Hybrid Approach to ITS and V2X in Concorda: an overview from NXP perspective

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NXP Is Global #1 In Auto Semiconductors
With Secure End-to-end Hardware and Software Solutions

Technology Leadership + Applications Focus = #1 in Auto Semiconductors

#1 Auto Analog / RF / DSP
#1 Auto Microcontrollers (ex. Japan)
#1 Merchant Auto MEMS Sensors
#1 Car Infotainment
#1 Secure Car Access
#1 Body & In-Vehicle Networking
#1 Safety
#1 Powertrain
Innovation Leader ADAS
Innovation Leader Security

2017 Global Auto Semi Market: $34.5B
Complete system solutions

COMPLETE SYSTEM SOLUTIONS

➢ FULL SCALABILITY

➢ LONG TERM COMMITMENT TO ADAS & V2X

➢ GLOBAL SUPPORT TEAM

➢ ZERO DEFECTS: CONTINUOUS QUALITY IMPROVEMENTS

➢ FUNCTIONAL SAFETY (ASIL)
Solutions in NXP Portfolio in Highly Automated Driving

**Car Radar: RF Frontend and Processing**

**S32R**
Scalable, highly Integrated, Safe and Secure family driving the digitalization of radar and sensor data fusion; designed in at 8 of top 10 OEMs

**802.11p Car to X solution**

**Vehicle to Vehicle**
- Hazard warnings
- Virtual Towbars / Platooning
- Intelligent logistics
- Quick loading and unloading

**Vehicle to Infrastructure**
- Dynamic low-emission zone
- Live fleet tracking
- Mobile payments at P+R areas, e.g. free for holders of a monthly travel card

**Car Vision Processing**

**S32V**
Automotive Open Platform
ASIL-B q
Open CL/ Open CV support w fully abstracted Accelerators
Low power
NN Squeezenet capabilities

**Gateway & In Vehicle Networking**

**Secure Gateway µC**

**Target Applications:**
- Domain Gateways
- Central Gateways
- High-end Body Controllers

**Key Value Proposition:**
- Safety – ASIL B solutions with roadmap to ASIL D
- Security – Secure Hardware Extension (SHE) and HSM
- Networking – Multiple CAN/LIN, FlexRay, Ethernet interfaces
- Processing – Multi-core processing with hardware acceleration

**OPEN VISION PLATFORM FOR SAFE AUTONOMOUS DRIVING**

HELLA Aglaia and NXP
Sensors beyond Line of Sight, provides **Early Intent**

Earlier, lower latency and more informative than regular ADAS sensors, allows for **safe, smooth** maneuvering.
Dedicated Short Range Communication over IEEE 802.11p

Characteristics 802.11p

- Ad-hoc, 2-way network
- Regulated spectrum for ITS
- 7 free channels
- Ultra low latency
- 360°, Range up to 2km
- Data rates from 6-27Mbps
- Signed messages using Public Key Infrastructure
Dedicated Short Range Communication over IEEE 802.11p

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GeoNet

Basic Transport Protocol

Cooperative Assist Messages
Decentralized Environmental Notification Message
SPAT, MAP

Road-Safety, Efficiency & Future ITS Apps

TCP/UDP

IPv6

ITS-G5 (Europe)

802.11p MAC

802.11p OFDM PHY (5.850 to 5.925 GHz)
Dedicated Short Range Communication over IEEE 802.11p

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Cellular solutions: LTE- Uu and LTE-V

LTE-Uu “cellular”
Base-station uses classical LTE Uplink & Downlink paths, but for a V2X final application.

Cloud server processing
Base-station
Resource allocation
Car data

Problems: latency & reliability, especially at high-speed, need network coverage
Cellular solutions: LTE-Uu and LTE-V

**LTE-Uu “cellular”**

Base-station uses classical LTE Uplink & Downlink paths, but for a V2X final application.

**LTE-V R14 - mode 3 and 4, require SEPARATE BAND and RADIO**

Mode 3 “V2X eNB scheduling”

Scheduling policy & users organization fully handled by base-station (master).

- **Cloud server processing**
- **Resource allocation**
- **Sidetlink (broadcast)**
  - Msg contains: Control header (PSCCH) & data (PSCCH)
- **Resource allocation**

Problems: latency & reliability, especially at high-speed, need network coverage

Need network coverage
Cellular solutions: LTE-Uu and LTE-V

**LTE-Uu “cellular”**

- Base-station uses classical LTE Uplink & Downlink paths, but for a V2X final application.

**LTE-V R14 - mode 3 and 4, require SEPARATE BAND and RADIO**

- Mode 3 “V2X eNB scheduling”
  - Scheduling policy & users organization fully handled by base-station (master).

- Mode 4 “V2X distributed scheduling”
  - Scheduling policy & users organization handled by V2X users autonomously.

Problems: latency & reliability, especially at high-speed, need network coverage

- Resource allocation
- Cloud server processing
- Basestation
- UEs select resources autonomously
- Sidelink (broadcast)
- Need network coverage

Very subtle: Congestion, mode-3/mode-4 transitions

Msg contains: Control header (PSCCH) & data (PSCCH)
NXP in Concorda
NXP in CONCORDA

1. Hybrid IEEE 802.11p & LTE architecture

2. Evaluate IEEE 802.11p and C-V2X (LTE, LTE-V)

3. LII longitudinal automation in CACC

- Hybrid communication architecture
- Newest communication technologies
- Coexistence
- Connected automated driving services
- Practical, real-life and complex environments
CONCORDA Phase 1
Hybrid architecture IEEE 802.11p & LTE-Uu re-using ETSI standards

Application

ITS-G5 (Europe)
- Cooperative Assist Messages
- Decentralized Environmental Notification Message
- SPAT, MAP

Basic Transport Protocol

GeoNet

WAVE (USA)
- Road-Safety, Efficiency & Future ITS Apps
- TCP/UDP
- IPv6

BSM Message Formats
- Min. Perf. Requirements (SAE J2735, J2945-1)

DSRC Wave Short Message Protocol (WSMP) with Safety Sub-Layer (IEEE 1609.3)

LTE-Uu 3GPP
- TCP/UDP
- IPv6

3GPP

802.11p MAC

802.11p OFDM PHY (5.850 to 5.925 GHz)
Example CONCORDA Applications
- CACC
- Green light optimal speed advise
- Road works warning
- Slow stationary vehicle
- Dynamic speed info
- Platooning

IEEE 802.11p & LTE-Uu: interoperable from application perspective.
CONCORDA Phase 2
Evaluate co-existence and interoperability LTE-V with IEEE 802.11p

Same applications, no user benefit of “2 parallel pipes” in 5.9GHz band

- Not interoperable on physical level
- Co-existence issues

CONCORDA will evaluate technical, interoperability, legal, business and traffic management aspects
Coexistence LTE-V & 802.11p in 5.9 GHz band: inefficient spectrum usage & performance degradations

Disadvantages of the proposed fixed spectrum partitioning:

Fixed spectrum partitioning does not reflect real deployment (not 50/50!):
- Leads to inefficient spectrum usage

Reduced performance with adjacent channel interference and incompatible synchronous/asynchronous scheduling:
- Degraded Packet Error Rate: adjacent channel leakage raises noise floor
- Performance degradation: limited range, missed messages etc.

Single technology deployment:
- Less cooperative V2X info: missing messages sent by cars with ‘other’ technology

Dual technology deployment:
- More messages lost, Inefficient spectrum usage, more expensive
CONCORDA Evaluations

Interoperability
- Impact spectrum allocation and Interference
- Quality of service (e.g., latency, reliability, robustness, range)
- Communication sub-system architectures to support automotive requirements for isolation/freedom of interference with CE applications, security, safety, ASIL, ....

Business model, Network operators support, LTE-mode 4, mode 3

Traffic Safety and Impact

Legal Framework
Platooning

Reduction air-drag through platooning
5 -10% fuel savings achievable
Fuel costs are up to 33% of transportation*

Collision avoidance in platooning requires
Cooperative Automatic Emergency Brake

<table>
<thead>
<tr>
<th>Headway (s)</th>
<th>Deceleration-difference (m/s²)</th>
<th>Allowed latency (ms) at 90 km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>-0.5</td>
<td>135</td>
</tr>
<tr>
<td>0.3</td>
<td>-1</td>
<td>25</td>
</tr>
<tr>
<td>0.5</td>
<td>-1</td>
<td>55</td>
</tr>
</tbody>
</table>

Latency budget for the complete electronics over 2 trucks.

Budget per wireless communication unit depends on architecture and implementation (eg event- vs sample-based)
→ In ultimate cases wireless budget can be as low 5-10

Results of NXP 802.11p solution in EcoTwin
• 99.9% messages within 3 ms over 2 wireless nodes
• 0.006% no message per 40 ms
• Antennas in left and right mirrors
• Redundancy and Diversity
• Dual core application processor
  • Process-, interrupt – optimized
  • Application separate core

DAF, NXP, TNO, Ricardo
Conclusion

IEEE 802.11p Mature & Ready to Be Deployed
- Toyota JPN & Cadillac in production
- VW 2019
- Toyota USA 2021
- Columbus Ohio 2018 3000 DSRC cars
- Premium OEMs confirm DSRC faster to deploy than C-V2X

IEEE 802.11p Expanding its Deployment
- Smart Cities, Infrastructure projects
- Railroads EU
- Truck Platooning EU Ensemble:
  - 802.11p technology of choice by all OEM’s
  - Targets 5.9 Ghz service channel in mass-deployment

NXP Supports & Investigates Hybrid Approach
- IEEE 802.11p in 5.9 GHz, focus on safety use cases
- Combine 802.11p with LTE-Uu for convenience use-cases, e.g. live 3D map navigation

Short range C-V2X
- To be investigated and clarified in CONCORDA
- Current status:
  - 5G (3GPP R15, 16, …) in 3.x GHz
    - Not expected in cars before 2023-25
    - PHY not compatible with LTE-V
  - R14 LTE-V mode 4
    - Does not have superior performance
    - Use in 5.9 GHz?
    - unsafe un-reliabilities and in-efficiencies
    - definitely not advised
QUESTIONS?