Quality of services in vehicular networks

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QoS in vehicular networks

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ITS overview
- Motivations
- Applications
- Projects

Issues
- Dynamic net.
- Vehicular net.
- QoS requ.
- Standardization

CALM

IP

WAVE
- Overview
- Wave stack
- Characteristics
- Priorities
- IEEE 802.11e
- Priorities (cont.)
- Multichannels
- Synchronization

IEEE 802.11p
- Overview
- Aim
- Architecture
- WBSS

Conclusion

1. Introduction to Intelligent Transportation Systems
2. Research issues
3. CALM
4. Internet Protocol
5. WAVE
6. IEEE 802.11p
7. Conclusion
1. Introduction to Intelligent Transportation Systems

2. Research issues

3. CALM

4. Internet Protocol

5. WAVE

6. IEEE 802.11p

7. Conclusion
Intelligent Transportation Systems

- Intended to improve the transportation in terms of safety, mobility, impact on the environment, productivity...
- Encompass a broad range of technologies: networking, electronic... integrated in the transportation system’s infrastructure as well as in vehicles themselves
- Rely mainly on new networks:
  - vehicle-to-infrastructure (V2I)
  - infrastructure-to-vehicle (I2V)
  - vehicle-to-vehicle (V2V or C2C)
  - vehicular ad hoc networks (VANET)

- Vehicular networks
  - Well identified research field
  - Strong applications requirements
QoS in vehicular networks

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1 Introduction to Intelligent Transportation Systems

Motivations

ITS Applications

Projects related to vehicular networks
ITS motivations

Road safety

• ≈ 43,000 deaths per year in USA
  ~ initiatives from Department of Transport (DoT) to reduce the fatalities on roads
  [http://www.its.dot.gov/itsoverview.htm]
• The European Commission (EC) targets to halve the number of road fatalities by 2010
  ~ large ITS projects launched
  [The eSafety initiative http://www.esafetysupport.org/]
ITS motivations

Resources

- Better resource management
  - transport productivity increases
  - infrastructure
  - car fleets
  - intermodal freight...

- Environmental preservation
  - better road management
    - both by the infrastructure and the drivers
  - avoiding traffic congestion
  - optimizing the car speed
  - easing public transportation
  - intermodality
  - organizing car sharing services...
• Consumers are more and more concerned by safety and environmental issues
  ➔ all these services became marketing arguments for car manufacturers
• Some of the ITS applications are studied by car manufacturers to propose well equipped vehicles
A new business related to on board services is expected in few years [video from Mercedes]

US Federal Communications Commission (FCC) allocated 75MHz of DSRC spectrum at 5.9 GHz for vehicular networks

- public safety applications that save lives and improve vehicular traffic flow.
- private services to lower the network deployment and maintenance costs to encourage DSRC development and adoption.
1 Introduction to Intelligent Transportation Systems

Motivations

ITS Applications

Projects related to vehicular networks
ITS applications
Examples: V2V in city

[C2C Communication Consortium http://www.car-to-car.org]
QoS in vehicular networks

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[http ://www.itsoverview.its.dot.gov/]
ITS applications
Example: traffic management systems

[L. Armstrong, “Classes of Applications”, 2002]
 ITS applications
Example of infotainment: cartorrent

Peer-to-peer network invites drivers to get connected
CarTorrent could smarten up our daily commute, reducing accidents and bringing multimedia journey data to our fingertips

Laura Parker
The Guardian, Thursday 17 January 2008
Article history
ITS Applications

Categorization

• **Infrastructure** oriented applications
  - optimizing their management
  - transit management, freeway management, intermodal freight...
  - emergency organization...

• **Vehicle** oriented applications
  - for increasing the road safety
  - incident management, crash prevention, collision avoidance, driver assistance...
  - for automatic/adaptive settings

• **Driver** oriented services
  - for improving the road usage
  - traffic jam, road work information, traveler payment, ride duration estimate...

• **Passengers** oriented applications
  - for offering new services on board
  - Internet access, distributed games, chats, tourist inf., city leisure inf., movies announces downloads
Introduction to Intelligent Transportation Systems

Motivations

ITS Applications

Projects related to vehicular networks
Projects related to vehicular networks

**USA (1/3)**

- **The Intelligent Transportation System**
  [http://www.its.dot.gov/its_overview.htm]

- **The national ITS architecture**
  functionnal architecture for the overall system
  [http://www.its.dot.gov/arch/index.htm]

[cited by IEEE draft standard 1609.0, 2009]
Projects related to vehicular networks

USA (2/3)

- **Vehicle Safety Communications Project**
  - **Goal**: identifying intelligent safety applications enabled by DSRC
  - **Five categories**
    - Intersection Collision Avoidance
    - Public Safety
    - Sign extension
    - Vehicle diagnostic and maintenance
    - Information from other vehicles

[Vehicular Networks: from Theorie to Practice, CRC Press 2009]
Projects related to vehicular networks

USA (3/3)

- **The Cooperative Intersection Collision Avoidance Systems (CICAS) initiative**
  - Improving the road safety by enhancing driver decision-making at intersections
    [http://www.its.dot.gov/cicas/]

- **The Vehicle Infrastructure Integration coalition**
  - US DoT, ten states, manufacturers
    - current safety technologies in vehicles are single-vehicle-based technologies
    - more advanced safety applications by using communications technologies in new vehicles and in roads
  - Advanced V2V and V2I communications to increase road safety and relieve traffic congestion
    [http://www.vehicle-infrastructure.org]

- **Intellidrive** [http://www.intellidriveusa.org]
Projects related to vehicular networks

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Europe - 1

- Major R&D projects supported by the EC
  - to constitute the basis of an European-wide intelligent transportation system
- The eSafety Forum
  - supported by the COMeSafety project
  - dedicated to the improvement of road safety using ITS [http://www.esafetysupport.org/]

- The Car-to-Car Communication Consortium (C2C-CC)
  - European car manufacturers and related industries + institutions
    [http://www.car-to-car.org]
Projects related to vehicular networks

Europe - 2

• The Cooperative Vehicle Infrastructure Systems project (CVIS)
  • focuses on the technologies that will enable V2V and V2I communications between the vehicles and the infrastructure
  • to develop a cooperative road transport system
    • to increase the road safety and efficiency
    • to reduce the environmental impact of the road transport on the environment
[http://www.cvisproject.org/]

• The SAFESPOT project
  • aims at developing a Safety Margin Assistant
  • will detect dangerous situations in advance, in order to extend the driver awareness of the surrounding environment
  • based on V2V and V2I communications
[http://www.safespot-eu.org/]
• The Cooperative Systems for Intelligent Road Safety (COOPERS) project
  • focuses on the development of innovative telematics applications on the road infrastructure to enable cooperative traffic management on motorway section
  • the goal is to enhance the road safety by providing direct and up to date traffic information to the motorized vehicles [http://www.coopers-ip.eu/]

• The PReVENT project
  • addresses the integration of new in-vehicles systems which sense the environment
  • the goal is to help the driver to avoid or mitigate an accident [http://www.prevent-ip.org/]
Projects related to vehicular networks

The Global System for Telematics (GST) project
- focuses on the creation of an open and standardized end-to-end architecture for automotive telematics services
- vehicle manufacturers, public services and certified companies will allow to provide and distribute their own infrastructure-oriented services to consumers
  emergency call services, enhanced floating car data services, safety warning and information services...
  [http://www.gstforum.org/]

- Sevecom security
- GeoNet
  IPv6 and geocast

- ...
QoS in vehicular networks

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1. Introduction to Intelligent Transportation Systems

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2 Research issues

Dynamic networks
Vehicular networks
QoS requirements
Protocols standardization efforts
Dynamic networks

• Unstable neighborhood
  • apparition/disappearance of nodes
  • large node mobility
  ~ highly unstable neighborhoods
Dynamic networks

- Unstable neighborhood
  - apparition/disappearance of nodes
  - large node mobility
〜 highly unstable neighborhoods
Dynamic networks

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    - highly unstable neighborhoods
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- Unstable neighborhood
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  - large node mobility
  \[\rightarrow\] highly unstable neighborhoods
• **Unstable neighborhood**
  
  • apparition/disappearance of nodes
  • large node mobility
  \[\Rightarrow\] highly unstable neighborhoods
Dynamic networks

Next step in networking?

- Wired networks
- Partially wired networks
- Networks without infrastructure
- Highly dynamic ad hoc networks

Internet core
cellular networks
MANET
VANET

Dynamic ad hoc networks

wired network
mobile user
mobile terminal
mobile network
mobile ad hoc networks

with infrastructure
without infrastructure

routers, fixed servers
dynamic hand-over...
virtual structures
management (tree...)

Internet, IP
MobileIP
Cellular
MANET
VANET
Design rules for dynamic networks – a tentative

- Do not learn about the network
  avoid routing table, route discovering

- Try to not learn about the neighborhood
  unstable: messages increase with dynamic while accuracy decreases

- Prefer no state processes

- Robust algorithms (anybody can leave/arrive)
2 Research issues

Dynamic networks

Vehicular networks

QoS requirements

Protocols standardization efforts
Vehicular networks

Characteristics

- A kind of dynamic networks
  Vehicular ad hoc network

- Some mobility patterns can be identified
  Depending on the area, the time, the weather...

- Irregularity
  - of the dynamic
    in some cases, the network is not dynamic
  - of the road traffic
    depending on the area, time, weather...
  - of the architecture
    with or without infrastructure access

- Global knowledge assumed
  on-line or embedded
  not always!
• Impact on network layers
  • physical layer
  • link layer
  • networking layer
  • transport layer

• Impact on the applications
  • robustness, fault tolerance
  • data sharing schemes
  • how to build applications
  • well known basic problems still have sense?

• Impact on trusty and security
  • who believe?
  • what information is reliable?
  • sensible applications!

• Algorithms necessary embedded
  • online optimizations required
  • adaptive algorithms
  • context aware optimizations
2 Research issues

Dynamic networks

Vehicular networks

QoS requirements

Protocols standardization efforts
### QoS requirements

<table>
<thead>
<tr>
<th>Applications</th>
<th>Lat. (ms)</th>
<th>Type</th>
<th>Range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life-critical safety</td>
<td>100</td>
<td>Event</td>
<td>300</td>
</tr>
<tr>
<td>Safety warning</td>
<td>100</td>
<td>Periodic</td>
<td>50-300</td>
</tr>
<tr>
<td>Electronic toll collection</td>
<td>50</td>
<td>Event</td>
<td>15</td>
</tr>
<tr>
<td>Internet access</td>
<td>500</td>
<td>Event</td>
<td>300</td>
</tr>
<tr>
<td>Group communications</td>
<td>500</td>
<td>Event</td>
<td>300</td>
</tr>
<tr>
<td>Roadside service finder</td>
<td>500</td>
<td>Event</td>
<td>300</td>
</tr>
</tbody>
</table>
QoS requirements
Some examples (1/3)

- **Cooperative forward collision warning**
  - communication: V2V, one-way, one-to-many
  - transmission: periodic
  - data: position, velocity, acceleration, heading, yaw-rate

<table>
<thead>
<tr>
<th>Min frequency (Hz)</th>
<th>Allowable latency (sec)</th>
<th>Max range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>100</td>
<td>150</td>
</tr>
</tbody>
</table>

- **Vehicle-based road condition warning**
  - communication: V2V, one-way, one-to-many
  - transmission: event-driven
  - data: position, heading, road-condition parameters

<table>
<thead>
<tr>
<th>Min frequency (Hz)</th>
<th>Allowable latency (sec)</th>
<th>Max range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.5</td>
<td>400</td>
</tr>
</tbody>
</table>

[Vehicular Networks: from Theorie to Practice, CRC Press 2009]
QoS requirements
Some examples (2/3)

- Emergency electronic break lights
  - communication: V2V, one-way, one-to-many
  - transmission: event-driven
  - data: position, heading, velocity, deceleration

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<td>300</td>
</tr>
</tbody>
</table>

- Lane change warning
  - communication: V2V, one-way, one-to-many
  - transmission: periodic
  - data: position, heading, velocity, acceleration, turn signal status

<table>
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<tr>
<th>Min frequency (Hz)</th>
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[Vehicular Networks: from Theorie to Practice, CRC Press 2009]
QoS requirements
Some examples (3/3)

- **Highway merge assistant**
  - communication: V2V, one-way, one-to-many
  - transmission: periodic
  - data: position, speed, heading
  
<table>
<thead>
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<tbody>
<tr>
<td>10</td>
<td>100</td>
<td>250</td>
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</table>

- **Visibility enhancer**
  - communication: V2V, one-way, one-to-many
  - transmission: periodic
  - data: velocity, position, heading

<table>
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2 Research issues

Dynamic networks
Vehicular networks
QoS requirements
Protocols standardization efforts
Standardization efforts - 1

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• **IEEE**
  - Wireless Access in Vehicular Environments (WAVE)
  - IEEE 802.1p : extensions of the 802.11 protocols for ITS, based on DSRC

• **ISO**
  - CALM : Communication Architecture for Land Mobile
  previously *Continuous Air-Interface for Long and Medium range telecommunication*
  - ISO Technical Committee 204, Work Group 16
  ISO TC204 WG16

• **IETF**
  - extensions of IP : Mobile IP, IPv6, Nemo...
  - autoconfiguration in Manet
  Autoconf working group
  Manet : *Mobile Ad hoc NETwork*
Standardization efforts - 2

- **CEN** (Comité Européen de Normalisation)
  - Intelligent Transport Systems Steering Group (ITSSG)
  - Road Transport and Traffic Telematics CEN/TC 278 [http://www.cen.eu]

- **ETSI** (European Telecom. Standards Institute)
  - Technical Committee on ITS ETSI TC ITS [http://www.etsi.org]

<table>
<thead>
<tr>
<th>WG1</th>
<th>WG2</th>
<th>WG3</th>
<th>WG4</th>
<th>WG5</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>Architecture</td>
<td>Transport</td>
<td>Media</td>
<td>Security</td>
</tr>
<tr>
<td>Application</td>
<td>and Cross Layer</td>
<td>and Network</td>
<td>and Medium related</td>
<td></td>
</tr>
<tr>
<td>Requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
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**Standardization efforts - 1**

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**Issues**
- Dynamic net.
- Vehicular net.
- QoS req.

**Standardization**
- CEN/TC 278 [http://www.cen.eu]
- ETSI TC ITS [http://www.etsi.org]
Standardization efforts - 3

- **C2C-CC (Car-to-Car Com. Consortium)**
  - specifies and experiments vehicular communication
  - promotes the harmonization of vehicular communication standards worldwide
  - [http://www.car-to-car.org](http://www.car-to-car.org)

- **OMA (Open Mobile Alliance)**
  - protocols for data management among mobile nodes

- **OSGi (Open Services Gateway initiative)**
  - Wire admin service: OSGi package for sensors inside vehicles

- …
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- ISO Technical Committee 204
  Intelligent Transportation Systems
  [http://www.iso.org/iso/iso_technical_committee.html?commid=54706]

- WG 16 Wide Area Communication
  Communication Architecture for Land Mobile
  [http://www.calm.hu]

<table>
<thead>
<tr>
<th>SWG 16.0</th>
<th>CALM Architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWG 16.1</td>
<td>CALM Media (low layers)</td>
</tr>
<tr>
<td>SWG 16.2</td>
<td>CALM IPv6 networking</td>
</tr>
<tr>
<td>SWG 16.3</td>
<td>Probe Data</td>
</tr>
<tr>
<td>SWG 16.4</td>
<td>Application Management</td>
</tr>
<tr>
<td>SWG 16.5</td>
<td>Emergency notifications (eCall)</td>
</tr>
<tr>
<td>SWG 16.6</td>
<td>CALM non-IP networking</td>
</tr>
<tr>
<td>SWG 16.7</td>
<td>Security, Lawful intercept</td>
</tr>
</tbody>
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### Dynamic net.

#### Vehicular net.

#### QoS requ.

#### Standardization
- CALM
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### Conclusion

[cited by T. Ernst]

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<table>
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<tr>
<th>Technology</th>
<th>Standard</th>
<th>Authority</th>
</tr>
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<tbody>
<tr>
<td>Cellular (CALM 2G/3G)</td>
<td>ISO 21212, 21213</td>
<td>ITU, ETSI</td>
</tr>
<tr>
<td>Infrared light (IR)</td>
<td>ISO 21214</td>
<td>Germany</td>
</tr>
<tr>
<td>Microwave (CALM M5)</td>
<td>ISO 21215</td>
<td>802.11p</td>
</tr>
<tr>
<td>Millimeter waves (CALM MM)</td>
<td>ISO 21216</td>
<td></td>
</tr>
</tbody>
</table>

---

**The generic Comm Architecture is CALM**

**Infrared light (IR)**
ISO 21214

**Cellular (CALM 2G/3G)**
ISO 21212 & 21213

**Microwave (CALM M5)**
ISO 21215 (IEEE 802.11 a/b/g/p and CEN DSRC)

**Millimeter waves (CALM MM)**
ISO 21216

---

- V2V, V2I with multiple radio technologies
- Media Diversity
  - V2V, V2I with multiple radio technologies
  - Cellular (CALM 2G/3G)
  - Infrared light (IR)
  - Microwave (CALM M5)
  - Millimeter waves (CALM MM)

---

[cited by T. Ernst]
CALM Architecture

QoS in vehicular networks

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Combined CALM host and router
(SWG16.2: ISO 21217)

CME
A-GAP
T-SAP

NME
NSAP
T-SAP

IME
M-SAP

CALM Communications Kernel

CALM Management Information Base (MIB)

Management Information Base (SWG16.1: ISO 24102)

CALM networking layer

CALM FAST
(SWG16.6: ISO 29281)
Geo-routing
Others

Internet
IPv6
(SWG16.2: ISO 21210)

CALM User Services / Applications

CALM FAST
(SWG16.3: Probe data)

Non-CALM-aware

SWG16.4: Application management

CALM IP-based

SWG16.5: eCall

CALM service layer

[ISO TC 204 Draft Business Plan, 2008]
- CALM is not developing handover protocols
- Relies on IETF IPv6 protocols for vertical handovers
- Relies on medium-specific protocols for horizontal handover
1. Introduction to Intelligent Transportation Systems

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7. Conclusion
• IETF Internet Engineering Task Force

• Towards a large deployment of IP
  Using several IP per vehicles

• IPv6
  • to be able to assign one address per object
  • while maintaining a end-to-end connexion without translation
  • improvements and extensibility

• IP in highly mobile networks?

• IP in MANET Mobile Ad hoc NETworks

• Address assignation : Autoconf WG
  Ad hoc Network Autoconfiguration Working Group

[Vehicular Networks, Techniques, Standards and Applications, CRC Press 2009]
• Two addresses per mobile nodes: permanent and temporary
  • home agent (HA) in the origin network
  • care-of address (CoA) in the visited network
• When the node joins a new network,
  • a new care-of address is assigned
  • it is sent to the home agent
• When a message arrives to the home agent
  • it is forwarded to the care-of address
• Routing optimization with Mobile IPv6 vs. IPv4
  not all messages have to reach the home agent
Mobile IPv6 does not support network mobility eg. in case of several IP per vehicles

**Nemo Basic Support** [RFC 3963]
- based on Mobile IPv6
- does not change addresses of Mobile Network Nodes (MNN) behind the Mobile Router (MR)
  - only the Mobile Router updates its home-agent
  - this home-agent forwards every messages with the suffix of the MR network to the MR

**Nemo Extended Support** [Ernst]
- optimization for multidomiciles, routing
- does not rely on Mobile IPv6
- in case the MR admits several interfaces while the HA registers a single care-of address
Internet Protocol
Address autoconfiguration

- RFC 4861 et 4862 for fixed networks cannot be used in mobile ad hoc networks
- **No standard for the moment**
- **VAC** [Fazio et al. 2007]
  - small linear clusters of vehicles
  - one leader per cluster runs a DHCP server
- **GeoSAC** [Baldessari et al.]
  - SLAAC (*Stateless Address Autoconfiguration*) using NDP (*Neighbour Discovery Protocol*) to check the unicity of IP
  - C2C-CC geographic routing for local broadcast
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5 WAVE

Overview

WAVE protocols stack
WAVE main characteristics
WAVE priorities management
IEEE 802.11e reminder
WAVE priorities management (cont.)
WAVE channels coordination
Synchronization
The WAVE system provides connectivity in support of pedestrian and in-vehicle applications offering safety and convenience to their users, while at the same time offering a level of confidentiality and data security.

- Provide a networked environment supporting very high speed transactions for V2V, V2I, and V2D hand-held devices
- For transportation services such as alerting drivers to potential hazards and notifying them of services of interest even at high speed or in high traffic density
- Enhancing the safety, mobility and convenience of everyday transportation.
WAVE overview

Covered area

[IEEE P1609.0/D0.7, January 2009]
5 WAVE

Overview

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WAVE channels coordination
Synchronization
### WAVE protocols stack

Standards and current status

- **IEEE P1609.1, P1609.2, P1609.3, P1609.4**
  - released for trial use in Feb. 2007, being updated as full standard
- **IEEE P1609.0** draft standard in Jan 2009

<table>
<thead>
<tr>
<th>P1609.0</th>
<th>architecture document, overview of the system</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1609.1</td>
<td>services and interfaces for the WAVE resource manager</td>
</tr>
<tr>
<td>P1609.2</td>
<td>security processing requirements</td>
</tr>
<tr>
<td>P1609.3</td>
<td>routing and transport services. Alternative to IPv6</td>
</tr>
<tr>
<td>P1609.4</td>
<td>multiple channels in the DSRC standard</td>
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</tbody>
</table>
QoS in vehicular networks

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Protocols stack and relationship

- IETF IPv6 vertical handover
- IETF UDP match well with the connectionless nature of WAVE
- WSMP: WAVE short messages protocols
- IEEE 802.11p extension of existing IEEE802.11 in the DSRC range

[IEEE Std 1609-3, 2007]
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WAVE main characteristics

Multichannels

- Two classes of radio channel:
  - a single control channel (CCH) (default channel)
  - multiple service channels (SCH)
- CCH reserved for short, application and system control messages
- Service channel use arranged between devices in support of general-purpose application data transfers via a WAVE service advertisement (WSA)

- IPv6 only allowed on SCHs
- Wave service advertisements on the CCH
- Wave short messages on any channel
WAVE main characteristics

Short messages

- **Wave Short Messages Protocol (WSMP)**
- Designed to consume minimal channel capacity
  Thus allowed on both CCH and SCHs.
- Sending applications can directly control
  physical characteristics
  Channel number, transmitter power...
- MAC address of the destination is required
  Or group of addresses.
- Messages delivered to the correct application
  thanks to Provider Service Identifier (PSID)
  Unique values managed by the IEEE Registration Auth.
**WAVE main characteristics**

**Service initiation**

- Devices are either provider or user of services
- **Persistent service**: advertised regularly
- A service is initiated by a provider application
  - request to the WAVE Management Entity
  - specifies the persistence, the dest. addresses
    - broadcast address for persistent service
    - unicast or broadcast otherwise
  - number of advertisement repetitions
    - for persistent services, sent each CCH interval
  - **SCH** to use or ask for the best available
- **On receipt of a WAVE service advertisement** (*WSA*),
  - checks if the advertisement is of interest locally
    - using the PSID
  - checks advertisement’s credentials, priority...
  - **MAC** config. to tune to the correct SCH at the correct time
  - upper layer config. to support the communic.
- **Only WAVE advertisement to set up a service**
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• Two types of priorities used in WAVE
  • Applications priority level, used by the networking services to decide which applications have first access to the communication services
  • MAC transmission priority for packet transmission on the medium

• IP packets:
  • MAC priority associated with the traffic class of the generating application

• WSM packets:
  • priority of the generating application (packet-by-packet)
WAVE priorities management

User priority

- Per channel user priorities, IEEE 802.11e EDCA
- At the arrival of a message to the MAC layer
  MSDU : MAC Service Data Unit
  - channel routing
  - mapping of the User Priority (UP) to Access Category (AC)
- Each AC has an independent channel access fct
- EDCA mechanism to prioritize AC
- Back-off computed for each AC according to IEEE Std 802.11
- The AC with the smallest back-off wins the internal contention
- It then contends externally for the wireless medium.
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Synchronization
**Arbitration inter-frame space (AIFS)**: minimum time interval between the wireless medium becoming idle and the start of transmission of a frame.

**Contention window (CW)**: An interval from which a random number is drawn to implement the random back-off mechanism.

**Transmit opportunity (TXOP) limit**: The maximum time duration for which a station can transmit after obtaining a TXOP. If 0, a single MSDU can be sent.
IEEE 802.11e reminder

Priorities

- **Enhanced Distributed Channel Access (EDCA)** in replacement of 802.11 DCF
- **Four priority levels for four Traffic Categories (TC)**
  - **TC-VO**: voice, largest priority ➔ small AIFS and CW
  - **TC-VI**: for video applications
  - **TC-BE**: for best effort traffic
  - **TC-BK**: for background applications, smallest priority ➔ large AIFS and CW
IEEE 802.11e reminder

How it works

[Val, Juanol, ETR 2005]
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How it works

[IEEE Std 1609-4, 2006]
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**WAVE priorities management (cont.)**

**EDCA parameters**

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### EDCA parameters for CCH

<table>
<thead>
<tr>
<th>AC</th>
<th>CWmin</th>
<th>CWmax</th>
<th>AIFSN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>aCWmin</td>
<td>aCWmax</td>
<td>9</td>
</tr>
<tr>
<td>Best effort</td>
<td>(aCWmin + 1)/2 - 1</td>
<td>aCWmin</td>
<td>6</td>
</tr>
<tr>
<td>Video</td>
<td>(aCWmin + 1)/4 - 1</td>
<td>(aCWmin + 1)/2 - 1</td>
<td>3</td>
</tr>
<tr>
<td>Voice</td>
<td>(aCWmin + 1)/4 - 1</td>
<td>(aCWmin + 1)/2 - 1</td>
<td>2</td>
</tr>
</tbody>
</table>

### EDCA parameters for SCH

<table>
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<th>AC</th>
<th>CWmin</th>
<th>CWmax</th>
<th>AIFSN</th>
</tr>
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<tbody>
<tr>
<td>Background</td>
<td>aCWmin</td>
<td>aCWmax</td>
<td>7</td>
</tr>
<tr>
<td>Best Effort</td>
<td>aCWmin</td>
<td>aCWmax</td>
<td>3</td>
</tr>
<tr>
<td>Video</td>
<td>(aCWmin + 1)/2 - 1</td>
<td>aCWmin</td>
<td>2</td>
</tr>
<tr>
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<td>(aCWmin + 1)/4 - 1</td>
<td>(aCWmin + 1)/2 - 1</td>
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WAVE channels coordination

- WAVE devices must monitor CCH during a common time interval for transmission of high-priority WSMP messages (priority \( \geq 4 \))
- Channel coordination required when some devices are not capable of monitoring the CCH during data exchange on SCHs.
- They must also know when they can cease monitoring the CCH

\( \Rightarrow \) CCH and SCH intervals are uniquely defined with respect to an absolute external time reference

[IEEE draft standard 1609-0, 2009]
WAVE channels coordination

- Guard interval to account for variations in channel interval time and timing inaccuracies
- No transmission during the guard interval
- At the end of an interval
  - MAC activities on the previous channel are suspended
  - prioritized access activities on the current channel are started or resumed
  - Random back-off to prevent simultaneous transmission attempts

[IEEE Std 1609-4, 2006]
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Synchronization
• **Synchronization** is the procedure by which a device adopts the time reference of another source of time.

• **Universal Time Coordinated (UTC)**
  - provided by GPS
    1 pps +/- 100 ns
  - WAVE time base sufficiently lenient to allow using the UTC time estimated from other devices thanks to management frames

• Once synchronized, single-channel devices can ensure they meet the requirement to monitor the CCH during specified CCH intervals

• **Synchronization** is not required to make data exchanges on SCHs useful for security purpose

• If not synchronized on UTC, a device monitors the CCH, is not provider and ignores SCHs
WAVE synchronization
Timing information

[IEEE Std 1609-4, 2006]

- Timing capabilities: capabilities of the sender
  - UTC synchronization required or not for data exchange on SCHs
    that is, the sender is a single-channel device or not
  - The sender has a GPS unit on-board
  - This time source is currently available

- TSF Timer offset
- Standard deviation
WAVE synchronization

Timing information

- Timing capabilities: capabilities of the sender
  - TSF Timer offset
    - give the best estimate UTC time when added to the WAVE device’s TSF timer
    - at the instant the first bit of the message was transmitted from the WAVE device’s antenna connector
    - 0 at the beginning
  - Standard deviation

[IEEE Std 1609-4, 2006]
WAVE synchronization
Timing information

[IEEE Std 1609-4, 2006]

- Timing capabilities: capabilities of the sender
- TSF Timer offset
  - Standard deviation
    - if maximal, then the offset should not be used to estimate UTC
    - maximal value at the beginning
[IEEE Std 1609-4, 2006]

- dot4SyncTolerance/2: threshold that determines with 95% probability whether a WAVE device is synchronized to UTC or not.
- a device is defined synchronized if 3 times standard deviation \( \leq \) dot4SyncTolerance/2
- local clocks at two devices may drift in opposite directions
- if not synchronized, it only monitors the CCH
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IEEE 802.11p

802.11p Overview

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Wave basic service set
IEEE 802.11p overview

Origines

- Task group of 802.11
- Defining enhancements to 802.11 required to support Intelligent Transportation Systems (ITS) applications.
- Based on ASTM E 2213-03
- ...which is inspired by 802.11a
- Physical layer of the WAVE standards

[http://grouper.ieee.org/groups/802/11/Reports/tgp_update.htm]
### IEEE 802.11p overview

**Origines**

![IEEE 802.11p Technology Overview]

> [from NHTSA 2006, cited by M. Weigle]

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IEEE 802.11p aim

Mode of operation for use by IEEE Std 802.11 devices in case of

- Physical layer properties are rapidly changing
- Very short-duration communications exchanges are required
  much shorter than the minimum possible with infrastructure or ad hoc 802.11 networks
- Time frames shorter than the amount of time required to perform standard authentication and association to join a BSS.
IEEE 802.11p aim
State diagram in IEEE 802.11

[ANSI/IEEE Std 802.11, 1999]
The P802.11p specification accomplishes the following:

- Describes the functions and services required by WAVE-conformant stations to operate in a rapidly varying environment and exchange messages either without having to join a BSS or within a WAVE BSS

- Defines the WAVE signaling technique and interface functions that are controlled by the IEEE 802.11 MAC
IEEE 802.11p current status

- **Latest timelines**
  - November 2009: Initial sponsor ballot
  - January 2010: Recirculation
  - July 10: Final 802.11WG approval
  - November 10: Final 802EC approval

  [http://grouper.ieee.org/groups/802/11/Reports/802.11_Timelines.htm]

- **Interesting evolutions from the first drafts**
  [http://odysseus.ieee.org]
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IEEE 802.11p architecture
Fixed vs. mobile stations

Roadside Unit (RSU)

On-board unit (OBU)

Mobile Station (MS)

IEEE 802.11p architecture
Fixed vs. mobile stations

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On-board unit (OBU)

Mobile Station (MS)
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Vehicle as a mobile stations
IEEE 802.11p: architecture
Connecting a vehicle to infrastructure

IEEE 802.11p: architecture
Connecting a vehicle to infrastructure

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WAN - wide area network

Local Computer

RSU Portal

RSU

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IEEE 802.11p: architecture

Concept of WBSS: WAVE basic service set

[IEEE P802.11p/D1.0, February 2006]
IEEE 802.11p: architecture

Concept of WBSS: WAVE basic service set

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Wave basic service set
A BSS of cooperating stations operating in WAVE that forms a self-contained network.

Initiated by a WAVE station using a WAVE Announcement action frame

No beacons due to its highly transient nature

Created in response to requests from cooperating applications

Terminates when applications have completed or sooner if higher priority requests are pending
IEEE 802.11p WBSS

WBSS announcement frame

Concept of WBSS

- **Category**: 5 representing WAVE
- **Action**: 0 representing WAVE announcement action
- **Timestamp**: similar to TSF in 802.11
- **Capability information**: similar to 802.11 BSS, IBSS, poll, privacy...
- **Wave Service Information (WSI)**: contains specific application information indicating the WAVE services being offered and the Service Channel being used (cf. IEEE 1609.4).
  - 2 bytes for the length, at most 2238 for the content
- **SSID**: identity of the WBSS
- **Supported rates**
- **EDCA parameter set**
  - EDCA (Enhanced Distributed Channel Access)
Summary

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Conclusion

• Importance of Intelligent Transportation Systems
• Rely mainly on Vehicular Networks
• ... which are a kind of dynamic (ad hoc) networks
• Still many research issues
  • protocols stacks
  • applications
distributed algorithms
  • embedded (software) architectures
  • trusty and security
  • adaptive algorithms, context aware techniques
  • quality of services

Conclusion

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