reach their destination because of packet collisions in network or channel fading.

There are two approaches to establish the way the vehicles will send warning messages. One is the passive approach in which vehicles broadcast their motion information. And the other is the active approach the messages are only send when the problem occurs, that is, when the vehicle acts abnormally. This protocol chooses the active approach because it causes much less traffic in the net. When an emergency occurs (i.e. change of direction, mechanical failure) then the vehicle is said to be Abnormal Vehicle (AV). This Vehicle must send an Emergency Warning message (EWM) to let the surrounding cars to know about this event.

a) Assumptions

In this protocol it is assumed that every vehicle is equipped with a system which is able to get the geographical position of the vehicle. It is also assumed that the vehicle has a wireless transceiver. All vehicles use the same IEEE 802.11 standard and share a common channel. The VCWC protocol does not require all vehicles to be able to send or receive these messages, since this protocol is also helpful when not all the vehicles have a transceiver. Even when the majority of vehicles do not count with this system, the VCWC protocol brings benefits to all vehicles.

b) Message Differentiation

The VCWC uses different types of messages. As they have different priorities, the protocol must support a mechanism of differentiation between messages. Of all the messages, EWMs have highest priority. The forwarded EWMs occurs when the vehicle receives EWM and must spread the warning alert to other vehicles. The third type of message is the non- time sensitive messages, which deal with control tasks. In order to perform this differentiation, the way 802.11 coordinates media access is analyzed. When a vehicle has a packet to transmit, it has to wait for the channel to be idle during the Inter Frame Space (IFS). Then, a random back off is selected to transmit. Different levels of priorities can be established using different IFS. For eg, message with high priority uses a small IFS.

c) Congestion Contorl of EWMs

It is common that more than one AV coexists in time. For example, if a car stops in the highway due to a mechanical failure, it remains sending EWMs messages to approaching vehicles and will remain AV until it is retired from the road. Also, due to the natural chain effect that is produced in emergency events, the coexisting AVs might send messages at the same time, leading to packet collisions. The VCWC protocol has to deal with multiple AVs.

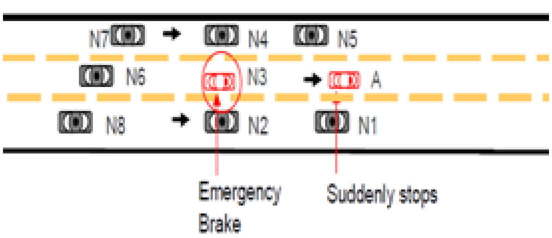

Figure 3: Collision Scenario

Another phenomenon might increase congestion in the network. This is known as Redundant EWMs. In Figure 3 is shown an example of this. Vehicle A suddenly stops, vehicle N3 breaks because of A's detention. In this case, the EWM sent by N3 and the EWM sent by vehicle A are actually warning about the same event.

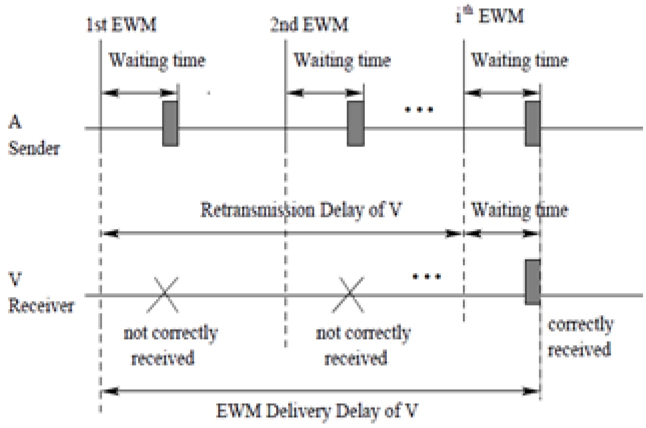

Figure 4: Waiting Time and Re-transmission Delay

To ensure a reliable communication over unreliable wireless channel, EWMs must be repeatedly sent at a certain rate. However, if the retransmission rate is too high, there are more EWM messages travelling in the same time which leads into a high congestion of the network. In addition, as a EWM cannot be transmitted until the previous has been transmitted; the inter-transmission duration of EWMs adds delay to the retransmission delay as shown in Figure 4.

$$Delay = Delay_{wait} + Delay_{retransmission} \ldots. (1)$$

Figure 4 shows the total delay, described by equation 1. Hence, a high transmission rate would contribute to high congestion, increasing the waiting time ($Delay_{wait}$). In the other hand, a low transmission rate would increase the retransmission time ($Delay_{retransmission}$). A good balance must be found. The strategy presented in the VCWC protocol takes into accounts the fact that at the beginning of an accident event the delay must be minimized.

However, once the closer vehicles have been warned, the higher distance with the approaching cars allows a certain delay relaxation. This is shown in Figure 5, where vehicle A must quickly alert vehicle N3, but can offer a bigger delay to warn vehicle N6. This relaxation delay allows the VCWC protocol to reduce the transmission rate, and consequently reduce the traffic congestion in the network.

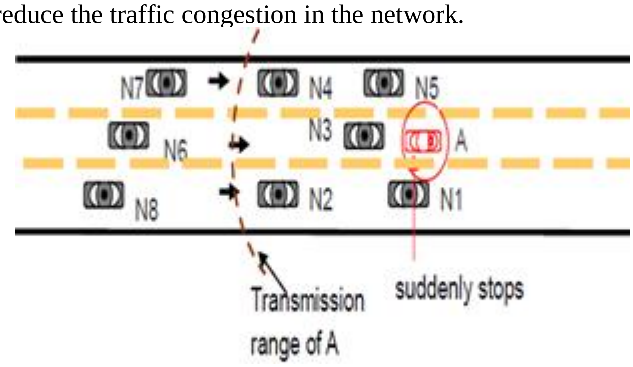

Figure 5: Delay Requirement Relaxation

5. Applications

Vehicular networking applications can be broadly categorized into:
1) Active road safety applications,
2) Traffic efficiency and management applications.

(a)Active Road Safety Applications

Active road safety applications are those that are primarily employed to decrease the probability of traffic accidents and the loss of life of the vehicle occupants. A significant percentage of accidents that occur every year in all parts of the world are associated with intersection, head-on, rear-end and lateral vehicle collisions. Active road safety applications primarily provide information and assistance to drivers to avoid such collisions with other vehicles. This can be accomplished by sharing information between vehicles and road side units which is then used to predict collisions. Such information can represent vehicle position, intersection position, speed and distance heading. Moreover, information exchange between the vehicles and the road side units is used to locate hazardous locations on roads, such as slippery sections or potholes. Some examples of active road safety applications are given below as,

- Intersection collision warning: In this scenario, the risk of lateral collisions for vehicles that are approaching road intersections is detected by vehicles or road side units. This information is signaled to the approaching vehicles in order to lessen the risk of lateral collisions.
- Lane change assistance: The risk of lateral collisions for vehicles that are accomplishing a lane change with blind spot for larger vehicles like trucks are reduced.
- Overtaking vehicle warning: Aims to prevent collision between vehicles in an overtake situation, where one vehicle, say vehicle1 is willing to overtake a vehicle, say vehicle3, while another vehicle, say vehicle2 is already doing an overtaking maneuver on vehicle3. Collision between vehicle1 and vehicle2 is prevented when vehicle2 informs vehicle1 to stop its overtaking procedure.
- Head on collision warning: the risk of a head on collision is reduced by sending early warnings to vehicles that are traveling in opposite directions. This use case is also denoted as "Do Not Pass" warning.
- Rear end collision warning: the risk of rear-end collisions for example due to a slow down or road curvature (e.g. curved hills) is reduced. The driver of a vehicle is informed of a possible risk of rear-end collision in front.
- Co-operative forward collision warning: a risk of forward collision accident is detected through the cooperation between vehicles. Such types of accidents are then avoided by using either cooperation between vehicles or through driver assistance.
- Emergency vehicle warning: an active emergency vehicle, e.g., ambulance, police car, informs other vehicles in its neighborhood to free an emergency corridor. This information can be re-broadcasted in the neighborhood by other vehicles and road side units.
- Pre-crash Sensing/Warning: in this use case, it is considered that a crash is unavoidable and will take place. Vehicles and the available road side units periodically share information to predict collisions.
- Co-operative merging assistance: vehicles involved in a junction merging maneuver negotiate and cooperate with each other and with road side units to realize this maneuver and avoid collisions.
- Emergency electronic brake lights: vehicle that has to hard brake informs other vehicles, by using the cooperation of other vehicles and/or road side units, about this situation.
- Wrong way driving warning: a vehicle detecting that it is driving in wrong way, e.g., forbidden heading, signals this situation to other vehicles and road side units.
- Stationary vehicle warning: in this use case, any vehicle that is disabled, due to an accident, breakdown or any other reason, informs other vehicles and road side units about this situation.
- Traffic condition warning: any vehicle that detects some rapid traffic evolution, informs other vehicles and road side units about this situation.
- Signal violation warning: one or more road side units detect a traffic signal violation. This violation information is broadcasted by the road side unit(s) to all vehicles in the neighborhood.
- Collision risk warning: a road side unit detects a risk of collision between two or more vehicles that do not have the capability to communicate. This information is broadcasted by the road side unit towards all vehicles in the neighborhood of this event.
- Hazardous location notification: Any vehicle or any road side unit signals to other vehicles about hazardous locations, such as an obstacle on the road, a construction work, oil spill or slippery road conditions.
- Control Loss Warning: if an additional use case is described that is intended to enable the driver of a vehicle to generate and broadcast a control-loss event to surrounding vehicles. Upon receiving this information the surrounding vehicles determine the relevance of the event and provide a warning to the drivers, if appropriate.

(b)Traffic Efficiency and Management Applications

Traffic efficiency and management applications focus on improving the vehicle traffic flow, traffic coordination and traffic assistance and provide updated local information, maps and in general, messages of relevance bounded in space and/or time. Speed management and Co-operative navigation are two typical groups of this type of application.

- Speed management: Speed management applications aim to assist the driver to manage the speed of his/her vehicle for smooth driving and to avoid unnecessary stopping. Regulatory/contextual speed limit notification and green light optimal speed advisory are two examples of this type.
- Co-operative navigation: This type of applications is used to increase the traffic efficiency by managing the navigation of vehicles through cooperation among vehicles and through cooperation between vehicles and road side units. Some examples of this type are traffic information and recommended itinerary provisioning, co-operative adaptive cruise control and platooning.

6. Conclusion

Inter- Vehicle communication promises to be an amazing technology that is being developed for future improvements in transportation. This technology has the capability to change the driving and travel experience throughout. IVC is an emerging area of interest in networks and an important area of research. IVC is an outcome of improvements of in-Vehicle computing and also the advancements in wireless communication and mobiles. Inter-vehicle communication has the potential to increase efficiency on the roadways as well as increase in safety.

Designing a protocol for IVC is extremely challenging since it has to deal with the high mobility of vehicles and also offer a secure communication. The VCWC protocol proposed in this paper aims to provide a solution in improving road safety.

7. Future Work

The future work will be to design an IOT based frame work for intervehicular communication.

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