International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 1, January-2014, pp: (473-479), Impact Factor: 1.252, Available online at: www.erpublications.com

# Designing an Effective Intersection Collision Warning System

## An Investigation into Important Criteria

Abdullah S. Almuttiri[1], Ohud M. Almutairi[2], Mohammad A. Alkhedher[3]
[1]School of Engineering, De Montfort University, Leicester, United Kingdom,
[2]School of Computer Science, University of Nottingham, Nottingham, United Kingdom,
[3]Faculty of Engineering, Al-Balqa Applied University, Amman, Jordan

**Abstract: The emergence of Vehicular Ad Hoc Networks has made effective communications between vehicle and infrastructure possible. Such systems enable the provision of many services in the automobile environment, including safety, traffic management and monitoring, and comfort. Moreover, there are many wireless communication technologies that have been developed and exclusively designed for Vehicular Networks to enable the distinct characteristics of such networks to be effectively implemented. Dedicated Short Range Communication is one wireless communication technology, amongst others, that has been developed for this purpose. Intersection collision warning applications have attracted wide attention as a potential way to improve vehicle safety at intersections. Accidents at or near to intersections account for the highest percentage of total accidents rate. In this paper, an investigation of vehicular networks and wireless communication technologies that support such networks is summarized as information about the implementation of potential safety applications. this paper also investigates effective criteria for designing a low-cost intersection collision warning application that will effectively improve vehicle safety at intersections.**

**Keywords: Vehicular Networks, DSRC, Intersection Collision Avoidance, Intersection Collision Warning, WAVE.**

### Introduction

#### A. History of Vehicular Networks

Vehicular Networks are a new type of wireless network; they are a form of mobile network developed to enable vehicles on the road to communicate with each other and/or with infrastructures on the road to provide intelligent transportation services[1]. These services are a part of the national Intelligent Transportation Systems (ITS) program run by the U.S. Department of Transportation to improve vehicle safety on the road, effectively manage traffic flow, and provide commercial and comfort related services to drivers and the passengers (e.g. in vehicle internet access)[1][2]. Vehicles that incorporate these systems,which are sometimes called smart vehicles[1], and the infrastructures on the road that support them have to be equipped with suitable wireless technology devices to support such communications.

Vehicular Networks have attracted global attention due tothe advanced development of wireless technologies to support the automobile industry. As the implementation of them would be expected to have significant positive effects (e.g. reduction and avoidance of fatal accidents), many researchers, automobile manufacturers, and government agencies are conducting research related to vehicular networks and vehicle applications for different purposes, with especial emphasis on those related to safety improvement[2][3]. Moreover, they are utilizing wireless communication technologies that support enabled communications in vehicular networks to meet the distinct requirements of the medium, such as a short time and very low latency as they are functioning in a very highly dynamic environment with changeable network topology. Those factors have been the driving force behind the innovations DSRC (Dedicated Short Range Communication) [4] and IEEE 802.11p standard [5].

Furthermore, using different technological devices such as positioning systems (e.g. GPS), sensing, computers, digital mapping, and wireless technologies has helped with the proposing and designing of many applications that are suitable in the automobile environment for safety and comfort purposes[6]. There are two main categories: safety and non-safety applications,representing the types ofpossible applications that fall intothe applications that can be implemented in vehicular networks[3].

#### B. Demands for Vehicular Networks

According to the U.S. Department of Transportation [7], in the United States in 2009, more than 2 million people were injured, 24,474 people were killed, and more than $3.9 million worth of damage was caused by car accidents. These numbers represent high losses for both the government andindividuals. Therefore, many government agencies, vehicle manufactories, and research communities are working together to improve vehiclesafety on the road[2]. Recently, many

Authors would like to express their greatest gratitude to the sponsorship of King Abdullah Al Saud Scholarship programme and the support of Saudi Ministry of Higher Education and Saudi Cultural Bureau in the United Kingdom.

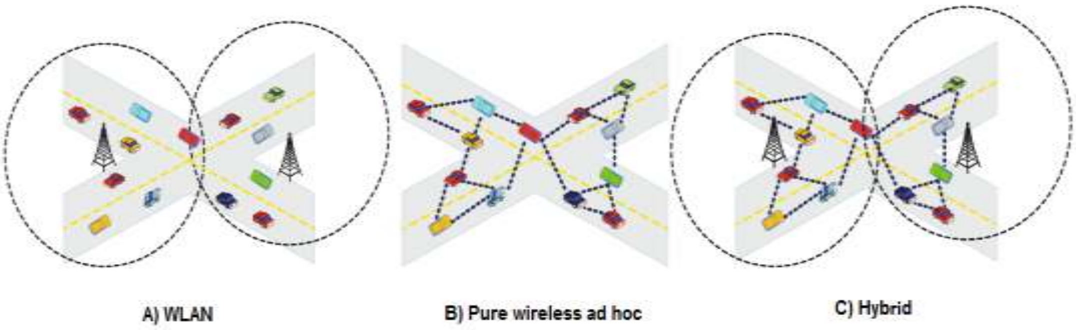


Figure 1.Network architectures for VANETs **[1]**

applications to improve safety on the road have entered the development phase. Many government agencies and vehicle manufacturers are working on developing intersection collision avoidance systems to avoid deadly accidents[2], as accidents on or near road intersectionsaccount for a high proportion of the above statistics.
Therefore, there is a pressing need for a reliable real-time collision warning system that could be used to alert drivers to any unsafe situations. The Intersection Collision Warning application is a safety application developed to warn drivers who areapproaching a dangerous intersection and about any potentially unsafe situations, with the idea being that thisforeknowledge will allow drivers to take early evasiveaction [2].

## Vehicular Networks Characteristics And Deployment

### A. Vehicular Networks Characteristics and Architectures

The significant developments in wireless technologies and networks make possiblethree vehicular networks architectures that can be deployed in urban, rural, and highway environments[3]. Fig. 1 depicts the three different environments. The Car2Car Communication Consortium (C2C-CC) Manifesto proposed a reference architecture that consists of 3 different domains for a vehicular network[8]. These domains are in-vehicle, ad hoc, and infrastructure domains[8], as shown in Fig. 2.
Vehicular networks have a number of a distinct characteristic that make them different from other forms of wireless networks[3][6]:

- Vehicular networks do not have a power constraint to ensure proper operation as a vehicle can continually provide onboard devices with sufficient power.
- Due to advanced computing and communication devices, the vehicles in vehicular networks have a high capability to compute information and communicate with other vehicles and/or the network.
- The vehicles in vehicular networks have high predictable mobility that depends on pre-constructed roads, streets, and highways; this information could be obtained from positioning systems such as Global Positioning System (GPS). When suitable information is fed into the GPS, the vehicle's future position would be predicted.

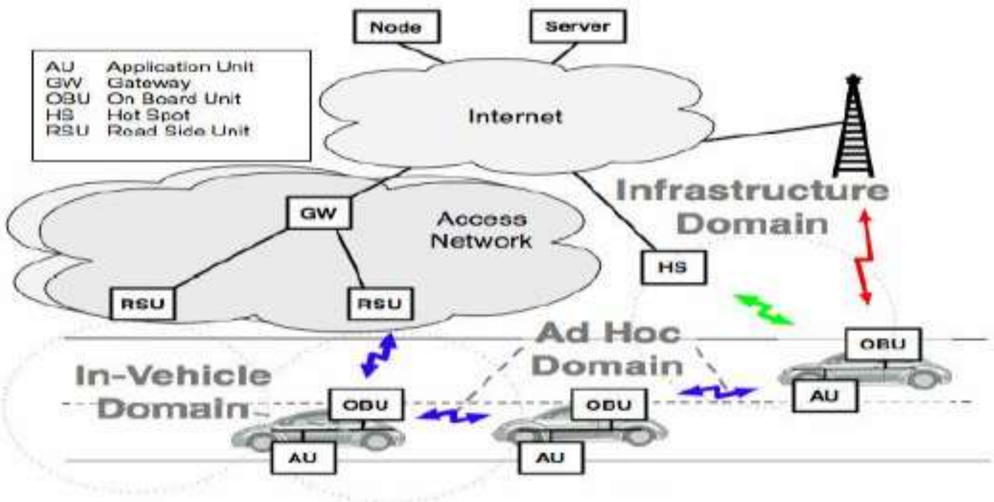


Figure 2. Different reference domains**[8]**

- Many resources are provided by vehicles supporting vehicular network adoption such as antennas and batteries.

However, some of their characteristics are considered to be issues needing to be resolved to allow reliable communication when vehicular networks are adopted, these are[3]:

- Vehicular networks have a highly dynamic environment as their mobile nodes move at a very high speed.
- Due to the vehicles' fast movement and frequent change in position (even if they are moving in the same direction), the network topology changes frequently over a very short time. According toJeremy *et al.*[9], a vehicle's direction and radio range would influence the link life between vehicles. The link life would be longer between vehicles moving in the same direction than between vehicles travelling in different directions.
- Many vehicles can participate in vehicular networks and it could extend to serve and cover the entire road network. Therefore, it does not have a limited size. Many researchers consider vehicular networks as large scale networks [3][1][10].

- As the connectivity in vehicular networks is restricted to short range communications and also depends on the number of vehicles that are equipped with suitable wireless devices and that participate in the connection, the vehicular networks would frequently be partitioned.

### B. Communication Scenarios and Applications of Vehicular Networks

Vehicular Networks, known as Vehicular Ad hoc Networks (VANETs),are a type of wireless network thatallows vehicles in the vicinity to communicate in real-time with each other and with nearby roadside infrastructure, known as road units [1].It provides connectivity to each vehicle and those road-side units that fall within the network coverage.
Dedicated Short Range Communications (DSRC) is deployed within vehicular network applications due to its high data rate, at 5.9 GHz with low latency [11]. This type of communication could solve the issue of communications between rapidly moving objects.
There are two modes of transmission that allow the network to predict and act quickly in response to any potentially unsafe situation [11]. Instant transmission allows the network to know the status of vehicles within its range and update it instantly (e.g. speed, acceleration, position and direction of vehicles). Moreover, event-driven transmission mode is instantiated by any unsafe situation detected.

**Applications of Vehicular Networks**

The demand for on-road safety applications has attracted most researchers working on safety applications, which are of great importance for road users. However, advancements in technology have created the possibility of running entertainment applications, e.g. internet access, in parallel with safety applications within the vehicular network.

The potential safety applications that can be designed and developed by using DSRC communications are classified into five main categories *[2]* as shown in Fig. 3. Public safety could be integrated with emergency agencies to request help and allow emergency vehicles to identify the fastest route to the accident scene and to warn other vehicles to give way to approaching emergency vehicles. Sign extension applications could warn drivers and update them about the road signs ahead, such as school zones, traffic direction and road work signs. Vehicle diagnostics and maintenance applications focus on sending reminders of issued safety recalls to the vehicles that have safety defects as well as alerting drivers about any needed maintenance. Vehicles could also exchange important information, e.g. lane change, intended turn, speed, direction and acceleration.

**Intersection Collision Avoidance**

Intersection collision avoidance systems assist drivers who are approaching an intersection to help them to cross it safely through the useof devices such as road-side sensors, warning devices, and infrastructure-vehicle communication devices[12].These coulddetect unsafe situations at intersections and warn drivers about them by instant monitoring of the speed and location [12].Mainly, the communications in most intersection collision avoidance systems are vehicle to

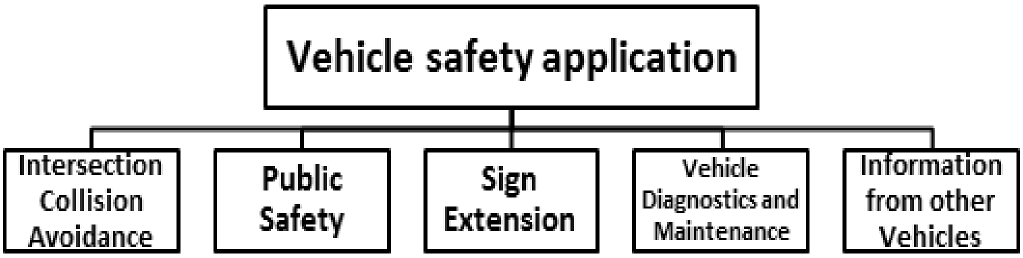


Figure 1. Vehicle safety application categories

infrastructure and/or infrastructure to/from vehicle communications [2]. However, vehicle to vehicle communication could be enabled in such an application [13]. The transmission mode is typically periodic transmission, so that a periodic message would be sent regularly [2].
There are a number of safety applications for intersection collision avoidance that have been developed for the purpose of enhancing vehicle safety at intersections [2], as shown in Fig. 8. Intersection collision avoidance applications need to support at least 10 Hz as a minimum frequency; at a distance range between 200 and 300 m for vehicles and infrastructure communication [2].

## Intersection Collision Warning System

### C. System Background

The intersection collision warning application is anintersection collision avoidance application that is developed to warn different drivers who are approaching the same intersection should any unsafe situation may occur [2]. It is indicated that the largest class oftraffic accidents is those that are intersection-related [14]. It is therefore important to design and develop an application that helps to avoid such incidents.

In order to detect unsafe situations, various data is required in advance, such as vehicle speed, direction, position, and acceleration; data about the intersection e.g. the shape; and data about weather conditions [12].

There are many different technologies that could be used for the applications to sense such data; for example, camera, radar, GPS, wireless sensor, etc. Furthermore, the process of collision detection could be done using in-vehicle devices [15] or via the infrastructure of the intersection [16].

The maximum range of communication that is required for such an application is 300 m, and at least 10 Hz as a minimum frequency is needed for the application to work effectively[11]. Generally, the transmission mode of this application is instant, as vehicles need to send their current status and position regularly to the infrastructure or to other vehicles in order to detect any potential incident[11].

### D. Investigation into Important Criteria

A number of studies related to intersection collision warning systems have proposed various ways of improving vehicle safety at intersections. They considered some of the important criteria that should be taken into consideration when designing or developing an intersection collision warning system. Each of those studies has considered different criteria, as shown in Table 1. These criteria were analyzed when considering each work.
These studies were compared to identify some of the important criteria that should be taken into consideration when designing and developing an intersection collision warning system, and to compare the proposed works based on these criteria.
The weight for each criterion would be suggested by the author depending on its importance and efficiency. The number beside each criterion indicates the importance, ranging from 6 (most) to 2 (least). For example, a 6 beside the low latency criterion indicates that it is more important than the type of communications criterion assigned the number 5. The criteria that have the same number are of the same level of importance to the application. These criteria are as follows:

1. Low latency criterion weight (6): A very low latency is required for the vehicle safety applications.
2. Warning range criterion weight (6): The allowed time of action before the incident occurrence.
3. Non-Line Of Sight (NLOS) situation criterion weight (6): It could occur when a vehicle cannot see the receiver.

The given weighting depends on the proposed application.If it solves the NLOS situation or does not suffer from such a situation, it is rewarded 6 points. If it partially solves the problem, it would receive 3 points. However, if it did not solve the problem or the problem was not mentioned in the proposal, the weighting would be 0 points for that proposed application. The low latency and warning range criterions are considered in all reviewed works. Therefore, they can be considered essential and will thus not be used in the comparison.

4. The means that are used for identifying important information about the vehicles on the road criterion weight (6):There is important information which needs to be known in advance in order for the application to detect a potentially unsafe situation, such as vehicle speed, direction, and position. There are different means that have been used to obtain this information, such as wireless sensor devices, GPS (Global Positioning System) and a vision

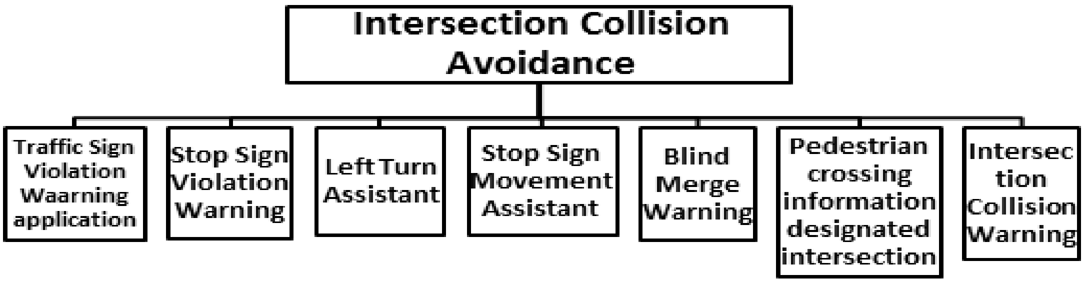


Figure 4.Intersection Collision Avoidance applications

based system.

The awarded weighting depends on quality of utility inside the network. When the proposed application uses wireless sensors, it receives 6 points because wireless sensors would be more accurate for obtaining the information [17]. If the proposed application uses GPS, it receives 4 points as it has some limitation of losing a signal when a vehicle passes through a tunnel or wide bridge or in bad weather conditions.However, it is more accurate than a vision based system for obtaining information as it does not ignore the existence of the vehicle when completely occluded by obstacles. If the proposed application uses a vision based system, it would have 2 points, as it is less accurate than the others.

5. Type of communications criterion weight (5): The type of communication, whether vehicle to vehicle or vehicle to/from infrastructure communications.

The weighting of the proposed application that only enables vehicle to vehicle communication receives 5 points: as the application merely enables this type of communication, it would not require infrastructure support, and would thus reduce the cost of implementation and maintenance. Therefore, vehicles would collaborate with each other to detect any unsafe situations and warn those vehicles that might become involved. Any proposed application enabling both vehicle to vehicle and vehicle to/from infrastructure communications, would be awarded 4 points. While using these two communication types together will be more effective than using vehicle to/from infrastructure communication, it is also more costly due to building and maintaining the network. For a proposed application that enables vehicle to/from infrastructure communication, the rewarded weighting would be 3 points.

6. Traffic volume criterion weight (5): the application's ability to deal with different traffic volumes is important to accurately detect a potentially unsafe situation, as the traffic volume could be changeable from day to day at a single intersection. For instance, a high density of vehicles at a road intersection might increase the occurrence of the non-line of sight problem with some applications.

The weightings for traffic volume criterion would be rewarded 5 points if it has the ability of dealing with different density of traffic volumes. When the proposed application is more suitable for intersections with low traffic volume, it would receive 2 points.

TABLE 1: Comparison of results in the proposed

| Criteria / Proposed work | Non-line of Sight (NLOS) situation | Means used to identify important information about the vehicles on the road | Type of communications | Traffic volume | Weather status | Unnecessary warning message | Method of displaying the warning message | Type of intersection | Total weighting |
|---|---|---|---|---|---|---|---|---|---|
| Mohammed, *et al.* (2009) [2] | Not mentioned (0) | Using GPS (4) | Vehicle to infrastructure (3) | Effectively works with low traffic (2) | Not mentioned (0) | Send message even if the driver took a suitable action (0) | In vehicle warning (2) | Signalized (1) | (12) |
| Juwan Kim and Jungsook Kim (2009) [17] | Does not suffer from the problem (6) | Using wireless sensors (6) | Infrastructure to vehicle (3) | Has ability to deal with different traffic volumes (5) | Not mentioned (0) | Sends message even if the driver has taken a suitable action (0) | In vehicle warning (2) | Signalized (1) | (23) |
| Stefan Atev, *et al.* (2005) [14] | Partially solved the problem (3) | Using a vision based system (2) | Infrastructure to vehicle (3) | Has ability to deal with different traffic volumes (5) | Could deal with weather condition (5) | Not mentioned (0) | Not mentioned (0) | Suits both types (2) | (20) |
| Yang, Kobayashi, and Katayama (2000) [18] | Did not solve the problem (0) | Using GPS (4) | Both vehicle to vehicle and infrastructure to vehicle (4) | Has ability to deal with different traffic volumes (5) | Could deal with weather conditions (5) | Sends message even if the driver has taken suitable action (0) | In vehicle warning (2) | Unsignalized (1) | (21) |
| Huang, *et al.*, (2002) [15] | Solved NLOS situation (6) | Using GPS (4) | Vehicle to vehicle (5) | Has ability to deal with different traffic volumes (5) | Not mentioned (0) | Does not issue unnecessary warning message (4) | In vehicle warning by voice (3) | Suits both types (2) | (29) |
| Chang, *et al.*, (2009) [19] | Solved NLOS situation (6) | Using GPS (4) | Vehicle to vehicle (5) | Effectively works with low traffic (2) | Not mentioned (0) | Does not issue unnecessary warning message (4) | In vehicle warning by voice and image (3) | Suits both types (2) | (26) |

7. The weather status criterion weight (5): dealing with different weather conditions is very important for an application to effectively achieve potential benefits, as the impact of this would affect the application's performance and safety on the road, especially in cases of collision detection and avoidance. The weightings for weather status criterion will be 5 points for those proposed applications that can deal with different weather statuses. However, if

the proposed application cannot deal with different weather statuses or the criterion is not considered for the proposed work, the rewarded weighting will be 0 points.

8. The unnecessary warning messages criterion weight (4): messages issued just after the driver has taken avoidance action. Furthermore, the warning message should be sent or displayed only to the vehicles that would be involved in the incident. Therefore issuing many warning messages may cause more issues than providing actual solutions. If the proposed application does not issue unnecessary warning messages, it will be given 4 points weight. However, it is given 0 points if it does issue unnecessary warning messages.
9. The method of displaying the warning message criterion weight (3): The message might be displayed in the vehicle or on the road, for example via a large screen. Displaying such messages in the vehicle is better and more efficient than displaying it on the road. When the message is displayed in the vehicle, it should be immediately noticed by the driver so as to immediately prompt appropriate action. The warning message that is displayed on the road might be occluded by temporary obstacles such as a truck; this would prevent the driver from being aware of the unsafe situation. Moreover, it might not be immediately noticeable. Meanwhile, in-vehicle voice, image, and/or written message are more likely to attract driver attention.

The weightings of this criterion will be thus: if the proposed application displays the warning message in vehicle by voice and with or without an image, it will receive 3 points. When the proposed application displays the warning message in vehicle but without mentioning the way that the message will be displayed, the weighting will be 2 points. Meanwhile, if the proposed application displays the warning message on the road, it will receive 1 point. When the way of displaying the warning message is not mentioned in the proposed work, the weighting is 0 points.

Type of intersection criterion weight (2): There are two main types of intersections: signalized and non-signalized intersection. The application that suits both types of the intersection would be better than using only one type as it would save the time, money, and effort required for designing two separate specialized applications. Furthermore, the causes of incidentsfor both types aresimilar. When the application suits both types of intersections, it is awarded 2 points weight, whereas application suitable for one type of intersection will receive 1 point.

## Conclusion

There are a number of criteria considered in this study, such as low latency, which is considered an essential criterion for any safety application. In this paper a number of criteria were investigated and discussed, which were determined by studying various proposed studies related to intersection collision warning systems based on those criteria. Of all the works involved in this comparison, the proposed application of Huang et al. (2002) [15] received the highest total weighting (29 points) as it supported by the most effective criteria in the intersection collision warning system.

Moreover, a cost effective intersection collision warning system needs to consider the capability to work at very low latency, as well as a warning range to help drivers avoid accidents. It is essential to deploy Non-line of sight transceiver that is capable of detecting vehicles behind obstacles at as low a battery level as possible. Furthermore, it is recommended that using a device that could provide the application with accurate positioning device, such as in-vehicle GPS. Ad hoc network communication between vehicles is the most cost effective, as there is no need for establishing and maintaining an infrastructure. Different weather conditions, traffic volume and suitability for all types of intersections also need to be considered in designing such systems.

## References

[1] Yu Wang and Fan Li, "Vehicular Ad Hoc Networks," in Guide to Wireless Ad Hoc Networks, Sudip Misra, Isaac Woungang, and Subhas Chandra Misra, Eds. London: Springer, 2008, pp. 503-525.

[2] Mohammed S. Almalag, "Safety-Related Vehicular Applications," in Vehicular Networks From Theory to Practice, Stephan Olariu and Michele C. Weigle, Eds. Boca Raton: Taylor & Francis Group, LLC, 2009, pp. 1-26.

[3] Hassnaa Moustafa, Sidi Mohammed Senouci, and Moez Jerbi, "Introduction to Vehicular Networks," in Vehicular Networks: Techniques, Standards and Applications.: Auerbach publications, 2009.

[4] John B Kenney, "Dedicated short-range communications (DSRC) standards in the United States," Proceedings of the IEEE, vol. 99, no. 7, pp. 1162--1182, 2011.

[5] "802.11p-2010 - IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements--Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular ," , July 2010.

[6] MAEN M. ARTIMY, WILLIAM ROBERTSON, and WILLIAM J. PHILLIPS, "Vehicular Ad Hoc Networks: An Emerging Technology Toward Safe and Efficient Transportation," in Algorithms and Protocols for Wireless and Mobile Ad Hoc Networks, Azzedine Boukerche, Ed. Hoboken, New Jersey: John Wiley & Sons, Inc., 2009, pp. 405-427.

[7] National Highway Traffic Safety Administration, "Traffic Safety Facts 2009," National Highway Traffic Safety Administration, Washington, 2009.

[8] "Car2Car Communication Consortium Manifesto," Technical report May 2007.

[9] Jeremy J. Blum, Azim Eskandarian, and Lance J. Hoffman, "Challenges of Intervehicle Ad Hoc Networks," IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, vol. 5, no. 4, pp. 347 - 351, 2004.

[10] Uichin Lee, Ryan Cheung, and Mario Gerla, "Emerging Vehicular Applications," in Vehicular Networks From Theory to Practice, Stephan Olariu and Michele C. Weigle, Eds.: Taylor & Francis Group, 2009, pp. 1-26.

[11] The CAMP Vehicle Safety Communications Consortium, "Vehicle Safety Communications Project Task 3 Final Report: Identify Intelligent Vehicle Safety Applications," National Highway Traffic Safety Administration, Washington, 2005.

[12] Fadi Basma and Hazem H. Refai, "Collision Avoidance System at Intersections," University of Oklahoma, Tulsa, 2009.

[13] Ronald Miller and Qingfeng Huang, "An adaptive peer-to-peer collision warning system," in the IEEE Vehicular Technology Conference, 2002, pp. 317 - 321.

[14] Stefan Atev, Hemanth Arumugam, Osama Masoud, and Ravi Janardan, "A Vision-Based Approach to Collision Prediction at Traffic Intersections," IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, vol. 6, no. 4, pp. 416 - 423, 2005.

[15] Qingfeng Huang, Ronald Miller, Perry MacNeille, Gruia-Catalin Roman, and David DiMeo, "Development of a Peer-to-Peer Collision Warning System," Ford Technical Journal, vol. 5, pp. 1-10, 2002.

[16] Mohammad Nekoui et al., "Development of a VII-enabled prototype intersection collision warning system," in 5th International Conference on Testbeds and Research Infrastructures for the Development of Networks & Communities and Workshops, 2009. TridentCom 2009., Washington, DC, 2009, pp. 1 - 8.

[17] Juwan Kim and Jungsook Kim, "Intersection collision avoidance using Wireless sensor network," in 2009 IEEE International Conference on Vehicular Electronics and Safety (ICVES), Pune, 2009, pp. 68 - 73.

[18] Zhengrong Yang, Takashi Kobayashi, and Tsuyoshi Katayama, "Development of an Intersection Collision Warning System Using DGPS," in SAE 2000 World Congress, Detroit, 2000, pp. 1-4.

[19] Chia-Hsiang Chang, Chih-Hsun Chou, Cheng-Jung Lin, and Ming-Da Lee, "A WAVE/DSRC-based intersection collision warning system," in International Conference on Ultra Modern Telecommunications & Workshops, St. Petersburg, 2009, pp. 1-6.