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SmartVANET: The Case for a Cross-Layer Vehicular Network Architecture

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***Abstract*—Dedicated Short Range Communication (DSRC) based Vehicular Ad Hoc Network (VANET) provides an opportunity to enable communication-based cooperative safety systems in order to decrease road traumas and improve traffic efficiency. VANET also offers a wide range of commercial and infotainment applications. VANET exhibits unique characteristics that create new challenges. This paper discusses the DSRC technology and its shortcomings in order to achieve reliable content dissemination. To optimise the performance of the vehicular networks, a novel network architecture using the cross-layer paradigm is presented. The architecture is called Smart Vehicular Ad-hoc Network (SmartVANET) architecture. The proposed SmartVANET architecture can support safety, traffic management and commercial applications. The SmartVANET architecture complies with the DSRC channel plan. The architecture divides road into segments and assigns a service channel to each segment. The SmartVANET combines a segment based clustering technique with a hybrid Medium Access Control (MAC) mechanism (termed as the SmartMAC protocol). Using cross-layer integration, SmartVANET also provides a solution for broadcast storm problems and offers scalability. The paper presents the SmartVANET architecture and argues its advantages.**

Keywords- Cross-layer design, DSRC, Road safety, VANET

I. INTRODUCTION

Reduction of road accidents and traffic congestion are two serious challenges in today's society. Existing active safety systems have improved safety of the occupants. However, the state-of-the-art expensive active safety systems provide limited range and view. Therefore governments and automotive industry are working towards communication-based cost effective safety systems. Vehicular Ad-Hoc Network (VANET) provides a unique opportunity to establish communication-based cooperative safety systems. VANET comprises two modes of communication: Vehicle-to-Vehicle (V2V) communication and Vehicle-to-Infrastructure (V2I) communication. Dedicated Short Range Communication (DSRC) technology is envisioned as a key enabler technology for VANET. DSRC technology is based on a cost effective local area network technology.

VANET opens doors for a plethora of mobile applications. Such proposed applications are mainly categorised into safety, transport efficiency and information/entertainment applications [1]. Different applications exhibit different networking requirements. According to [1], safety applications like Cooperative Collision Warning (CCW) require single-hop broadcast in a periodic manner as information is only useful in limited neighbourhood and generated periodically. On the other hand, applications like Emergency Electronics Brake Light (EEBL) generate information based on an event and require information dissemination in multi-hop fashion. Commercial applications which require unicast networking like Content, Map and Database Download (CMDD) are triggered on demand basis.

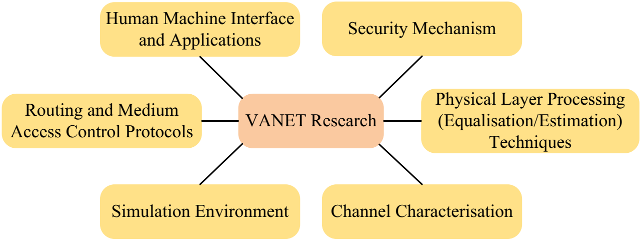

Figure 1 An overview of VANET research

VANET exhibits unique features and such unique features present challenges at different layers of the communication protocol stack. Fig. 1 provides an overview of overall VANET research. Channel conditions, node density, and dynamic topology changes create challenges in VANET. Speed of vehicles and communication scenarios (buildings, trees etc.) directly impact the signal quality and Bit Error Rate (BER) performance. High node density (due to an accident or traffic jam) deteriorates the performance of the contention based non-deterministic DSRC medium access control (MAC) layer by inducing network congestion and high rate of collisions. This paper discusses the poor Packet Delivery Ratio (PDR) performance of DSRC MAC protocol. Dynamically changing network topology and frequent link ruptures cause redundant route discovery and thus poor routing performance for routing protocols. Furthermore, protocols based on a layered architecture suffer due to inability of making joint decisions and thus do not provide optimised network performance. For example packet loss due to channel noise and interference may mean packet loss due to broadcast storm issues (excessive collision, contention etc.) to MAC layer. Network layer may misjudge the same as a route failure due to disappearance of the node and may encourage route rediscovery. Thus it becomes indispensible to develop cross-layer architecture for VANET that can share the information regarding network conditions across layers and make joint decisions for optimal performance. In this paper such an architecture called Smart Vehicular Ad-Hoc Network (SmartVANET) is proposed.

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Proposed cross-layer design based SmartVANET architecture combines the DSRC channel plan, a location based deterministic channel access mechanism and a cluster-based routing concept. SmartVANET employs a cluster-based message dissemination technique to achieve reliable message dissemination in highly dynamic VANETs. SmartVANET integrates MAC and routing layers. The architecture divides the road into small segments and allocates one service channel to each segment. According to the architecture vehicles already have this information embedded in their system. SmartVANET proposes to use a hybrid MAC protocol, termed as SmartMAC protocol that uses schedule-based Time Division Multiple Access (TDMA) scheme for intra-cluster communication and contention-based IEEE 802.11 MAC for inter-cluster communication. According to the proposed architecture, Cluster-Head Vehicle (CHV) acts as a management entity. CHV slots the channel and allocates specific time slot to each vehicle so as to achieve timely delivery of safety messages with higher Packet Delivery Ratio (PDR) in multi-hop fashion. SmartVANET architecture solves broadcast storm issues and provides efficient single-hop and multi-hop broadcast solution.

The remainder of this paper is organised as follows. Section II presents a vehicular scenario and discusses the potential problems allied with DSRC technology in order to achieve reliable message dissemination for the particular scenario. Section III surveys the related work done in the same direction as the SmartVANET architecture. Section IV provides an overview of the SmartVANET architecture with the proposed SmartMAC protocol. Section V discusses the advantages of proposed SmartVANET architecture and Section VI concludes this paper with indication of future work.

II. PROBLEM FORMULATION AND CHALLENGES

A vehicular traffic scenario is given in Fig. 2. This scenario presents three key situations. Our main objective here is to define potential problems with existing methods, used in actual vehicular scenarios. The given scenario shows a traffic jam situation due to an accident or at traffic light/railway crossing. Other vehicles that are approaching this traffic jam condition are slowing down. The vehicles which are far from this are still travelling at high speeds. From this, three very important observations are made. The first observation is that the proposed physical layer must cater for high speed environments and provide optimal Bit Error Rate (BER) performance in varied vehicular scenarios. The second observation is that the proposed MAC layer must work efficiently in high node density situations. The third observation is that the routing protocols should include node velocity and link quality information in decision making processes in order to provide delay bounded services in the dynamically altering network topology. Furthermore, the proposed protocols must be scalable to accommodate newly arrived vehicles without performance degradation.

This section discusses the performance related issues of physical and MAC layers of proposed DSRC technology, keeping in mind the requirements provided in this scenario.

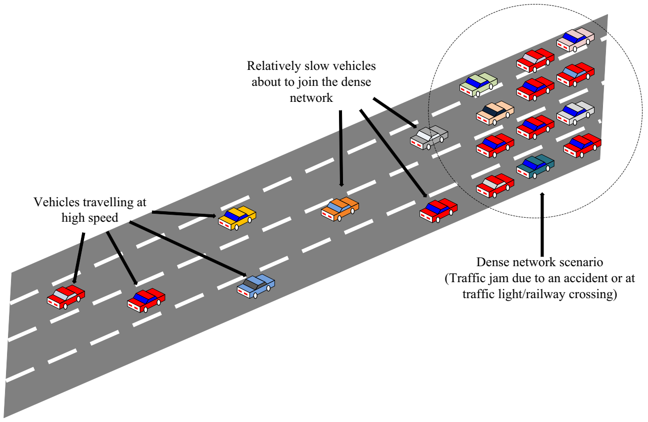


Figure 2 A realistic vehicular scenario with different networking requirements

A. *DSRC Physical Layer Challenges*

Wireless Access in Vehicular Environments (WAVE) standards comprise IEEE 802.11p and IEEE 1609.X (1, 2, 3, and 4) standards. IEEE 802.11p standard or commonly known as DSRC technology refers to short to medium range (up to 1000m) wireless communication technology with potential of supporting high speed data transfer (up to 27 Mbps) in vehicular environments. Fig. 3 shows a proposed WAVE protocol stack given in [2].

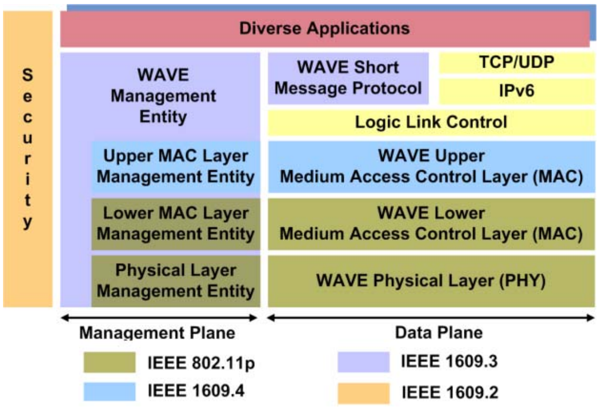


Figure 3 Wave protocol stack

Considering the technological advancements and high production rate or in other words low price of devices, IEEE 802.11 technology is the most suitable option to support vehicular networking demands. IEEE 802.11p is an extension of IEEE 802.11a technology in vehicular environments which provides physical layer (PHY) and MAC layer specifications. According to [3], 75 MHz of spectrum at 5.9 GHz band is allocated for vehicular communications in north America. This 75 MHz spectrum is further divided into seven channels of 10 MHz bandwidth with 5 MHz of guard band. Channel 178 is a Control Channel (CCH). This CCH is used for all safety message dissemination and other management aspects of communication. The rest of the band is divided into six Service Channels (SCHs). SCHs can be used for safety as well as non-safety application usage.

IEEE 802.11p uses Orthogonal Frequency Division Multiplexing (OFDM) technique. Vehicles travelling at high speeds suffer from the worst channel scenarios that induce multipath fading related issues. Signal coming from different paths arrive at different times and phases. This phenomenon deteriorates the signal quality. Again vehicles travelling at different speed, with different node density and in different locations experience different channel characteristics. Authors in [4] measured DSRC wireless channels by conducting field experiments in urban, rural and highway environments with mixed traffic. From their collected data they noted that with the coherence time of 0.26ms to 1.02ms, a channel may remain invariant for small packets only and for larger packets (>367 bytes) the channel may experience fluctuations. Channel variations within a packet duration demands intelligent signal processing techniques. To alleviate issues allied with rapid changes in vehicular channels, Woong *et al.* [5] proposed a new scheme for channel estimation. Their scheme utilises mid-amble for updating and tracking the channel information. Their results proved that mid-amble aided channel estimation improves the Bit Error Rate (BER) performance in harsh channel environments.

It is clear from the literature that proposed DSRC parameters cannot fulfill BER requirements for all channel conditions. So that in order to improve the reliability of communication, further processing in terms of equalisation and channel estimation is required. Due to space limitations, we do not discuss equalisation techniques in this paper and assume that we have such equalisation functioning at the physical layer with improved BER performance in harsh channel conditions. We will investigate this subject matter in the future.

B. *DSRC MAC layer Challenges*

The IEEE 802.11p standard proposes implementation of the IEEE 802.11 MAC protocol which uses asynchronous Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) technique. The IEEE 802.11 MAC protocol employs the Distributed Coordinated Function (DCF) mechanism. DCF supports ad hoc mode of communication without any need of infrastructure. Furthermore, to meet Quality of Service (QoS) requirements of different applications, WAVE standards propose using Enhance Distributed Coordinated Function (EDCF).

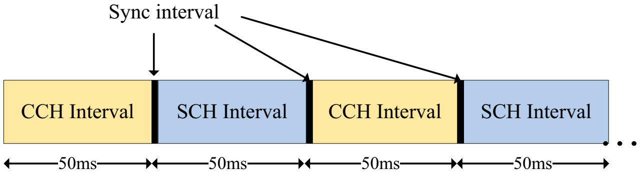
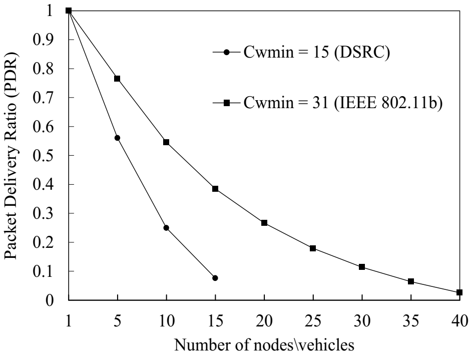


Figure 4 Channel switching mechanism from IEEE 1609.4

The WAVE standard for multi-channel operations (IEEE 1609.4 [6]) proposes implementation of a channel switching mechanism as shown in Fig. 4. Here, all vehicles use Coordinated Universal Time (UTC) to get synchronised, according to which channel time is divided into 100ms of synchronisation intervals. One such interval comprises CCH period and SCH period. All safety related messages are being exchanged using CCH period. After predefined CCH period WAVE device switches to SCH for non-safety information exchange.

Safety applications generate messages which are useful for all the surrounding vehicles and thus should be broadcasted. Broadcasting achieves timely delivery of safety information. According to [7], the driver reaction time is in the order of 0.7 seconds or higher. To meet this delay requirement, it is imperative to achieve end-to-end packet delivery within 0.4 to 0.5 seconds. Furthermore, successful packet reception is indispensable in order for the driver to identify the emergency situation.

DCF based IEEE 802.11 MAC implements contention based medium access in order to provide fair medium access. According to DCF, a wireless station observes the medium. If medium is idle for Distributed Inter Frame Space (DIFS) time period than it checks the current value of the back-off counter. If the back-off counter is non-zero, then it selects a random value within the range of [0, Contention Window (CW) - 1] and starts decrementing the back-off counter on a slot-by-slot basis. When the medium is sensed busy, the back-off counter is frozen. The back-off countdown process is restarted when the medium becomes free again. If the back-off counter reaches zero and the medium is not busy, the station transmits the packet. The DCF mechanism does not involve any kind of acknowledgement of broadcast messages and thus there is no retransmission for lost broadcast messages. On arrival of new packets, the procedure for medium contention begins again.



Graph 1 Packet Delivery Ratio Vs Number nodes

It is shown in [8] that DSRC MAC parameters are capable of fulfilling latency requirements of safety messages. Using the mathematical model, they observed a maximum delay of 0.6ms. We use the mathematical model proposed in [9] to evaluate Packet Delivery Ratio (PDR) performance using the DSRC MAC related parameters given in [3]. Graph 1 depicts that with increased number of node density and lower minimum CW size (CWmin =15 for DSRC standard), we find that PDR performance deteriorates very quickly compared to IEEE 802.11b standard (CWmin = 31).

Hence, it becomes very clear that the DSRC MAC protocol can support stringent delay requirements related to safety applications. However, in dense traffic scenarios where many stations are trying to acquire the medium, we discovered that the DSRC MAC cannot support reliable safety message exchange. Additionally, when interference induced packet loss adds to this situation the performance further deteriorates. High node density and blind flooding create broadcast storm issues like congestion, excessive collisions, contention and redundant rebroadcast. To improve PDR performance of the DSRC MAC protocol and address broadcast storm issues, further research and a new network architecture, is required as we show later.

III. RELATED WORK

The concept of clustering of vehicles and sharing this cluster information between MAC and routing layers to guarantee special QoS requirements was proposed in [10]. However, the authors did not mention support for DSRC channel band and other WAVE standards. Other approaches [11, 12] presented cluster based DSRC architecture. The concepts were DSRC channel band compliant and used different DSRC channels for the specific tasks. Their work focused on development of MAC solutions to achieve reliable message dissemination supporting QoS requirements. All the above mentioned proposals utilized schedule based channel access (using TDMA) in their MAC protocols for intra-cluster communication. Furthermore, another cross-layer design approach presented in [13] divided roads into small segments and used a cluster-based mechanism to collect information from vehicles within segment. The collected information then relayed to the infrastructure using inter-cluster communication. But the scheme presented in [13] used IEEE 802.11 MAC protocol and cluster member vehicles to unicast their information to cluster-heads using the RTS-CTS mechanism. This approach targeted unicast communication only, and so, supporting broadcasting safety information in VANETs still remains a major challenge.

IV. SmartVANET: CROSS-LAYER DESIGN ARCHITECTURE

DSRC based VANETs present unique research challenges. Multi-hop communication with limited resources calls for coordination amongst nodes. Clustering of nodes is a very well-known concept and widely discussed in the literature. SmartVANET architecture employs cross-layer integration between network and MAC layers. A CHV is selected based on a cluster-head election algorithm. This CHV provides deterministic medium access to all Cluster-Member Vehicles (CMVs) in that respective cluster. This way, when any CMV has significant safety related information to disseminate, even in dense traffic scenarios, it surely gets medium access as bandwidth assignment is done centrally and all CMVs are aware of this. This lessens chances of collision. Fig. 5 shows the working of the SmartVANET architecture and DSRC spectrum. Event 1 (E1) refers to an incident and broadcast of the message on segment specific SCH (CH 174 in this case). During this event CHV and all CMVs of segment A receive this broadcast. Event 2 (E2) shows that only CHV of segment A unicast this information to the CHV of the adjacent segment during CCH period. According to event 3 (E3) CHV of the segment B determines the importance of the message and decides to rebroadcast it in segment B during its beacon period using SCH 182. CHV of the segment B further relays this message to CHV of the segment C using CCH during Event 4. CHV of the segment C does the same job as CHV of the segment B based on the importance of the message.

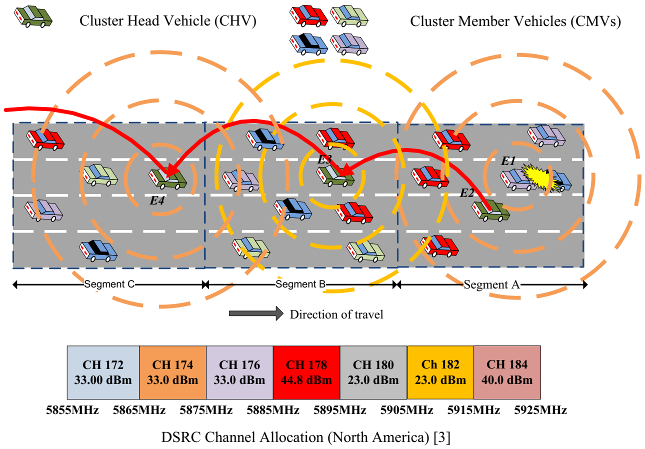


Figure 5 SmartVANET working scenario and DSRC channel plan

Furthermore, when any CMV wants to exchange non-safety/commercial application related packets, it can acquire required bandwidth by registering its demand with CHV. This way, QoS requirements are also efficiently met. Our novel concept guarantees to fulfill delay, PDR and QoS requirements in VANET. As mentioned, our concept is based on the DSRC channel plan and acts in accordance with IEEE 802.11p/1609.X standards. In this section, we provide a complete description of our proposed novel concept arguing qualitatively how it can improve the performance of DSRC based vehicular communications.

A. Channel Allocation and Assumptions

Out of seven channel plan, one service channel is assigned to one segment of 300meters for intra-cluster communication. According to [14], for the given DSRC parameters adjacent channel interference is an issue which leads to higher packet error rates whereas non-adjacent channel interference is not an issue. As shown in Fig. 6, as a starting point, we have used two non-adjacent service channels. We have assigned CH 174 to one segment and CH 182 to an adjacent segment. Again these channels are not adjacent to CH 178, so we avoid channel interference issues. In future, we plan to use all the available SCHs from the DSRC spectrum and assign them carefully to the segments.

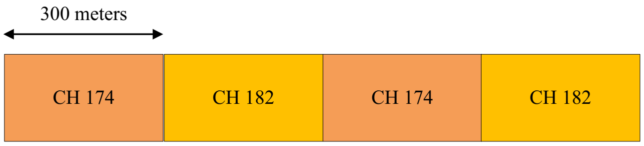


Figure 6 Road is divided into 300meters long segments and a specific service channel is allocated to each segment.

We assume that all the vehicles are fitted with DSRC radio and navigation system (GPS/Galileo). Also, all vehicles have systems with geographical maps pre-installed, in which roads are already (statically) divided into segments of 300m length (by virtue of their locations). Mapping of channels to segments is already done and pre-installed in systems. We also assume that vehicles are synchronised on the basis of slots and the navigation systems work with adequate precision (so that cars know when they are within a particular segment and when not). As a starting point, we only consider linear road segments with multiple lanes without any junctions.

B. *Cluster Formation*

In our SmartVANET architecture, each vehicle operates under three states at any given time: 1) Cluster-Head Vehicle (CHV), 2) Cluster-Member Vehicle (CMV) and 3) Undecided state. When a new vehicle joins the road, it is in the undecided state. Based on its location information, it selects a segment specific SCH. Upon reception of a CHV beacon a vehicle in undecided state understands the presence of CHV and decides to join the cluster. All vehicles exchange beacon messages, also known as CMV beacon messages, during the beacon period (random access phase) of the SCH. If there is no CHV beacon at the beginning of the SCH interval then based on the cluster-head election algorithm, one vehicle becomes the CHV and advertises its state in the next SCH and starts accepting cluster joining requests from vehicles in the undecided state. In the succeeding CCH interval, the CHV announces its presence for other CHVs in adjacent segments,enters the particulars of the cluster joining requests from vehicles in undecided state and prepares transmission schedule to broadcast in next SCH interval with its beacon. This way, vehicles in the undecided state change their status to CMV when they find their transmission slot information in the CHV's beacon message.

C. *Cluster-Head Election Algorithm*

SmartVANET architecture employs a unique cluster-head election algorithm. This algorithm uses location information to elect a cluster-head. Vehicles entering into the segment first listen for the CHV beacon to detect the presence of a cluster-head. If no CHV beacon is received for a threshold time (T_{thr}), recently entered vehicles set a random timer. A vehicle whose timer expires first, announces itself as a CHV in SCH. As this vehicle just arrived into the segment, it can serve as a CHV for a longer period. Furthermore, in case of roads with multiple lanes, it is possible for more than one vehicle to enter the segment at the same time. Selection of random timer value makes the cluster-head election process fair and random. Once a CHV is elected, the normal cluster formation process continues where vehicles register themselves with this CHV as CMVs. The CHV maintains a table of CMVs. Furthermore, it also collects the information regarding the CHVs in adjacent segments using CCH. This way CHVs play the role of an administrative entity. The CHV also has one more responsibility in SmartVANET: when a particular CHV is about to leave the segment, it elects a new CHV. From the CMVs table it selects the last arrived CMV as a new CHV for the segment. CHV assembles this information into its beacon message. All present CMVs receive this beacon message and change their respective CHV entries to the newly selected CHV. This is shown in the Fig. 7. Hereafter, the newly selected CHV takes charge and starts its duty as a CHV. This way, the latest arriving CMV becomes the CHV so it is likely to be in the segment longest to serve as a CHV.

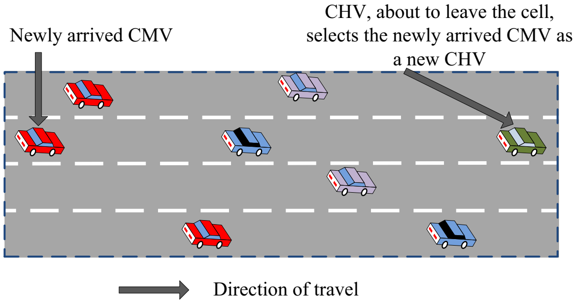


Figure 7 CHV selects the new CHV from its table

On the event when CHV meets with an accident and becomes unavailable as a cluster-head, new CHV election process starts. All CMVs expect beacon from CHV in the beginning of the SCH period. Absence of CHV beacon for T_{thr} indicates unavailability of the CHV. Newly arrived vehicles based on their location sets the timer and begin the countdown process to become CHV. This way new CHV gets elected which takes charge of the segment and recreates the tables with entries regarding CMVs of the same segment and CHVs of the adjacent segments.

D. *SmartMAC:Intra-Cluster Communication*

Reliable medium access is very crucial in order to bring DSRC based VANETs into reality. One of the unique features of VANETs is unpredictable node density. Node density shows temporal and spatial dependencies. Protocols developed for VANET must cater for highly congested network scenarios as well as sparse network scenarios. As we showed in graph 1, DSRC MAC parameters do not provide optimal PDR performance when node density is high. To achieve reliable medium access, SmartVANET proposes SmartMAC solution, which is based on TDMA, for intra-cluster communication. According to SmartMAC, the CHV employs a scheduling mechanism over segment specific SCH (CH 174 and CH 182). SmartMAC divides SCH period into three different phases.

Fig. 8 shows TDMA frame for the SmartMAC protocol. This structure of the frame is based on the frame proposed in [10]. The CHV slots the schedule based phase (T_{SBP}) of the SCH into small time slots (T_s) and broadcasts the schedule. This way, the CHV can guarantee that each CMV gets a chance to broadcast its information.

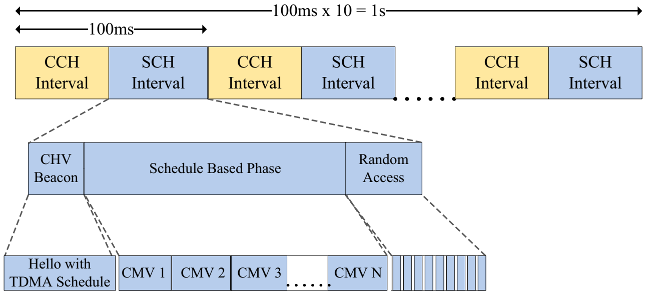


Figure 8 TDMA frame of SmartMAC protocol

All CMVs broadcast related information in their respective time slots only. As shown in Fig. 8, at the beginning of a SCH interval, the CHV advertises its presence with slot assignment information. The advantages of this method are twofold. First, all present CMVs and vehicles in undecided state get to know the presence of the CHV. Secondly, all CMVs are informed about their time slot for transmission in that SCH interval. In this slot assignment information, all nodes are provided with a unique slot. Upon reception of this information CMVs determine when they are scheduled to transmit. This way safety application messages are disseminated rapidly in that particular segment within the SCH interval.

According to [11], an average number of CMVs in any given cluster with radius C*r* can be determined by:

$$Cn = \frac{2CrLn}{Vl+Vg} \qquad (1)$$

Where Ln is number of lanes in one way on highway, Vl is the average length of a vehicle and Vg is the average gap between two vehicles. As shown in [11], T_s can be calculated by $T_s = T_{SBP}/Cn\text{-}1$. As TDMA offers contention free medium access, for a given packet size P (payload + overhead) and data rate R, we can obtain the time required (T_d) for packet transmission. It is very obvious that T_s length must be greater than T_d in order to successfully transmit the packet within one slot.

Furthermore, when the node density is very high (in case of increased number of lanes with fixed cluster size), so that $T_d > T_s$, it again becomes an issue. To solve this problem, we propose a variable slot length allocation mechanism. As shown in Fig. 8, SmartMAC uses frame of 1s length with 10 cycles of 100ms time period. The key idea here is to provide slots on basis of the demand when required. For example, when node density is high and available slot length is short, the CMV can request its CHV for a longer slot period reservation in the next SCH period. Thus SmartMAC protocol guarantees deterministic channel access with higher PDR even in high node density scenarios.

The last part of the SCH interval is the random access phase. Again this period is slotted and slots are only of size required to transmit small beacon packets. Newly arrived vehicles first switch to the segment specific SCH and, upon reception of the CHV beacon, detects the CHV. During the beacon period they select a beacon slot randomly and transmit their CMV beacons containing their unique ID (MAC address) and vehicular specific information to join the cluster. During the CCH interval, the CHV processes this information from the present CMVs and deals with new cluster membership requests from newly arriving vehicles. The CHV again prepares the schedule for slot assignment and broadcasts it with its beacon in the next SCH interval. This makes our SmartMAC protocol scalable; as newly arrived vehicles can join the network and receive time slots without disturbing the ongoing communication, even in dense scenarios.

E. SmartMAC: Inter-Cluster Communication

In our scheme, CHV to CHV communication takes place on CCH. CHVs use CCH for two reasons. Once a CHV receives a safety message during the SCH period from a "victim" CMV, it unicast the same information on CCH to the adjacent segments' CHVs. These CHVs then rebroadcast the same information within their segments. This mechanism further improves reliability in case of multi-hop broadcasts. As CCH supports a higher power level (44.8 dBm), the CHV can unicast the message over longer regions. CHVs trying to access CCH use the IEEE 802.11 MAC and as there are only CHVs trying to access CCH, the probability of collision decreases drastically. Upon reception of safety messages from the CHV from the "front" segment, a CHV makes a decision regarding rebroadcasting within its own segment.

Another use of CCH is to support non-safety application messages. For unicast applications, CHVs play a role as a virtual "backbone" infrastructure. A CMV enquires regarding destination vehicles with CHV. The CHV checks its table and if the entry of the destination is found in the table, it provides the channel slot on the SCH for direct communication between source and destination. If the destination is not within the segment, then the CHV enquires regarding the destination with other CHVs on CCH. In this way, CHVs act as routers and improve network performance by providing an administrative support.

V. ADVANTAGES OF SmartVANET ARCHITECTURE

The SmartVANET architecture has potential to solve issues allied with DSRC based VANET. This section summarises the advantages of the SmartVANET architecture. The advantages are listed below:

1) SmartVANET architecture can support safety, non-safety and commercial applications. It can successfully support single-hop broadcast, multi-hop broadcast and unicast communication.
2) SmartVANET is DSRC compliant and efficiently utilises the DSRC spectrum. It also supports multichannel operation proposed in IEEE 1609.4 standard.

3) SmartVANET architecture uses physical layer adaptive equilisation technique to address channel impairments.
4) SmartVANET uses non-adjacent SCHs in adjacent segments. Thus, it avoids co-channel and adjacent channel interference. Use of segment based channel access avoids the hidden terminal problem as vehicles in adjacent segments are communicating over different channels simultaneously.
5) The architecture improves broadcast reliability. Non-deterministic contention based IEEE 802.11 MAC protocol suffers from lower PDR and broadcast storm issues in high node density scenarios. SmartVANET employs hybrid SmartMAC protocol that uses schedule based channel access mechanism to alleviate collisions and contention. Transmission during allocated time slots guarantees the packet delivery. Random access phase of the SmartMAC protocol ensures scalability as vehicles can join the network without disrupting the ongoing communication.
6) A CHV collects the relevant information from the segment and exchanges with other CHVs on CCH. When it is required, this CHV re-broadcasts the collected information. Thus, SmartVANET improves the multi-hop broadcasting.
7) The architecture also supports unicast applications. CHVs maintain separate tables regarding CMVs and adjacent CHVs. The provision to allocate more bandwidth to CMVs on demand is also made so that the QoS performance of unicast applications can also be improved.

VI. FUTURE WORK AND CONCLUSION

DSRC technology proposes the use of IEEE 802.11 MAC technology with IEEE 1609.4 standard as an extension. This paper discussed that the DSRC physical layer and MAC layer performance raise questions about their ability to support reliable communication in VANETs. The DSRC physical layer can support reliable communication using further processing techniques. However, DSRC MAC shows degraded performance in congested traffic scenarios. With the aim of improving DSRC based VANET performance in dense scenarios, this paper presented the SmartVANET architecture. SmartVANET is based on a cross-layer paradigm. SmartVANET implements a location based channel access mechanism with coordinated medium access on SCH. SmartVANET employs a clustering scheme and assigns a CHV in each segment. CHV schedules transmissions on a segment-specific SCH so that all CMVs get a chance to transmit in a collision-free manner. SmartVANET architecture can solve broadcast storm issues and provide scalability. We contend that implementation of the SmartVANET architecture can guarantee delay bounded information dissemination with high delivery rates. We are currently developing the appropriate simulation environment to experimentally evaluate SmartVANET. Its performance will be evaluated for safety and non-safety applications. The performance of our cluster-election algorithm and the SmartMAC protocol will be evaluated under different traffic conditions and different channel scenarios. SmartMAC protocol will be mathematically analysed and all the time related parameters will be extensively studied and discussed in our future papers.

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