SAFETY APPLICATIONS (CONTINUE)

1. Intersection Collision Avoidance:
   - more than 9,000 Americans died and about 1.5 million Americans were injured in 2003.
   - I2V and/or V2I
   - Periodic messages
   - Minimum frequency 10 Hz
   - Range of communication is between 200m to 300m
   - Sensors around intersections (collect, process and analyze)
   - Warning message to certain vehicles

Safety Applications (Continue)

1. Intersection Collision Avoidance

- Communication for improving intersection safety[3]:
  - Related Work
    - Europe
    - Japan
    - The U.S.
  - Applications

SAFETY APPLICATIONS (CONTINUE)

1. INTERSECTION COLLISION AVOIDANCE

- Communication for improving intersection safety[3]:
  - Related Work
    - Communication-Based Intersection Safety in Europe:
      - Sensors and communications technologies
      - First, a vehicle detect others
      - Second, a traffic light controller communication
      - Uses static IPv4
      - No Geographic routing/Multi-hop forwarding
    - Communication-Based Intersection Safety in Japan:
      - Driving Safety Support System (DSSS)
      - RSU, infrared beacon and DSRC beacon
      - First, delivers static information (infrared beacon)
      - Second, informs approaching vehicles (infrared beacon)
      - Broadcast periodically/dynamic information (DSRC beacon)
      - Received positive feedback from test subjects

SAFETY APPLICATIONS (CONTINUE)

1. INTERSECTION COLLISION AVOIDANCE

- Communication for improving intersection safety[3]:
  - Related Work
    - Communication-Based Intersection Safety in The U.S.:
      - Cooperative Intersection Collision Avoidance Systems Initiative (CICAS)
      - Real-time warning (in vehicle and at infrastructure)
      - DSRC communications

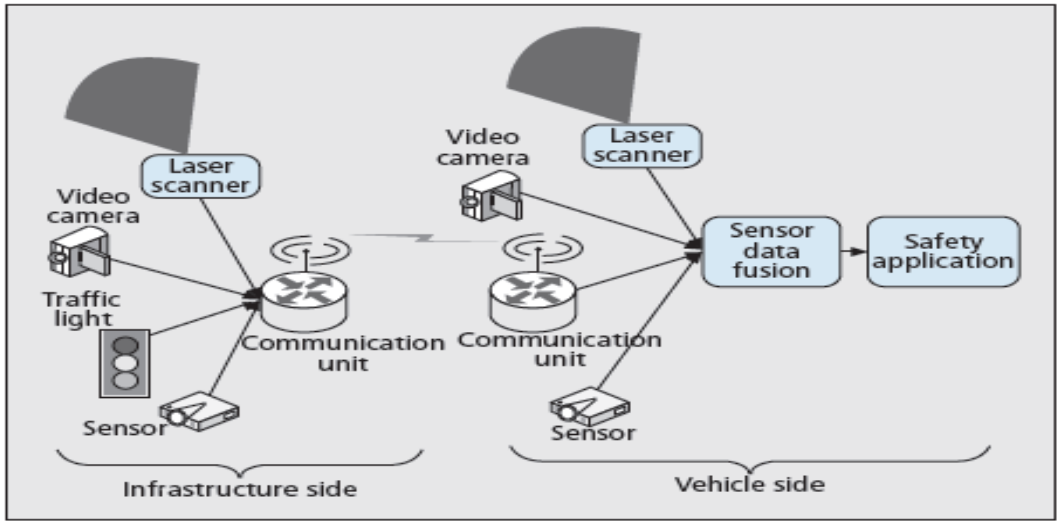


Figure 1. *High-level view of a cooperative intersection safety system.*

SAFETY APPLICATIONS (CONTINUE)

1. INTERSECTION COLLISION AVOIDANCE

- Intersection Collision Avoidance applications:
  1. Traffic Signal Violation Warning
  2. Stop Sign Violation Warning
  3. Left Turn Assistant
  4. Stop Sign Movement Assistant
  5. Intersection Collision Warning
  6. Blind Merge Warning
  7. Pedestrian Crossing Information Designated Intersection

SAFETY APPLICATIONS (CONTINUE)

1. INTERSECTION COLLISION AVOIDANCE

Application	Types of Communication	Transmission Mode	Minimum Frequency (Hz)	Allowable Latency (msec)	Data to be Transmitted and/or Received	Maximum Required Range (m)
Traffic signal violation warning	I2V One-way One-to-many	Periodic	~10	~100	Traffic signal status, timing, directionality, position of the traffic signal stopping location, weather condition, road surface type near traffic signal	~250
Stop sign violation warning	I2V One-way One-to-many	Periodic	~10	~100	Directionality, position of the stopping location, weather condition, road surface type near the stop sign	~250
Left turn assistant	V2I and I2V One-way One-to-many	Periodic	~10	~100	Traffic signal status, timing, and directionality; road shape and intersection information; vehicle position, velocity, and heading	~300
Stop sign movement assistance	V2I and I2V One-way One-to-many	Periodic	~10	~100	Vehicle position, velocity, and heading; warning	~300
Intersection collision warning	I2V One-way One-to-many	Periodic	~10	~100	Traffic signal status, timing, and directionality; road shape and intersection information; vehicle position, velocity, and heading	~300
Blind merge warning	I2V One-way One-to-many	Periodic	~10	~100	Velocity, position, heading, and acceleration	~200
Pedestrian crossing information at designated intersections	I2V One-way One-to-many	Periodic	~10	~100	Presence of a pedestrian	~200

SAFETY APPLICATIONS (CONTINUE)

2. Public Safety:
   - Assists emergency teams
   - The national reported average response time is between 6 to 7 minutes
   - I2V and/or V2I
   - Event-driven messages
   - Minimum frequency of 1 Hz
   - Range of communication is 300m ~ 1000m
   - Popular public safety applications:
     1. **Approaching Emergency Vehicle Warning**
     2. **Emergency Vehicle Signal Preemption**
     3. **SOS Services**
     4. **Post-Crash Warning**

SAFETY APPLICATIONS (CONTINUE)

2. PUBLIC SAFETY

Application	Types of Communication	Transmission Mode	Minimum Frequency (Hz)	Allowable Latency (sec)	Data to be Transmitted and/or Received	Maximum Required Range (m)
Approaching emergency vehicle warning	V2V One-way One-to-many	Event-driven	~1	~1	Emergency vehicle position, lane information, speed, and intended path/route	~1000
Emergency vehicle signal preemption	V2I Two-way One-to-one	Event-driven	N/A	~1	Emergency vehicle position, speed, direction of travel, and intended path/route	~1000
SOS services	V2I or V2V One-way One-to-many	Event-driven	~1	~1	Position, vehicle status, vehicle description, and time	~400
Postcrash warning	V2I or V2V One-way One-to-many	Event-driven	~1	~0.5	Position, heading, and vehicle status	~300

SAFETY APPLICATIONS (CONTINUE)

3. Sign Extension:
   - Alerts drivers about all types of signs
   - I2V
   - Mostly periodic messages
   - Minimum frequency of 1 Hz
   - Range of communication is100m ~ 500m
   - Sign Extension applications:
     1. In-Vehicle Signage
     2. Curve Speed Warning
     3. Low Parking Structure Warning
     4. Wrong Way Driver Warning
     5. Low Bridge Warning
     6. Work Zone Warning
     7. In-Vehicle AMBER Alert

SAFETY APPLICATIONS (CONTINUE)

3. SIGN EXTENSION

Application	Types of Communication	Transmission Mode	Minimum Frequency (Hz)	Allowable Latency (ms)	Data to be Transmitted and/or Received	Maximum Required Range (m)
In-Vehicle Signage	I2V One-way One-to-many	Periodic	~ 1	~ 1000	Condition, position, direction of travel	~ 200
Curve Speed Warning	I2V One-way One-to-many	Periodic	~ 1	~ 1000	Curve location, curve speed limits, curvature, bank, road surface condition	~ 200
Low Parking Structure Warning	I2V One-way One-to-many	Periodic	~ 1	~ 1000	Clearance height and location of parking structure	~ 100
Wrong Way Driver Warning	V2V One-way One-to-many	Periodic	~ 10	~ 100	Position, direction, warning	~ 500
Low Bridge Warning	I2V One-way One-to-many	Periodic	~ 1	~ 1000	Height of bridge, distance to bridge	~ 300
Work Zone Warning	I2V One-way One-to-many	Periodic	~ 1	~ 1000	Distance to work zone, reduced speed limits	~ 300
In-Vehicle Amber Alert	I2V One-way One-to-many	Event-driven	~ 1	~ 1000	Amber Alert information	~ 250

SAFETY APPLICATIONS (CONTINUE)

4. Vehicle Diagnostics and Maintenance:
   - provide alerts and reminders to vehicle owners about safety defects and maintenance schedules
   - I2V
   - Event-driven messages
   - Range of communication is 400m
   - Vehicle Diagnostic and Maintenance applications:
     1. **Safety Recall Notice**
     2. **Just-In-Time Repair Notification**

SAFETY APPLICATIONS (CONTINUE)
4. VEHICLE DIAGNOSTICS AND MAINTENANCE

Application	Types of Communication	Transmission Mode	Minimum Frequency	Allowable Latency (sec)	Data to be Transmitted and/or Received	Maximum Required Range (m)
Safety recall notice	I2V One-way One-to-one	Event-driven	N/A	~5	Safety recall message	~400
Just-in-time repair notification	V2I and I2V Two-way One-to-one	Event-driven	N/A	N/A	Position, heading, fault code information; location of nearest services	~400

SAFETY APPLICATIONS (CONTINUE)

5. Information from other Vehicles
   - V2V and/or I2V
   - Periodic or event-driven messages
   - Minimum frequency of 2 Hz to 50 Hz
   - Range of communication is 50m ~ 400m
   - Information from Other Vehicles applications:
     1. **Cooperative Forward Collision Warning**
     2. **Vehicle-Based Road Condition Warning**
     3. **Emergency Electronic Brake Lights**
     4. **Lane Change Warning**
     5. **Blind Spot Warning**
     6. **Highway Merge Assistant**
     7. **Visibility Enhancer**
     8. **Cooperative Collision Warning**
     9. **Cooperative Adaptive Cruise Control**
     10. **Road Condition Warning**
     11. **Pre-Crash Sensing**
     12. **Highway/Rail Collision Warning**
     13. **Vehicle-To-Vehicle Road Feature Notification**

SAFETY APPLICATIONS (CONTINUE)
5. INFORMATION FROM OTHER VEHICLES

Application	Types of Communication	Transmission Mode	Minimum Frequency (Hz)	Allowable Latency (ms)	Data to be Transmitted and/or Received	Maximum Required Range (m)
Cooperative Forward Collision Warning	V2V One-way One-to-many	Periodic	~ 10	~ 100	position, velocity, acceleration, heading, yaw-rate	~ 150
Vehicle-Based Road Condition Warning	V2V One-way One-to-many	event-driven	~ 2	~ 500	position, heading, road condition parameters	~ 400
Emergency Electronic Brake Lights	V2V One-way One-to-many	event-driven	~ 10	~ 100	position, heading, velocity, deceleration	~ 300
Lane Change Warning	V2V One-way One-to-many	Periodic	~ 10	~ 100	position, heading, velocity, acceleration, turn signal status	~ 150
Blind Spot Warning	V2V One-way One-to-many	Periodic	~ 10	~ 100	velocity, position, heading, acceleration, turn signal status	~ 150
Highway Merge Assistant	V2V One-way One-to-many	Periodic	~ 10	~ 100	position, speed and heading	~ 250
Visibility Enhancer	V2V One-way One-to-many	Periodic	~ 2	~ 100	velocity, position, heading	~ 300

OUTLINE

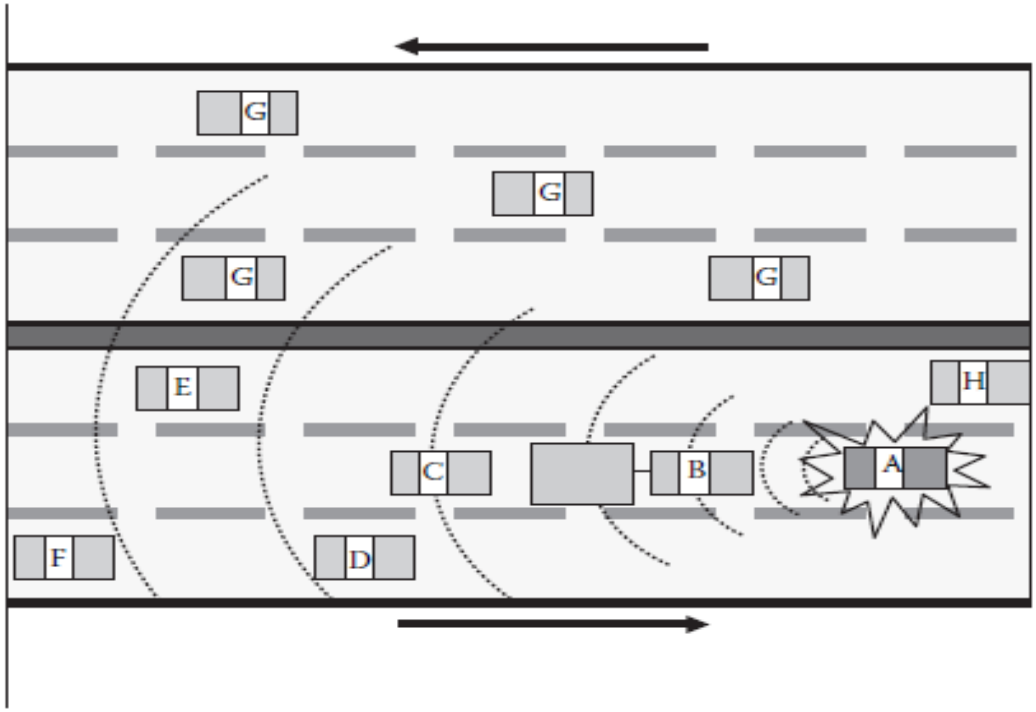
1. Introduction
2. Communications Overview
   - Overview of DSRC based vehicular safety communication
   - Control channel
   - Type of messages
     1. Periodic
     2. Event-driven
3. **Vehicular Safety Communication**
4. Message Broadcast
   - Message dispatcher
5. Safety applications
   1. Intersection 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

SAFETY APPLICATIONS EXAMPLES

- **Extended Emergency Brake Light system**(EEBL)
- **Cooperative Intersection Collision Avoidance System** (CICAS)

SAFETY APPLICATIONS EXAMPLES
EXTENDED EMERGENCY BRAKE LIGHT SYSTEM(EEBL)

- Pure V2V communication
- Alerts the driver when a preceding vehicle performs severe braking

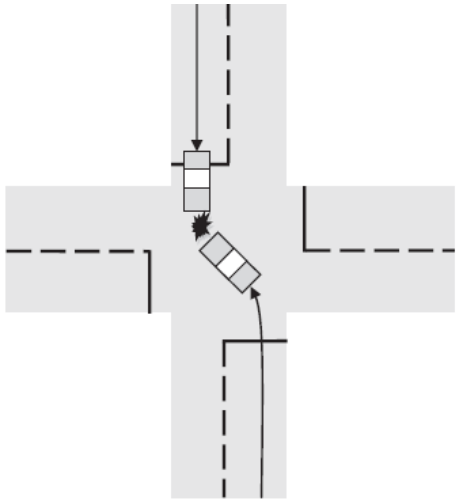


SAFETY APPLICATIONS EXAMPLES
COOPERATIVE INTERSECTION COLLISION AVOIDANCE SYSTEM (CICAS)

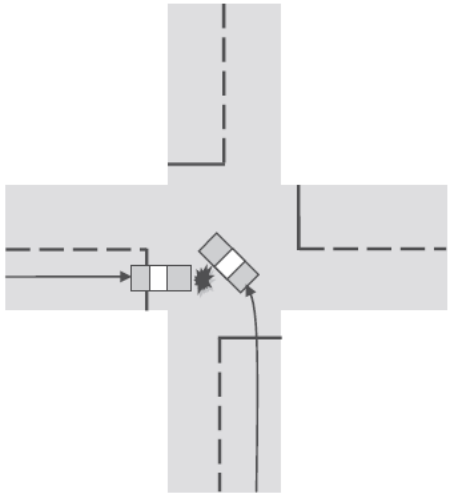
- V2I and I2V communications
- Prevents accidents between vehicles approaching or crossing intersections
- Traffic light intersections and stop sign intersections
- Scenarios of vehicle accidents at intersections:
  1. Left turn across path – Opposite Direction
  2. Left turn across path – Lateral Direction
  3. Left turn into path
  4. Right turn into path
  5. Straight crossing path

SAFETY APPLICATIONS EXAMPLES

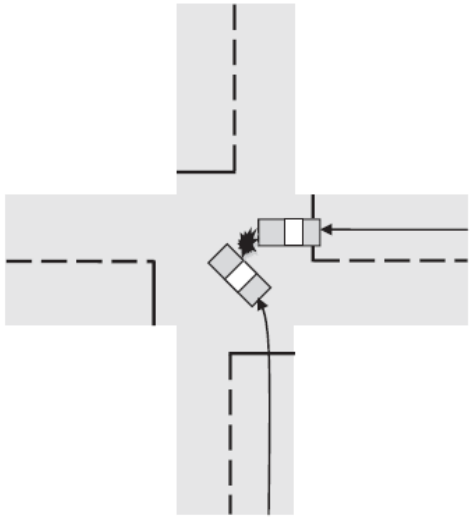
COOPERATIVE INTERSECTION COLLISION AVOIDANCE SYSTEM (CICAS)



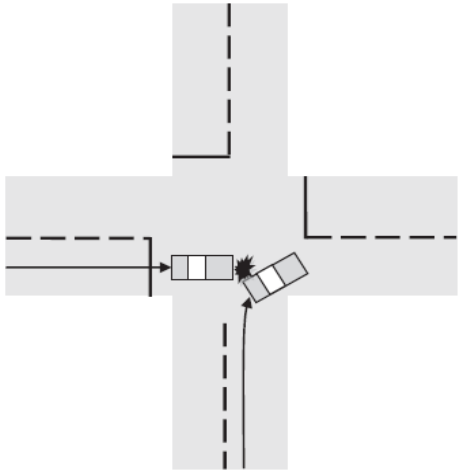
Left turn across path—opposite direction.



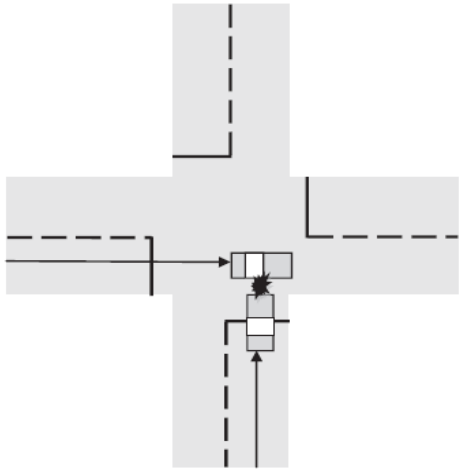
Left turn across path—lateral direction.



Left turn into path.



Right turn into path.



Straight crossing path.

SAFETY APPLICATIONS EXAMPLES
COOPERATIVE INTERSECTION COLLISION AVOIDANCE SYSTEM (CICAS)

- Two systems:
  1. An in-vehicle system:
     - Sends messages about the speed, acceleration, position and heading
  2. A roadside system:
     - Receives messages and process the data
     - Determines the unsafe situations
     - Sends a warning message to the vehicle

SAFETY APPLICATIONS EXAMPLES
COOPERATIVE INTERSECTION COLLISION AVOIDANCE SYSTEM (CICAS)

- GeoNetworking [3]:
  - An ad hoc routing protocol
  - Communications using geographical positions
  - *geographical addressing*
  - Assumes:
    1. Every node has a partial view of the network topology
    2. Every packet carries a geographical address
  - on a per-packet basis (No maintain routes)
  - three main protocol components:
    1. Beaconing
    2. Location service
    3. Forwarding
  - Destination :
    1. A single node (*GeoUnicast)*
    2. *A* group of nodes (*GeoBroadcast)*
    3. Any node in a geographical area (*GeoAnycast)*

Safety Applications Examples
Cooperative Intersection Collision Avoidance System (CICAS)

- GeoNetworking and Intersection Safety:
  - Provides three main networking services:
    1. Periodic messages
    2. Multi-hop dissemination
    3. GeoUnicast

Safety Applications Examples
Cooperative Intersection Collision Avoidance System (CICAS)

- Communication Architecture [3]:
  - An RSU installed at an intersection
  - The RSU has an Ethernet interface
  - The RSU serves as a gateway and relay node
    - GeoNetworking
  - How can a vehicle configure an appropriate IP address in order to exchange safety information with an RSU?
    - GeoNetworking operates as a sub-IP layer and offers the IP layer a single, link-local multicast capable link that spans multiple physical links
  - The header of GeoBroadcast packet specifies the geographic surrounding that the packet is to be transmitted to
  - VANET appears as a flat network topology to the IP layer

SAFETY APPLICATIONS EXAMPLES
COOPERATIVE INTERSECTION COLLISION AVOIDANCE SYSTEM (CICAS)

- Communication Architecture [3] (continue):
  - The link seen by the IP layer includes nodes that are not in direct communication range of each other
  - Using the virtual link provided by GeoNetworking, vehicles can perform IP address configuration to exchange safety information with the RSU
  - In IPv6:
    - The RSU periodically broadcasts a Router Advertisement (RA) contained a Geo- Broadcast packet
    - The header specifies the geographic area of an intersection
    - a vehicle applies geographic filtering before delivering the RA to the IPv6 layer
    - IPv6 processes these message as if the vehicles were directly connected to the RSU and performs address configuration
    - After completing IP address configuration, a vehicle can exchange safety information with the RSU

SAFETY APPLICATIONS EXAMPLES
COOPERATIVE INTERSECTION COLLISION AVOIDANCE SYSTEM (CICAS)

- Communication Architecture [3] (continue):

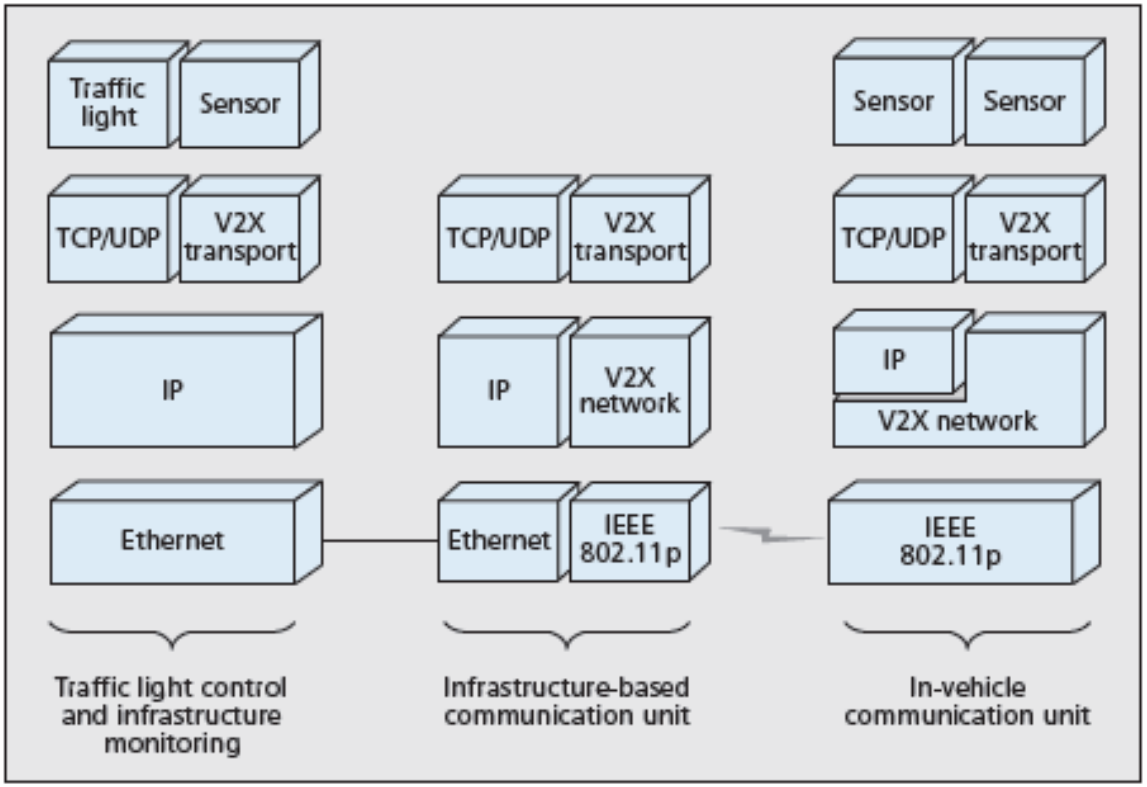


Figure 2. *Communication architecture for intersection safety.*

SAFETY APPLICATIONS EXAMPLES
COOPERATIVE INTERSECTION COLLISION AVOIDANCE SYSTEM (CICAS)

- **SIMULATION**[3] (continue):

Description	Value
Lanes per approach	2
Approach length	1 km
Mean inter-vehicle distance	100 m (low vehicle density)
	50 m (medium vehicle density)
Average speed	50 km/h
Traffic light phase	60 seconds

Table 1. *Intersection parameters.*

SAFETY APPLICATIONS EXAMPLES
COOPERATIVE INTERSECTION COLLISION AVOIDANCE SYSTEM (CICAS)

- **SIMULATION results**[3] (continue):

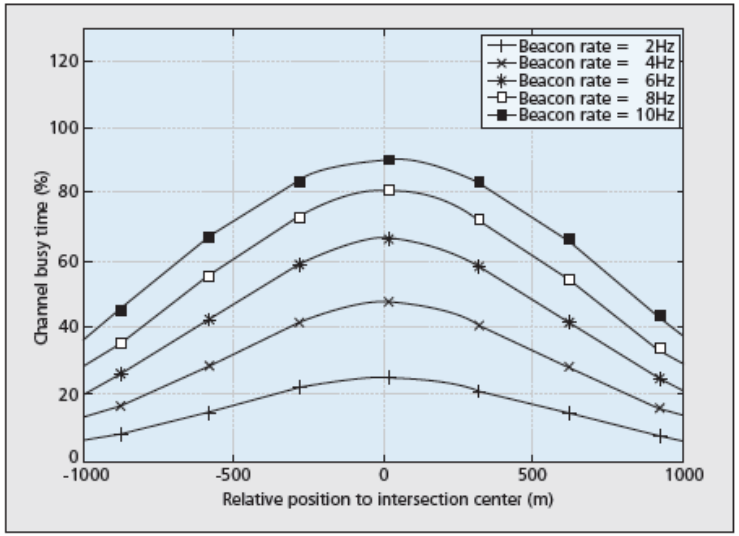


Figure 3. *CBT for low vehicle density.*

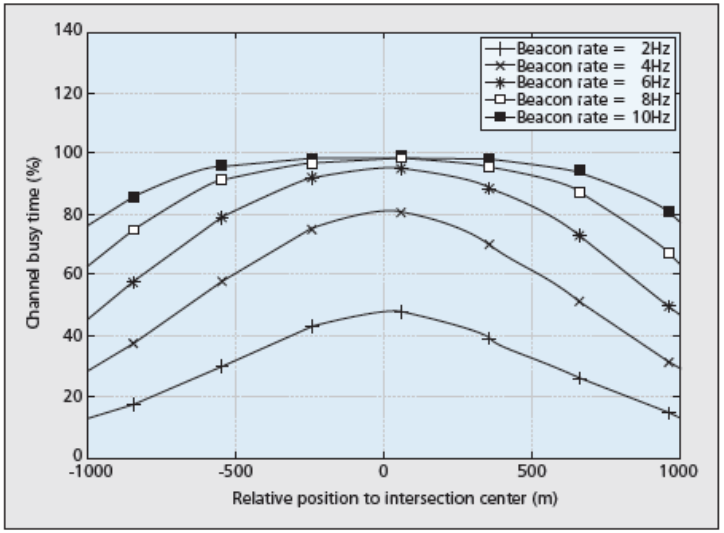


Figure 4. *CBT for medium vehicle density.*

SUMMARY

- Summarized the current state of the art of safety applications in VANETs
- Some official statistics
- Message Dispatcher (MD) eliminates the redundant data elements
- Safety applications are classified to five different categories

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