Mobility – Vital to Modern Societies

- Reflecting economic concerns of industry and trade
  - Transport providing more than 18 million jobs in EU
  - Automotive industry caring for further 14 million jobs
  - Transport holding 13% share of EU GDP
- Facilitating cultural and sporting events
- Satisfying individual needs

⇒ Need for fast, reliable, safe and secure transport
Mobility – Adverse Effects

- 7,500 kilometers of road traffic jam
- 16,000 kilometers of railway bottlenecks
- 40,000 fatalities in road traffic accidents
- 1,000,000 flights delayed in air traffic
- 200,000,000 annoyed by transport noise
- 30% of total energy consumption

⇒ Increasing with growing transport demand
Outline

- Intelligent Transportation Systems
  - Transportation: Today – Tomorrow
  - Applications

- ICT for Transportation
Transportation

Movement of people and goods from one place to another

- Modes of transport:
  - Pedestrian
  - Air transport
  - Water transport
  - Rail transport
  - Road transport

Transport Growth in EU (1995-2006)

Source: European Commission

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Transportation
Nowadays

- 1.4 M road accidents with injured (2005) in EU with:
  - 2 M persons injured (2005)
  - 41.600 fatalities in EU (2005)
  - Costs of 50 billion EUR every year (0.5% of EU GDP)
- 7500 km traffic congestion on EU main roads every day
- Costs of 200 billion EUR every year (2% of EU GDP)
Transportation
Tomorrow = Intelligent Transportation

- Platooning
- Adaptive Gantry Signs & In-vehicle signage
- Assisted Driving
- Intelligent Portable Infrastructure
- Autonomous Driving
- Intermodal transportation

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Intelligent Transportation
Evolution

Intelligent Vehicles

Intra-vehicle networking required

Multi-modality
(eg. Road, Rail, Air)

Intelligent Infrastructure

Infrastructure networking required

Infrastructure sensors: Induction Loops, Cameras, etc.
Infrastructure actuators: Variable message signs, Traffic lights, etc.
Intra-vehicle sensors: Radar, Yaw rate, steering angle, etc.
In-vehicle actuators: Human Machine Interfaces, brake force, etc.

Intra-vehicle networking
Inter-vehicle networking
Vehicle-Infrastructure networking
Infrastructure networking

Intelligent Transportation

Inter-modality
Transportation of people and goods with the optimal mode of transport

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Intelligent Transportation Systems

ITS

- ITS improves transportation safety and mobility and enhances productivity through the use of advanced information and communications technologies. [1]
- ITS is the integration of information and communications technology with transport infrastructure, vehicles and users [2]

Examples:
- Advanced Driver Assistance Systems
- Networked Traffic Infrastructure
- Electronic Toll Collection
- Electronic Freight Management
- eCall
- Cooperative Systems

[1] U.S. Department of Transportation

M. Röckl and T. Strang, 2009
Intelligent Transportation Systems
Example: Advanced Driver Assistance Systems (ADAS)

ADAS are systems that support the driver in her/his task of driving a vehicle in order to increase safety, efficiency and comfort.

Detection of situational parameters by sensors and, if necessary, performance of appropriate measures by actuators:

- **Sensors**: Devices that measure a physical quantity and convert it to a readable signal (e.g. odometer, thermometer, yaw rate sensor)
- **Actuators**: Devices that transform a signal into an action in order to perform a certain effect (e.g. brake, steering column, HMI)

Applications:
- Electronic Stability Control (ESC)
- Adaptive Cruise Control (ACC)
- Lane Departure Warning (LDW)
Intelligent Transportation Systems
Example: Advanced Driver Assistance Systems (cont’d)

Electronic Stability Control

Combined active and passive safety

Adaptive Cruise Control

Source: http://www.youtube.com/watch?v=NI2jeeMExY4
Source: http://www.youtube.com/watch?v=ywQBX6efDiM
Source: Bosch CAPS
Driver Assistance Systems
Preventive vs. Active vs. Passive safety

Preventive and Active Safety
- Information: Foresighted driving
- Support: Warning & assistance systems
- Intervention: Active vehicle control

Passive Safety
- Crash probability
- Safety systems
- Rescue systems & services

Applications
- Traffic information
- Hazard warning
- Stop sign violation
- Road conditions
- Lane merging
- Emergency braking
- Adaptive cruise control
- Traffic efficiency
- Emergency vehicle clearing
- Airbags
- Materials (energy absorption)
- eCall

Capability
- Car to Car Communication
- Cellular Communication

(adapted from: Car-to-Car Communication Consortium)

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Intelligent Transportation Systems
Example: Networked Traffic Infrastructure

- Adaptive Traffic Light Systems:
  - “Green light phase” adaptation based on induction loops
  - Alignment of subsequent traffic lights

- Variable Message Signs (VMS):
  Centralized/Decentralized controlled adaptive display of:
  - speed limit,
  - overtake allowance,
  - route (e.g. lane blocking, bypass),
  - traffic flow information,
  - hazardous situations,
  - amber alert,
  - wrong-way driver, etc.
Intelligent Transportation Systems

Example: Electronic Toll Collection

- **DSRC-based:**
  - DSRC: Dedicated Short Range Communication (5.8 GHz or infrared)
  - Toll collection at gantries
  - Used for truck tolling in Austria

- **GNSS/GSM-based:**
  - GNSS: Global Navigation Satellite System (Global Positioning System GPS, Galileo)
  - Position of the vehicle is determined by GNSS (optional infrared), aggregated and sent to tolling center via GSM/GPRS
  - Up-to-date consistent road map required
  - Enforcement via DSRC
  - Used for truck tolling in Germany

- Advantages of both systems:
  - No waiting delays at toll gates (free flow tolling)
  - Less infrastructure requirements
Intelligent Transportation Systems
Example: Electronic Freight Management

- Continuous localization of vehicles and goods
- Application for shipping & taxi companies
- Positioning via GNSS
- Communication via GSM/UMTS
- Evaluation of decentralized gathered Floating Car Data (FCD) for:
  - Route optimization
  - Driver/fuel management
  - Vehicle diagnostics
  - Hazardous goods monitoring
- eXtended Floating Car Data (XFCD) including speed, travel time, fuel consumption, etc.

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Intelligent Transportation Systems
Example: eCall

- Automatic (based on in-vehicle sensors, e.g. airbag/crash sensor) or manual notification of Public Safety Answering Point (PSAP) via GSM/UMTS
- Emergency message includes time, GPS position, driving direction, vehicle identification number (VIN), accident severity and type, etc.
- eCall will probably be enforced by European Commission in the next years
Intelligent Transportation Systems
Example: Cooperative Systems

- **Safety:**
  - Traffic Jam Ahead Warning
  - Intersection Assistance
  - Black Spot Warning
  - Curve Speed Warning

- **Efficiency:**
  - Decentralized Floating Car Data
  - Optimal Speed Advisory

- **Infotainment/Comfort:**
  - Point-of-Interest Notification
  - Free-flow tolling
Intelligent Transportation Systems
Objectives

- **Safety:**
  - Mitigation of accident severity (passive safety)
  - Prevention of accidents (active safety)
  - Avoidance of hazardous situations (preventive safety)

- **Efficiency:**
  - Reduction of travel times
  - Reduction of fuel/energy consumption
  - Reduction of CO\textsubscript{2} emission
  - Reduction of noise emission

- **Infotainment/Comfort:**
  - Increasing comfort of driving
  - Additional information services

- **Monetary:**
  - Cost reduction (e.g. less sensors, less road infrastructure maintenance)
  - “Competitive edge”: Prevailing over competitors
Intra-Vehicle Communications

(short wrap-up)

for details see

http://www.sti-innsbruck.at/teaching/courses/ws200809/details/?title=vehicle-networks-(vo)
Intra-vehicle Communications
Automotive Evolution

- **In the past**: VW Käfer (1950)
  - 50 m copper wires
  - 0 Electronic Control Units (ECUs)

- **Today**: VW Phaeton (2004)
  - 3860 m copper wires
  - 45 networked Electronic Control Units (ECUs) / 61 ECUs total
  - 11,136 electrical parts in total
  - 3 different bus networks
Intra-vehicle Communications
Vehicle Electronics

Total complexity of vehicle electronics:
- Customer demand driven

Complexity of SW:
- More integration takes place in SW
- How do we manage safety, cost, ...?

Complexity of HW (number of ECUs):
- No space in vehicle for more ECUs
- Fewer, larger ECUs more cost effective (Moore’s law)

Source: Volvo 2002

Cost of Electronic Embedded systems = \[
\begin{align*}
&\frac{1\%}{1980} \\
&\frac{20\%}{2005} \\
&\frac{40\%}{2015}
\end{align*}
\]

Cost of a car

Intra-vehicle Communications

Sensors and actuators

- Atmospheric pressure sensor (transmission control, motronic)
- Manifold absolute pressure sensor (Electronic diesel control, motronic)
- Knock sensor (Motronic)
- Mass air flow sensor (Motronic – air intake)
- Angular position sensor (Motronic – cam and crankshaft position)
- Piezo actuator (Fuel injection)
- Rotational speed sensor (Electronic transmission control, motronic)
- Oil quality sensor (Transmission and engine)
- Boot sensor (Motronic – exhaust)
- High pressure sensor (Fuel injection system, common rail)
- Oxygen sensor (Motronic – lambda)
- Pedal position sensor (Electronic accelerator, electro-hydraulic brake)
- Radar 77 GHz (lateral control, obstacle detection)
- Infrared (Night vision system)
- Radar 24 GHz (Pre-crash, parking aid)
- Steering wheel angle sensor (Vehicle dynamics)
- Rotational speed (Antilock braking system)
- Pressure sensor (Crash sensor)
- Yaw rate (Electronic stability program)
- Angular rate sensor (Roll over)

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Intra-vehicle Communications
Degree of networking

- Electronic fuel injection
- Cruise Control
- Central locking system
- ...
Intra-vehicle Communications

Network Evolution

- **Standalone ECUs:**
  - No networking between ECUs required

- **Directly connected ECUs (partially meshed):**
  - ECUs that require other ECUs are directly connected

- **Star topology with central gateway:**
  - Central gateway controls message flow

- **Partitioned bus topology with interconnecting gateway:**
  - Shorter wires
  - Gateway connects different bus systems
Intra-vehicle Communications
In-vehicle bus systems

- Special-purpose networks interconnected by one or more gateways
Intra-vehicle Communications
Partitioned bus systems

Fail-safe:
In case of failure the system automatically switches to a safe state (often with reduced functionality)

Fail-operational:
In case of failure the system remains in an operational state (e.g. mechanical backup system)
Intra-vehicle Communications
In-vehicle bus systems

- Engine-CAN (500 kps)
- 2 private CAN (500 kps)
- Instrument-CAN (500 kps)
- Infotainment-CAN (100 kps)
- Convenience-CAN (100 kps)
- 1 Diagnostics-CAN (500 kps)
- 2 LIN-Networks
- K-Wire
Intra-vehicle Communications
Network Categories

- **Class A:**
  - Data rate: < 10kbit/s
  - Usage: Low-end general-purpose event-driven communication (e.g. sub-busses)
  - Examples: LIN, TTP/A, J-1850, I²C

- **Class B:**
  - Data rate: 10 – 125 kbit/s
  - Usage: non-critical communication (e.g. instruments)
  - Examples: TTP/B, Byteflight, Low-speed CAN

- **Class C:**
  - Data rate: 125 kbit/s – 1 Mbit/s
  - Usage: High-end, fast, real-time communication (e.g. engine timing, fuel delivery)
  - Examples: TTP/C, High-speed CAN, MOST, D2B

- **Class D:**
  - Data rate: > 1 Mbit/s
  - Usage: Very high speed communication (e.g. multimedia)
  - Examples: MOST, IDB-1394

---

Source: SAE
# Intra-vehicle Communications

## Network types

<table>
<thead>
<tr>
<th></th>
<th>LIN</th>
<th>CAN</th>
<th>FlexRay</th>
<th>MOST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. data rate</td>
<td>20 kbit/s</td>
<td>1 Mbit/s</td>
<td>2 x 10 Mbit/s</td>
<td>25 Mbit/s</td>
</tr>
<tr>
<td>Medium access</td>
<td>Time triggered master-slave</td>
<td>CSMA/CA</td>
<td>TDMA</td>
<td>TDMA and CSMA</td>
</tr>
<tr>
<td>Cables</td>
<td>1 Cu</td>
<td>2 Cu</td>
<td>2 Cu per channel</td>
<td>1 optical</td>
</tr>
<tr>
<td>Max # of nodes</td>
<td>typ. &lt; 16</td>
<td>typ. 40</td>
<td>max. 64 per segment</td>
<td>max. 64</td>
</tr>
<tr>
<td>Costs per node $</td>
<td>0.5</td>
<td>1</td>
<td>2.5</td>
<td>5</td>
</tr>
</tbody>
</table>

Based on: Luckenbach (Fraunhofer FOKUS)  2007

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Inter-Vehicle Communications

(short outline)
Inter-vehicle Communications
Communication between ...

- Vehicles
  - Cars
  - Trucks
  - Buses
  - Motorcycles
  - Optional:
    - trains, trams, pedestrians, etc.

- Infrastructure and vehicle:
  - Road-side Units (RSUs): variable message signs (VMS), traffic light signals (TLS), portable infrastructure (intelligent cones), ...
  - Broadcast systems: Digital Video/Audio Broadcast (DVB/DAB), RDS-TMC, TPEG, ...
  - Cellular network infrastructure: GSM/UMTS, WiMAX, ...
Inter-vehicle Communications
Decentralized Local Danger Warning

- Distribution of locally detected danger warnings (black ice, aquaplaning, obstacles, etc.) to vehicles and roadside units in the vicinity
- Vehicles as moving sensor platforms
- Enlargement of sensing range extending line-of-sight horizon of local sensors:
  - Short range: Ultrasound
  - Medium range: Radar, Lidar, Camera
  - “Long” range: V2V communications
- Impact through improved safety: extended foresight enables timely reaction

Extended Environmental Information
Local Danger Warning via Vehicle to Vehicle and Vehicle to Infrastructure Communication

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Inter-vehicle Communications
Cooperative Adaptive Cruise Control

- Automatic longitudinal gap keeping assistant based on Vehicle-2-Vehicle Communication
- Exchange of speed, heading, position, brake/acceleration action, vehicle type, etc.
- Impact through:
  - Improved safety: timely & reliable reaction
  - Improved traffic efficiency: closer safe gaps
  - Improved comfort: less unnecessary deceleration
  - Improved energy and material usage: e.g. use of engine brake or recuperator instead of service brake
Inter-vehicle Communications
Traffic Efficiency

Optimization of global journey times, fuel consumption and pollution by V2X communications

EU project iTETRIS
http://www.ict-itetris.eu

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# Wireless communication technologies

<table>
<thead>
<tr>
<th>Coverage</th>
<th>Technology</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide Area</td>
<td>Satellite Data/Voice Communication</td>
<td>Global Coverage</td>
<td>Very expensive, Low data rate</td>
</tr>
<tr>
<td></td>
<td>AM/FM Radio</td>
<td>Regional Coverage</td>
<td>Only Broadcast, Low data rate, No uplink</td>
</tr>
<tr>
<td></td>
<td>Digital Satellite Radio</td>
<td>Continent Coverage</td>
<td>Only Broadcast, No Uplink</td>
</tr>
<tr>
<td></td>
<td>Digital Audio Broadcast</td>
<td>Regional Coverage High Data Rate</td>
<td>Only Broadcast, Not widely deployed yet, No uplink</td>
</tr>
<tr>
<td></td>
<td>Cellular</td>
<td>Sufficient Population Coverage, Reasonable data rate (2.5G+)</td>
<td>Relative expensive for data, Low data rate (1 and 2 G)</td>
</tr>
<tr>
<td>Local Area (Short to Medium Range)</td>
<td>Wireless LAN (WLAN)</td>
<td>No license cost, Inexpensive, High bandwidth, Strong industry support</td>
<td>Hotspot coverage</td>
</tr>
<tr>
<td></td>
<td>Infrared</td>
<td>No license, inexpensive, already established</td>
<td>Limited range, limited bandwidth, only line of sight</td>
</tr>
<tr>
<td>Personal Area (Immediate Proximity)</td>
<td>Infrared</td>
<td>No license, inexpensive</td>
<td>Limited range, limited bandwidth, only line of sight</td>
</tr>
<tr>
<td></td>
<td>Bluetooth</td>
<td>No license, Inexpensive</td>
<td>Limited range, limited bandwidth</td>
</tr>
<tr>
<td></td>
<td>UWB</td>
<td>No license, Very high bandwidth</td>
<td>No standards yet</td>
</tr>
</tbody>
</table>
The BIG picture