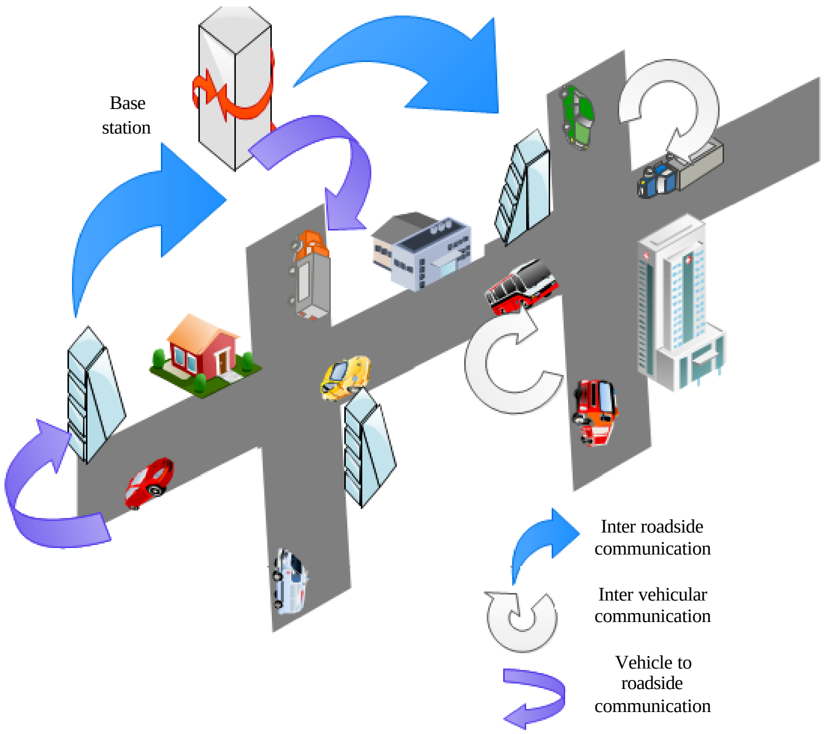

Fig. 1: VANET architecture

Other protocols proposed are VMESH MAC, ADHOC MAC, directional antenna based MAC (DMAC) (Yanamandram and Shahnasser, 2009), RMAC and Clustering based MAC (CMAC) (Rathore *et al.*, 2010).

Network layer: Vehicular densities in VANETs can be dense or sparse depending on the location. The network layer protocols provide algorithms for wireless multi hop communication, routing, congestion control and movement dissemination. Many applications of VANETs rely on routing. The routing protocols used for Ad hoc networks have been modified to meet the needs of VANETs. Broadcasting is most commonly used for delivering caution messages in safety related applications. The different approaches used for broadcasting in VANETs are flooding, probabilistic broadcast and cluster based broadcast. The efficient ways of broadcasting in VANETs have been discussed by Wisitpongphan *et al.* (2007). Unicast, multicast, position based and geocast routing protocols have been discussed by Ferreiro-Lage *et al.* (2009), Bernsen and Manivannan (2009), Allal and Boudjit (2012) and Ghafoor and Aziz (2011).

VANET SIMULATORS

An ideal VANET simulator should support two different types of simulations: simulating the mobility of the vehicles and simulating the wireless communication between them. There are many high quality network and traffic simulators existing. Here are a few:

Network simulators:

- NS-2
- QualNet
- GloMoSim
- OPNET
- SWANS
- GTNetS
- SNS

Traffic simulators:

- SUMO
- MOVE
- VanetMobiSim
- FreeSim
- Paramics
- Corsim
- GrooveSim
- CityMob
- Netstream
- STRAW

Most of the VANET simulators do not allow feedback to be communicated from the network simulator to the traffic simulators. This is sufficient for infotainment applications like checking emails in vehicles, media applications, etc. In these cases pre-generated traces can be used and dynamic mobility information is not required. However, when it comes to safety related applications, two way communication between the traffic and network simulator is essential. The traffic simulator has to feed dynamic information like the vehicle position, speed, acceleration, direction, etc. to the network simulator. The VANET application that runs on top of the network simulator uses this information along with the surrounding vehicles information to give back a warning about possible collision or congestion. This information is used to take appropriate decisions and is fed back to the traffic simulator.

Unidirectional communication is straight forward and is achieved by combining a traffic simulator with a network simulator. The trace from the traffic simulator is fed to the network simulator. Some of the existing simulators that support unidirectional communication are classified in Fig. 2. Bidirectional communication is little more complex as it is challenging to couple the traffic and network simulator (Fig. 3). The interface TraCl was developed to couple SUMO with NS-2 or QualNet.

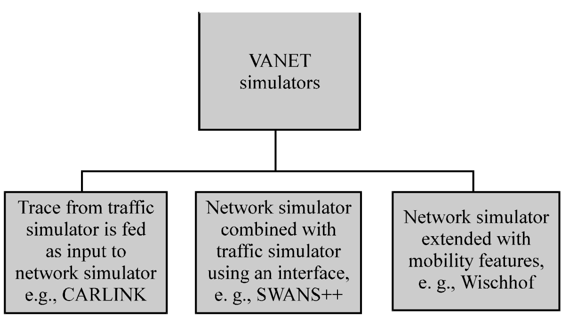

Fig. 2: Types of simulators that support unidirectional communication

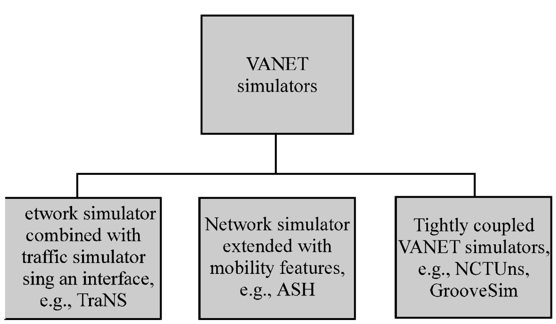

Fig. 3: Types of simulators that support bidirectional communication

The traffic simulator VanetMobiSim was extended as CanuMobiSim by incorporating IDM. Similarly SWANS was extended as ASH (Application aware SWANS with Highway mobility). GrooveSim and NCTUns are integrated simulators with tightly coupled network and traffic simulators.

MOVE: MOVE (Mobility model generator for Vehicular networks) is a tool developed to generate realistic models for VANET simulations. It is a Java-based application built on top of an open source micro-traffic simulator SUMO. MOVE provides GUI facility that's makes it easy for the user to generate simulation scenarios without writing scripts. The user does not have to worry about learning the details and scripting of the simulator. It generates mobility traces from the TIGER database. MOVE has a Map editor and a Vehicular Movement editor. The Map editor creates maps for network scenario. The vehicular movement editor generates movement patterns. MOVE generates a mobility trace file as its output which can be used by network simulators like NS-2 or QualNet.

TraNS: Traffic and Network Simulator Environment (TraNS) is a simulator that integrates both mobility generator SUMO and network simulator NS-2. It is an open source project written in Java and C++. The main features of TraNS are 802.11p support, automated generation of networks from TIGER, generation of mobility trace for NS-2 and ability to simulate road events like accidents. A lighter version called TraNS Lite is developed for mere mobility modeling without network simulations. The downside of TraNS is lack of real time results. The output from NS-2 cannot be passed back to SUMO and hence it does not produce results like real life.

VanetMobiSim: This is an extension of CanuMobiSim (Communication in Ad hoc Networks for Ubiquitous Computing Mobility Simulator). CanuMobiSim cannot generate random graphs and produce high levels of details in specific scenarios. VanetMobiSim produces more realistic details at both macroscopic and microscopic levels.

At macroscopic level, VanetMobiSim supports multi-lane roads, separate directional flows, traffic lights and human mobility dynamics. At microscopic level VanetMobiSim supports car-car and car-infrastructure communication. It has a parser to extract road topologies from TIGER and GDF (Geographical Data Files) which are passed on to network simulators like NS-2, GloMoSim, QualNet and NET. However, the downside of this simulator is that it lacks feedback mechanism. The traces from the network simulator can not be fed back to VanetMobiSim.

NCTUns: NCTUns (National Chiao Tung University Network Simulator) http://nsl.csie.nctu.edu.tw/nctuns.html) is a simulator and emulator written in C++. It has a powerful GUI and can simulate various protocols used in both wired and wireless networks. NCTUns included ITS support in its 4th Version. It provides vehicular simulation environment and includes both traffic and network simulator in a single module. It also has a powerful feedback support.

The main features of NCTUns are: it can be used as an emulator, NCTUns supports parallel simulation approach for fixed networks on multi-core machines and it provides a professional GUI that helps the users to draw network topologies, configure protocol modules, specify the moving path of the nodes and plot the network performance easily.

The drawbacks of NCTUns are: it can support a maximum of 4096 nodes in a single simulation, NCTUns also allows only a single instance of TCP/IP version unlike other network simulators that support multiple TCP/IP versions and it requires Fedora to be installed which limits its usage considerably.

GrooveNet: GrooveNet (Martinez *et al*., 2011) is a hybrid simulator that uses TIGER database and enables communication between simulated vehicles and real vehicles. It incorporates modeling with real street map based topology and mobility over a variety of communication models. It provides multiple network interfaces and also supports simulations based on real vehicles on-board computer (like GPS). GrooveNet supports 3 types of nodes in its simulations: vehicular nodes, fixed roadside infrastructure nodes and mobile gateways that is capable of V2V and V2I communication. GrooveNet supports hybrid simulations in which the real vehicles can communicate with the simulated vehicles within its transmission range. The messages from the simulated vehicles are broadcast from the infrastructure nodes.

MobiREAL: MobiREAL (Martinez *et al*., 2011; MobiREAL, 2008) is a simulator that is able to simulate realistic mobility of humans and vehicles. It is a rule based simulator that can be used in the cognitive modeling of human behavior. It is used in MANET simulations by using the mobility support in the Georgia Tech Network Simulator (GTNetS).

A mixture of mobility models can be simulated concurrently. For vehicular mobility it uses a traffic simulator called NETSTREAM developed by TOYOTA. MobiREAL can also use other traffic simulators to support vehicular mobility.

Comparison: The comparison of the different simulators is given in Table 1. A sample road model was developed using GrooveNet simulator. The screenshot is shown in Fig. 4. The top left panel shows the list of real and simulated vehicles. The vehicles current position, heading direction and speed is displayed. GrooveNet simulator is ideal for all researchers working on vehicular protocols due to the following features:

- It supports multiple network interfaces for both vehicle to vehicle communication and vehicle to infrastructure communication
- GrooveNet is a hybrid simulator that supports communication between simulated vehicles and real vehicles
- It can also be used to communicate with the On Board Unit (OBU) to take decisions related to deceleration, direction changing, sudden braking, etc
- Three types of nodes can be defined in GrooveNet-vehicular nodes, road side nodes and gateways to communicate with the internet
- The network and traffic part of the simulator is tightly coupled making it easy to use

Table 1: Comparison of VANET simulators

Simulators	MOVE	TraNS	VanetMobiSim	NCTUns	GrooveNet	MobiREAL
Mobility generator	SUMO	SUMO	VanetMobiSim	NCTUns	GrooveNet	GTNetS
Network simulator	NS-2, QualNet	NS-2	NS-2, GloMoSim, QualNet, NET	NCTUns	GrooveNet	
Graphs	TIGER database and user defined	TIGER database	TIGER database and GDF	Bitmap image	TIGER database	NETSTREAM
Topologies	Any	Any	Any	User defined	Any	Any
Traffic lights at intersections	Stoch turns	Stoch turns	Manually defined	Automatically generated at intersections	Manually defined	Manually defined
GUI support	Moderate	Good	Moderate	Moderate	Good	Moderate
Mobility Models	Random	Random and manual routes	Random	Random and manual routes	Random	Rule based
Ease of setup	Moderate	Moderate	Moderate	Hard	Moderate	Easy
Ease of use	Hard	Moderate	Moderate	Hard	Hard	Hard

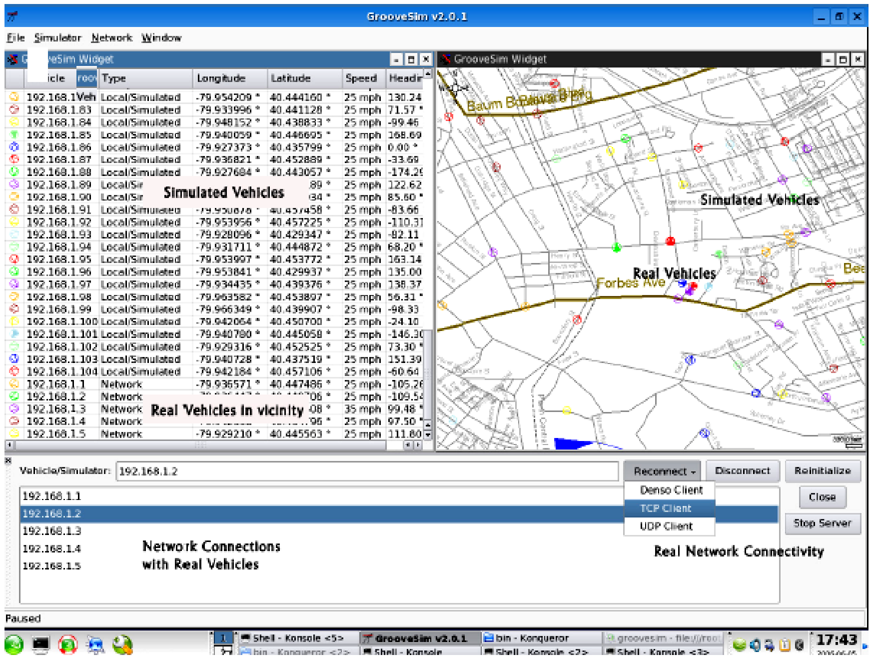

Fig. 4: A sample screenshot of GrooveNet

CONCLUSION

With increasing use of ad hoc networks in different applications, the focus on VANET, a type of ad hoc network has also gained a lot of attention. In this study, researchers make a detailed survey about VANETs and the research trends in this area. With this, all researchers can have a thorough understanding of vehicular ad hoc networks. Researchers have presented the architecture, prospective applications, the ongoing research and the different supporting simulators that will surely make VANETs a reality in the near future. Although, there are quite a few challenges for which researchers do not have solutions till now, the fast growth and developments in this area assures us that VANET will soon become part of the global wireless network. VANET not only provides safety related applications but also improves the navigation system and vehicular entertainment. Finally, researchers conclude that VANET is indeed a promising approach for all future vehicular applications.

REFERENCES

Allal, S. and S. Boudjit, 2012. Geocast routing protocols for VANETs: Survey and guidelines. Proceedings of the 6th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, July 4-6, 2012, Palermo, Italy, pp: 323-328.

Bernsen, J. and D. Manivannan, 2009. Unicast routing protocols for vehicular Ad hoc networks: A critical comparison and classification. Pervasive Mobile Comput., 5: 1-18.

Chandrasekaran, G., 2007. VANETs: The networking platform for future vehicular applications. Rutgers University, May 2007, pp: 45-51.

Dotzer, F., 2006. Privacy Issues in Vehicular Ad Hoc Networks. In: Privacy Enhancing Technologies: 5th International Workshop, PET 2005, Cavtat, Croatia, May 30-June 1, 2005, Danezis, G. and D. Martin (Eds.). Vol. 3856. Springer, Berlin, Heidelberg, ISBN: 978-3-540-34746-0, pp: 197-209.

Ferreiro-Lage, J.A., C.P. Gestoso, O. Rubinos and F.A. Agelet, 2009. Analysis of unicast routing protocols for VANETs. Proceedings of the 5th International Conference on Networking and Services, April 20-25, 2009, Valencia, pp: 518-521.

Fujii, H., K. Seki and N. Nakagata, 1995. Experimental research on protocol of inter-vehicle communication for vehicle control and driver support. Proceedings of the 2nd World Congress on Intelligent Transport System, November 9-11, 1995, Yokohama, Japan, pp: 1600-1605.

Ghafoor, H. and K. Aziz, 2011. Position-based and geocast routing protocols in VANETs. Proceedings of the 7th International Conference on Emerging Technologies, September 5-6, 2011, Islamabad, Pakistan, pp: 1-5.

Kremer, W., D. Hubner, S. Holf, T. Benz and W. Schafer, 1993. Computer aided design and evaluation of mobile radio local area networks in RTI/IVHS environments. IEEE J. Select. Areas Communi., 11: 406-421.

Martinez, F.J., C.K. Toh, J.C. Cano, C.T. Calafate and P. Manzoni, 2011. A survey and comparative study of simulators for vehicular ad hoc networks (VANETs). Wireless Commun. Mobile Comput., 11: 813-828.

Mizui, K., M. Uchida and M. Nakagawa, 1994. Vehicle-to-vehicle 2-way communication and ranging system using spread spectrum technique: proposal of double boomerang transmission system. Proceedings of the Vehicle Navigation and Information System Conference, August 31-September 2, 1994, Yokohama, Japan, pp: 153-158.

Rathore, N.C., S. Verma, S. Verma and G.S. Tomar, 2010. CMAC: A cluster based MAC protocol for VANETs. Proceedings of the International Conference on Computer Information Systems and Industrial Management Applications, October 8-10, 2010, Krackow, pp: 563-568.

Sasaki, I., T. Hirayama and T. Hatsuda, 1994. Vehicle information network based on inter-vehicle communication by laser beam injection and retro reflection techniques. Proceedings of the Vehicle Navigation and Information System Conference, August 31-September 2, 1994, Yokohama, Japan, pp: 165-169.

Sourour, EE.A. and M. Nakagawa, 2008. Mutual decentralized synchronization for inter-vehicle communication. Alexandria University and Keio University, pp: 1-4.

Valade, J.M., 1995. Vehicle to vehicle communications: Experimental results and implementation perspectives. Proceedings of the 2nd World Congress on Intelligent Transport System, November 9-11, 1995, Yokohama, Japan, pp: 1606-1613.

Wisitpongphan, N., O.K. Tonguz, J.S. Parikh, P. Mudalige, F. Bai and V. Sadekar, 2007. Broadcast storm mitigation techniques in vehicular ad hoc networks. IEEE Wireless Commun., 14: 84-94.

Yanamandram, S. and H. Shahnasser, 2009. Analysis of DSRC based MAC protocols for VANETs. Proceedings of the International Conference on Ultra Modern Telecommunications and Workshops, October 12-14, 2009, St. Petersburg, pp: 1-6.