Chapter 2
System Model

2.1 VANET Description: Elements and Applications

The VANET under consideration consists of a set of RSUs and a set of vehicles moving in opposite directions on two-way vehicle traffic roads. A vehicle is said to be moving in a left (right) direction if it is currently heading to any direction from north/south to west (east). Based on this definition, as shown in Fig. 2.1, if two vehicles are moving in opposite directions on a two-way road, it is guaranteed that one vehicle is moving in a left direction while the other vehicle is moving in a right one, regardless of the orientation of the road. The vehicles and RSUs broadcast safety messages (periodic and event-driven) for the purpose of safety applications. The periodic safety messages broadcast by different vehicles have the same (fixed) message size[1]. Also, the periodic safety messages broadcast by an RSU have equal message size, which may differ from the size of the periodic messages broadcast by another RSU based on the application.

2.2 Communications Channels

The VANET has one CCH and N_{sch} service channels (SCHs), denoted by $c_1, c_2, \ldots,$ $c_{N_{sch}}$. The CCH is used for transmission of two kinds of information: high priority short applications (such as periodic or event driven safety messages), and control information required for the nodes to organize the communications over the service channels. The N_{sch} SCHs are used for transmission of safety or non-safety related application messages. It is assumed that the transmission power levels on all channels are fixed and known to all nodes. All channels are symmetric, in the sense that node x

[1] A generic format of a periodic safety message, called the Basic Safety Message (BSM), is specified in the SAE J2735 application layer standard [1] to be broadcast by vehicles. The BSM makes use of the large similarity among the vehicle state information required by various V2V applications in order to avoid using a specific message for each application, which may result in a waste of the wireless network resources [2].

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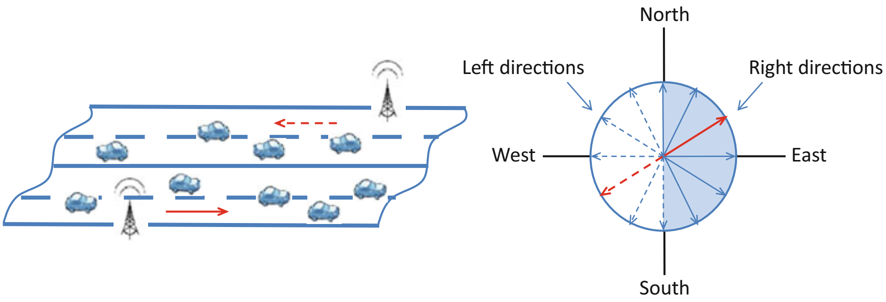

Fig. 2.1 Right and left directions of vehicle movement [3]

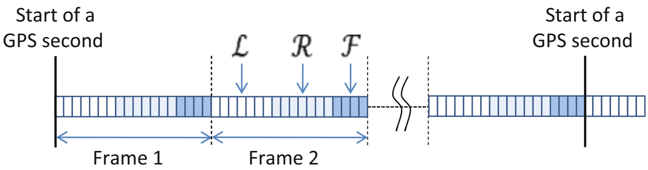

Fig. 2.2 Partitioning of each frame on the CCH into $\mathcal{L}, \mathcal{R}$ and $\mathcal{F}$ sets [3]

is in the communication range of node y if and only if node y is in the communication range of node x.

On the CCH, the time is partitioned to frames consisting of a constant number L of time slots of equal duration t. Each frame is partitioned into three sets of time slots: $\mathcal{L}$, $\mathcal{R}$, and $\mathcal{F}$, in that order, as shown in Fig. 2.2. The $\mathcal{F}$ set is associated with RSUs, while the $\mathcal{L}$ and $\mathcal{R}$ sets are associated with vehicles moving in left and right directions respectively. Each second contains an integer (fixed) number of frames, and each time slot is identified by the index (from 0 to $L - 1$) of the time slot within a frame.

2.3 Node Equipment and Identification

Each node (i.e., vehicle or RSU) has two transceivers: Transceiver1 is always tuned to the CCH, while Transceiver2 switches among the SCHs. Also, each node is equipped with a global positioning system (GPS) receiver and can accurately determine its position and moving direction using GPS. The current position of each node is included in the header of each packet transmitted on the CCH. Each node is identified by a unique MAC address and a set of short identifiers (IDs), called VeMAC ID, where each VeMAC ID corresponds to a certain time slot that the node is accessing per frame on the CCH (more details in Chap. 3). Each VeMAC ID is chosen by a node at random, included in the header of each packet transmitted in the corresponding time slot, and changed if the node detects that its ID is already in use by another node [4].

2.4 Time Slot Synchronization

Synchronization among nodes is performed using the one pulse per second (1PPS) signal provided by any GPS receiver. The rising edge of this 1PPS is aligned with the start of every GPS second with accuracy within 100 ns even for inexpensive GPS receivers. Hence, this 1PPS signal can be used as an accurate common time reference among all the nodes. Consequently, at any instant, each node can determine the index of the current slot within a frame on the CCH, and whether it belongs to the $\mathcal{L}$, $\mathcal{R}$, or $\mathcal{F}$ set. In case of a temporary loss of GPS signal, the synchronization among different nodes can still be maintained within a certain accuracy for a time duration which depends mainly on the stability of the local oscillator of the GPS receiver at each node [5]. If the GPS signal is lost in a certain area for a duration longer than a specified threshold, a distributed synchronization scheme, e.g., [5], should be employed until the GPS signal is recovered. Details of such a back up distributed synchronization scheme are out of scope of this brief.

2.5 Definitions

For a certain node, x, set $\mathcal{N}_x$ denotes the set of one-hop neighbours of node x, from which node x has received VeMAC Type1 packets (defined in Sect. 3.1.3) on the CCH in the previous L slots. Set $\mathcal{T}_x$ is defined as the set of time slots that node x must not use on the CCH in the next L time slots. This set is used by node x to determine which time slots it can access on the CCH without causing any hidden terminal problem. How each node x constructs and updates sets $\mathcal{N}_x$ and $\mathcal{T}_x$ is discussed in Chap. 3.

A two-hop set (THS) is defined as a set of nodes in which each node can reach any other node in two hops at most. The term ‘packet’ refers to a MAC layer protocol data unit (MPDU), and the term ‘message’ refers to a MAC layer service data unit (MSDU), i.e., the unit of information arriving to the MAC layer entity from the layer above.

References

1. “Dedicated short range communications (DSRC) message set dictionary,” *SAE J2735 Standard*, Nov. 19, 2009.
2. F. Zaid, F. Bai, S. Bai, C. Basnayake, B. Bellur, S. Brovold, G. Brown, L. Caminiti, D. Cunningham, H. Elzein, J. Ivan, D. Jiang, J. Kenny, H. Krishnan, J. Lovell, M. Maile, D. Masselink, E. McGlohon, P. Mudalige, V. Rai, J. Stinnett, L. Tellis, K. Tirey, and S. VanSickle, “Vehicle safety communications-applications (VSC-A) second annual report,” The CAMP Vehicle Safety Communications 2 Consortium, Tech. Rep. DOT HS 811 466, Aug. 2011.
3. H. A. Omar, W. Zhuang, A. Abdrabou, and L. Li, “Performance evaluation of VeMAC supporting safety applications in vehicular networks,” *IEEE Transactions on Emerging Topics in Computing*, vol. 1, no. 1, pp. 69–83, Jun. 2013.

4. F. Borgonovo, A. Capone, M. Cesana, and L. Fratta, “ADHOC MAC: New MAC architecture for ad hoc networks providing efficient and reliable point-to-point and broadcast services,” *Wireless Networks*, vol. 10, pp. 359–366, Jul. 2004. [Online]. Available: http://dx.doi.org/10.1023/B:WINE.0000028540.96160.8a.
5. K. Kutzner, J.-J. Tchouto, M. Bechler, L. Wolf, B. Bochow, and T. Luckenbach, “Connecting vehicle scatternets by Internet-connected gateways,” in *Proc. Workshop on Multiradio Multimedia Communications (MMC 2003)*, University of Dortmund, Germany, 2003. [Online]. Available: http://i30www.ira.uka.de/research/publications/p2p/.

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