HOCHSCHULE
HANNOVER
UNIVERSITY OF
APPLIED SCIENCES
AND ARTS
–
Fakultät IV
Wirtschaft und
Informatik

Fahrzeugvernetzung – V2X

Lecture 1: Introduction and Basics

Hugues Tchouankem, 05.10.2022

Lecture 1

Short Bio

- Born and grew up in Cameroon
- Electrical Engineering at RWTH Aachen
  - Information and communications technology

RWTH AACHEN UNIVERSITY

- Ph.D. degree from the Leibniz University of Hannover
  - Vehicular communication and networking (V2X)

Leibniz Universität Hannover

- Research Scientist at Robert Bosch GmbH

BOSCH
Technik fürs Leben

- Research Interests
  - Wireless communication
  - Artificial Intelligence (AI) for mobile networks
  - Cooperative autonomous driving

Lecture 1

Schedule

- **Lecture (V2)**
  - Wednesday 14:15 – 15:45
  - Lecture Hall 1H.019
  - Course overview: https://moodle.hs-hannover.de/course/view.php?id=21235

- **Exercise (Ü2)**
  - Wednesday 16:00 – 17:30
  - Lecture Hall 1H.019
  - Start: October 19

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Examination Information

- Written or oral depending on the number of registered students
- Only the lecture/exercise are relevant for the exam
- Number of credit points: 6
- Repetition session at the end of the semester
  - Highly recommended

- Consultation hour (On-demand)
  - Fixed dates if needed
  - Virtual room will be provided by mail

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General Information

- Prerequisites
  - Interest in mobile communication and connected mobility
  - Knowledge from the lecture “Betriebssysteme/Netze 1/3” is an advantage

- Attending the lecture/exercise and taking notes is highly recommended

- Course material will be provided on the Moodle course page
  - https://moodle.hs-hannover.de/course/view.php?id=21235
  - Lecture slides and exercise/solution documents
  - No course code required to attend the course

Lecture 1
Outline

- Motivation
- Road Safety Applications
- V2X Protocol Stacks
- ITS Reference Architecture
- Course Overview

Lecture 1

Mobility and Transport (1/3)

- **Mobility** of people and goods as key factor in the economic expansion
  - Self-determination and personal freedom
  - Access to a large range of products
  - Ability to achieve long-distance travels
  - Job/study opportunity abroad
- **People** needs to reach other **people**, goods, places and services

Lecture 1

Mobility and Transport (2/3)

- **Transport** is the instrument required for the implementation of mobility

  - Transport is seen as a "**tool**" to satisfy the need for mobility
  - Targeted **change of location** of persons or goods using energy and information

- Transport includes **vehicles**, **infrastructures** and **traffic rules**

- It is hard to say **how much traffic** is generated or required in the **movement of people**

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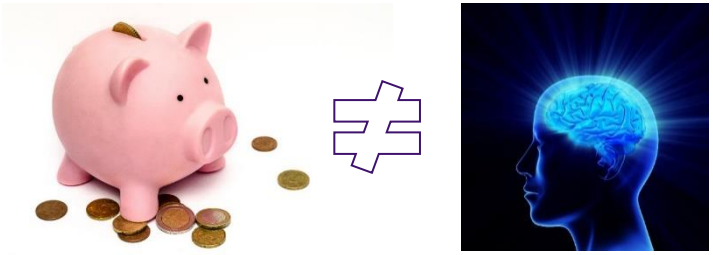
Mobility and Transport (3/3)

- The **growth** of mobility is **socially commendable** for the political and economical policy makers
- The growth of traffic is an **undesirable objectives** for traffic scientists



- The success of mobility depends on the **quality** and **efficiency** of transport system
  - **Safe** travelling conditions
  - Enhance the **quality of life**
  - Avoid the waste of material **resources** and **energy**

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Accident Statistics from WHO

- **1.35 million** people die each year as a result of road traffic crashes
  - **3698** people each day - **154** each hour
- Road traffic injuries are the leading cause of death for children and young adults aged **5-29 years**
- More than **half of all road traffic deaths** are among **vulnerable road users**: pedestrians, cyclists, and motorcyclists
- WHO set a target of **halving the global number of deaths** and injuries from road traffic crashes by 2020

Source: World Health Organization (WHO)

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Causes of Accidents from WHO (1/2)

- **Speeding**
  - In car-to-car side impacts the fatality risk for car occupants is **85%** at **65 km/h**
- **Driving under the influence of alcohol and other substances**
  - May increase the risk of a crash that results in death or serious injuries
- **Nonuse of motorcycle helmets, seat-belts, and child restraints**
  - Correct helmet use can lead to a 42% reduction in the risk of fatal injuries and a 69% reduction in the risk of head injuries
  - Wearing a seat-belt reduces the risk of death among drivers and front seat occupants by 45 - 50%

Source: World Health Organization (WHO)

Lecture 1

Causes of Accidents from WHO (2/2)

- **Distracted driving**
  - The distraction caused by **mobile phones** is a growing concern for road safety
  - Using a phone while driving **slows reaction times**: longer **braking reaction** time, longer **reaction to traffic signals**

- **Unsafe road infrastructure and vehicles**
  - Measures such as footpaths, cycling lanes, safe crossing points, and other traffic calming measures can be critical to reducing the risk of injury among these road users
  - Vehicle manufacturers should meet front and side impact regulations by including **electronic stability control** and ensuring that **airbags** and **seat-belts** are fitted in all vehicles

Source: World Health Organization (WHO)

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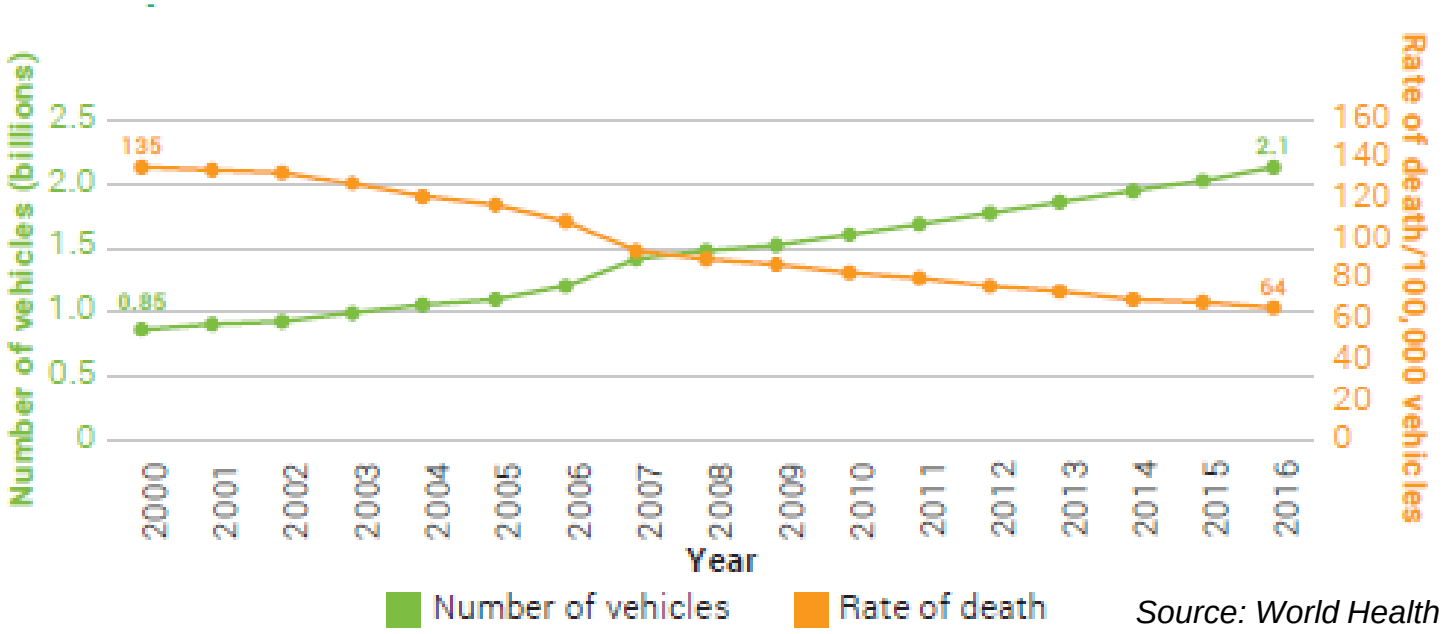
Rate of Death vs. Number of Vehicles Worldwide

- Steadily increase of registered vehicles
- Reduction of number of death of more than 50% in the last 15 years
  - **Progress** in mitigating the adverse effects of **increasing motorized transport** (Enhanced technologies: ABS, EPS)
  - **Not fast enough** to compensate for rapid **population growth**



Source: World Health Organization (WHO)

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Intelligent Transportation Systems (ITS)

- Growth of economy and mobility has generated an increase in the volume of road transport
  - Rise of congestion of road infrastructures
  - Air and water pollution, noise
- **Expansion of existing road infrastructure** not always the optimal solution
- A **communication** between different road actors: cars, buses, trains, motorcycles, bicycles and pedestrians is rather beneficial
- ITS integrates **information and telecommunication** into traffic engineering to efficiently control and manage transport systems
- ITS brings advanced applications providing **innovative services** to all kind of **modes of transport**

- **Main goal: Achieve traffic efficiency by minimizing traffic problems**

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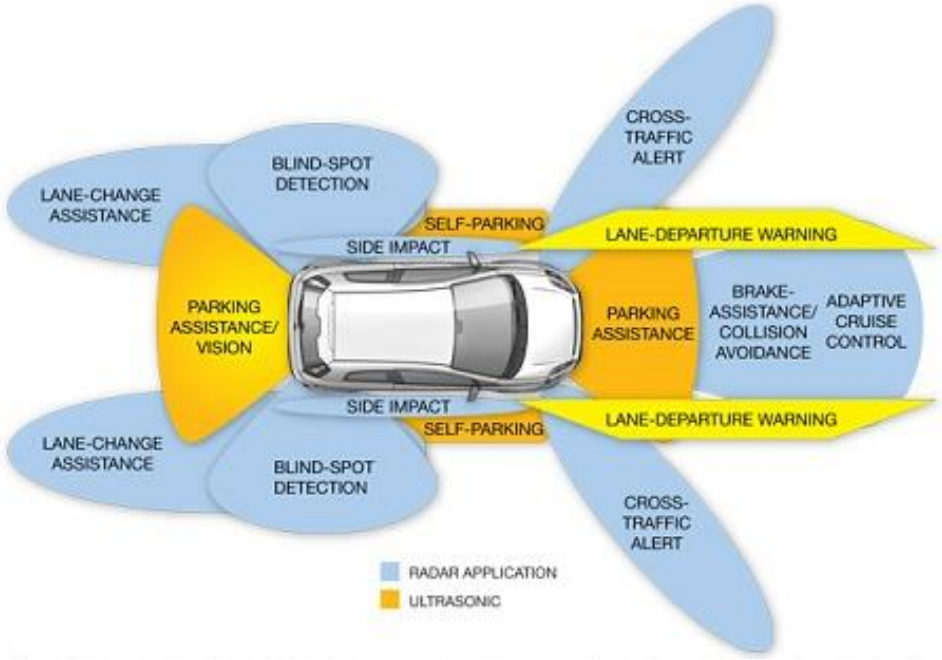
Intelligent Transportation Systems (ITS)

- Through ITS
  - Traffic participants are **better informed**, road infrastructures are **optimal utilized**
  - **Traffic signal** are controlled according to **traffic conditions** in urban environments

- Advanced Driver Assistance Systems (ADAS) will be extended by increasing the **driver's horizon**



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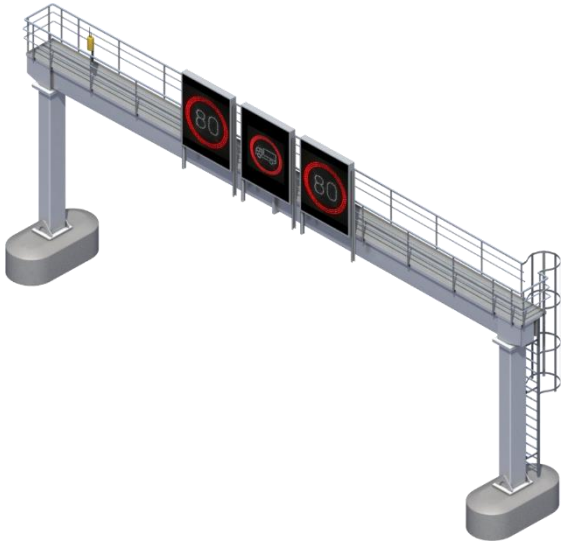
Intelligent Transportation Systems (ITS)



Source: CAR 2 CAR Communication Consortium

- The main goal is to use **advanced applications** for different modes of transport to better inform traffic participants
- Embrace a various forms of **wireless communication-related services** intended to
  - Increase **travel safety**
  - Improve **traffic efficiency**
  - Minimize **environmental impact**

- Some already implemented applications
  - Variable speed limit sign
  - Emergency vehicle notification (eCall)

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Cooperative Intelligent Transportation Systems (C-ITS)

- Twelve European vehicle manufacturers signed a Memorandum of Understanding to bring **Cooperative Intelligent Transport Systems and Services** (C-ITS) onto European roads (In October 2012)
- **Cooperation/Interaction** between road users, infrastructure, vehicles to deliver the most safe, secure, efficient and comfortable journey
- Extend ITS with cooperation between traffic participants by means of **V2X Communication**

Source: www.intelligenttransport.com

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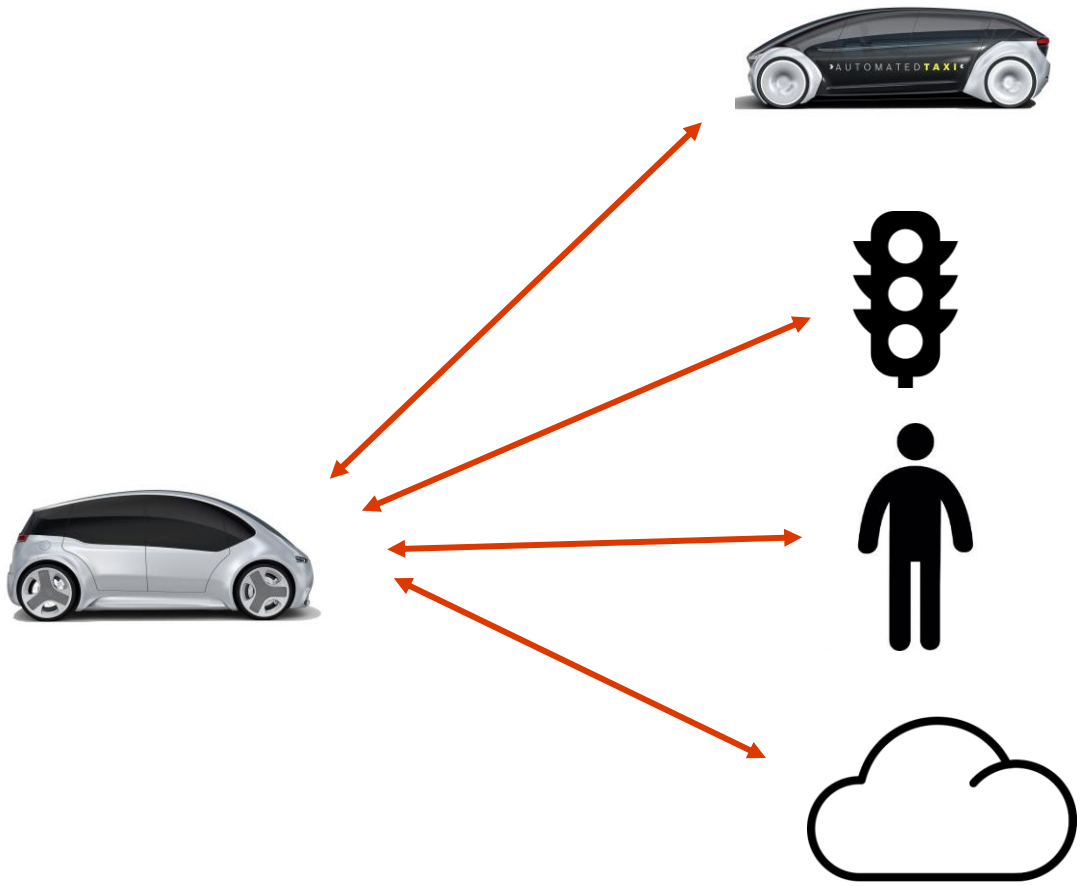
V2X Communication

- V2X stands for 'vehicle to everything‘
- There are several components of V2X
  - **Vehicle-to-vehicle (V2V)**
    - Cars talk to other cars
  - **Vehicle-to-infrastructure (V2I)**
    - Cars talk to infrastructure
  - **Vehicle-to-pedestrian (V2P)**
    - Cars talk to pedestrian
  - **Vehicle-to-network (V2N)**
    - Cars talk to datacentres



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Some Safety Applications

Application	Description	Direction
Emergency Electronic Brake Lights	Transmits a dedicated warning message if a vehicle is braking hard; receiving vehicles can warn their drivers in spite of Line of Sight (LOS) obstructions (other vehicles, fog, etc.)	V2V
Traffic Lights Violation Warning	Warns the driver to stop at the legally prescribed location if the traffic signal indicates a stop and it is predicted the driver will be in violation	I2V
Forward Collision Warning	Warns the driver of an “impending rear-end collision” with a vehicle “ahead in traffic in the same lane and direction of travel”	V2V
Lange Change Warning	The lane change warning application warns the driver if an intended lane change may cause a crash with a nearby vehicle	V2V
Intersection and Cross Traffic Assistant	It informs the driver about crossing vehicles with right of way, especially when there is no line-of-sight between crossing vehicles	V2V, I2V

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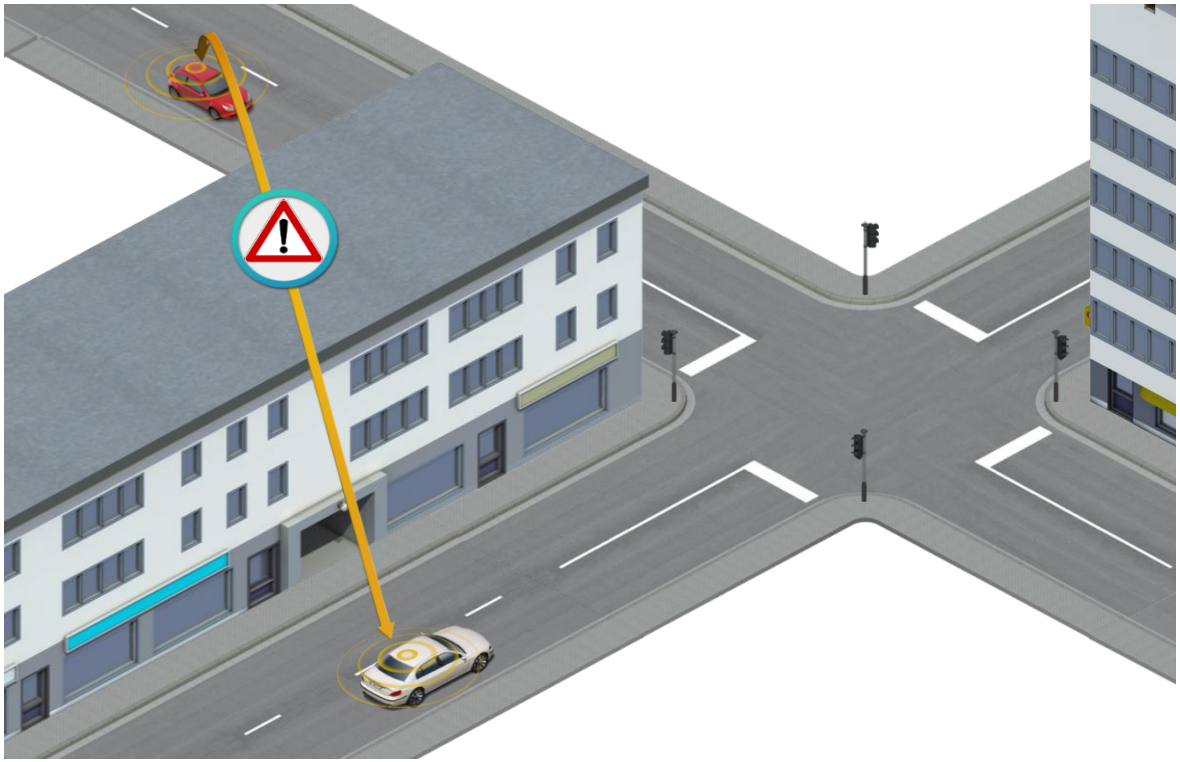
Intersection and Cross Traffic Assistant

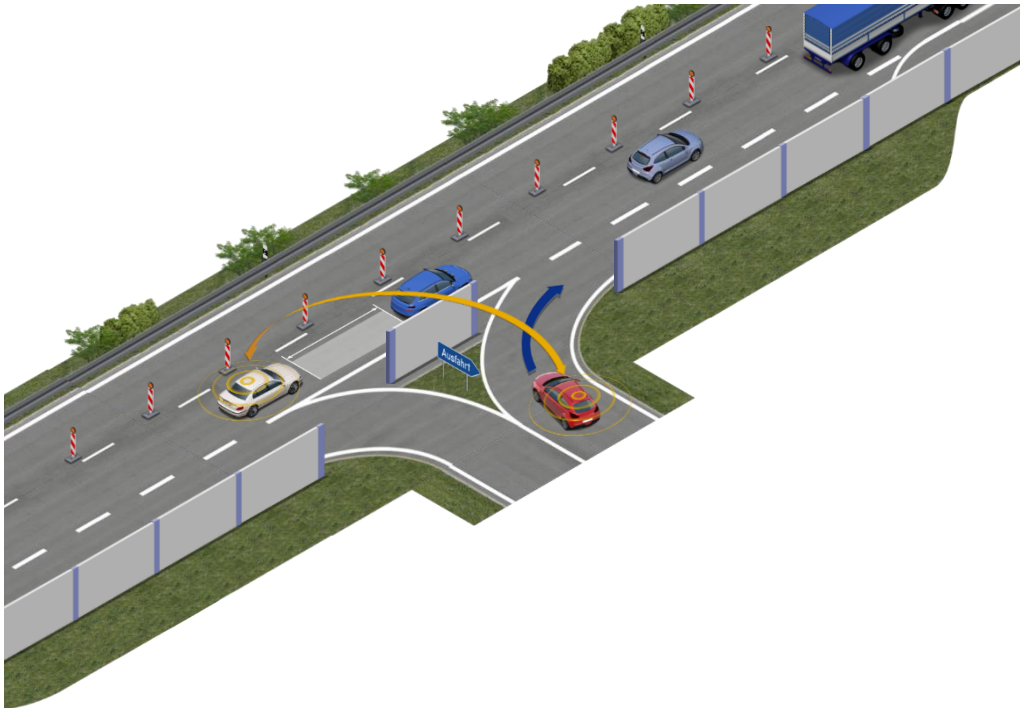
Red vehicle is informed about the crossing vehicle (yellow) with right of way, even when there is **no line-of-sight** between both vehicles



Source: CAR 2 CAR Communication Consortium

Lecture 1

Vehicle Merging assisted by V2V Communication (1/2)



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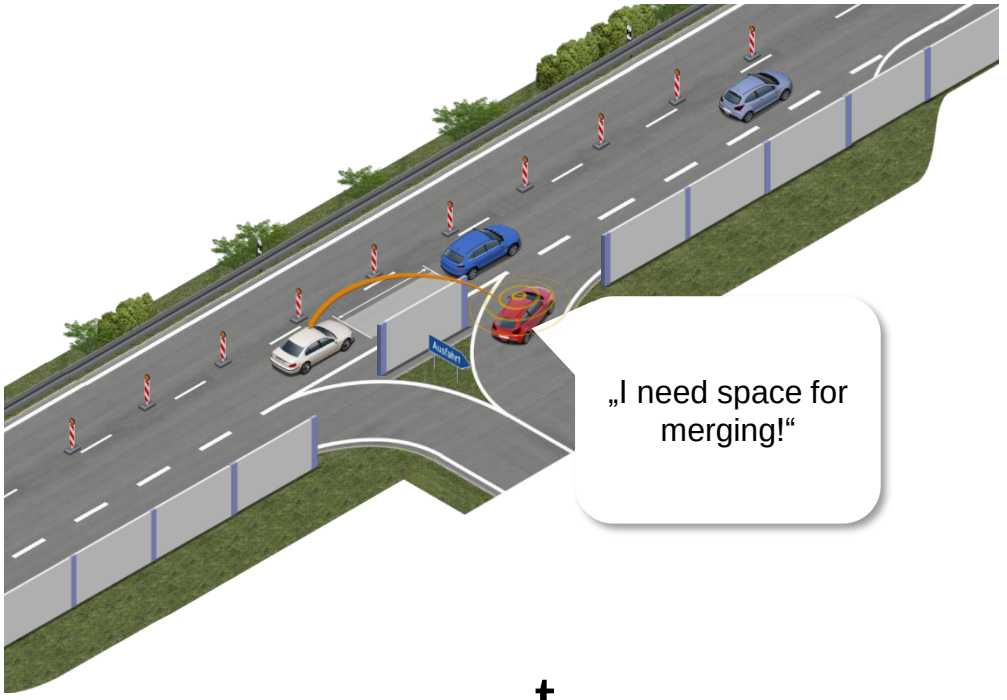

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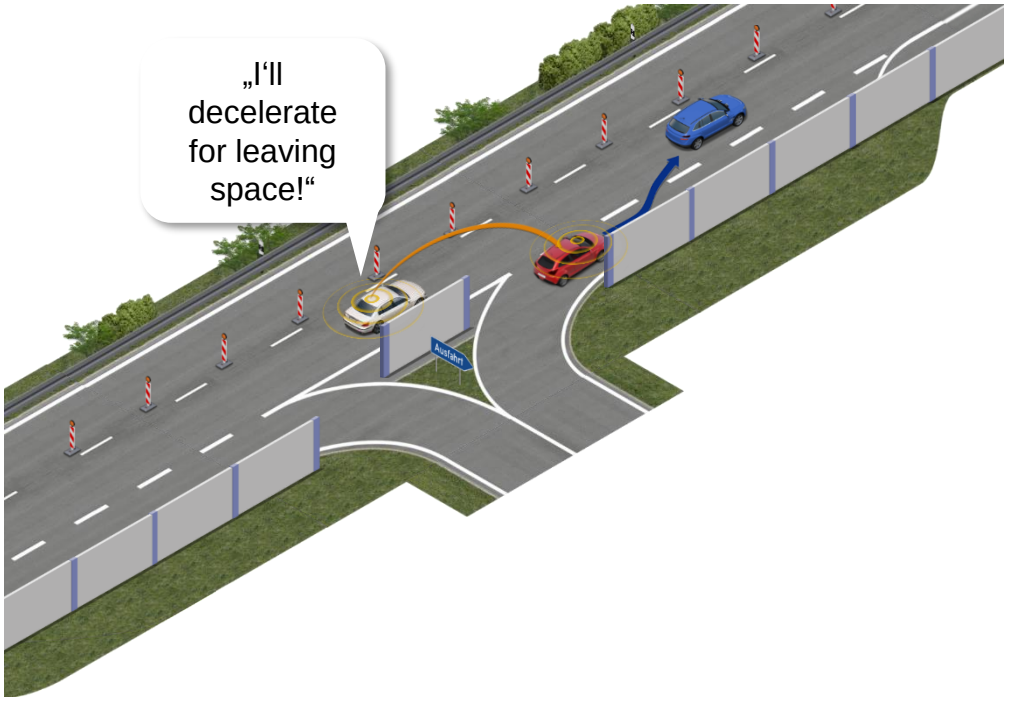
Source: CAR 2 CAR Communication Consortium

Lecture 1

Vehicle Merging assisted by V2V Communication (2/2)



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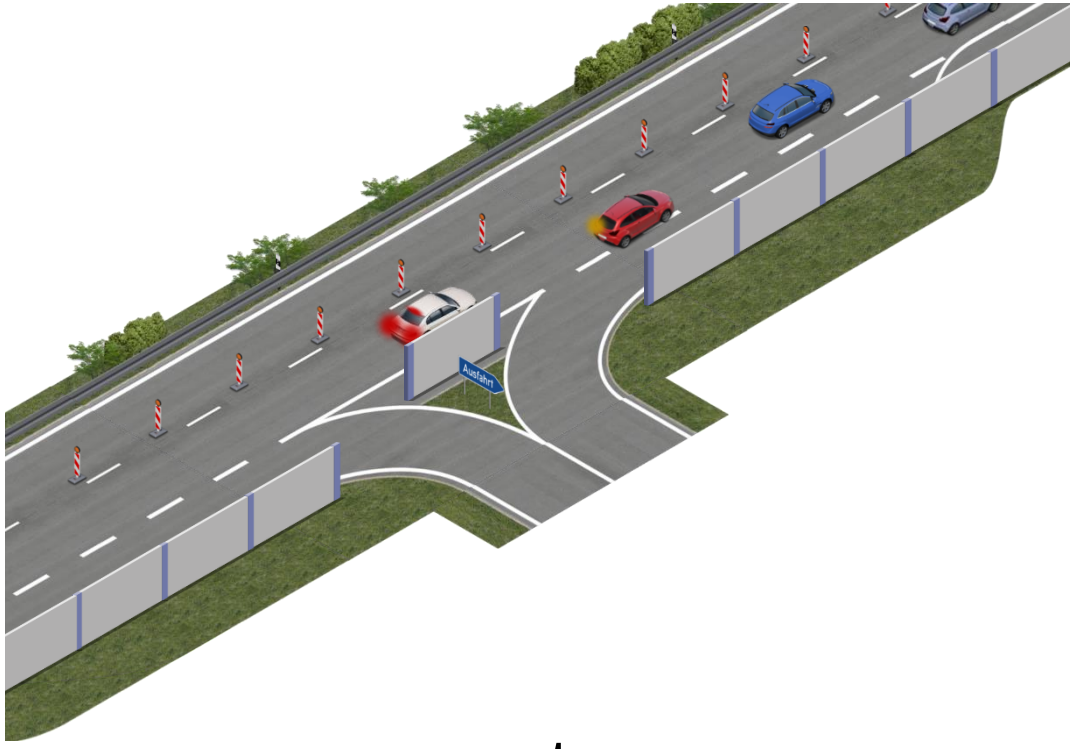

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Source: CAR 2 CAR Communication Consortium

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V2X Standardization

- Why to standardize?
  - Ensure **interconnection among V2X systems** and components
  - Enable **interoperability** of implementations from different vendors
  - Create **trust of customers** in products and services
  - Create **larger markets** than proprietary systems

- V2X standardization is addressed by several standardization development organizations (SDOs)
  - Europe: **ETSI** (European Telecommunications Standards Institute)
  - Europe: **C2C-CC** (Car-to-Car Communication Consortium)
  - US: **IEEE** (Institute of Electrical and Electronics Engineers)
  - US: **SAE** (Society of Automotive Engineers)
  - Japan: **ARIB** (Association of Radio Industries and Businesses)

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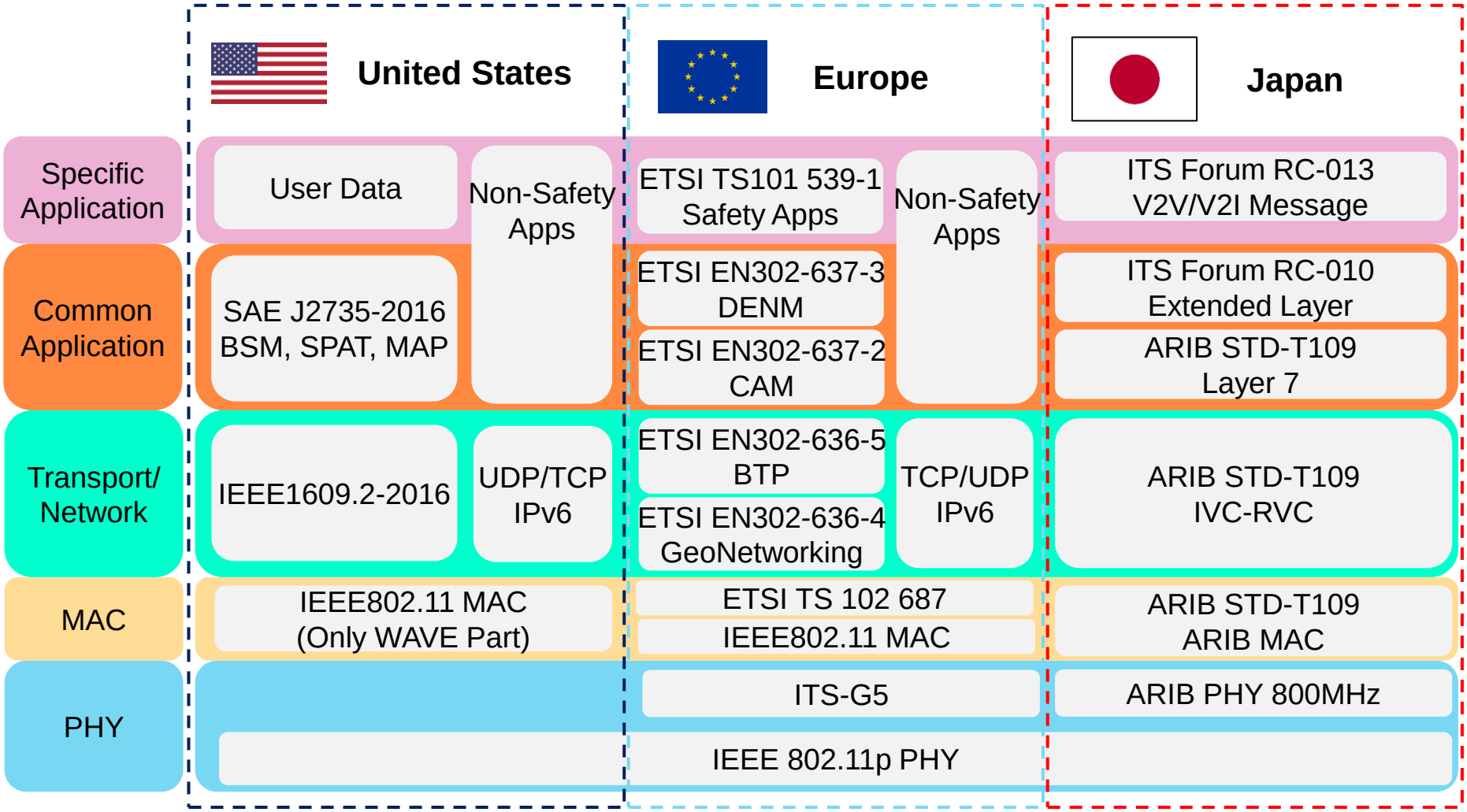
V2X Protocol Stack – Regional Standards



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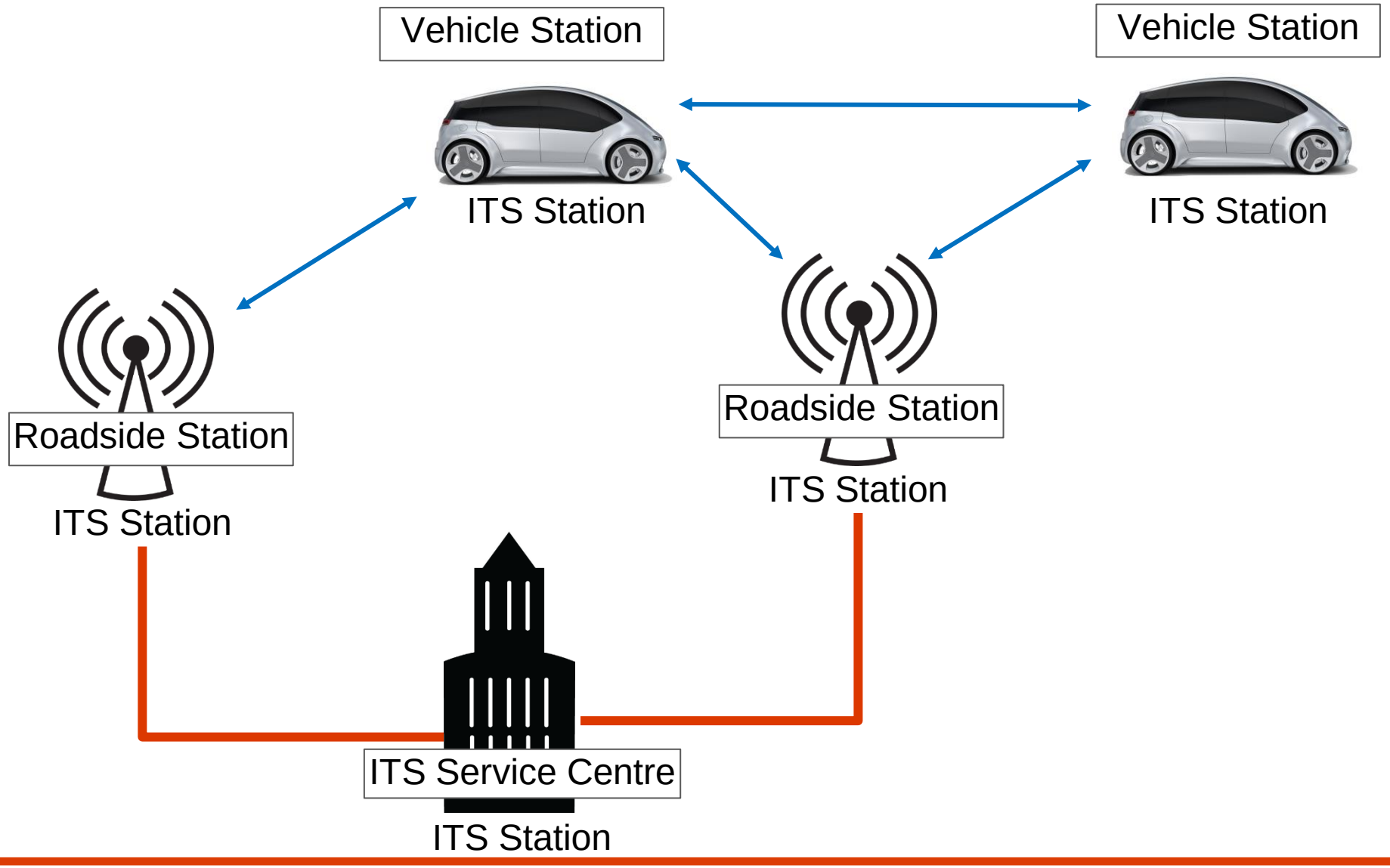
ITS Architecture



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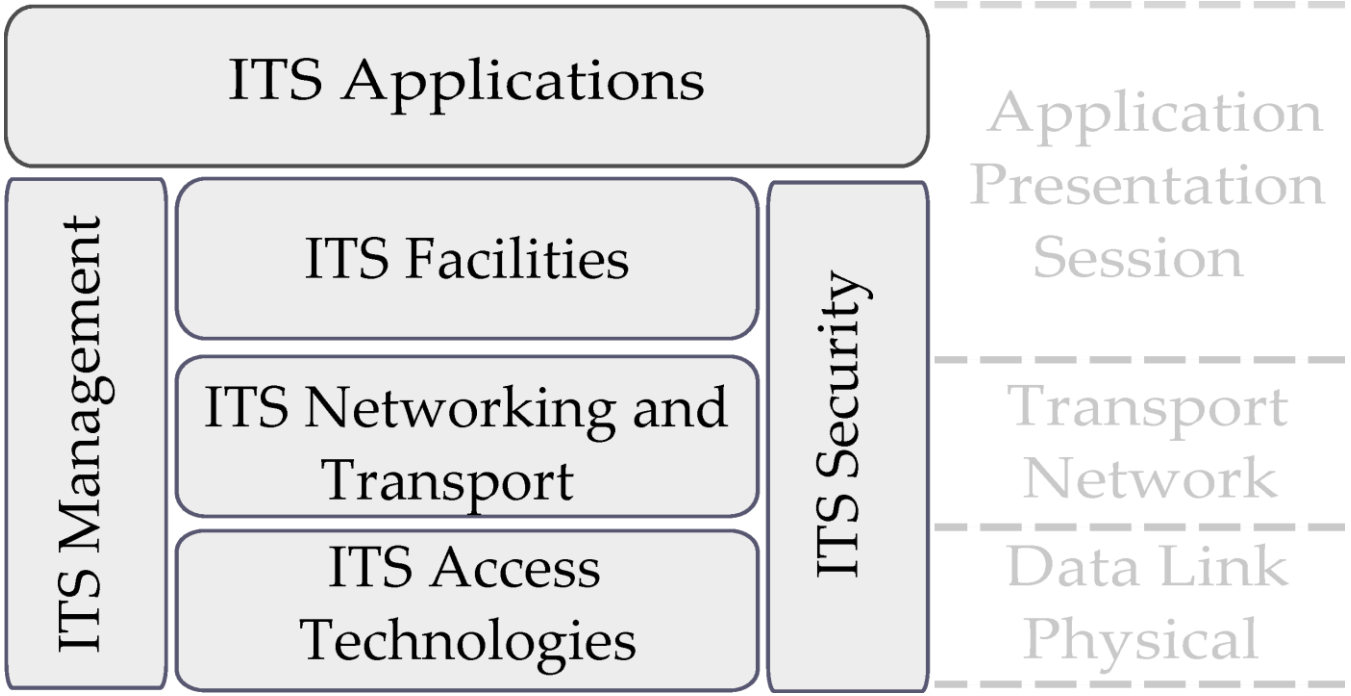
ITS Station Reference Architecture (1/2)

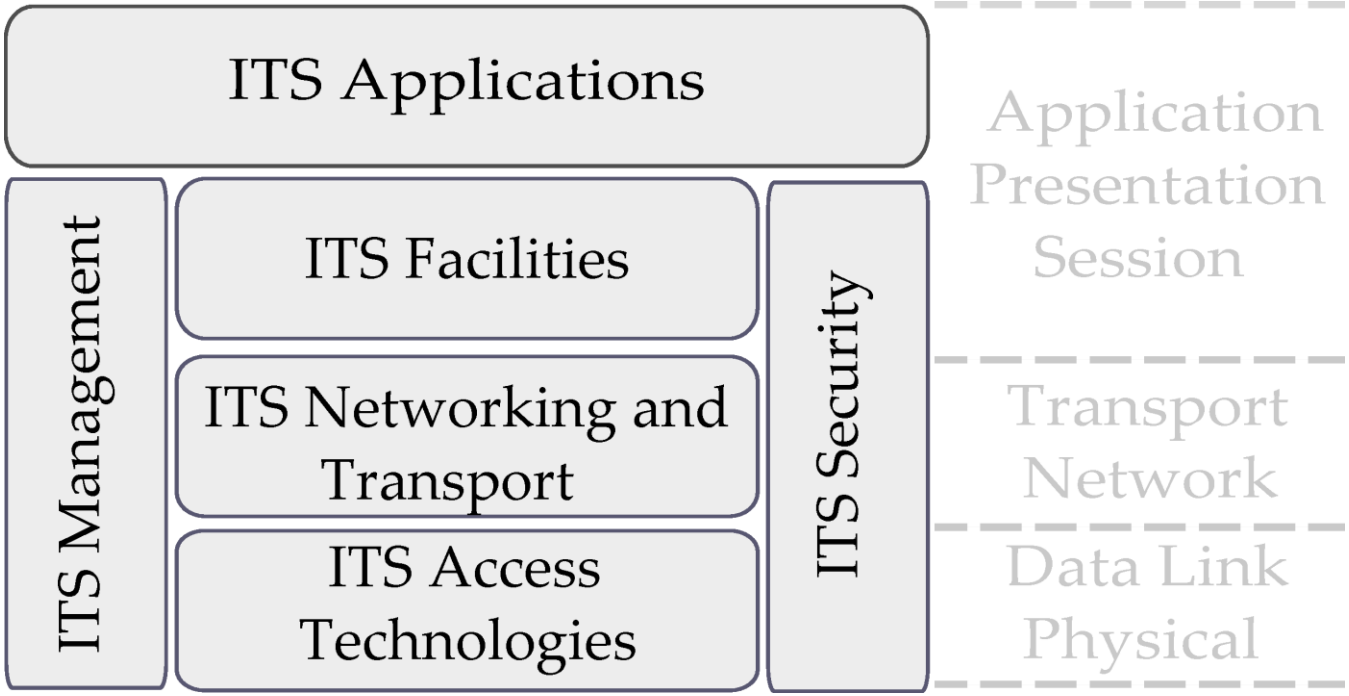
- Application and facilities blocks correspond to OSI layers 7 through 5
- Transport and networking blocks correspond to OSI layers 4 and 3
- Data link and physical layers correspond to OSI layers 2 and 1



Lecture 1

ITS Station Reference Architecture (2/2)

- **Management entity** is responsible for the configuration of an ITS station as well as the cross layer information exchange among different layers and tasks
- **Security entity** is responsible for security and privacy services



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ITS Application Layer

- **Road traffic safety**
  - Improvement of road safety in critical situations
- **Traffic efficiency**
  - Improvement of the traffic flow by exchanging traffic information between traffic management central and drivers on the road network
- **Other applications**
  - Covers all type of application which do not belong to the safety or efficiency
  - Services related to infotainment, comfort and vehicle life cycle management
  - Media downloading, automatic access control/parking access

Lecture 1

ITS Application Layer – Some Safety Applications

- **Longitudinal** collision refers to the collision between vehicles at any part of the **front** or **rear** side of the vehicle
- **Lateral** collision belongs to collision vehicles at any part of the vehicle **side**

Collision Type	Application	Description
Longitudinal	Forward Collision Warning	Avoid or mitigate a risk of forward or rear-end collision in the same lane
	Emergency Electronic Brake Lights	Inform a severe braking to local followers on the same lane
	Stationary Vehicle Warning	Alert approaching vehicles of the risk of collision with vehicles dangerously immobilized on the road
Lateral	Overtaking Vehicle Warning	Inform overtaking manoeuvre to concerned vehicle to secure the overtaking action
	Lane Change Assistance	Inform a lane change intention to vehicle on neighboring lanes
	Cooperation Merging Assistance	Negotiate the merging process together with involved vehicles to avoid collision

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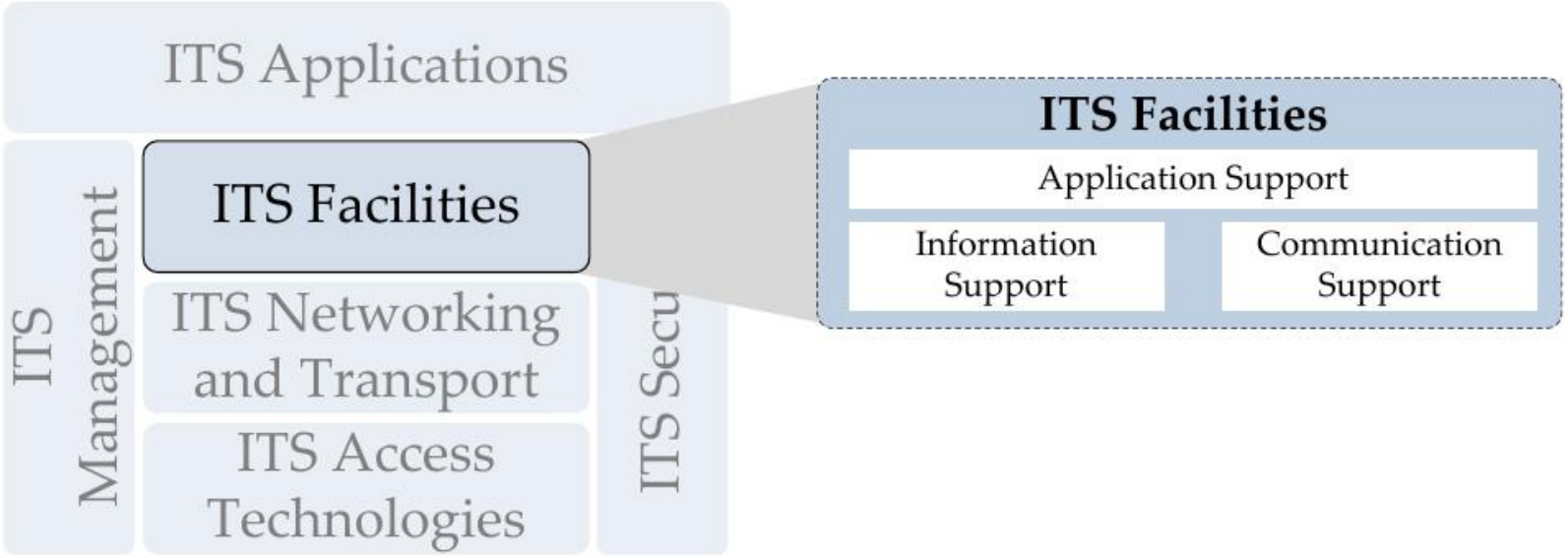
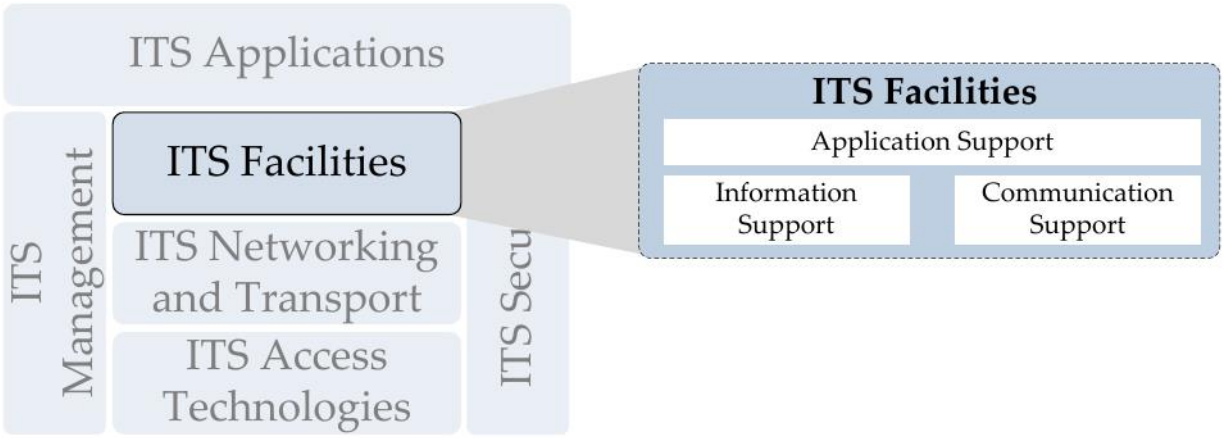
ITS Facilities Layer (1/2)

- Provides a collection of functions to **support ITS application** while satisfying **functional** and **operational** requirements
- Provides **data structure** to store, aggregate, and maintain from **different type and source**



Lecture 1

ITS Facilities Layer (2/2)



- **Application support** supplies the application layer with common services and functionalities
  - Generation, transmission and reception of messages
  - CA (Cooperative Awareness) basic service responsible for the processing of **CAM (Cooperative Awareness Message)**
  - DEN (Decentralized environmental Notification) for **DENM (Decentralized environmental Notification Message)**
- **Information support facility** assures the maintenance of **Local Dynamic Map**
- **Communication support facility** determines the **addressing mode** for messages according to the **dissemination destination**

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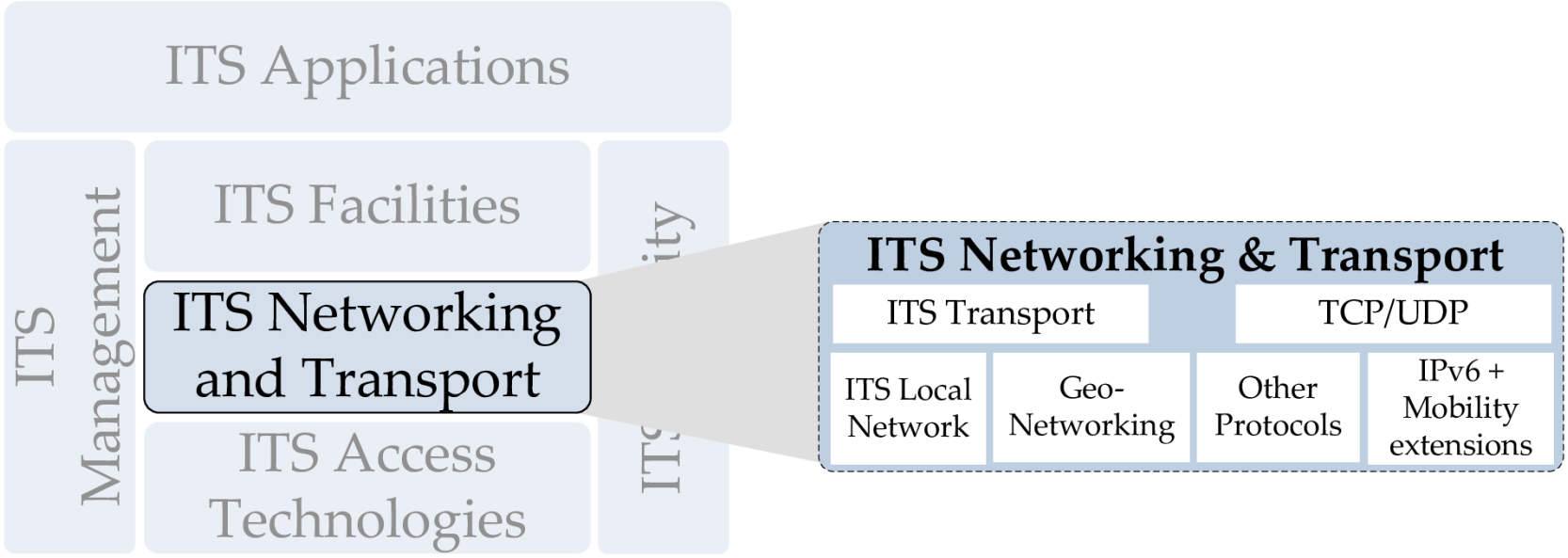
ITS Networking and Transport Layer

- Provides the capability to deliver data **among ITS stations** and from ITS station to other network node
- Provides the **end-to-end delivery of data** by ITS transport protocol
- **Basic Transport Protocol (BTP)** enables a connection-less transport service similar to UDP
- Enables a novel **addressing scheme** based on geographical areas called **GeoNetworking**



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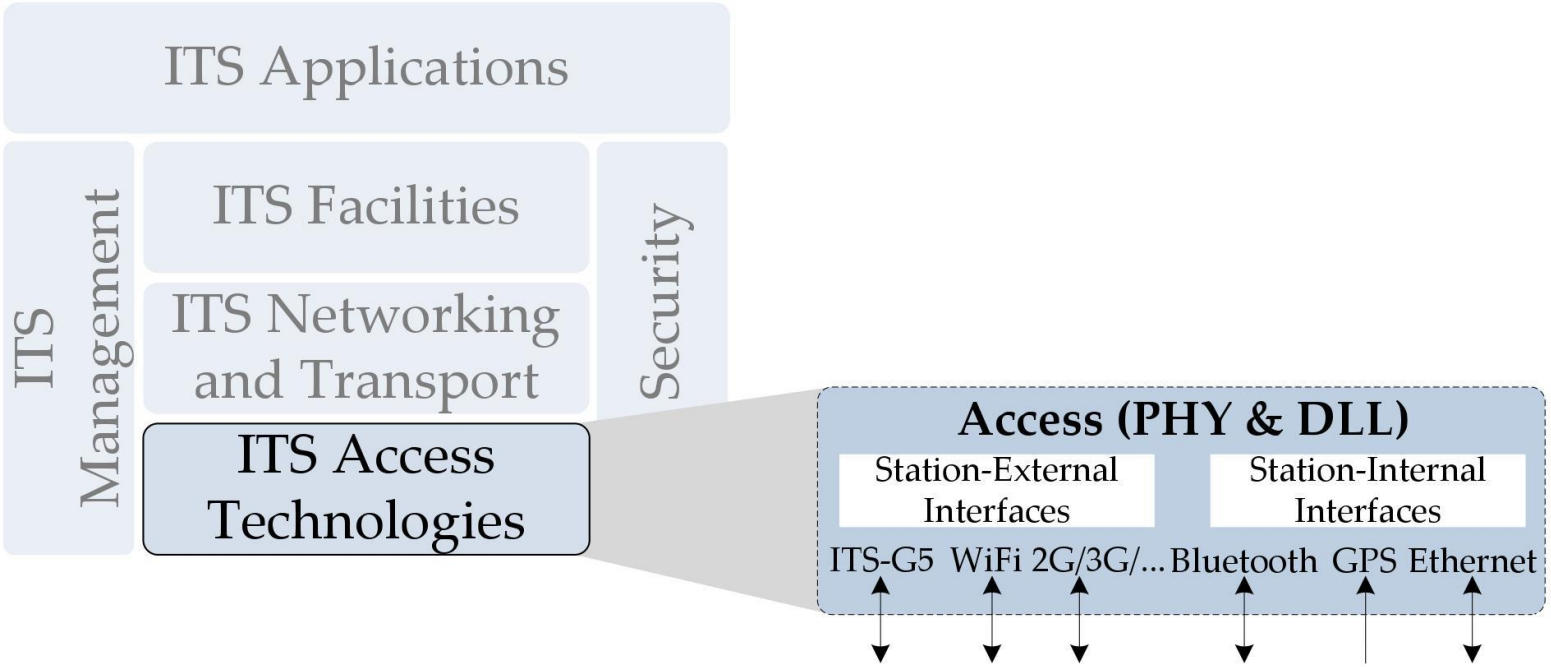
ITS Access Technologies Layer

- Groups the two lowest layers: **Data link** layer and **physical** layer
- Includes various types of media on wireless communication for external communication (ITS-G5), **conventional wireless LAN** technologies and cellular radio technologies



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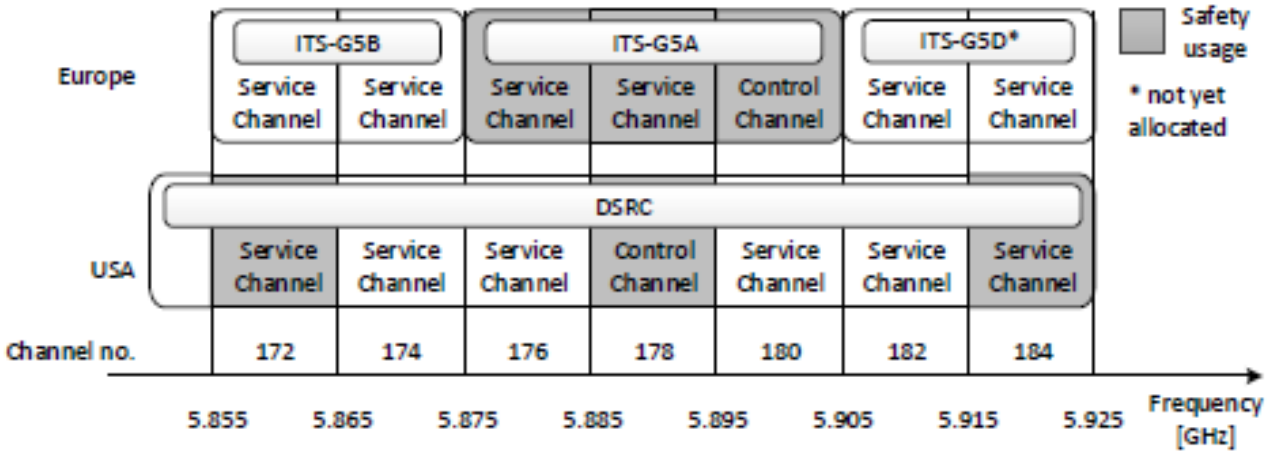
Spectrum and Channel Allocation

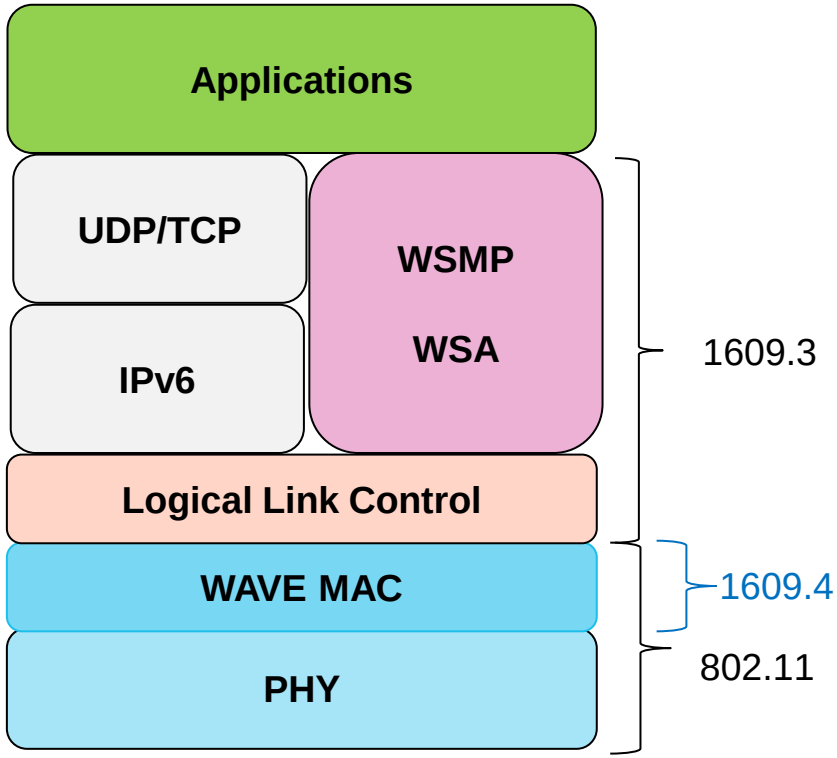
- Spectrum divided into **7 dedicated channels** in the 5.9-GHz band
  - **ITS-G5** for Europe
  - **DSRC (Dedicated Short Range Communication)** for US
- **Control channel** as a common "**meeting point**" which all vehicles are required to **listen** to on a regular basis
- **Service channels** are reserved for **safety** or **non-safety** usage



Lecture 1

IEEE 1609: WAVE - ITS stack for the US (1/2)

- **WAVE: Wireless Access in Vehicular Environments**
  - Designed with the assumption that vehicles might be equipped with just a single radio
  - But should be able to communicate on all channels
- Functionality on the physical layer enabling the **switching** between channels during a defined time intervals

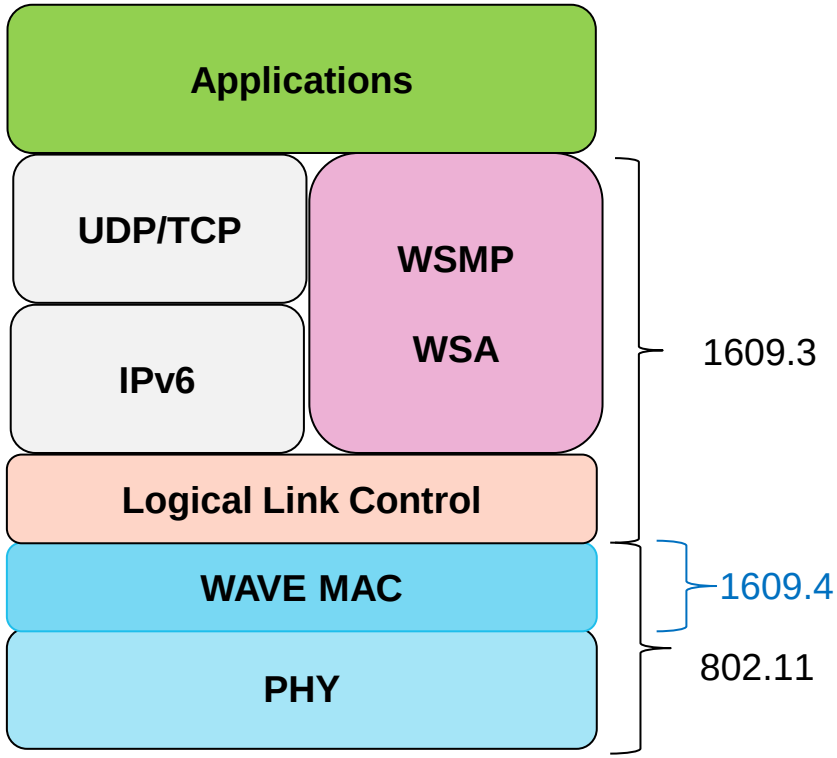


- **1609.4** includes the **upper half** of the WAVE MAC
  - An extension to the MAC sublayer allowing for **multi-channel communications**
- **1609.3** includes the **Logical Link Layer (LLC)**, **WAVE Short**, IPv6, and **UDP/TCP** protocols

Lecture 1

IEEE 1609: WAVE - ITS stack for the US (2/2)

- The **1609.3** standard specifies the **network** and **transport** layer services
  - **WAVE Service Advertisements (WSA)**
    - Used to announce the availability of a service
    - Dissemination of network parameters
    - **Transmissions** only on **control channel**
  - **WAVE Short Message Protocol (WSMP)**
    - **Networking** protocol specifically designed for V2X communications
    - **Transmissions** either on **control channel** or **service channel**



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Course Overview (1/2)

Lecture	Title	Topics	Date
Lecture 1	Introduction	ITS/C-ITS, V2X protocol stacks, ITS station reference architecture	05.10
Lecture 2	Facilities Layer – Message type, format and structure	Road safety and traffic efficiency applications, derivation of application requirements, overview on message types	12.10
Lecture 3	Geographic routing and forwarding	Geographic routing, forwarding algorithms, location service, duplicate packet detection	19.10
Lecture 4	Medium access protocols	Access mechanisms, CSMA/TDMA, semi-persistent scheduling	26.10
Lecture 5	Physical layer and channel modeling	802.11p, Signal propagation characteristics, V2X channel models	02.11

Lecture 1

Course Overview (2/2)

Lecture	Title	Topics	Date
Lecture 6	Security and privacy	Security objectives, trust and privacy management	09.11
Lecture 7	Congestion control algorithms	Channel load, packet collision types, adaptive beaconing, decentralized congestion control, LIMERIC	16.11
Lecture 8	Cellular-based V2X communication	Cellular network, transmission modes, 5G for V2X	23.11
Lecture 9	5G for V2X communication	Overview on 5G and challenges	30.11
Lecture 10	Performance evaluation: Methods and measurement based analysis	Evaluation methodologies, field testing, impact of vegetation and interference	07.12
Lecture 11	Performance evaluation: Simulative analysis	Vehicular mobility, network simulation, road traffic simulation, bidirectional vehicular simulation, scenarios Modeling	14.12

Lecture 1

Literature

- IEEE 802.11p-2010 - IEEE Standard for Information technology - Local and metropolitan area networks - Specific requirements
- SAE J2735, 2020 Edition, July 2020 - (R) V2X Communications Message Set Dictionary
- 1609.2-2016 - IEEE Standard for Wireless Access in Vehicular Environments--Security Services for Applications and Management Messages
- ETSI EN 302 665 V1.1.1: Intelligent Transport Systems (ITS); Communications Architecture
- "700 MHz Band Intelligent Transport Systems" in English ARIB STD T109-v1.2, ARIB, Dec. 2013
- Tessa Tielert: Rate-Adaptation Based Congestion Control for Vehicle Safety Communications. Karlsruhe Institute of Technology, 2014