Platooning in VANETs

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Outline

1. Platooning for Connected Vehicles
2. Existing Platooning Protocols
3. Cyber Attacks on Platoons
4. Bibliography

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Introduction to Platooning

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Platooning

Group of vehicles that drive on the same roadway in the same lane at a proximity of each other.

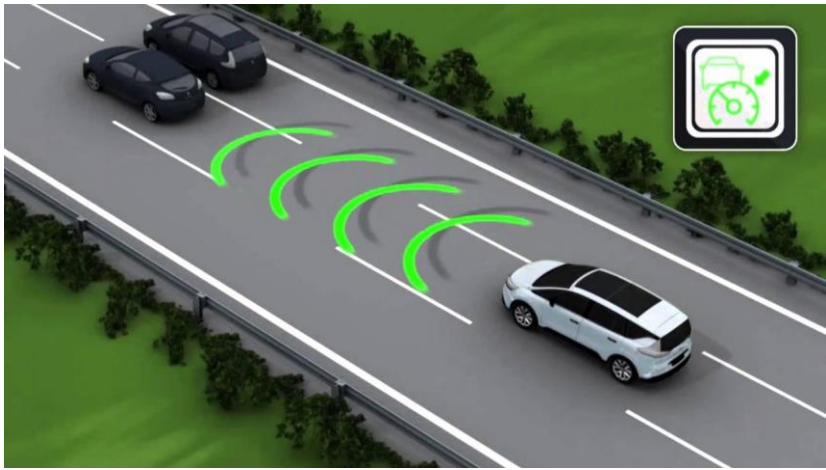
This application ensures:

- the safety of road users (rear-end collision avoidance)
- fuel efficiency and less CO_2 emissions
- traffic flow improvement
- driving comfort for drivers

Adaptive Cruise Control

Platoon of 2 vehicles

Step 1: Use of sensor data to calculate inter-vehicle distances



System Input:

- Radar/Lidar/Camera data
- Vehicle's speed
- Braking system status

System Output:

- Speed and longitudinal distance range
- Commands sent to the engine, pedal, and brake control system
- Status information for the driver

Step 2: Cooperation between vehicles to calculate minimal inter-vehicle distances

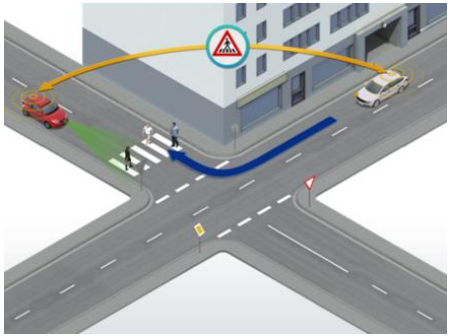
Cooperative Intelligent Transport Systems (C-ITS)

ITS Stations (ITS-S)

- Onboard Unit (OBU)
- Roadside Unit (RSU)

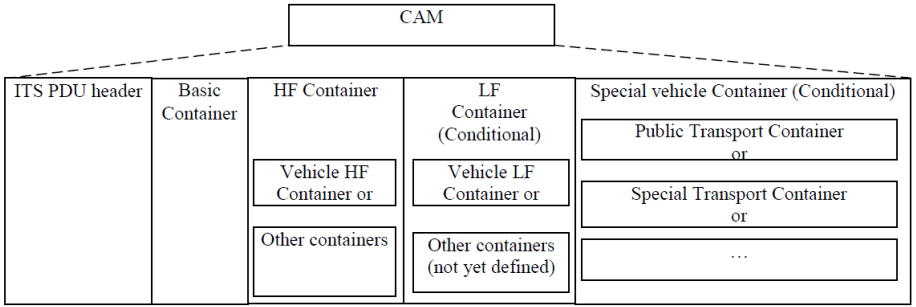
Main V2V Messages in Platooning

- Cooperative Awareness Messages (CAM)
- Collective Perception Messages (CPM)
- Platooning Messages (to be standardized)



Cooperative Awareness Message (CAM)

- Status and attribute information of the originating ITS-S
- Periodic messages
- Transmission frequency: 1 to 10Hz
- Modified version is used for platooning

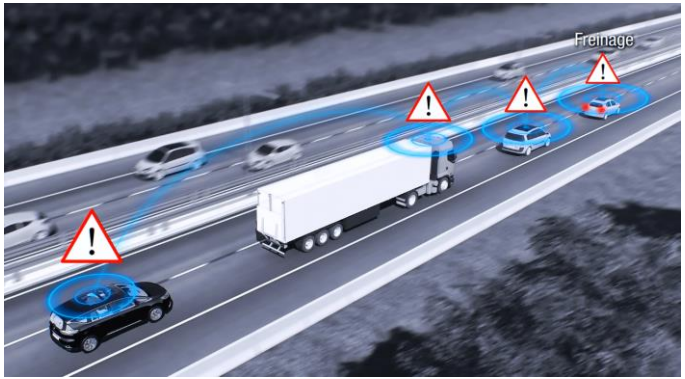


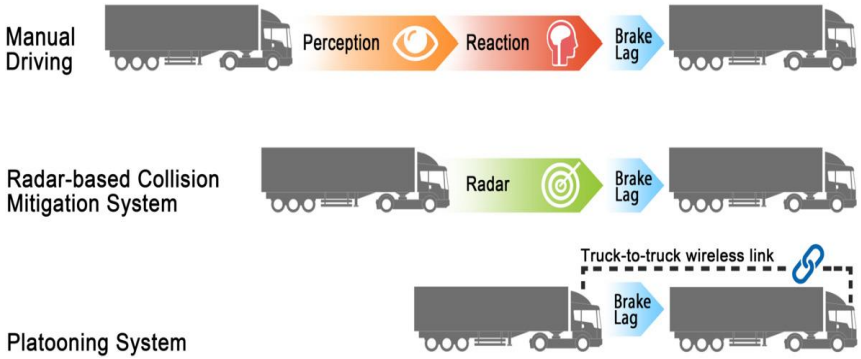
CAM General Structure: ETSI EN 302 637-2 [1]

Container	Data element
	GenerationDeltaTime
Basic	Station Type
	Reference Position
HighFrequency	Heading
	Speed
	Drive Direction
	Vehicle Length
	Vehicle Width
	Longitudinal Acceler.
	Curvature
	Curvature Calc.Mode
	Yaw Rate
Low Frequency	Vehicle Role
	Exterior Lights
	Path History

Platooning for Connected Vehicles

Use of sensor data and exchange of V2X (V2V, I2V) messages to locate other vehicles, estimate their driving speeds, and calculate the minimal inter-vehicle distance

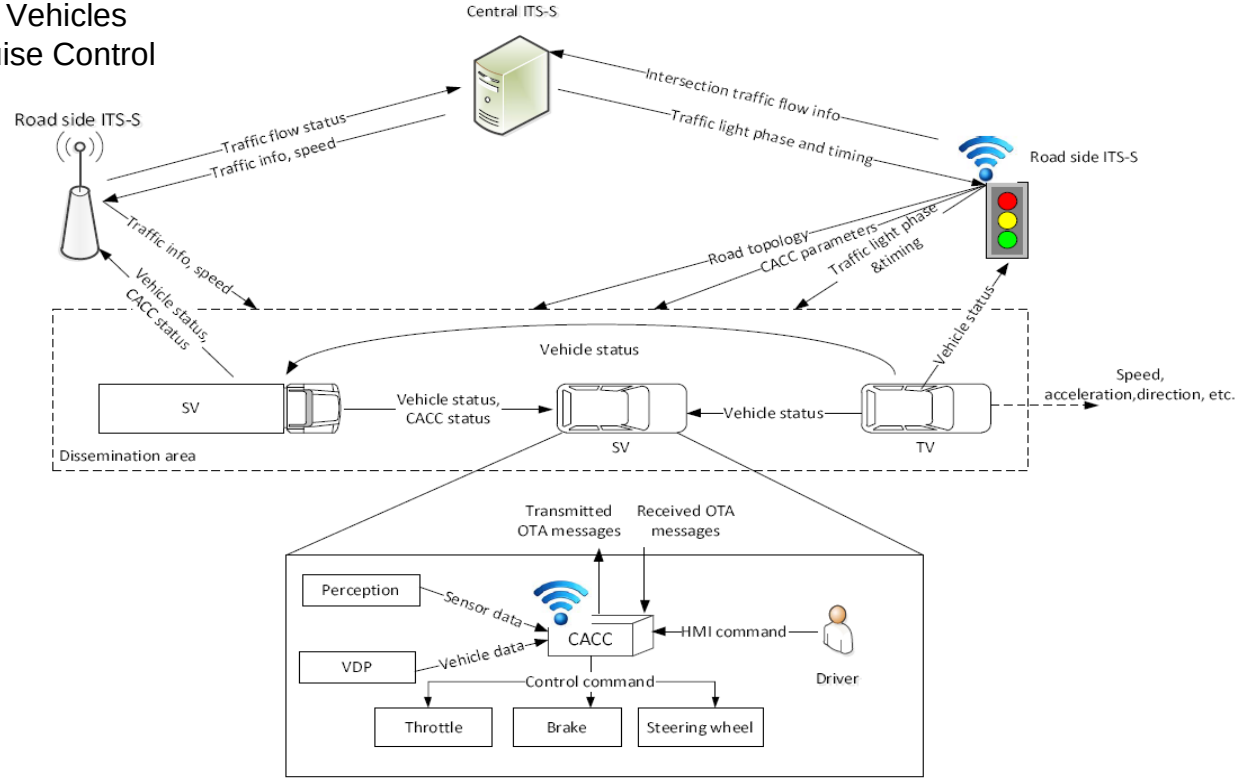




Platooning Systems [6]

Cooperative Application Architecture

- Platooning for Connected Vehicles
- Cooperative Adaptive Cruise Control



CACC Architecture – ETSI TR 103 299 V2.1.1 [2]

CAR 2 CAR USE CASE [3]

Cooperative Driving

Share of trajectories and coordination of maneuvers

RSU may give the vehicles advices about their speed, time gap, lane change…

Platooning Functions

- Forming: at least 2 vehicles are needed to create a platoon
- Joining: a vehicle joins an existing platoon
- Merging: a platoon joins another platoon
- Leaving: a platoon member leaves the platoon
- Splitting: a platoon divides into 2 platoons
- Dissolving: the platoon ends

Join platoon scenario

Create platoon scenario

Merge platoon scenario

A member leaves the platoon and causes its split

Wireless Technologies

Direct communication

- Standardized
- Short-range ad-hoc broadcast
- Low latency
- Free technology (no communication costs)

Long distance communication (Mobile networks)

- More Mature
- Longer communication range
- Higher latency
- Communication costs

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Existing Platooning Protocols

KONVOI [6]

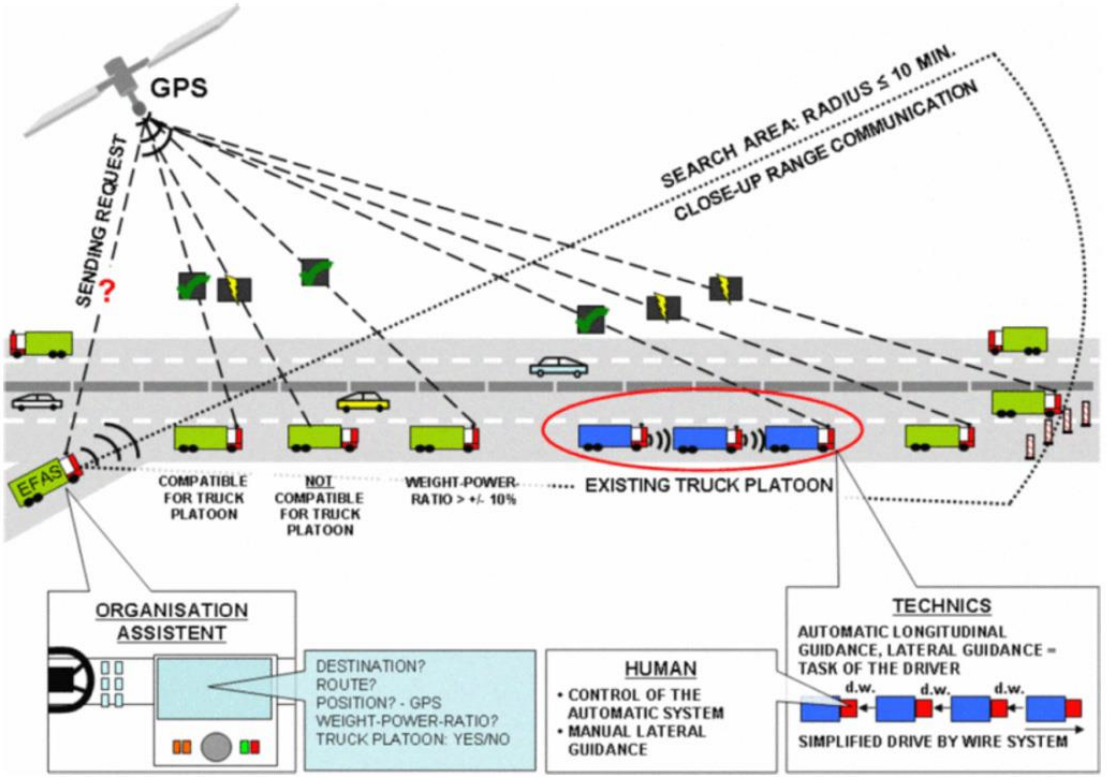
German Project, 2005-2009

- V2V, V2I
- Lidar, radar, monocamera
- ITS G5, 3G

Driver <-> central server exchange:
Find/join an existing platoon
Create a platoon
Order platoon members

Platooning Scenarios:
- Build, dissolve initiated by a driver
- Lane Change

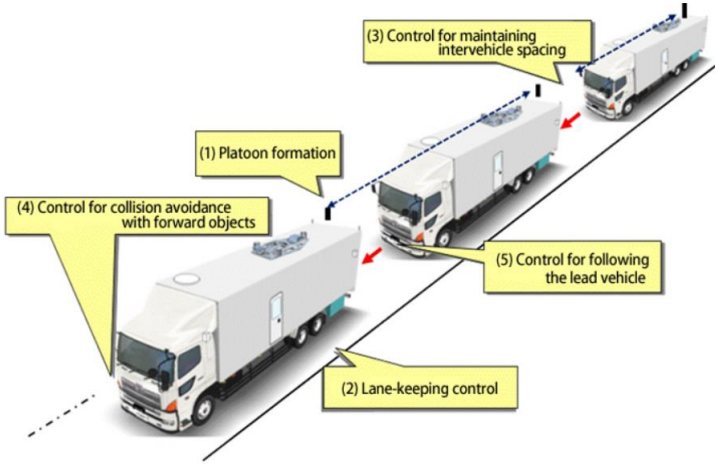
Testing:
- 4 trucks, 60-80 km/hr, 10m spacing
- Results: Fuel savings on test sites only



Energy ITS [4] [5] [6]

Japanese Project, 2008-2012

- Radar, Lidar, lateral cameras for lateral control
- DSRC / IEEE 802.11p for longitudinal control

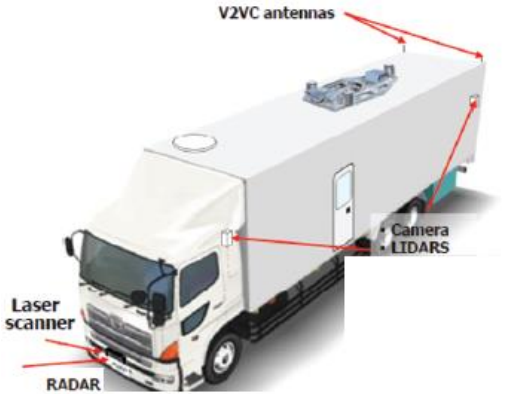


Protocol:

- Vehicles are already in a platoon, predefined gaps/speed
- Exchange of CAM + platooning data to maintain intervehicle spacing:

Truck position, velocity, acceleration, the velocity of each truck, the braking signal, platoon ID and a truck position in a platoon, an obstacle location

- Truck control period: 10 ms
- 2 machine vision units for the lateral control based on lane marker detection



Energy ITS [4] [5] [6]

Testing:

- 4 trucks, a passenger car
- Constant speed of 80 km/h, gaps of 10m and 4m

Scenarios:

- Passenger car driving at 60 km/h in front of the platoon -> detection, deceleration
- Passenger car trying to get into the gap between trucks -> detection, deceleration, lane change
- Platoon lane changing
- Platoon LV braking (manually)

Results:

- Energy consumption improvement: 14% at 4.7m gap.
- CO_2 emissions: reduced by 2.1% and 4.8% at 10m and 4m gaps respectively

SAfe Road TRains for the Environment (SARTRE) [6]

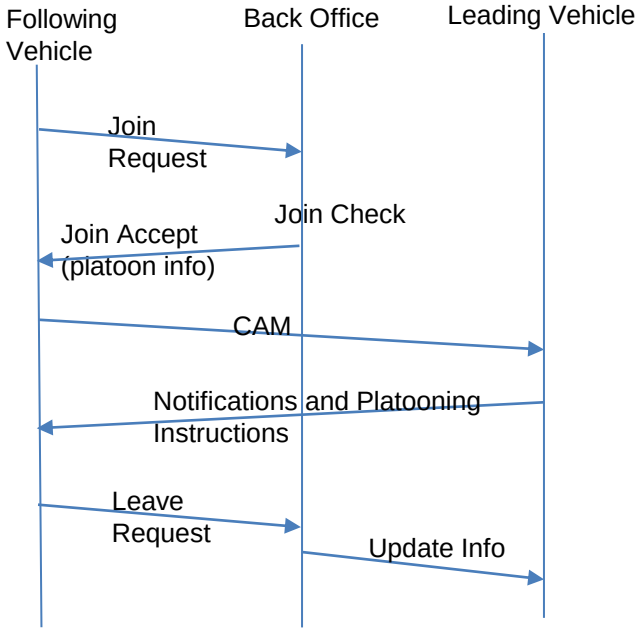
EU Project, 2009-2012

- V2V, V2I
- ITS G5, 3G

CAM/DENM are exchanged to maintain a dynamic safe distance between vehicles.
Updated CAM and DENM with platooning information (ID, order,…)

Scenarios:
Dynamic gaps, Platoon max. size,
Create, join, leave, maintain

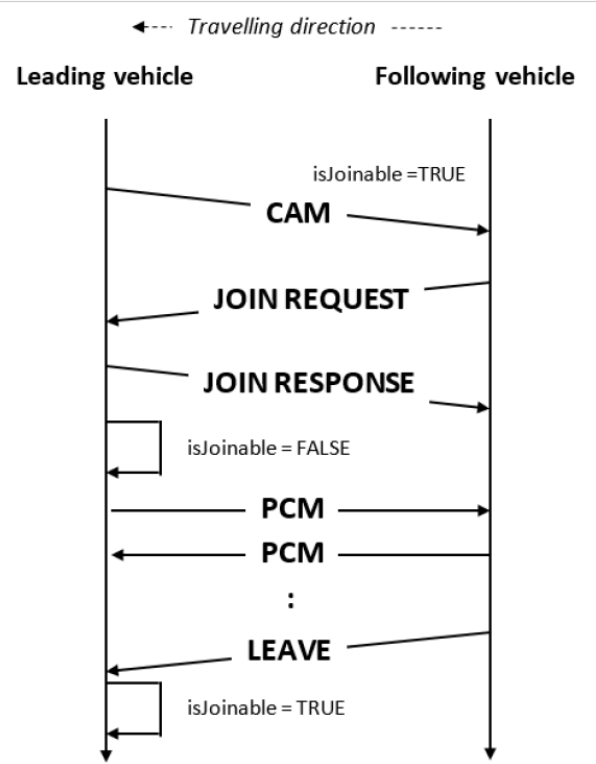
Testing Results:
2 trucks, 3 passenger cars
Highest fuel saving: 16%, at 5m gap



Enabling SafE Multi-Brand pLatooning for Europe (ENSEMBLE) [7]

EU Project, 2018-2022

- CAMv2: Extended CAM with PlatooningContainer contains isJoinable flag
- Platooning Management Messages (PMM): are messages that contain the join request, join response, and the leave request.
- Platooning Control Messages (PCM): messages that contain data to control the vehicles in the platoon longitudinally and laterally.

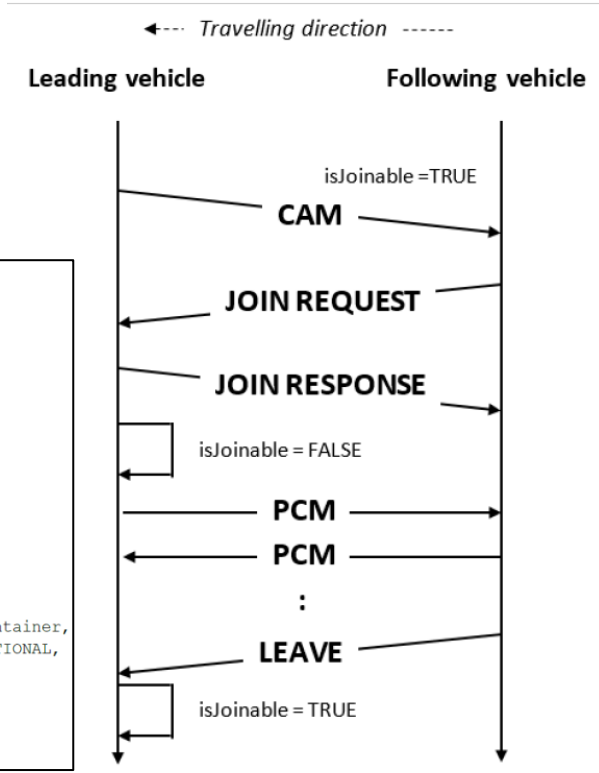


ENSEMBLE [7]

```
PMM ::= SEQUENCE {
        header ItsPduHeader,
        stationType StationType,
        referencePosition ReferencePosition,
        heading Heading,
        generationDeltaTime GenerationDeltaTime,
        message CHOICE {
                joinRequest JoinRequest,
                joinResponse JoinResponse,
                leaveRequest LeaveRequest
        }
}
```

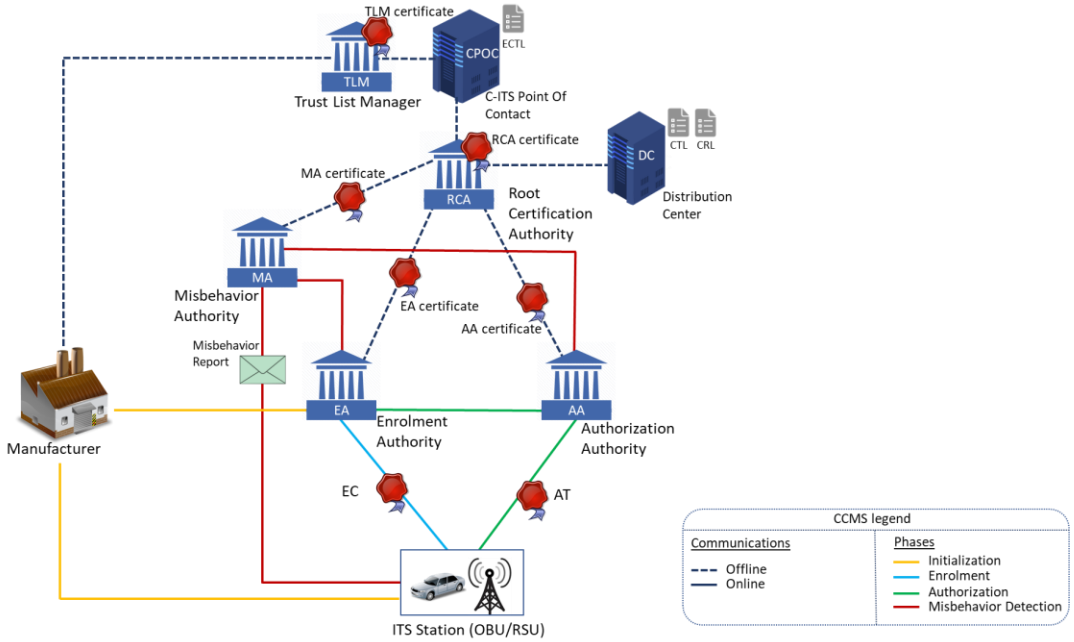
```
PCM ::= SEQUENCE {
        header ItsPduHeader,
        platoonControlContainer PlatoonControlContainer
}


PlatoonControlContainer ::= SEQUENCE {
        stationType StationType,
        referencePosition ReferencePosition,
        heading Heading,
        generationDeltaTime GenerationDeltaTime,
        sequenceNumber SequenceNumber,
        platoonPosition PlatoonPosition,
        vehicleID VehicleID,
        vehicleInFrontID VehicleID OPTIONAL,
        vehicleLength VehicleLength,
        longitudinalControlContainer LongitudinalControlContainer,
        lateralControlContainer LateralControlContainer OPTIONAL,
        causeCode CauseCode OPTIONAL
        aboutToLeave BOOLEAN OPTIONAL,
        readyToLeaveInFront BOOLEAN OPTIONAL
}
```

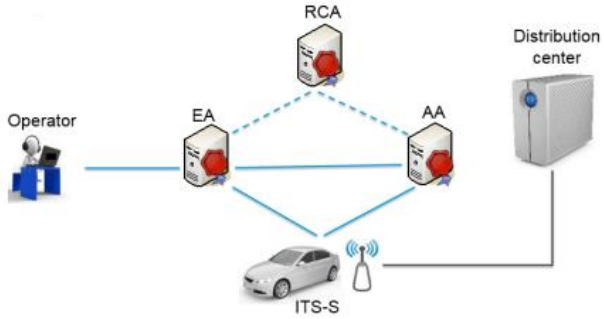


Cyber Attacks on Platoons

Security and Privacy



EU C-ITS PKI

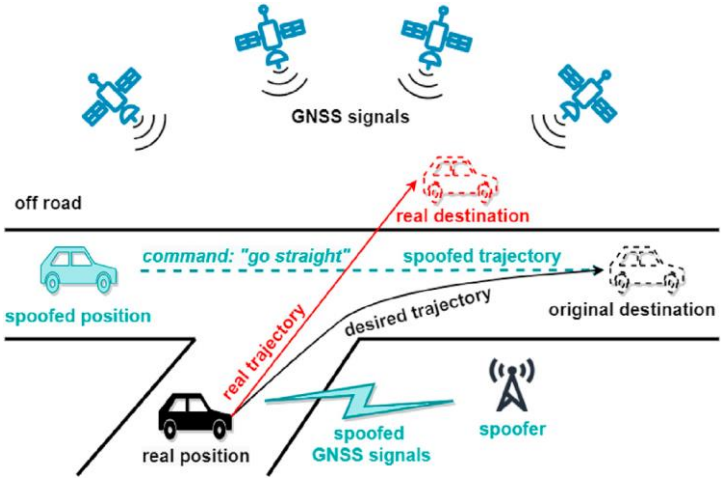


ISE PKI Architecture

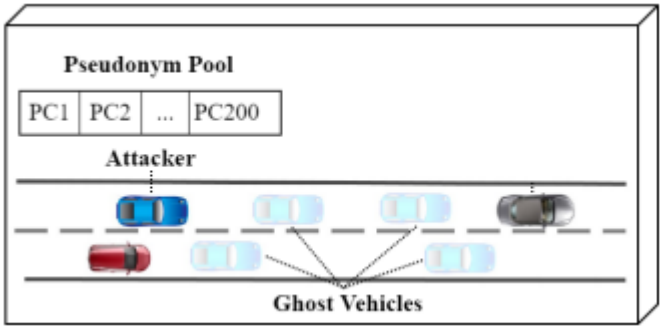
Threats

Modification of exchanged info from inside or from outside the platoon

- Geolocation Spoofing: the attacker impersonates another vehicle
- Sybil attack: the vehicle uses fake identities to inject data in the network related to fake nodes



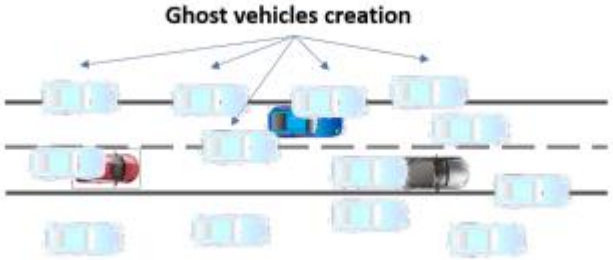
GPS Spoofing [9]



Sybil Attack System Model [10]

Threats

DOS Attack: radio jamming due to real or fake vehicles that downgrades the cooperative application to ACC mode!



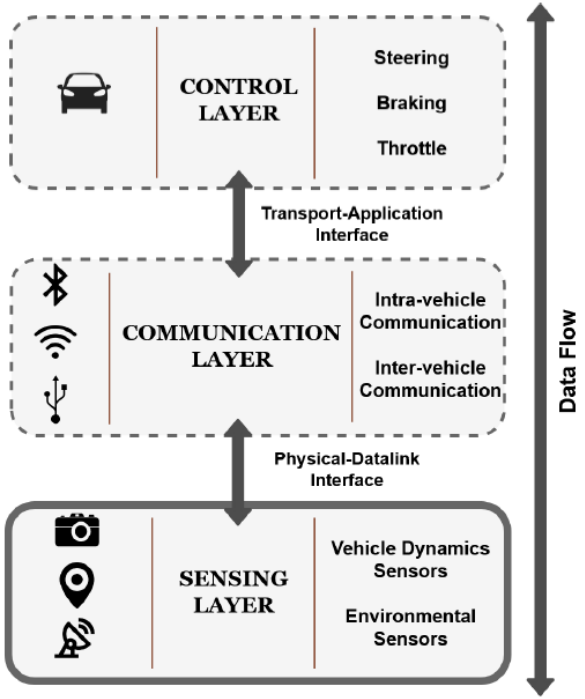
DOS Sybil Attack [10]

Threats

Vehicular system attacks (soft or hard)

Attacks on sensors (blinding, spoofing, replay…) to generate false information [11]:

- Attacks on LiDARs may cause overcalculation or undercalculation of the distance to an object.
- Eavesdropping attacks on sensors allow monitor readings and transmissions.
- Blinding attack on cameras disables its function.



Data flow for Connected or Automated Vehicle [11]

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