Medium Access Control in Vehicular Ad Hoc Networks

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Introduction
What is a VANET?

• Vehicular *ad hoc* networks
• Dezentralized network topology
  – No access point or base station
  – Peer-to-peer communication
• Self-organization
• Can contain roadside units (RSU)
Characteristics of VANETs

• Share a common communication channel
• Broadcast
  – Traditional Automatic Repeat reQuest (ARQ) are not available
• The multipath environment where the radiowaves propagate
  – 5.9 GHz has been chosen for VANETs
• The number of participating nodes in a VANET cannot be restricted
Why Traffic Safety Applications?

Why Traffic Safety Applications?

.... decrease the number of traffic accidents by introducing traffic safety applications, but also to reduce congestion, travel-time, and pollution through traffic efficiency applications...

• Lane change warning
• Overtaking vehicle
• Merge assistance
• Use different communication technologies depending on application
  – IEEE 802.11p, 3G, Mobile WiMAX
Real-Time Communication

• Traffic safety applications have concurrent requirements on delay and reliability
• Packets have a deadline to meet
• Time-triggered position messages
  – 2-10 Hz, 300-800 byte
  – Cooperative awareness messages (CAM)
  – Facility: Local dynamic map
• Event-driven hazard warnings
  – Packet size and periodicity depend on traffic safety application

Broadcast

Here I am!
Medium Access Control in VANET

• Responsible for scheduling channel access to minimize interference to increase reliability
• How to guarantee these low delay applications that the packet arrives in time?
• The MAC method must be decentralized, scalable and predictable
• Only standard supporting direct vehicle-to-vehicle communication is 802.11p – 5.9 GHz
WAVE

WAVE = Wireless Access in Vehicular Environment

WAVE = IEEE 802.11p, 1609.0, 1609.1, 1609.2, 1609.3, 1609.4 and 1609.5
IEEE 802.11p

• Ratified July 2010
• PHY and MAC amendment
  – No support for access points
  – Peer-to-peer mode (ad hoc)
• IEEE 802.11a OFDM physical layer
  – 3, 4.5, 6, 9, 12, 18, 24 and 27 Mbps
  – 5.850-5.925 GHz Intelligent Transportation Systems Radio Service (ITS-RS)
  – 10 MHz channels
  – 1 control channel and 6 service channels (WAVE 1609.4)
• European standard (ETSI) – ITS G5
• Worldwide standard (ISO) – CALM M5
IEEE 802.11p – MAC

• Carrier sense multiple access with collision avoidance (CSMA/CA)
• IEEE 802.11e QoS
  – Provides 4 different priority levels
• Starts listening to the channel during one AIFS
  – Arbitration InterFrame Space (58 μs, highest priority in 802.11e)
• Channel becomes busy during listening period
  – Perform backoff by selecting a random number
  – Decrement backoff only when channel is free
• A node sends directly if the channel was free during one AIFS
CSMA/CA drawbacks

• Unpredictable channel access delay
  – Periodic messages need to be sent within its time period
  – The random backoff may cause a delay longer than the time period
  – Causes packet drops at sending node

• Collisions
  – The random backoff time chosen are discrete and thus nodes may choose the same
    • For example in 802.11e highest priority – {0 µs, 13 µs, 26 µs, 39 µs}
  – Two concurrently transmitting nodes may be located very close together

CSMA is not predictable nor scalable.
STDMA – a potential remedy?

- Self-organizing time division multiple access (STDMA)
- Already in commercial use
  - Automatic Identification System (AIS)
  - VDL mode 4
- Specially designed for position messages, e.g., CAM
- Predictable channel access delay regardless of the number of competing nodes
- In overloaded situation “collisions” are scheduled to minimize interference
- Needs synchronization between nodes
- Fixed packet length

STDMA is predictable and scalable.
Every node is allowed to choose a transmission slot from 20% of all available slots.

A certain slot is used for 3-8 consecutive frames.

Fixed number of slots in the frame. All nodes have a unique frame start!

STDMA needs position messages for scheduling transmissions in space when all available slots are occupied, i.e., the 20% of all available slots that is accessible to one particular node.
Simulator in Matlab

Data traffic model – time-driven position messages, i.e., CAMs
Vehicle traffic model – Poisson distributed, approx. 1 vehicle/100 meter

Highway scenario with 5 lanes in each direction.

We are evaluating the sending side of the system.
Channel access delay

300 byte packets, 6 Mbps, 10 Hz,

Channel access delay is not a problem in STDMA!
Interference distance

Probability that two nodes initiate a transmission at the same time.

2 Hz, 800 byte, 6 Mbps
Countermeasures

• To overcome the scalability problems with CSMA/CA
• Transmit power control
• Congestion control
  – Restrict the data traffic at the sending nodes
• Adjust the backoff window
Summary

• VANET uses a common wireless channel for broadcast communication directly between vehicles at 5.9 GHz
• CSMA has been selected as the MAC method for the first generation of VANETs through IEEE 802.11p
• When penetration of ITS equipped vehicles increases 802.11p may experience problems with unbounded channel access delay and close concurrent transmissions
• Potential remedy STDMA
Summary

• In STDMA the position information is required to schedule transmissions resulting in non-overlapping transmissions
  – Beneficial in order to protect the receivers located closest to the transmitter

• CSMA supports variable packet sizes and no synchronization is needed

• STDMA requires slot synchronization and position messages
Thank you!

Questions?

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Publications