Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 2; January-March, 2015, pp. 89-92

http://www.krishisanskriti.org/jbaer.html

Vehicle Collision Warning System based on IEEE 802.15.4 MAC/PHY Standard and GPS

Pramod K. Pallewad[1] and Pravin P. Ashtankar[2]

[1]M.Tech, ECE Dept, PCE, Nagpur, India
[2]Research Scholar, ECE Dept, G. H. Raisoni COE, Nagpur, india
E-mail: [1]pkpallewad@gmail.com, [2]praveen24nov@rediffmail.com

Abstract—*Detection of any other vehicles in the vicinity of a moving vehicle is more important to help the driver safely negotiate acceleration, deceleration and parking. In these situation vehicle must acquire its positional information with respect to other and be able to identify a possible accident. This paper gives an alarming system for detecting a collision between two or more vehicles using Global Positioning System and IEEE 802.15.4 MAC/PHY specification compatible system on chip . We develop a generic system for the safety coordinates of a vehicle based on its size, current speed, acceleration and its braking power. Such safety parameters are communicated among all vehicles in its range and is used to determine overlaps thus detecting a possible collision. The IEEE 802.15.4 standard is designed for low rate wireless personal area networks and we find its applicability in a VANET. At First, we simulate a scenario of upto 20 vehicles in near area and test the system in NS2 and study the packet loss as a function of periodicity of packet transmission the number of nodes and the mode of data transmission.*

1. INTRODUCTION

Invention of automobiles was one of the greatest achievements of mankind in the past century and which helps in many ways to the growth of a world. However, we can't ignore the fact that hundreds of people lose their life or suffer a lot from these accidents due to vehicular accidents or collision every year. Research in vehicular anti-collision systems has received worldwide attention with active work being carried out for over four decades. Causalities in traffic accidents are mainly caused by collision between vehicles due to the inability of the drivers to know the perimeter of their vehicles. This is particularly accentuated in large vehicles like dumpers where there are many blind spots. Recent efforts have been made at designing a cooperative anti-collision system where an ad-hoc wireless communication network is formed among vehicles in range. Coupled with positional information from a Global Positioning System, these devices are relatively cheap to realize and holds the potential for use of unite applications like tracking of vehicles, traffic management and stricter regulation of vehicular speed. A vehicle collision avoidance system based on cooperative wireless communication and Global positioning system can remove the drawbacks of the optical based technology even under high speeds or under near-zero visibility [16].

This paper introduces an active alarming system for moving Vehicles using Global Positioning System (GPS) and a wireless communication module adhering to the IEEE 802.15.4 MAC and Physical layer. To the best of the our knowledge, this is the first work developing a vehicular anti-collision system on IEEE 802.15.4. The motivation for our work comes from the authors visit to an open cast mine of Maharashtra Here, dumpers of huge proportions, ferry cargo from the mining to the dumping area. The visibility from inside the cabin of the dumper is next to minimal. Blind spots exist at the rear and the sides of the Dumper. also, the dumpers are huge, around twenty feet in height and it is difficult to gauge the distance of obstacles on the ground surface. Collisions are therefore an daily issue with serious accidents leading to human casualties. A collision between two dumpers leads to losses both due to the repairs needed to dumper and the loss of money by their unavailability till the repairs are completed. Due to the the size of the dumpers applicability of conventional collision warning systems like infrared and optical based systems reduces, since the number of devices needed to cover the entire perimeter of the dumper . The dumpers operate in an open space where there are few obstacles. Direct reception from satellites is possible thus allowing the use of Global Positioning System. A dumpers used in coalmines is pictorially shown as follow

Fig. 1: A dumpers used in an open cast mine

We design a collision warning system for use in such dumpers where an important aspect is the calculation of the perimeter of the truck. Our system, however, is generic enough for use in daily vehicular traffic where conditions similar to an open cast mine exists, like that in a highway or open crossroads. Progressing further, our focus lies on dumpers in an open cast mine, unless otherwise stated. The active alarming system uses Global Positioning System to collect the current latitude and longitude position of the moving vehicle along with the azimuth and speed. Based on these information the system calculates the rectangular perimeter of the vehicle represented by four safety- coordinates. The four coordinates are then share with neighboring vehicles using the IEEE 802.15.4 standard. Simultaneously, observations are made to ensure the rectangular perimeter of an incoming packet, which corresponds to other vehicles, does not overlap with its own perimeter.

The paper is divided into differnt section. In section II we given the related work and the motivation for our work in this paper. Section III gives the system model . We provide the scope for further work and conclude in last section .

2. RELEATED WORK

Vehicular collision warning systems (CWS) are Traditionally divided into two categories. Initial work focused on design of system where a vehicle would gauge obstacles in its path through the use of cameras, radars, acoustic systems, etc [6] where each vehicle is independent and is capable of detecting obstacles, even of heterogeneous types. However, such devices are cost forbid Further, research has developed to identify potential collisions between moving vehicles meeting at a cross road. In such type of systems, Inter Vehicular Communication is necessitated between vehicles that are not in the line of sight. Inter vehicular communication has received wide spread attention with the near omnipresent nature of 802.11 [13]. A collision warning system based on inter vehicular communication involves the broadcast of the vehicle coordinates and other information like speed and direction, braking potential on a wireless channel. These systems are thus known as cooperative collision warning systems (CCWS) [6]. A CCWS cannot detect heterogeneous obstacles, however, based on the propagation property of the wireless system they can see through buildings to minimize blind spots. Numerous studies have been made on CCWS where GPS data including speed and direction are share with other vehicles using 802.11 [12][13].

A common assumption of such systems is the alike of vehicles, where the dimension of each vehicle does not feature in the determination of collision boundaries. Further, the future position of a vehicle is determined by the vehicle receiving the broadcasted information. In this paper, we pervert from the conventional CCWS in three aspects. Firstly, every vehicle based on its direction of travel computes, in longitude and latitude, the four corners of its safety zone as shown in fig. 2. Thus vehicles of varying profiles are composed. Secondly, the safety zone is made a function of the speed, acceleration and the braking power of the vehicle. For example, a vehicle traveling at high speeds would require a longer braking distance to successfully abstain a collision. This is made possible by awaring the user in advance by having a longer front . Similar dimensions can be obtained for a vehicle whose braking power is compromised. Thirdly, we use the newly ratified 802.15.4 standard for inter vehicular communication. We use the commercial off-the-shelf GPS devices with a precision of 7 meters. We do not examine Differential GPS (DGPS) systems for its cost and non availability in most parts of India. The IEEE 802.15.4 standard was mainly designed for low cost systems and the modules are of a small form factor, fairly cheap and easy to program. They are able to give a line of sight range of around a kilometer and a non-line of sight of around 100 meters. In comparison with 802.11, the memory requirement of 802.15.4 is less, easily implementable and power requirement is also low. The data rates provided are a theoretical maximum of 250 kbps (kilo bits per second). We try to investigate the applicability of IEEE 802.15.4 for collision warning systems.

3. SYSTEM MODEL

Among the different formats available from the GPS receiver we use the GPRMC format, also known as the recommended minimum [7]. The GPRMC sentence is around 80 ASCII characters which are updated every second.

A. Calculation of vehicles safety zone coordinates :

Fig. 2 gives the calculation of the four safety-coordinates of a vehicle. The front (F) and back (L) and width (W) would be different for vehicles of various sizes. Such generic mechanisms is partially applicable in city traffic where cars would require a smaller safety clearance than a truck .

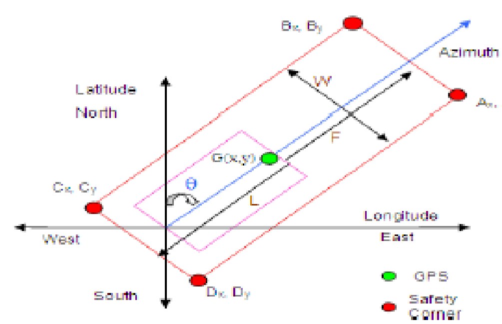

Fig. 2: diagram for calculating the four safety coordinates

The GPS receiver is supposed to place at the middle of the sideways safety clearance (W/2). The GPS coordinates are received at the point G (x, y). Let F = Front safety distance of the vehicle from G, L = Back safety distance of the vehicle from G, W = Width of the safety clearance of the vehicle side wise, θ = Azimuth angle in degree. The four coordinates are then calculated as:

$$C_x = x - L \sin\theta - \frac{W}{2}\cos\theta$$
$$C_y = y - L \cos\theta + \frac{W}{2}\sin\theta$$
$$D_x = x - L \sin\theta + \frac{W}{2}\cos\theta$$
$$D_y = y - L \cos\theta - \frac{W}{2}\sin\theta$$
$$A_x = x + F \sin\theta + \frac{W}{2}\cos\theta$$
$$A_y = y + F \cos\theta - \frac{W}{2}\sin\theta$$
$$B_x = x + F \sin\theta - \frac{W}{2}\cos\theta$$
$$B_y = y + F \cos\theta + \frac{W}{2}\sin\theta$$

The various dimensions are incorporated in the values of L and W. The speed and the brakingpotential of a vehicle are included in different values for *F*.

B. Calculation of front safety distance: F

The calculation of the safety distance *F*, is made taking into Consideration the current speed, acceleration and the braking power of the vehicle and it Also include the human reaction time .it is defined as the amount of time taken on average to apply the brakes once an indication is given. We consider in the calculation that the brakes are applied at its maximum potential. Denote *P* as the current location of the vehicle, *u* as its current speed and *a* as acceleration of it.Let *th* be the human reaction time and the retardation due to the brakes is given by *Br*.

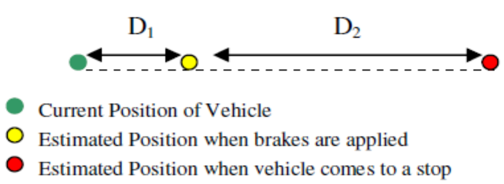

Figure 3: Schematic diagram of the final position of the vehicle (in red) with respect to its initial speed and acceleration.

Then, if T*stop* is the time the vehicle takes to stop, the sum of *D1* and *D2*, to calculate F, as shown below

$$T_{stop} = \frac{u + at_h}{B_r}$$

$$D_1 = ut_h + \frac{1}{2}at_h^2$$

$$D_2 = V_1 T_{stop} + \frac{1}{2}B_r (T_{stop})^2$$

where $$V_1 = u + at_h$$

$$F = D_1 + D_2 = ut_h + \frac{1}{2}at_h^2 + \frac{3}{2}\frac{(u + at_h)^2}{B_r}$$

C. Transmission of safety coordinates:

We build a packet that contains the calculated coordinates and transmit on the 2.4 GHz ISM band using the 802.15.4 standard.The packet structure is shown in Fig. 4. Each communication device is pre-burned with a 16 bit unique address that built the short address (as defined in the standard) and represents a vehicle. The time field that is obtained from the GPS system is transmitted in ASCII in the format '*ddmmhhmmss*' corresponding to the date, month, hour, minutes and seconds . The Latitude is given in 9 bytes and is of the form yyyy.yyyy while the longitude is of the form xxxx.xxx and thus is transmitted as a 8 byte ASCII value. The payload then comes to 68 (9 * 4 + 8 * 4) bytes for the four coordinates. The overall payload of 80 bytes fits with the IEEE 802.15.4 standard well. The generated packet needs to be transmitted at periodic intervals to all vehicles in range and we need to design this periodicity. We also need to decide on the type of data transmission viz. a broadcast or an unicast transmission. Every device is preburned with a unique address of 16 bit and thus there is no association and assignment of address . The data packets are sent only to a device's in proximity and thus there is no routing required.

12 Bytes		68 Bytes							
ID	Time	Ax	Ay	Bx	By	Cx	Cy	Dx	Dy

Figure 4: Packet structure with the coordinates of the safety zone. This packet is transmitted periodically by every vehicle.

C.1 Broadcast Transmission

In broadcast transmission, a device transmits its data packet once the channel is sensed clear. Denoting Tpkt as the time needed to send or receive the payload of 80 bytes we can calculate the total time a device is busy, Tbusy_b, as:

$$T_{busy\_b} = T_{pkt} + (N-1)(T_{pkt})$$

C.2 Unicast Transmission

In Unicast, a device needs to first know the number of other devices are in its range. This is calculated by performing an 802.15.4 MAC primitive, ACTIVE_SCAN of the channel. A device which performing an scanning operation sends a beacon request which is of 8 bytes in size. After receiption of a beacon request, a device responds with a beacon. We setup the beacon payload to zero. Then size of the beacon frame is 13 bytes, then we assume MAC level ACK is enabled. The length of ACK packet is 5 bytes in length. In addition to the variables defined above, let Tack be the time to send or receive the acknowledgement. Let Tbeacon and TbeaconReq be the time required to send and receive a beacon .

$$T_{busy\_u} = T_{beacon\,Req} + (N-1)T_{beacon} + (N-1)(T_{pkt} + T_{ack}) + (N-1)(T_{beacon\,Req} + T_{beacon} + T_{pkt} + T_{ack})$$

The total time has been obtained as follows. At first, the device sends a beacon request and receives the beacon from all the other devices. This corresponds to the first two fields.Then, the device sends the packet with the GPS coordinates to all devices separately. It receives an ACK as signal from each of them. Similarly, it gets the beacon request from the other devices and responds to them. It also receives the coordinate packets which contain information, from all the other devices and sends an ACK to each one of them. The PHY layer header is of 6 bytes and the MAC layer header and trailer is of 9 bytes.

D. Determination of overlapping safety zones:

The detection of the overlap between two perimeters is simplified by working on four safety corners coordinates, thus reducing the complexity from an area (O(n2)) to an edge O(n) . We have two possibilities – either vehicle A's coordinate(s) is inside the perimeter of vehicle B, or the other way around. We ignore the case when the areas are overlapping without any safety coordinate being in the perimeter of the other vehicle. This cannot happen without the coordinate having been inside the perimeter while the vehicle moves. Referring to Fig. 5, vehicle A would ring the alarm since its upper right coordinate is inside the perimeter of vehicle B. Vehicle C would buzz because the coordinate of B is inside its perimeter. Similarly vehicle A also sounds the alarm.

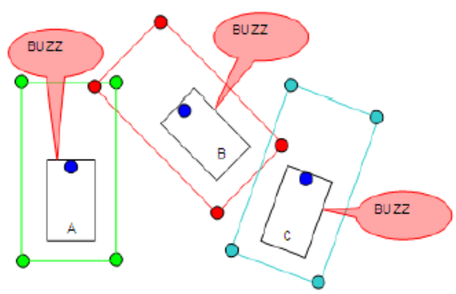

Figure 5: Schematic diagram for alarm generation in vehicles with overlapping safety zones

We use the standard and easy to implement algorithm to determine if a coordinate is within another perimeter.

4. CONCLUSION

In this paper we have proposed the effectiveness of an active anti-collision alarming system for vehicles using IEEE 802.15.4, where each anti-collision system installed in a particular vehicle transmits its positional information or coordinates and simultaneously listens to similar information from other vehicles in proximity. We have designed a generic estimator for the safety-coordinates and shown the applicability of IEEE 802.15.4. . In our ns-2 simulation, we got poor performance of the unicast mode of transmission over broadcast. Taking these analysis forward, we would like to develop a better scheme for unicast transmissions where certain information can be piggy backed on other packets. The easy implementation, low cost and easy programmability of the IEEE 802.15.4 standard gives us impetus to enhance the application in wireless vehicular networks.

REFERENCES

[1] A. Wheeler, "Commercial Applications of Wireless Sensor Networks using ZigBee", IEEE Communications Magazine, April 2013.

[2] Akyildiz, I.F., Xudong Wang: "A Survey on Wireless Mesh Networks", IEEE Communications Magazine, Volume 43, Issue 9, September2012, pp. S23 - S30.

[3] Benliang Li, Houjun Wang, Bin Yan and Chijun Zhang, "The Research of Applying Wireless Sensor Networks to Intelligent Transportation System ITS) Based On IEEE 802.15.4", 6th International Conference on ITS Telecommunications Proceedings, 2012, pp. 939-942.

[4] CC2430: http://focus.ti.com/docs/prod/folders/print/cc2430.html

[5] G Gilster, "High accuracy performance capabilities of the military standard ring laser gyro inertial navigation unit", IEEE Position Location and Navigation Symposium, April 2010, pp. 464 - 473.

[6] Han-ShueTan and JihuaHuang, "DGPS-Based Vehicle-to-Vehicle Cooperative Collision Warning: Engineering Feasibility Viewpoints", IEEE Transactions on Intelligent Transportation Systems, vol.7, no.4, December 2009, pp. 415 – 428.

[7] http://gpsinformation.org/dale/nmea.htm

[8] IEEE Std. 802.15.4-2003, Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks, 2008.

[9] Jin-Shyan Lee, "Performance Evaluation of IEEE 802.15.4 for Low-Rate Wireless Personal Area Networks", IEEE Transactions on Consumer Electronics, Volume 52, No. 3, August 2006.

[10] Mats Rydstrom, Erik G. Strom, Arne Svensson and Andreu Urmela, "Practical Automotive Applications of Cram&-Rao Bound Analysis", in proceedings of the IEEE Intelligent Vehicles Symposium 2005, pp. 61 - 66.

[11] MaxStreamXBeePRO: http://www.digi.com/products/wireless/zigbeemesh/xbee-pro-series2-module.jsp

[12] Mimoza Durresi, Arjan Durresi and Leonard Barolli, "Sensor Intervehicle Communication for Safer Highways", in proceedings of the 19th International Conference on Advanced Information Networking and Applications, AINA 2005.

[13] Samer Ammoun, Fawzi Nashashibi, Claude Laurgeau "Real-time crash avoidance system on crossroads based on 802.11 devices and GPS receivers", in proceedings of the IEEE ITSC 2006, IEEE Intelligent Transportation Systems Conference Toronto, Canada, September 2006.

[14] The Network Simulator-ns2, www.isi.edu/nsnam/ns/

[15] Y. Cui and S. S. Ge, "Autonomous vehicle positioning with GPS in urban canyon environments," IEEE Transactions on Robotics and Automation. vol. 19,110. 1; February 2003, pp. 152