Medium Access Control in Vehicular *Ad Hoc* Networks

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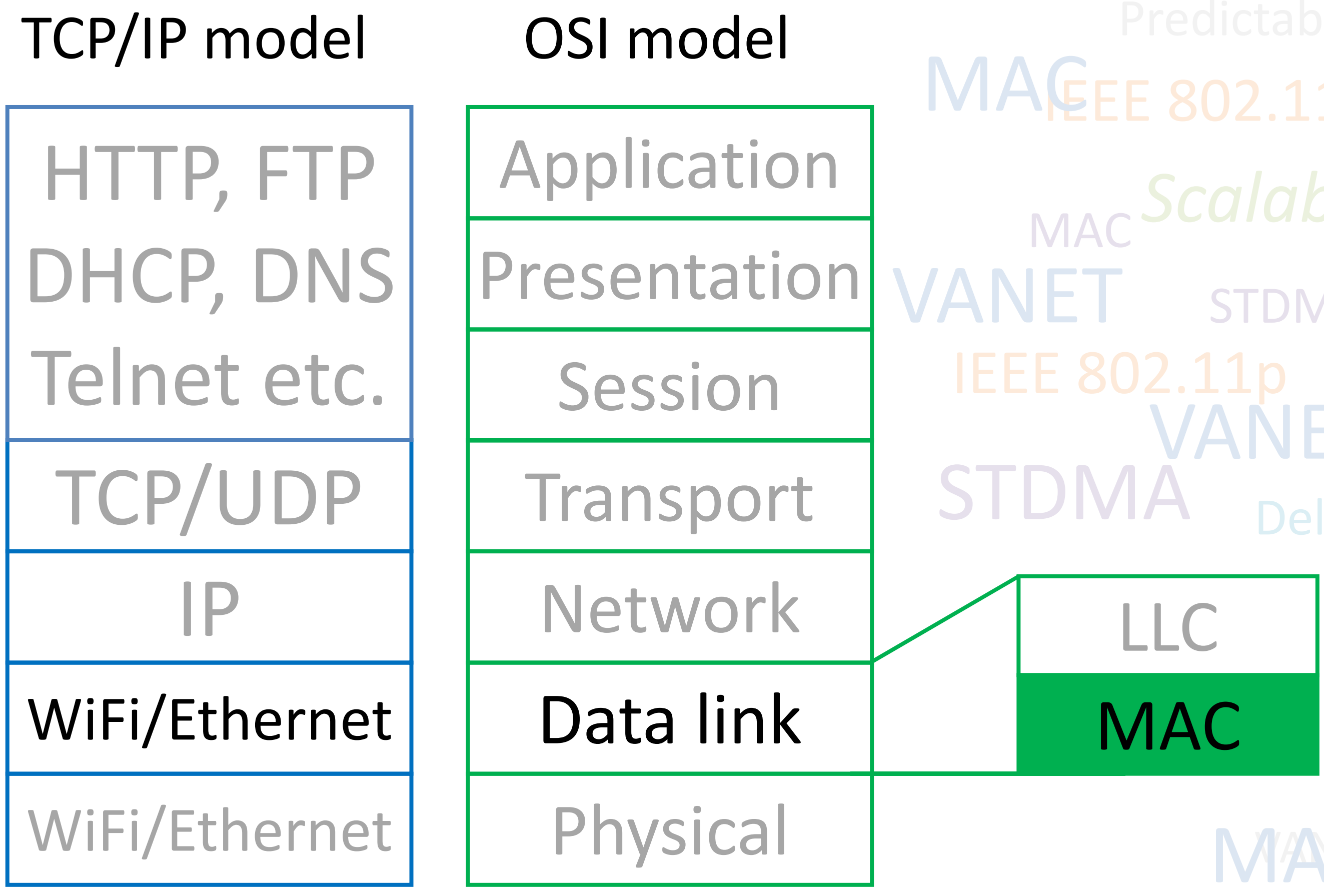
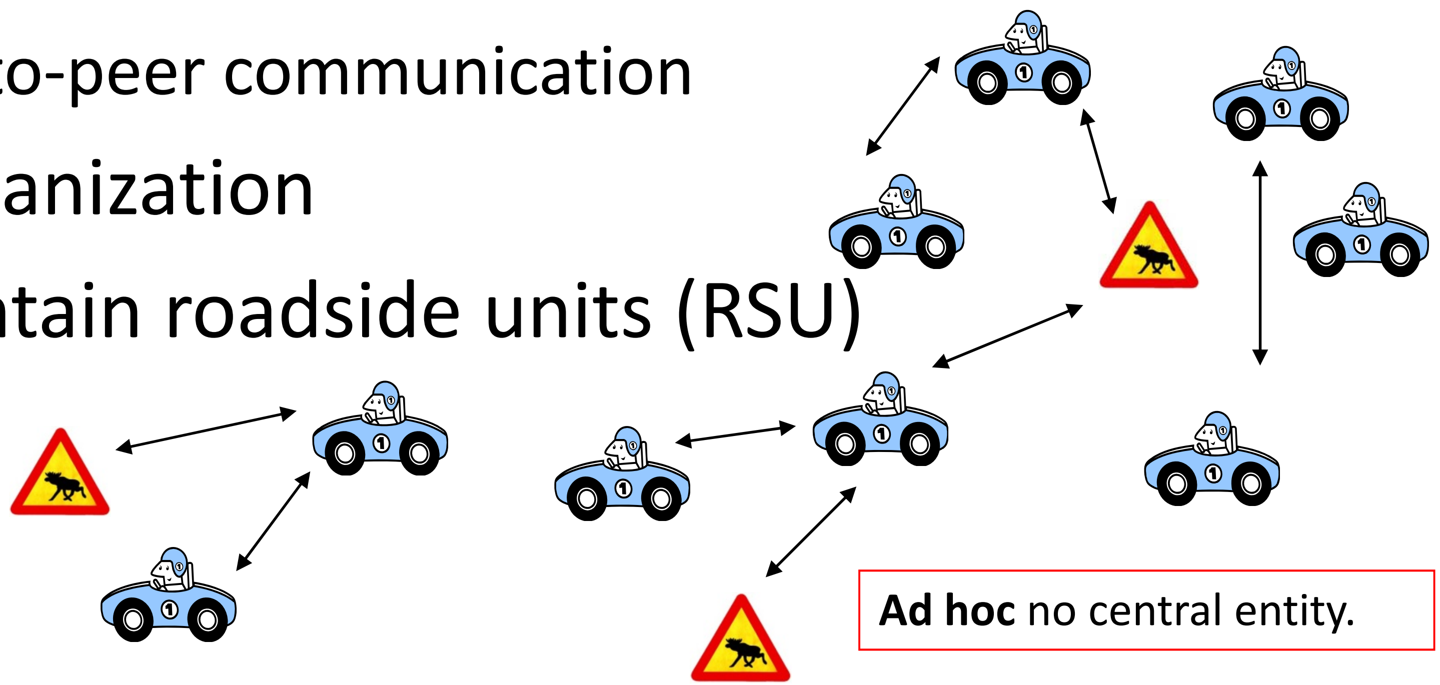
Introduction



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?

…. 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

  Broadcast

  - 2-10 Hz, 300-800 byte
  - Cooperative awareness messages (CAM)
  - Facility: Local dynamic map

- Event-driven hazard warnings

  Broadcast

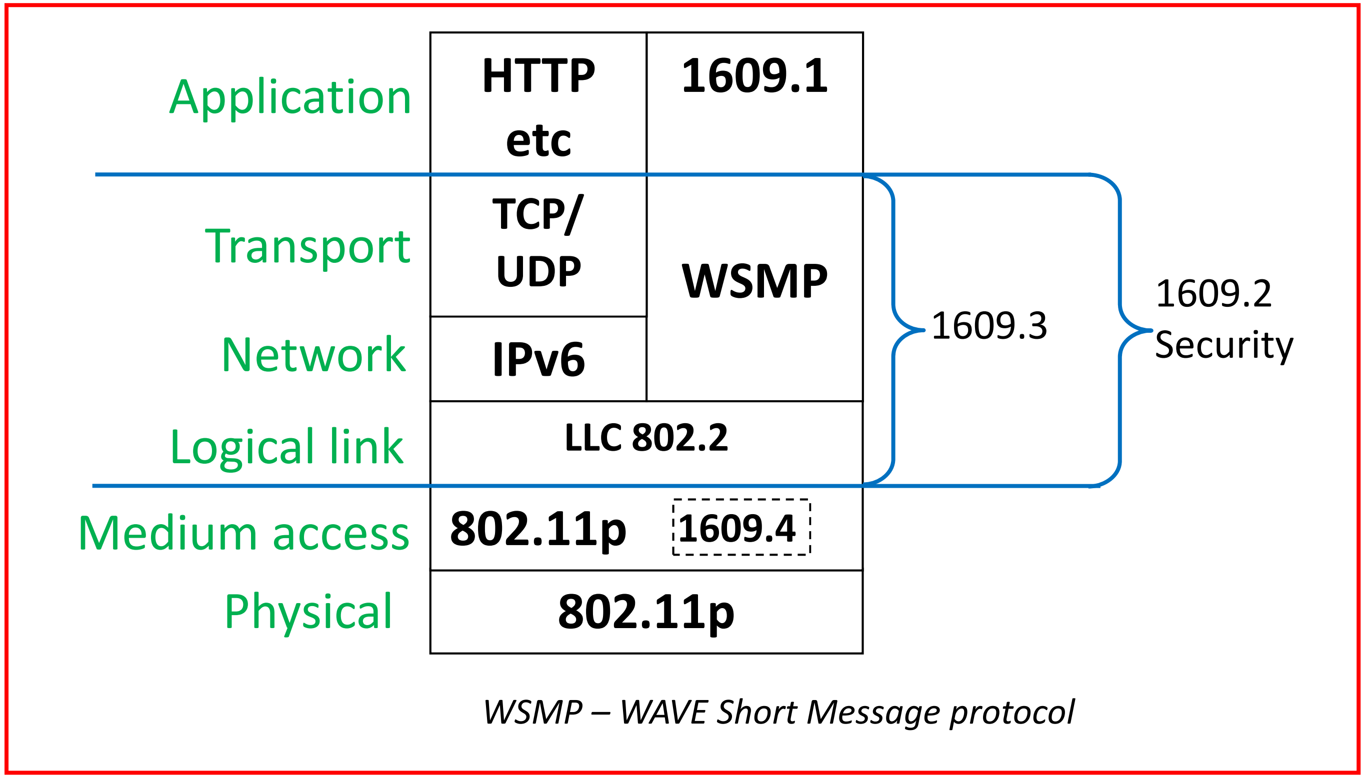
  - Packet size and periodicity depend on traffic safety application

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



1609.0 WAVE Architecture

1609.5 WAVE Communications Manager started during spring 2008.

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

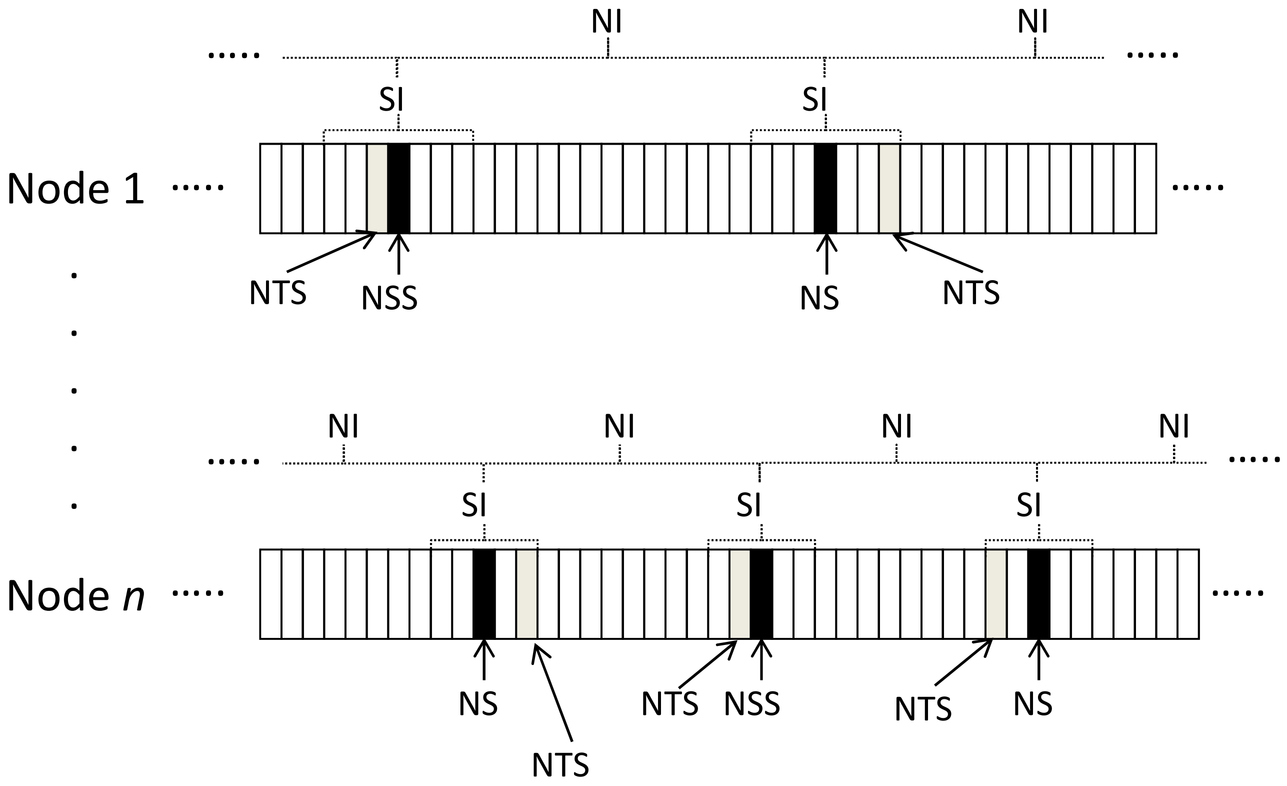
CSMA is not predictable nor scalable.

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.

STDMA



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

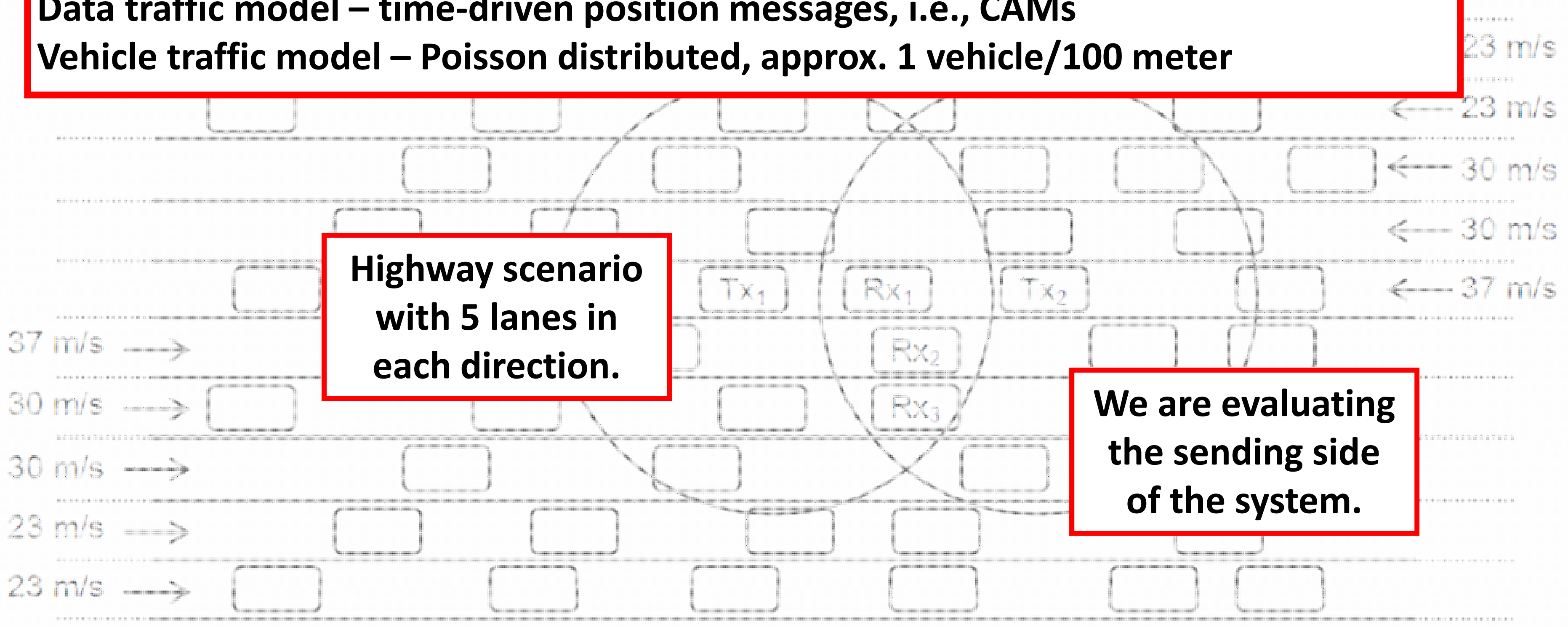
A certain slot is used for 3-8 consecutive frames.

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

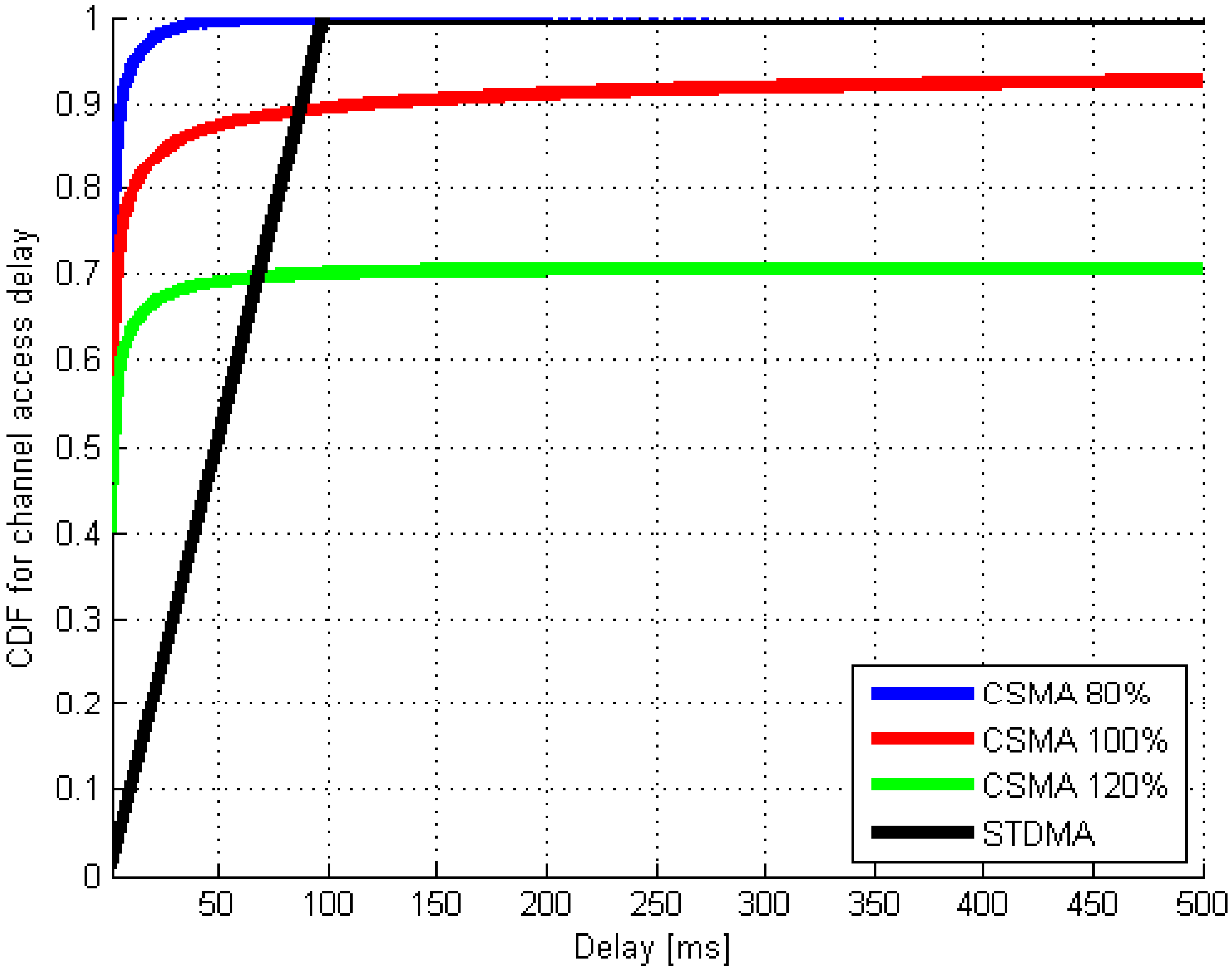
Data traffic model – time-driven position messages, i.e., CAMs
Vehicle traffic model – Poisson distributed, approx. 1 vehicle/100 meter



Highway scenario with 5 lanes in each direction.

We are evaluating the sending side of the system.

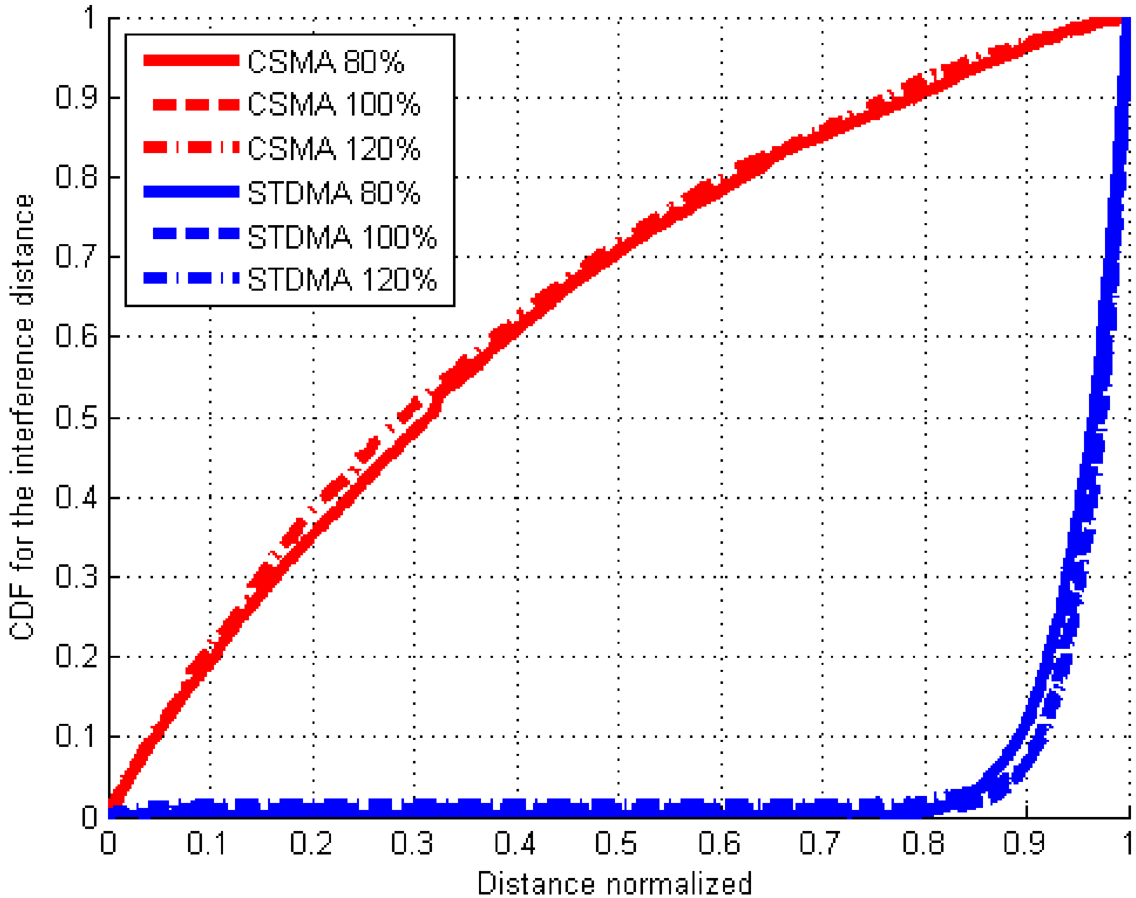
Channel access delay



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

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