SAFETY-RELATED VEHICULAR APPLICATIONS

By
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OUTLINE

1. Introduction
2. Communications Overview
   - Overview of DSRC based vehicular safety communication
   - Control channel
   - Type of messages
     1. Periodic
     2. Event-driven
3. Vehicular Safety Communication
4. Message Broadcast
   - Message dispatcher
5. Safety applications
   1. Intersection collision Avoidance
      - Communication for improving intersection safety
   2. Public Safety
   3. Sign Extension
   4. Vehicle Diagnostics and Maintenance
   5. Information from other Vehicles
6. Safety applications examples
   1. EEBL
   2. CICAS
7. Summary

INTRODUCTION

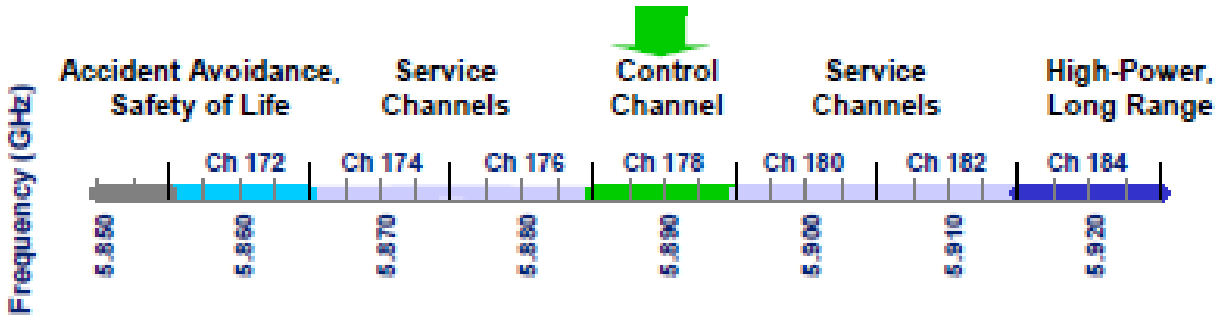
- In 2005, more than 43,000 people were killed and more than 2.6 million were injured in car accidents in the U.S.
- Safety application concept (CAAI):
  - Collect sensor information and broadcast vehicle's own status via messages
  - Aggregate information from other vehicles and infrastructure
  - Analyze, continuously, for predefined trigger conditions
  - Inform or warn the driver in an appropriate manner

COMMUNICATIONS OVERVIEW

- Overview of DSRC based vehicular safety communication:
  - Based on Dedicated Short Range Communications (DSRC):
    - Allocated 75 MHz
    - At 5.9 GHz
    - Divided into seven 10 MHz wide channels
    - Channel 178 is the control channel (CCH)
    - 2 channels reserved for future advanced accident avoidance applications
    - The reset are service channels
    - Up to 1000 meters
- Types of communication:
  - Vehicle-to-vehicle (V2V)
  - Vehicle-to-infrastructure (V2I)

COMMUNICATIONS OVERVIEW

OVERVIEW OF DSRC BASED VEHICULAR SAFETY COMMUNICATION



(c) DSRC Channel Arrangement

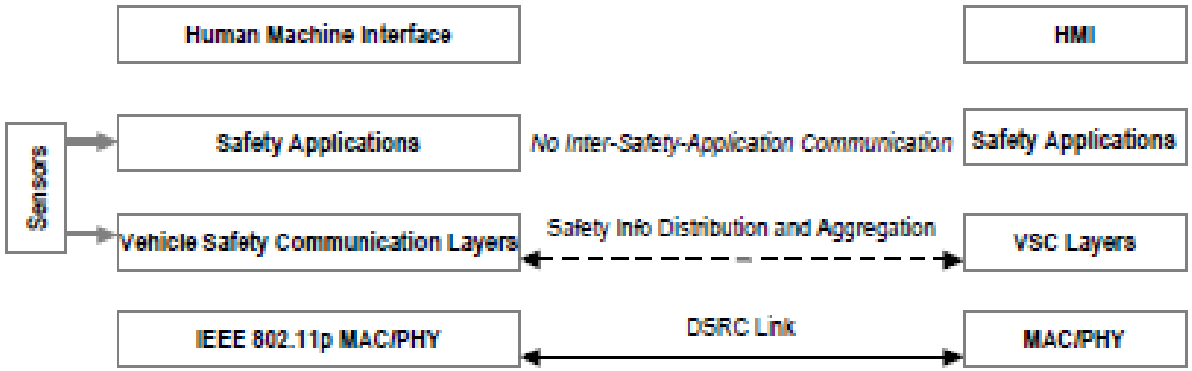
COMMUNICATIONS OVERVIEW

- Control channel [2]:
  - Control-Channel Link-Layer behavior:
    - Single-hop
    - Uncoordinated
    - Broadcast
    - Messaging
    - Unbounded system
    - All neighboring equipped vehicles
    - Dedicated channel

COMMUNICATIONS OVERVIEW

CONTROL CHANNEL

- Operational concept in control channel [2]:
  - Safety communication is not application-to-application
  - An intermediate layer is responsible for safety information distribution
  - Applications analyzing the information



Inter-vehicle Safety Communications in the Control Channel

COMMUNICATIONS OVERVIEW (CONTINUE)

- Type of messages:

1. Periodic (Routine) Messages:
   - Inform nearby vehicles about the vehicle's current status
   - May cause the broadcast storm problem

2. Event-Driven Messages:
   - Based on unsafe situations that have been detected
   - very high priority

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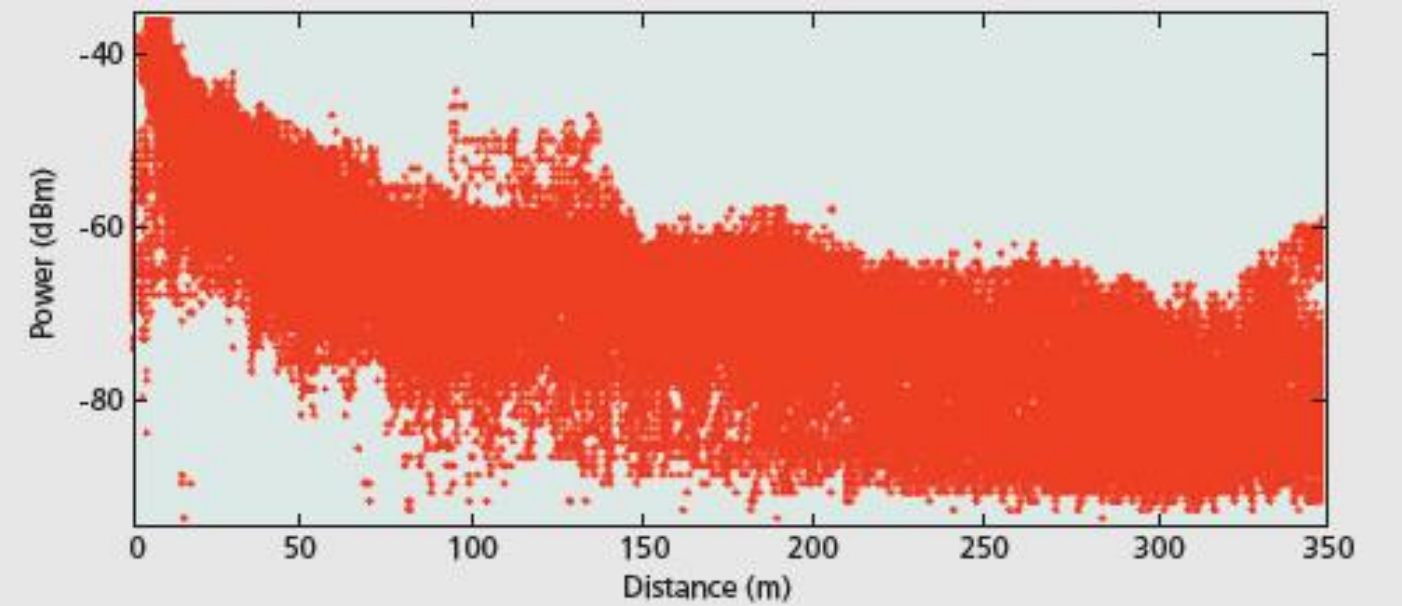
VEHICULAR SAFETY COMMUNICATION

- Control channel congestion control [2]:



(a) Distribution of received power vs. distance on freeway

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

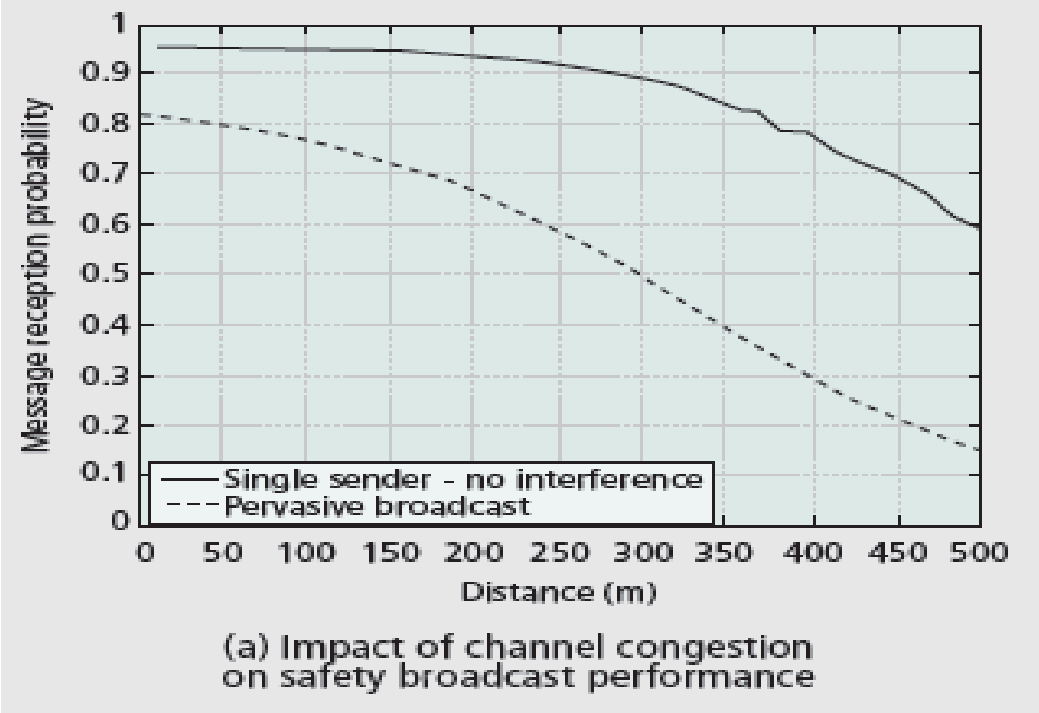
- When the channel load is heavy
  - MAC-level collisions (carrier sense mechanism)

- For DSRC safety communications, we need:
  1. Congestion Control
  2. Broadcast Performance Enhancement

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

1. Congestion Control:
   a) Motivation:

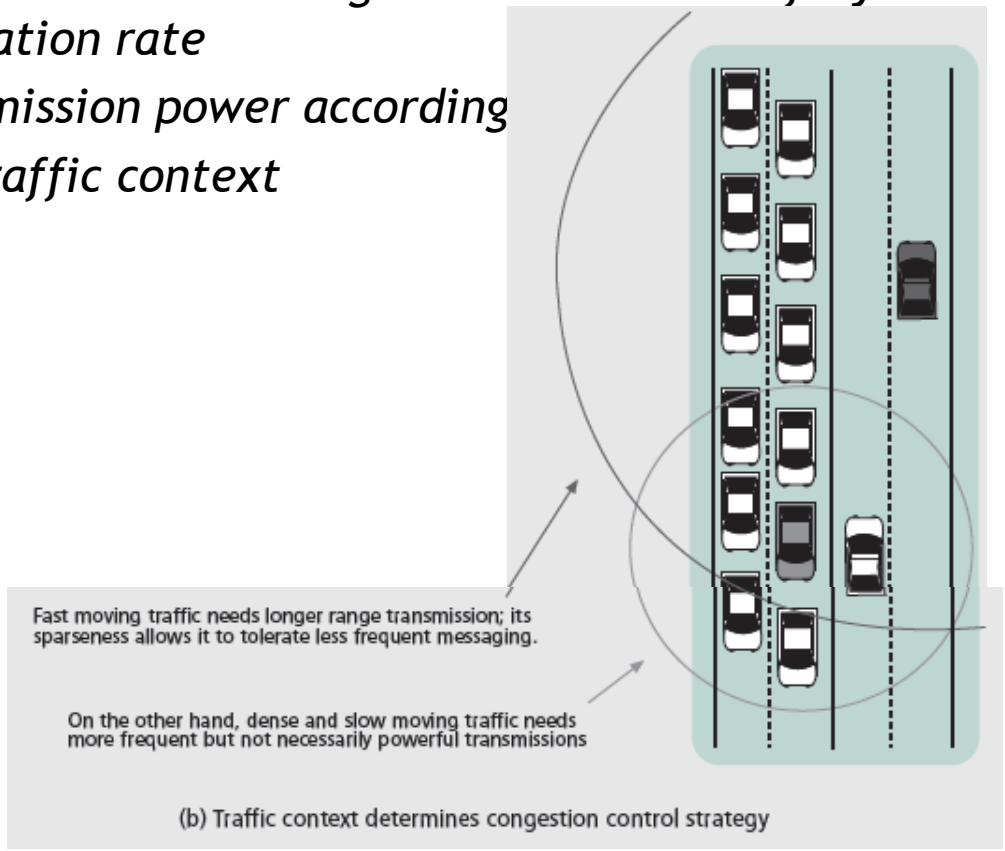


(a) Impact of channel congestion on safety broadcast performance

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

1. Congestion Control:
   b) Requirement:
      - *Each vehicle should regulate its routine safety message generation rate*
      - *Transmission power according to its traffic context*



VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

1. Congestion Control:
   c) Channel Congestion Metric:

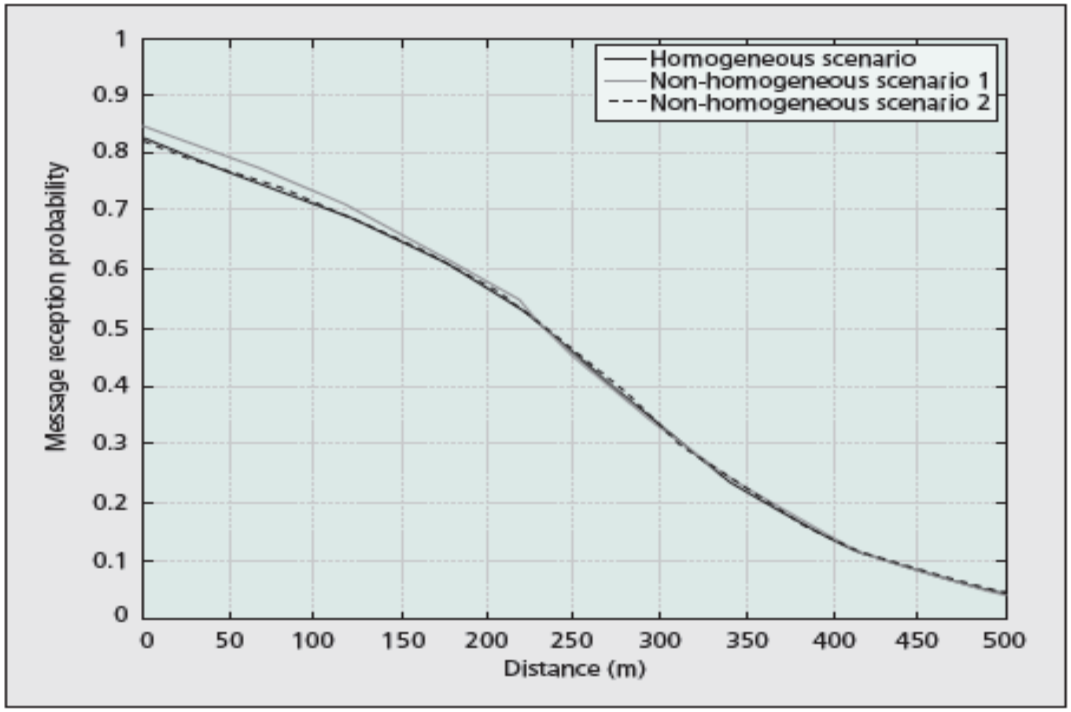


Figure 5. *Validating communication density concept*

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

1. Congestion Control:
   d) Congestion-Control Scheme:
      - should be done in the following steps:
        1. Listen and estimate the number of neighboring nodes
        2. Adjust routine safety message transmission power and generation rate
      - Timing!

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

2. Broadcast Performance Enhancement:
   a) Motivation:

      improve the reach and coverage of safety messaging

   b) Requirement:

      The communication stack should attempt to improve the average reception rate of safety messages while ensuring the best possible reception rate for each event safety message in the timeliest manner

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

2. Broadcast Performance Enhancement:
   c) Broadcast Performance Feedback:
      - Piggybacked Acknowledgment (PACK) protocol:
        - Sender's position
        - The intended range of reception
        - A randomly generated message ID
        - IDs of most recently received messages
        - The reception time

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

2. Broadcast Performance Enhancement:
   c) Echoing Routine Safety Messages :
      - each frame does not have to contain only one safety message
      - ECHO protocol:
      1. Each sender includes a recently received routine safety message body in its own frame
      2. Each receiver compares the message ID of the echoed message with history of recent receptions

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

2. Broadcast Performance Enhancement:
   d) Echoing Event Safety Messages :
      - Relatively rare
      - Better reception rates
      - ECHO protocol (Event):
      1. Each sender is required to echo a recent (e.g., originated within last 100 ms) and nearby (e.g., within 100 m) event safety message
      2. If there are more than one such messages, the sender is required to include the IDs of the additional event safety messages as well

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

- **CONCURRENT MULTICHANNEL OPERATION FOR SAFETY AND NONSAFETY APPLICATIONS:**

  a) Motivation:

  A vehicle with a conventional single-channel radio

  b) Requirement:

  a concurrent multichannel communication mechanism

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

- **CONCURRENT MULTICHANNEL OPERATION FOR SAFETY AND NONSAFETY APPLICATIONS:**

  c) Related Work:

  - All based on some synchronization-oriented schemes
  - Starves out nonsafety communication

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

- **CONCURRENT MULTICHANNEL OPERATION FOR SAFETY AND NONSAFETY APPLICATIONS:**

  d) **Peercast Concept:**

  relies on trusting peer vehicles' description of recent control-channel safety messaging activities through the ECHO protocol

  - A vehicle operating in a service channel must regularly switch back to the control channel and transmit its safety messages as usual
  - Periodically (e.g., every 100 ms), it is required to return to the control channel and listen for a few (e.g., 2–3) messages from its neighbors
  - While on the control channel:

  1. return back to the service channel, If it hears no event safety message
  2. –Else if it hears a nearby event safety message, it passes up the message to safety applications and may return to the service channel
  3. Else if it hears indication of an event safety message with an unknown ID, it is required to stay on the control channel to capture the repetition or echoing of that message before eventually returning to the service channel

VEHICULAR SAFETY COMMUNICATION

CONTROL CHANNEL CONGESTION CONTROL

- **CONCURRENT MULTICHANNEL OPERATION FOR SAFETY AND NONSAFETY APPLICATIONS:**
  - **d) Peercast Concept (continue):**
    - It must return to the control channel at any time if requested by a safety application
    - It must return to the control channel every a few seconds for a short while (e.g., 500 ms) to reorient itself with other vehicles' routine safety messages

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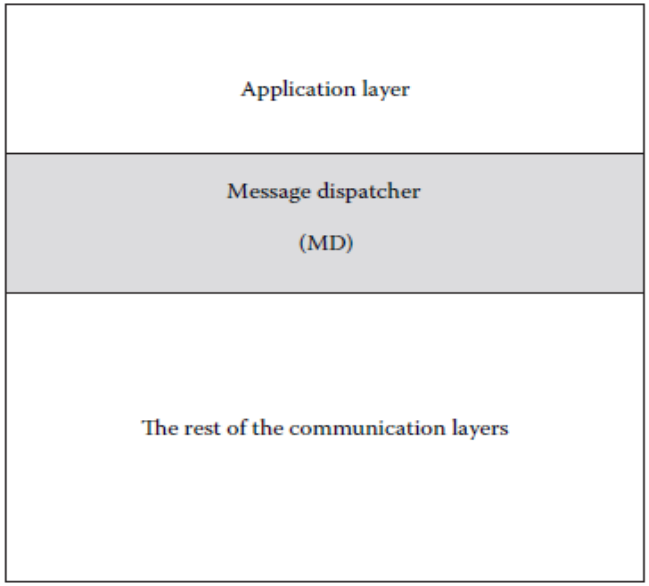
MESSAGE BROADCAST

- Vehicles exchange similar data elements
  - e.g. speed, acceleration, position, etc
- avoid redundancy
  - using data element compression

Data Element	Signal Violation	Curve Warning	Emergency Brake	Precrash Warning	Collision Warning	Turn Assistant	Lane Warning	Stop Sign Assist	No. of Uses
Acceleration	✓	✓	✓	✓	✓	✓	✓	✓	8
Airbag count					✓				1
Antilock brake state	✓		✓		✓				3
DSRC message ID	✓	✓	✓	✓	✓	✓	✓	✓	8
Elevation		✓		✓					2
Heading	✓	✓	✓	✓	✓	✓	✓	✓	8
Speed	✓	✓		✓	✓	✓	✓	✓	7
Vehicle length				✓	✓	✓	✓	✓	5
Vehicle mass		✓	✓	✓	✓				4

MESSAGE BROADCAST (CONTINUE)

- Message Dispatcher (MD):
  - An interface between different safety applications running on a vehicle and lower-layer protocols
  - One packet serves multi-applications



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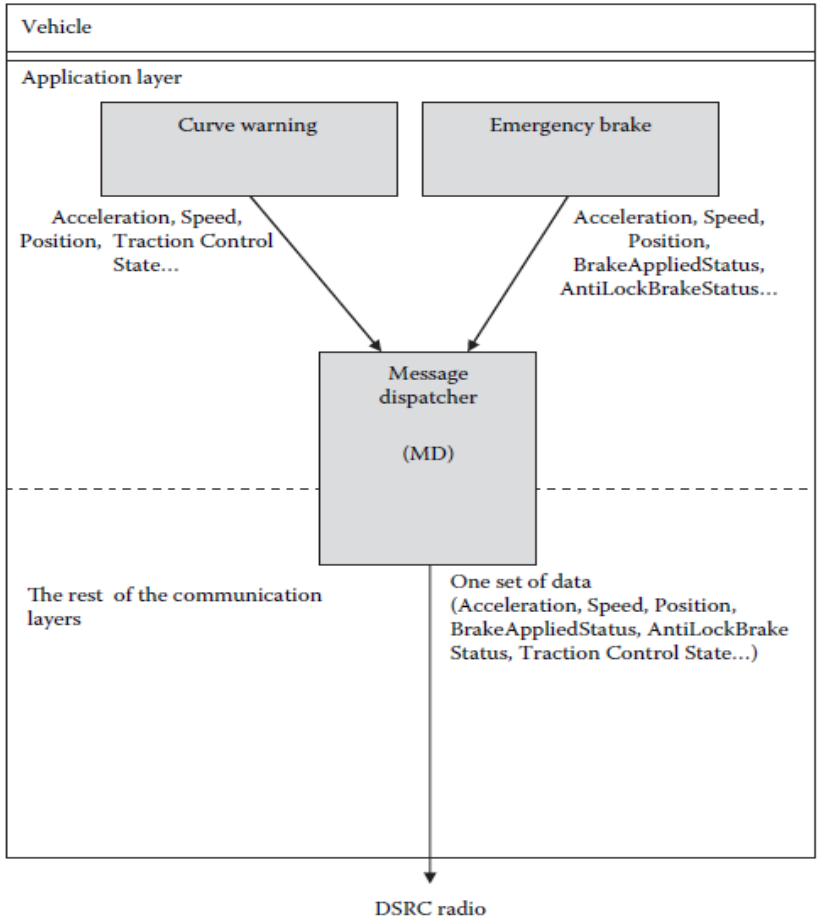

MESSAGE BROADCAST (CONTINUE)

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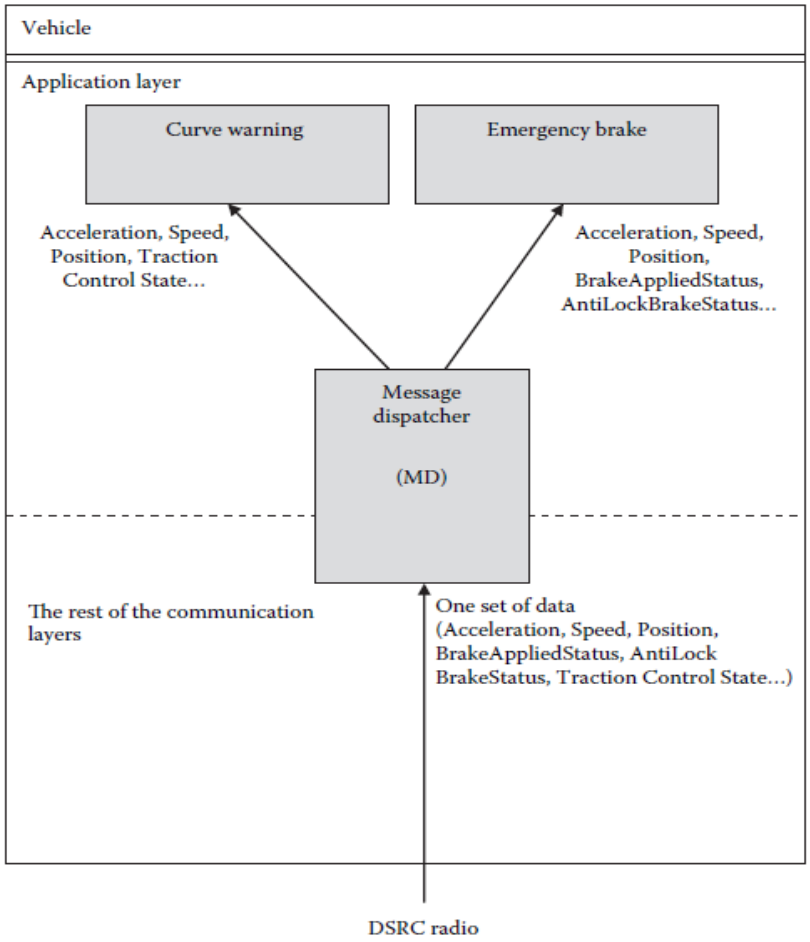

MESSAGE BROADCAST (CONTINUE)

- Data Element Dictionary:
  - 70 elements.
  - SAE data element dictionary:
    - Standard Name
    - Unique Identifier
    - Unit of Measure
    - Accuracy of Measure
    - Range of Measure
    - Description
  - data frame
    - Unique ID

Message Broadcast (Continue)

- Message Construction:

1. data frames
2. data elements
3. newly defined terms

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SAFETY APPLICATIONS

- Current safety technologies in vehicles are single vehicle-based technologies
  - No sharing with nearby vehicles
- Here, safety application are based on:
  - V2V
  - V2I and I2V

SAFETY APPLICATIONS (CONTINUE)

- Five categories:
  1. Intersection Collision Avoidance
  2. Public Safety
  3. Sign Extension
  4. Vehicle Diagnostics and Maintenance
  5. Information from other Vehicles