



JOINT ETSI-OSA WORKSHOP: OPEN IMPLEMENTATIONS AND STANDARDIZATION

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A Real-Time SDR Modem for Early LTE-V2X Testing: Development Activities & First Field Tests in Vehicles

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Session 04: Open platforms as an early testing and validation tool



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Outline

- ▶ Introduction
 - ▶ Company Expertise & Portfolio
 - ▶ R&D Project Highlights
 - ▶ V2X Communication Technologies: Background & State of Play
- ▶ A Real-Time SDR Modem for Early LTE-V2X Testing
 - ▶ Motivation
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 - ▶ Development Methodology
 - ▶ Core Building Blocks
 - ▶ First Tests with Vehicles
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 - ▶ Wrap-Up
 - ▶ Thoughts & Roadmap

Part I - Profile & Background

The background features abstract, overlapping geometric shapes in various shades of blue, ranging from light sky blue to deep navy blue. These shapes are primarily located on the right side of the frame, creating a modern, layered effect against the white background.

Profile & Portfolio



FERON is a dynamic, telecom SME, aspiring to be a point of excellence for R&D in high-end radio and network communication technologies



▶ Software Implementation of Telecom Systems (Libraries & Soft-Modems)

- ▶ 3GPP LTE
- ▶ LTE D2D (Rel.12-13)
- ▶ LTE V2X (Rel.14)
- ▶ 802.11p/ITS-G5
- ▶ Wi-MAX
- ▶ ITU G.hn
- ▶ Planned: NB-IoT, 5G-NR, NR-V2X, NGV

▶ Prototypes based on in-house software modems and customized HW/SW

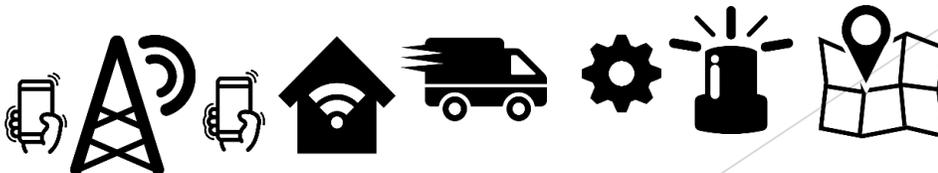
- ▶ Passive Probe for Live 4G Mobile Data Networks
- ▶ Connected Vehicle Modem
- ▶ First-Responder 4G/WiFi/D2D-enabled Solution

▶ Integration of COTS HW/SW

- ▶ IoT Platforms for Smart Sensing
- ▶ Active 4G/WiFi Probing Tools
- ▶ Indoor Localization

▶ Organization of PoC, Measurement Campaigns, Demos

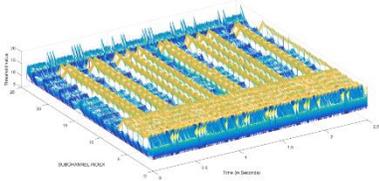
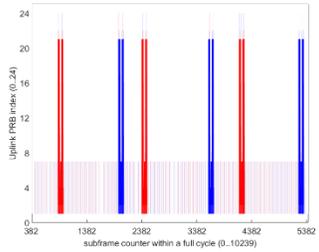
- ▶ Channel modeling
- ▶ Network Benchmarking
- ▶ Radio technology field tests and applications



EU R&D Project Highlights



LTE Downlink Sniffer and Uplink Filter-Bank Detector/Sensor



Open-Source Sidelink MATLAB Library



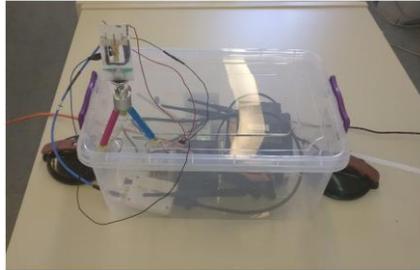
Apr-16



Jun-16



Software-controlled beam-steering prototype for ITS-G5 communications



Jan-17



ITS & Public Safety experiments



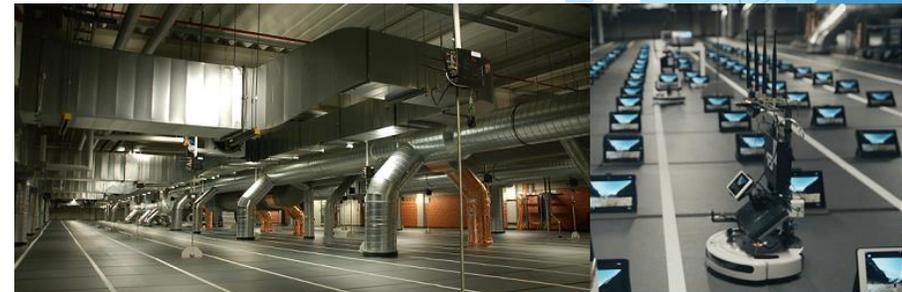
D2D/C-V2X soft modem prototypes



Sep-17



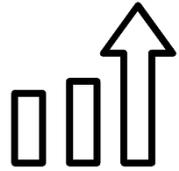
Open-Source Network Monitoring Tools



V2V measurements in lab and field environments

V2X Communication Technologies for ITS

State of Play



MARKET

Connected vehicle industry:

A €141 billion business opportunity and a key 5G Vertical



ITS STANDARDS

ETSI Automotive ITS specifying the global ITS system

- ❑ **Radio technology agnostic:** initially based on ITS-G5, recently added LTE-V2X
- ❑ **Architecture definition:** Layers, Management, Security
- ❑ **ITS stack:** Geonetworking/Transport Layers & Messages (CAM, DENM, etc.)

RADIO TECHNOLOGIES



State of The Art

- ❑ **802.11-based** : 802.11p as of ITS-G5 (EU) and WAVE (US), 2010
- ❑ **Cellular-based** : LTE-V2X/3GPP Release 14, 2017 (“C-V2X Phase 1”)

Evolution

- ❑ **Cellular-based** : LTE-V2X enhancements (Rel.15) , NR-eV2X (3GPP Rel. 16, end of 2019)
- ❑ **802.11-based** : NGV group formed in mid-2018, expected to deliver a new standard by mid-2020

TRIALS/DEPLOYMENT



- ❑ EU Delegated Act (expected for end 2018)
- ❑ Projects/Initiatives:
 - ✓ C-Roads for deployment
 - ✓ C2C-CC for vehicles
 - ✓ 5GAA for telcos/automotive cooperation
 - ✓ 5GPPP projects for cross-corridor trials

Part II - An LTE-V2X SDR Modem

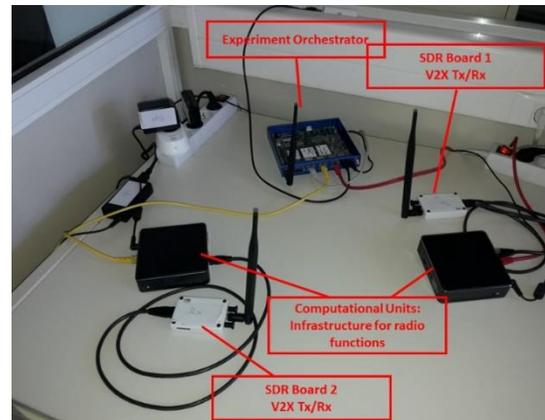
Motivation

- ▶ **Limited availability of publicly available V2X devices and open experimental platforms**
 - ▶ Market currently dominated by a small number of *802.11p* closed solutions
 - ▶ First chipset for *LTE-V2X* (Qualcomm 9150) arrived in mid-2018 & Quectel announced in November a new *LTE-V2X (AG15)* module based on the 9150 chipset
- ▶ **The SDR paradigm for implementing V2X**
 - ▶ An old technology whose time has come: Various showcases of full GPP-based “**network-in-a-box**” implementations (OpenAirInterface, AMARI LTE, srsLTE)
 - ▶ **The “Lifecycle” Challenge:** The lifecycle of a vehicle is usually significantly longer than that of a mobile device
 - ▶ “Software Radio Reconfiguration model as highly efficient and a modular means to ensure upgradability of in-vehicle radio systems” (ETSI white paper 2017 & ETSI EN 303 146)

High-Level Description

- ▶ A binary application for the 3GPP D2D/V2X radio technology, including:
 - ▶ An optimized **real-time** implementation of the sidelink transceiver functionality [all PHY and a baseline MAC] in C/C++, running in typical x86 Linux-based hosts
 - ▶ An interface with **general-purpose SDR boards** (such as Ettus USRP B210/LimeSDR boards) for real-time and over-the-air signal transmission and reception
 - ▶ **Interfaces with 3rd party code/applications** through standard UDP sockets (custom applications, ITS stacks, Wireshark analysis tool, real-time monitoring)
 - ▶ A set of easily human-readable text files for **full system configuration** (protocol-level, RF-level, external interfaces, KPIs reporting)

First Real-Time OTA C-V2X implementation using general purpose commodity and easily accessible equipment (GPPs and SDRs).

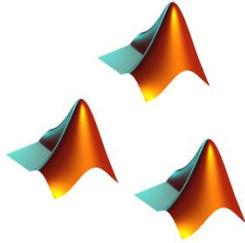
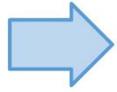


Development Methodology



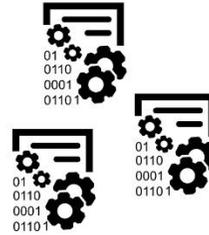
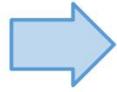
ETSI TS 136 331 specifications
Specs
3GPP 36 Series
36.211-36.213
36.321, 36.331

- * Understand blur/ambiguous parts of the C-V2X specifications
- * Abstractions for higher layers (E.g. SIBs/RRCs)



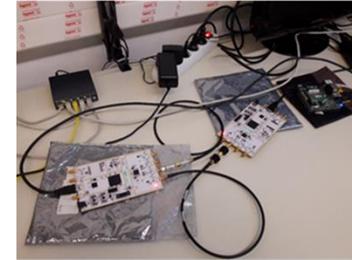
Ite-sidelink
An open software library developed in MATLAB that implements the functionalities of the 3GPP LTE sidelink interface

- * Follow standards (TSs/TRs)
- * Add receiver processing functionalities
- * Lack of reference waveforms (at least initially)



Code (C++) Implementation
Iterations of:
> *debug mode*
> *benchmarking mode*
> *unit-testing mode*
=> *Ready for production*

- * Continuous integration
- * Code optimization for real-time operation
- * Cross-Platform Validation



Lab-based OTA Validation
- SDR integration
- Application interfacing
- Performance Monitoring & Characterization (BER, PER, EVM) in ideal (loopback) and realistic conditions

- * RF impairments
- * Validation when operating in real-time



In-Vehicle Demonstration
- Integration in vehicle
- Connectivity (4G/WiFi)
- External sensors (GPS, accelerometers)
- Performance Monitoring & Characterization in-the-wild with mobility

- * Compact setup
- * Power supply
- * Management
- * RF Interference
- * Stability

lte-sidelink



A public software library (3GPP Rel.14-compatible) developed in MATLAB, that implements the radio functionalities of the 3GPP LTE sidelink interface.

Introduction

- ▶ Initially designed for D2D, now supporting the V2X “flavour”
- ▶ Development started in Q1-2017
- ▶ Freely and openly available in : <https://github.com/feron-tech/lte-sidelink>
- ▶ Licensed under the GNU Affero General Public License v3.0
- ▶ Latest stable release v1.4.0 (06/2018) includes full implementation of sidelink V2X broadcast and communication functionalities

Potential Usage Scenarios

- ▶ An LTE sidelink waveform generator
- ▶ An end-to-end sidelink link-level simulator
- ▶ A core component of a sidelink system-level simulator
- ▶ A platform for testing new resource allocation/scheduling algorithms for D2D/V2V
- ▶ A tool to experiment with live sidelink signals with the help of SDR boards
- ▶ Education/Training tool

LTE-V2X Soft Modem Features & Release Plan

Release Type/ID	Date	Major Features/Comments
-	Jan 2017	Project Begins
Alpha v0	Q2-2017	Support for D2D Sidelink Synchronization and Broadcast Mode 
Alpha v1	Q3-2017	Added support for V2X Sidelink Synchronization and Broadcast Mode
Alpha v2	Q1-2018	Added support for sidelink discovery mode and external interfaces 
1 st complete Alpha	Q2-2018	Added support for V2X sidelink communication mode; Basic MAC integration; Tested in lab conditions 
Beta	Q4-2018	Complete L1 processing; Lab & field testing; Integration with external sensors (GPS, accelerometers, etc); Experimental ITS stacks integration tested.
Release Candidate	Q1-2019	Bug fixes; Optimization of USRP interface; New features support of LTE-V2X radio functionalities (e.g. sensing-based resource reservation); Results of feasibility studies related to integration with other implementations (e.g. ITS stacks, 3GPP L2+, etc.)

First Experiments with Vehicles*: *Setup Preparation*

Node assembly



Experiment node tested in lab



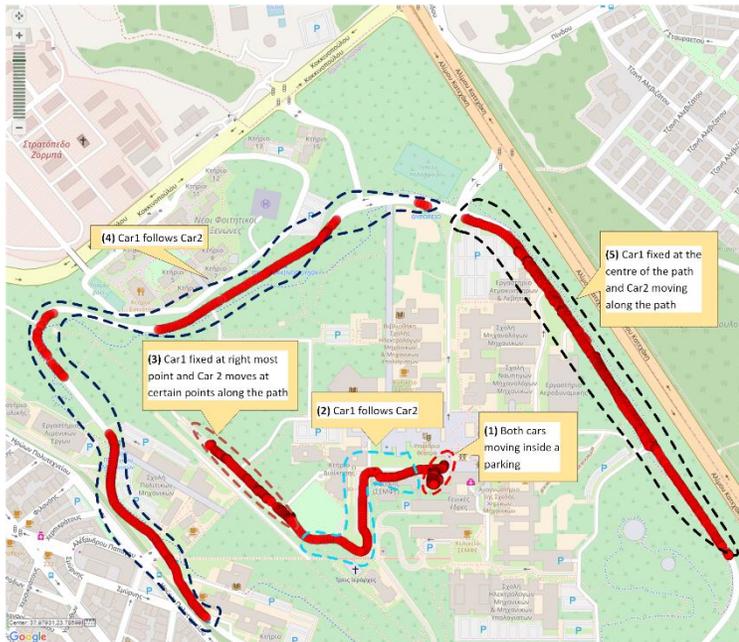
Experiment nodes mounted in vehicles ("SDR-OBUs")



* This activity was partially funded by EU Project Fed4Fire+, in the context of Open Call 2 Project FIVE, run through 09/2017-10/2018. Equipment offered by FERON, University of Piraeus Research Center (FLEX Project) and iMinds w-llab.t Test-bed Facility.

First Experiments with Vehicles: *Field Tests*

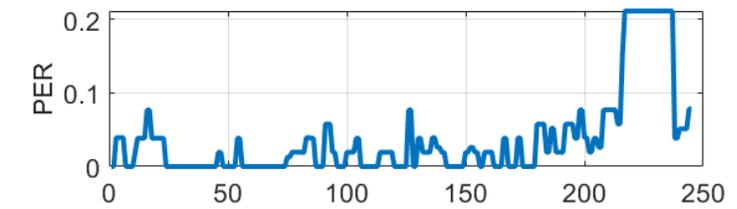
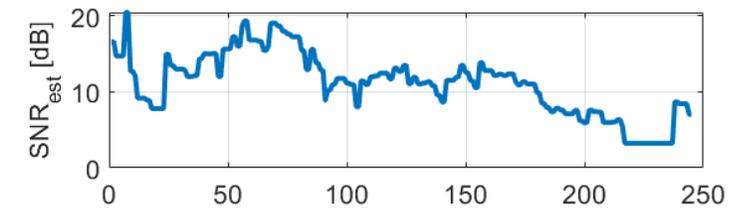
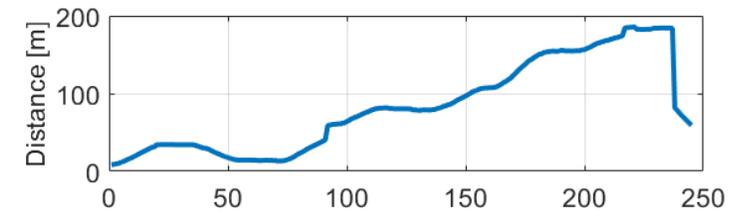
GPS traces



Real-time monitoring



Indicative field results



<http://147.102.25.188/five-videos/>

Wrap-Up, Thoughts & Potential Roadmap

We introduced the first* complete LTE-V2X SDR implementation which we believe it can aid on accelerating C-V2X testing.

** to the best of our knowledge*

- ▶ **Continue maintenance of Open MATLAB Library**
 - ▶ Enrich Rel.14 features (sensing-based allocation); add new test cases (multi-link)
 - ▶ Introduce NR-V2X support by following the 3GPP NR_eV2X WI (first batches of TRs at 3GPPRAN1#94, 08/2018)
 - ▶ Follow IEEE 802.11 NGV developments?
- ▶ **What comes after LTE-V2X modem finalization (Q1-2019)?**
 - ▶ Commercialization aspects: open-source it / open APIs / closed binary?
 - ▶ Complete Integration with ETSI ITS protocol stacks
 - ▶ Integration with other initiatives/projects
 - ▶ Is it possible to build a complete C-V2X SDR-OBU or SDR-RSU?

We highlight the importance of having early implementations for newly or pre-standardized radio technologies using commodity and easily accessible equipment, well before closed commercial solutions and actual deployments begin to appear.



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