46TH ASECAP STUDY & INFORMATION DAYS

Electronic toll service via ITS-G5 communication

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Organized by

The context of C-ITS

- The European Commission has launched a lot of initiatives towards C-ITS development and deployment
  - C-ITS platform, ITS Directive, CEF programme
  - A lot of on-going projects with EC funding: SCOOP@F, C-ROADS, InterCor, etc.
- A C-ITS Delegated Act in preparation
- Car manufacturers have announced the equipment of new models of vehicles with C-ITS in 2019-2020
- ITS-G5 is a standardized V2V / V2I / I2V communication system, available for many future services
- Possible interferences between ITS-G5 and DSRC tolling systems
  - ASFA + Sanef carried out studies and tests in 2016-2017
  - Mitigation techniques to be implemented in C-ITS equipment (ETSI standard)

Contributions of Sanef in C-ITS

- Sanef is participating to 4 C-ITS projets: SCOOP@F, C-ROADS, InterCor and PAC V2X
  - 26 RSU already deployed on Sanef network (A1, A4, A13)
  - + 15-20 more RSU to be installed in 2018
- To anticipate the needs and expectations of their clients => Sanef want to explore the use of ITS-G5 for tolling and has started a R&D project: "Toll gates crossing with C-ITS equipment"

RSU deployed on A4 Paris - Strasbourg (about 450 km)

Toll gates crossing with C-ITS equipment

- A PhD thesis was started in February 2016 between Sanef and ESIGELEC/IRSEEM, with support of ANRT, in the framework of an R&D project
  - PhD student: Malalatiana Randriamasy
- In October 2017, a NWI (New Work Item) was submitted to ETSI, in order to gain support and consensus of industry and develop a standard
- Draft ETSI Technical Report expected by December 2018

Context: C-ITS Applications

- Based on I2V and V2I communications
- Exchange of CAM (Cooperative Awareness Message) or DENM (Decentralised Environmental Notification Message) or other messages
- Challenges:
  - to cross the toll gate in case of stop-and-go situation, and free-flow situation!
  - Other applications: digital tachograph, road charging ("ecotaxe"), electric vehicle charging

Requirements for ETC application

- High quality positioning of the vehicle during the transaction
  - < 1 meter

- Secure communication during the transaction
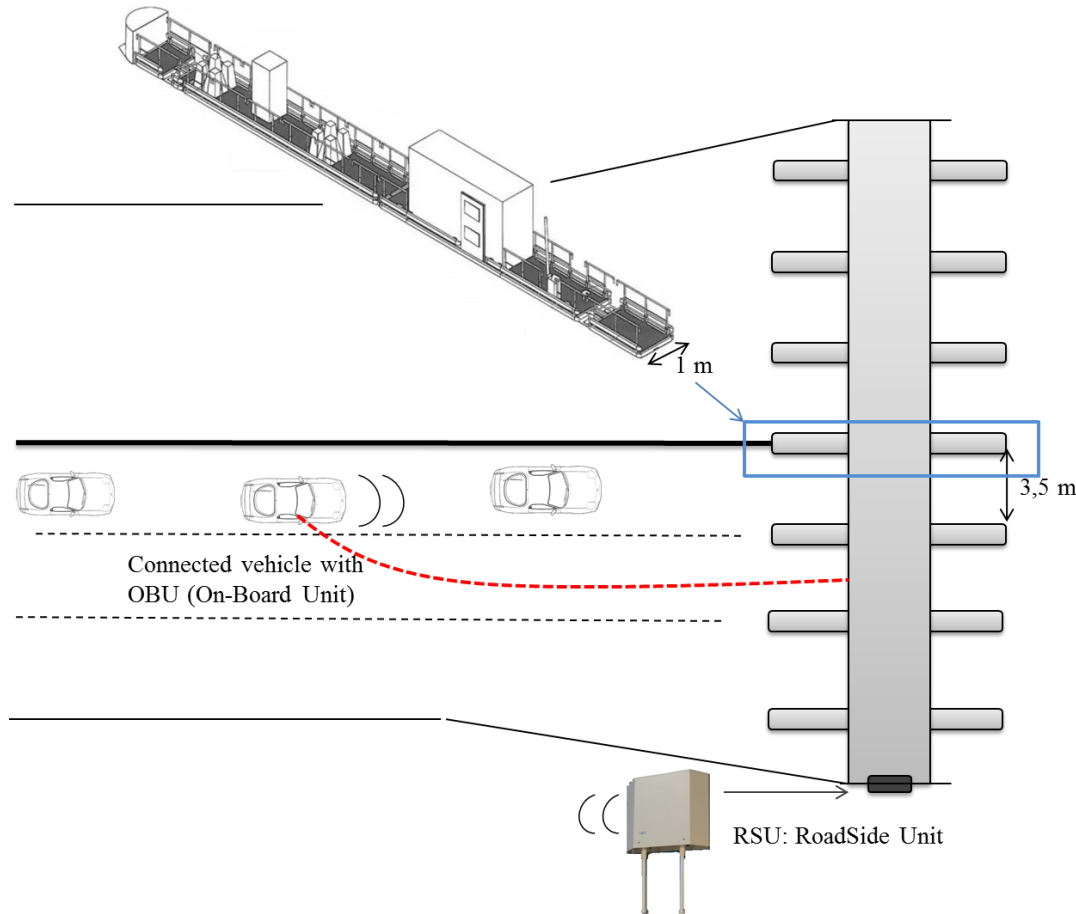
- Real-time data transfer
  - <100 ms

Toll plaza situation
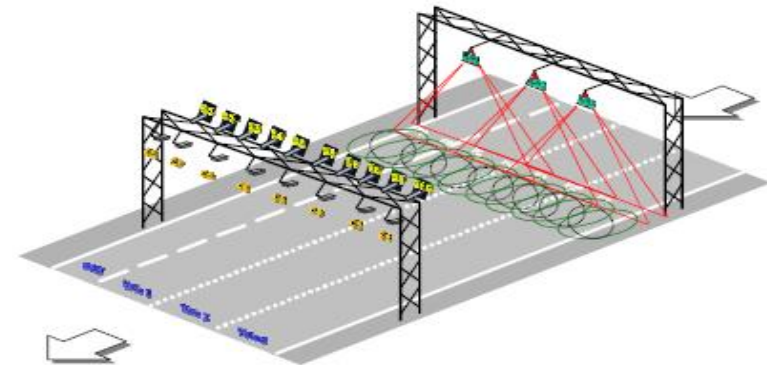
Free-flow situation

Why an accurate location of the vehicles?

1 m

3,5 m

Connected vehicle with
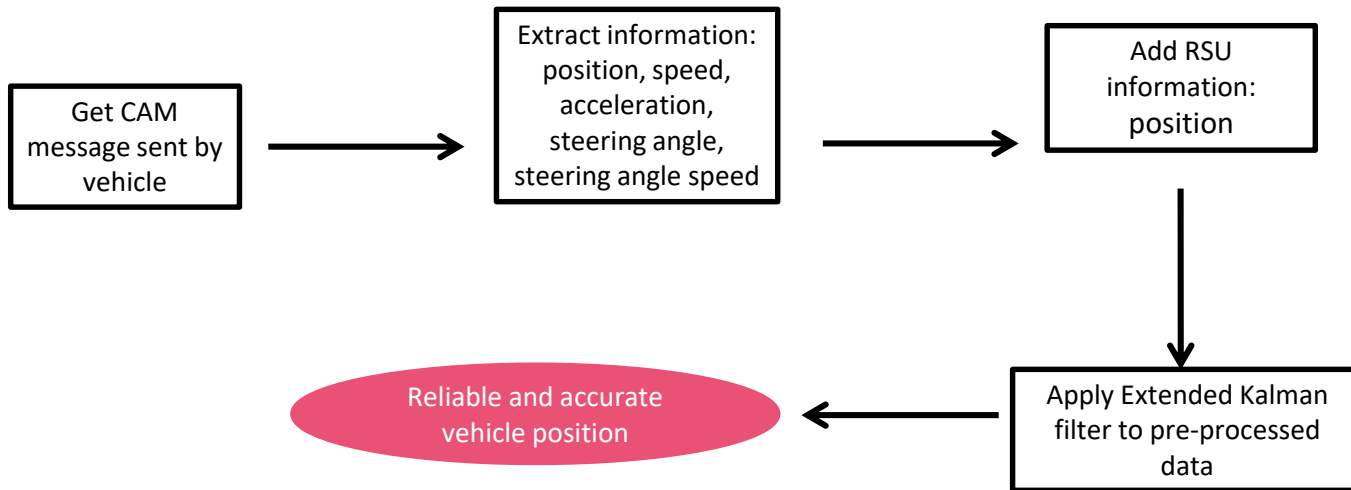OBU (On-Board Unit)

RSU: RoadSide Unit

- The RSU shall locate and track the connected vehicles while approaching the toll plaza, to distinguish
  - 2 vehicles in 2 adjacent lanes
  - 2 vehicles that follow each other in the same lane
- Needed accuracy: less than 1 meter

Characteristics of ITS-G5 technology

- Based on 802.11p standard (a WiFi designed for communication between vehicles)
- Allow communication: vehicle to vehicle (V2V), vehicle to infrastructure (V2I), and/or vice-versa
- Exchanges of different message types (already standardised or on-going, depending on the applications)
  - CAM (Cooperative Awareness Messages)
  - DENM (Decentralized Environmental Notification Messages)
  - SAM (Service Announcement Message)
- Transmission modes
  - Broadcast
  - Unicast possible for some applications

Proposed localisation solution

- Use of V2I communication
  - Processing of relevant information of CAM message from OBU
  - Location information of RSU
- Apply Extended Kalman filtering, to improve the vehicle position accuracy

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┌──────────────┐     ┌──────────────────┐     ┌──────────────┐
│ Get CAM      │     │ Extract          │     │ Add RSU      │
│ message sent │ ──> │ information:     │ ──> │ information: │
│ by vehicle   │     │ position, speed, │     │ position     │
│              │     │ acceleration,    │     │              │
│              │     │ steering angle,  │     └──────────────┘
│              │     │ steering angle   │            │
│              │     │ speed            │            v
└──────────────┘     └──────────────────┘     ┌──────────────┐
                                               │ Apply        │
   ( Reliable and accurate  ) <────────────────│ Extended     │
   ( vehicle position       )                  │ Kalman       │
                                               │ filter to    │
                                               │ pre-processed│
                                               │ data         │
                                               └──────────────┘
```

Process for vehicle positioning and tracking

| Container	Data elements
ITS PDU header	Protocol version
	Message ID
	Station ID
	Generation delta time
Basic Container	Station Type
	Reference Position
High Frequency Container	Heading
	Speed
	Drive Direction
	Vehicle Length
	Vehicle Width
	Longitudinal Acceleration
	Curvature
	Curvature Calculation Mode
	Yawrate
	Steering wheel angle
	Lateral acceleration
	Vertical acceleration
Low Frequency Container	Vehicle Role
	Exterior Lights
	Path history

Content of a CAM message

Sequence diagram for toll transaction
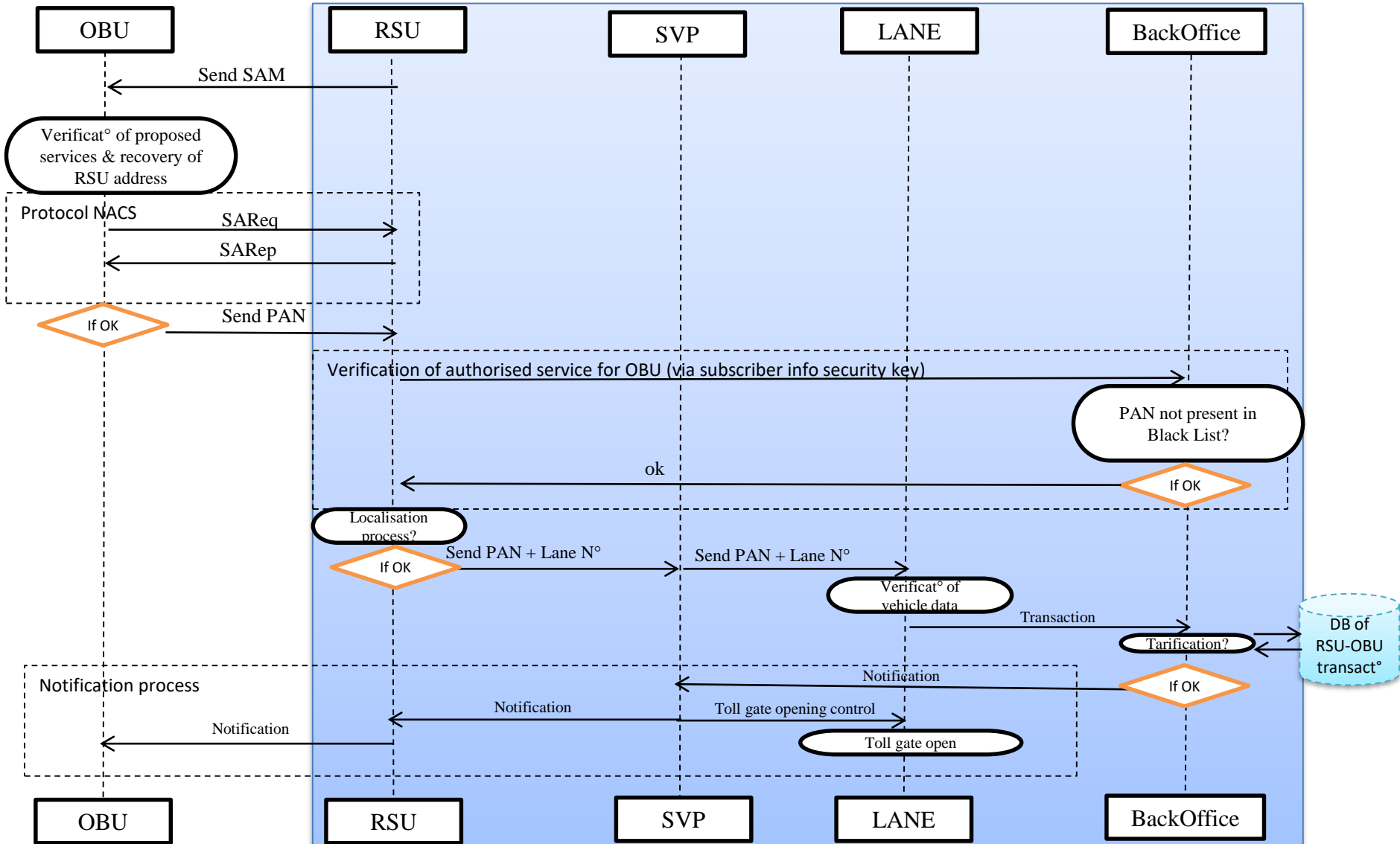
Extended Kalman filter?

- Algorithm that can use and process several types of information in real time
- Already several applications identified in literature: guidance, navigation, …
- Requirement: modelling the system under study (to observe the vehicle behaviour)
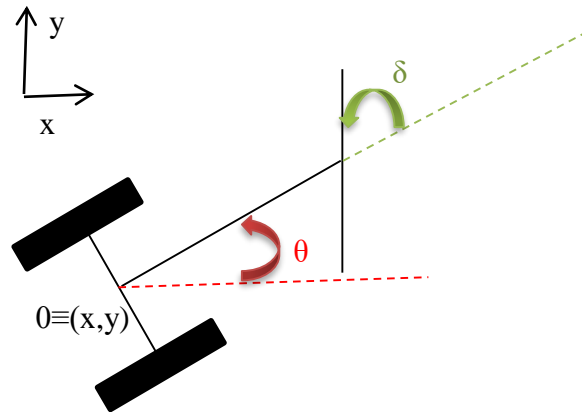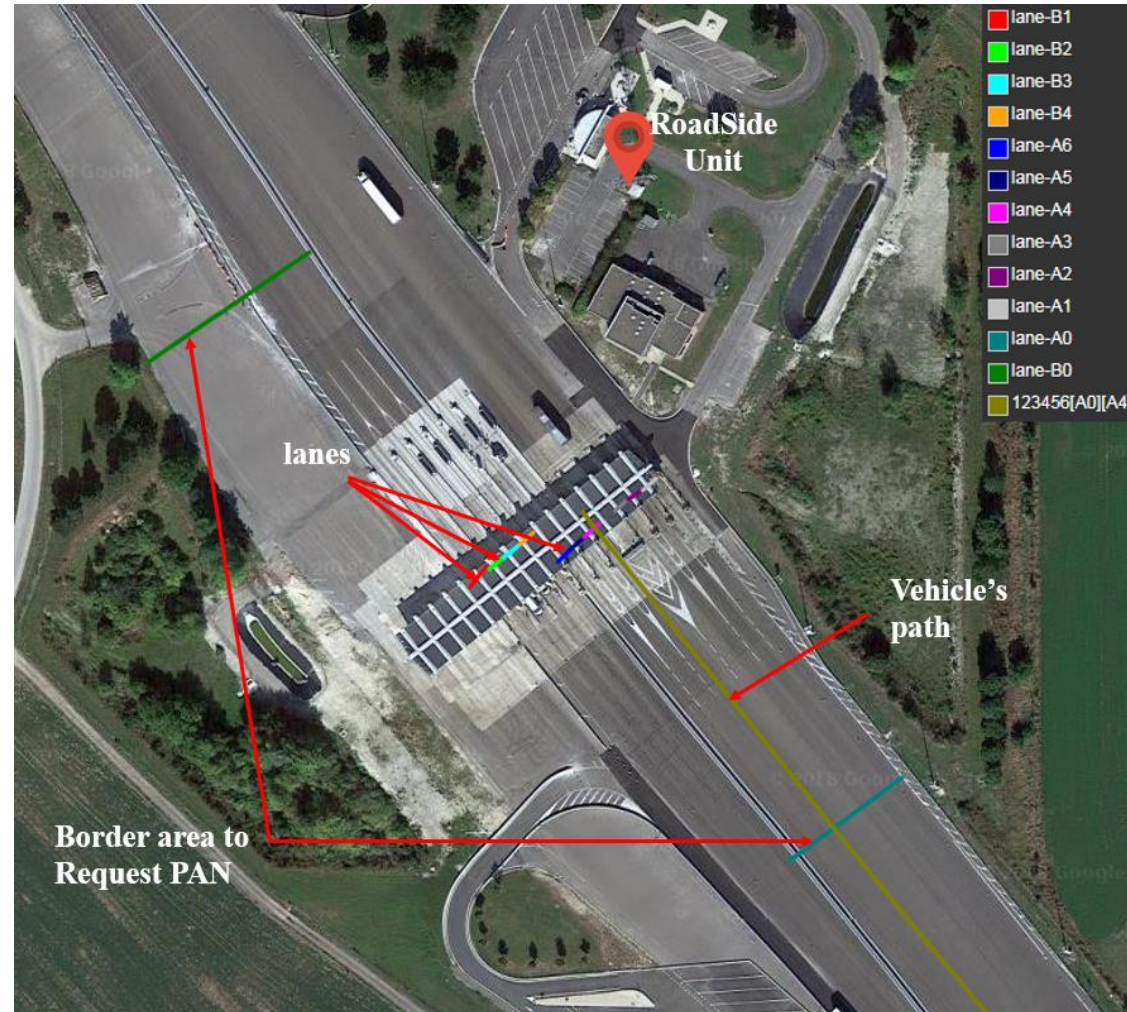

Characteristics of a vehicle status [1]

Where:

δ: steering angle

θ : vehicle direction

x, y : projections in Mercator plan of latitude and longitude

[1] Jaime Gomez-Gil, Ruben Ruiz-Gonzalez, Sergio Alonso-Garcia and Francisco Javier Gomez-Gil, "A Kalman Filter Implementation for Precision Improvement in Low-Cost GPS Positioning Tractors", SENSORS 2013, 13, 15307 – 15323

Vehicles localisation and tracking

View of the specific application developed to track the connected vehicles in the communication range of the RSU at Taissy toll plaza

Current work

- Edition of the functional specifications document for ETC service
- Development of a tool software to track the connected vehicles when crossing the tollgate
- Real time experiments are on-going, to test the technics and the algorithms for positioning (Senlis toll plaza on A1 and Taissy toll plaza on A4 highway)
- Development of toll application on RSU and OBU (on-going)
- Contributions to the ETSI Work Item on ETC service

Thank you for your attention

Any question ?

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