Smart Cities Workshop
14.04.2015

Mobility in Smart Cities

Overview: Top-down approach

- Application-pull for “Smart” Mobility
  - Autonomous driving
  - Demand-driven traffic flow control
  - On-demand transportation
- Technological requirements
  - Data acquisition / Sensors and actuators
  - Vehicle-to-vehicle/infrastructure communication
  - Energy efficient traction
- Demand for semiconductor devices

Overview

- Application-pull for “Smart” Mobility
  - Autonomous driving
  - Demand-driven traffic flow control
  - On-demand transportation
- Technological requirements
  - Data acquisition / Sensors and actuators
  - Vehicle-to-vehicle/infrastructure communication
  - Energy efficient traction
- Demand for semiconductor devices

Application pull for “Smart Mobility”

- Citizen-oriented transportation solutions
  - Autonomous driving
  - Demand-driven traffic flow control
  - On-demand transportation
- Advantages for the City
  - More efficient use of existing infrastructure (i.e. streets)
  - Less delays, less pollution, stress-reduction for drivers
  - Faster traffic flow and shorter time-to-destination

  → Power of IoT in Mobility to sky-rocket Smart Cities
    - Mobility in Smart Cities provides new opportunities

Autonomous driving: Demand-driven traffic flow control

- Today: Traffic governed by decision of drivers
  - Lack of information for anticipatory driving
  - Reckless driving, Driver related delays
    - At green light, roundabouts, etc.
- System requirements for autonomous driving
  - Distance radar, automatic throttle (cruise control)
  - Automatic parking pilot,
  - Traffic sign identification, traffic tracking
  - Position tracking (GPS), …

    → All necessary sensors and actuators demonstrated

Autonomous driving: Demand-driven traffic flow control

- First seeds for autonomous driving sprouting
  - "Autonomous driving lane" on German highway A9
    - Playing grounds for IoT
  - Delphi Automotives' Audi SUV
    - Cross-country trip from SF to NY
    - Autonomous driving is reality

  - However: Highest traffic density in urban areas

Autonomous driving: Demand-driven traffic flow control

- Prevention of unnecessary delays
  - Adaptive traffic lights with flexible phase schedule

Today

- Fixed Phase (no control) – todays “favorite”
  - No sensors required
- Flexible Phases
  - Inductive loops, sensors

Smart City

- On-approach detection
  - V2I communication
- Traffic-light-free intersection
  - V2I and V2V communication
  - Destination information

Traffic lights with bus priority system in Erlangen

Information-assisted driving: Basic traffic flow control

- Prevention of unnecessary delays
  - Green Light Optimal Speed Advisory
    - Notifies driver of speed to catch green light
      - Infrastructure to user via (App), I2V communication

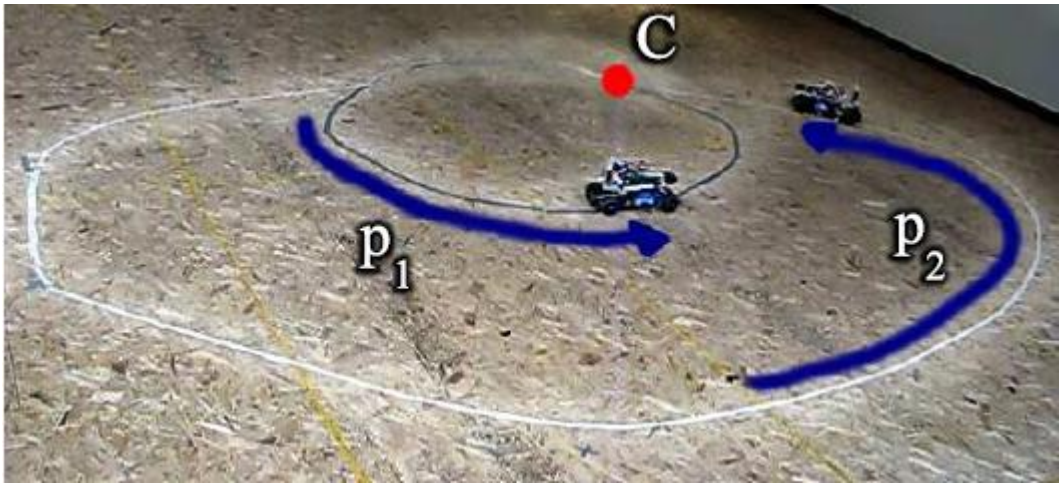
Traffic-app “EnLighten” feeds off real-time traffic data supplied by several US cities

Audi’s “Car-2-x” fleet test

Autonomous driving: Demand-driven traffic flow control

- Prevention of unnecessary delays
  - Traffic-light-free intersection control in roundabouts
    - "Vehicle back-off" for collision prevention

  → Increases vehicle capacity per hour



Desaraju et al., "Partial Order Techniques for Vehicle Collision Avoidance: Application to an Autonomous Roundabout Test-bed", ICRA 2009

Demand-dependent traffic flow control

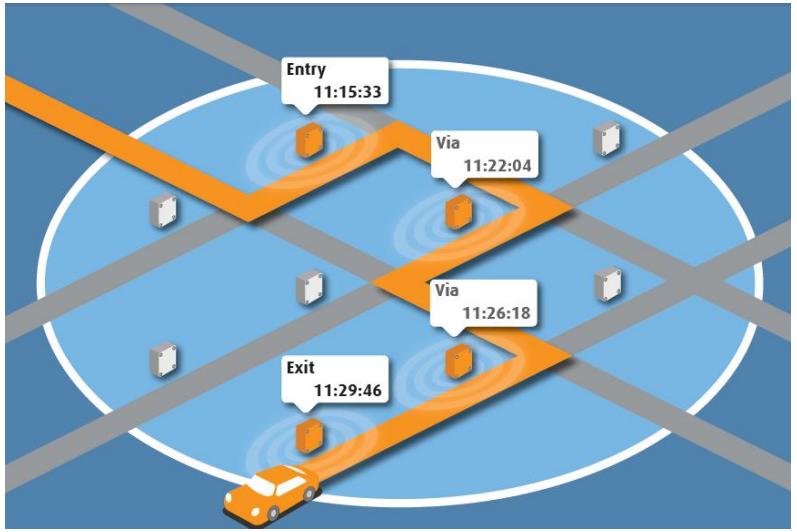
- Utilization of existing infrastructure (roads)
  - Today: Priority lanes (buses, taxis, car pooling)
    - Permanent or (fixed) temporary
    - Occurance-driven – but not demand-driven!

Bus lane in Germany

Static car pooling („diamond“) lane in Canada

Demand-dependent traffic flow control

- Better utilization of existing infrastructure
  - Smart City: Collect/provide data on users' destination
    - Traffic flow becomes predictable
      - → Individual detour planning and re-routing
      - – Synergizes with navigation systems
        - » Already proven with Radio Traffic Messages
    - Requires car-to-cloud (*e*-infrastructure) communication



Origin and destination analysis (e.g. BlipTrack)

Demand driven last mile transportation

- Key acceptance issue for public transportation

Car / Taxi	Bus / Tram / Subway
At door-step	At „vicinity“ of destination
Ride on-demand	Fixed schedule
Priority lanes	Priority lanes + traffic flow mod.
Single user → Expensive	Multiple users → Cost-sharing

  - Smart City: IoT enables demand-driven solutions
    - Customers voluntarily provide destination and schedule requests to local transportation operators

→ Take a bus or a taxi? → P&R and take a “buxi”?

Interaction with other aspects of Smart cities

- EV-based energy storage
  - Utilization of electric vehicle traction batteries
    - Peak-cutting and peak-shifting of power supply
      - See “Smart Energy”
    - Business models for EV owners?
      - EU (H2020) SME calls on business models
      - ICT Strategy: Digital Germany 2015

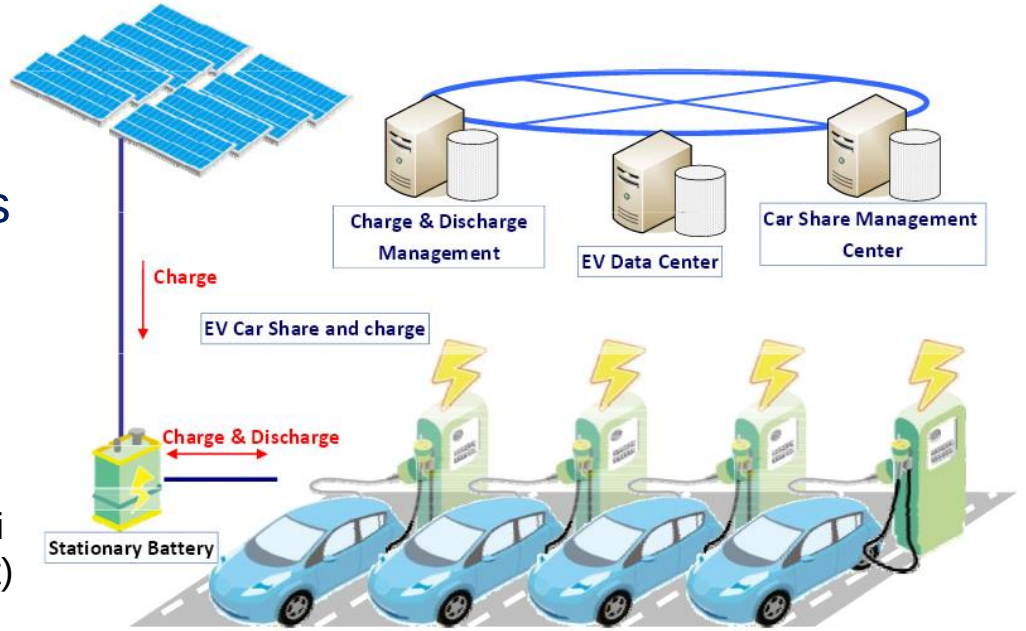


Illustration: Hitachi (YSCP Project)

Interaction with other aspects of Smart cities

- Parking space surveillance
  - Overhead mounted radar sensors
    - Vacant parking lots
    - Parking violations (bus lanes, bicycle lanes etc.)
  - Transmission to data center by GSM/UMTS
    - Data processing using IoT platform
    - Traffic forecasting
  - RFID tag capability
    - Assignment of (special) parking permits to vehicles
  - Pilot phase designated in Berlin, Germany

Photos: Siemens

Overview

- Application-pull for “Smart” Mobility
  - Autonomous driving and demand-driven traffic flow control
  - On-demand transportation
- Technological requirements
  - Data acquisition / Sensors and actuators
  - Vehicle-to-vehicle/infrastructure communication
  - Energy efficient traction
- Demand for semiconductor devices

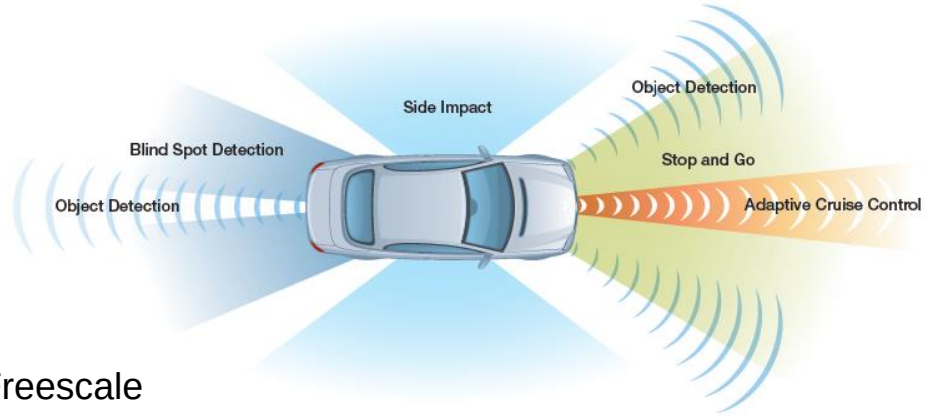
Demanding applications for Mobility

- Information collection (sensing)
  - Fast acquisition rates, low power consumption
    - → Compact, precise, durable
- Information transmission (“Big data”, IoT)
  - High data rates to cope with additional information
    - → Large bandwidth, secure
- Energy “transmission” (converters, inverters)
  - Autarc systems, small form-factors for vehicles
    - → High energy efficiency, small size/weight, reliable

V2V and V2I communication and sensors

- Interaction with environment
  - 77 GHz Radar
  - Sensors
    - CCD-Cameras
    - IR and UV sensor array
  - 5.9 GHz Wireless-LAN
    - e.g. IEEE 802.11p
    - “Cooperative Awareness Messages”

Application	Detection Range	Safety Aspect	Technology
Adaptive Cruise Control	200 meters	Normal driving, accident avoidance	• 77 GHz Radar
Pre-Crash	30 meters	Accident, mitigation of impact	• 77 GHz Radar/24 GHz Radar • 76/81 GHz Radar
Blind Spot Detection	20 meters	Normal driving, accident avoidance	• 77 GHz/24 GHz Radar/ Vision sensor
Lane Departure Warning	60 meters	Normal driving, accident avoidance	• Vision sensor
Stop and Go	30 meters	Normal driving, accident avoidance	• 77 GHz/24 GHz Radar • 76/81 GHz Radar

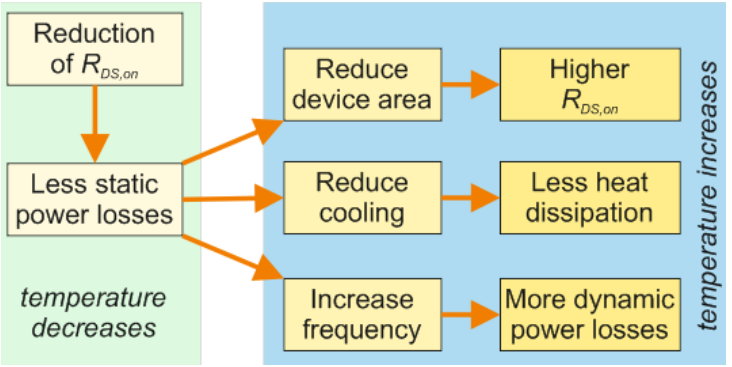


e.g. Freescale

Energy efficient traction

- Traction inverters and bus supply
  - Low volume, weight
  - High efficiency
    - → High switching frequencies required
  - System components
    - Vehicle traction and power supplies
    - Integrated power converters

Single-wheel axle drive with attached double inverter



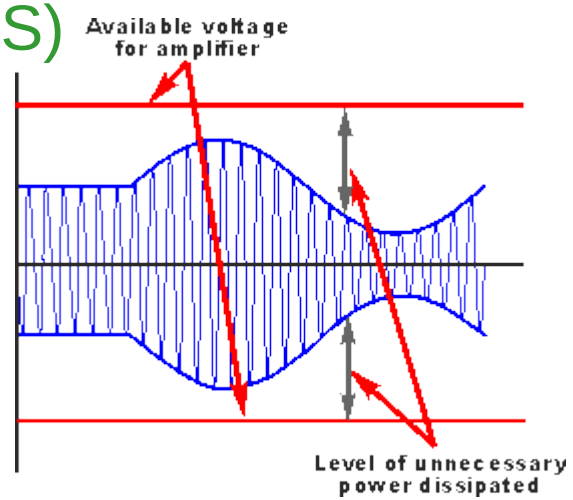
Potential benefits of using SiC / GaN power devices

Overview

- Application-pull for “Smart” Mobility
  - Autonomous driving and demand-driven traffic flow control
  - On-demand transportation
- Technological requirements
  - Data acquisition / Sensors and actuators
  - Vehicle-to-vehicle/infrastructure communication
  - Energy efficient traction
- Demand for semiconductor devices

Technological requirements for Mobility

- RF information transmission
  - Increasing frequencies (higher data throughput)
    - RF power amplifiers (Class-C, Class-S)
      - GaN HEMTs, Si-RF CMOS
    - Envelope tracking
      - Si LDMOS (integrated in front-end)
      - GaN HEMT (integrated in PA/supply)
  - Integrated RF CMOS circuits
    - 90nm CMOS and below
      - → More-Moore integration
    - Hardware encryption

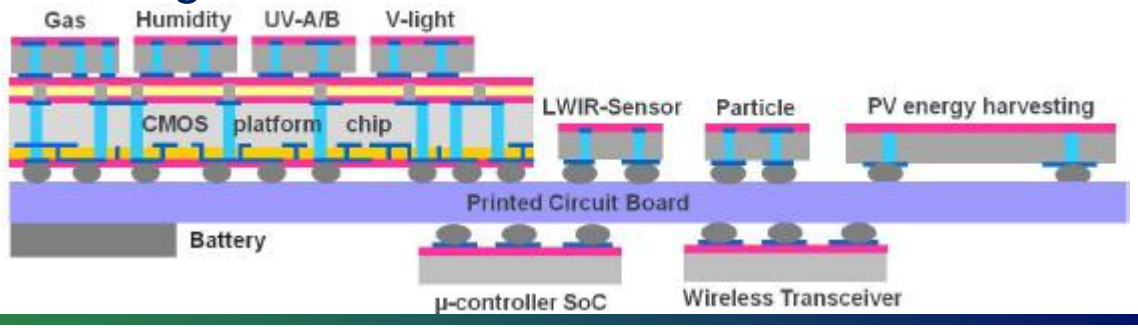


Envelope tracking reduces RF power losses

Data acquisition for Mobility

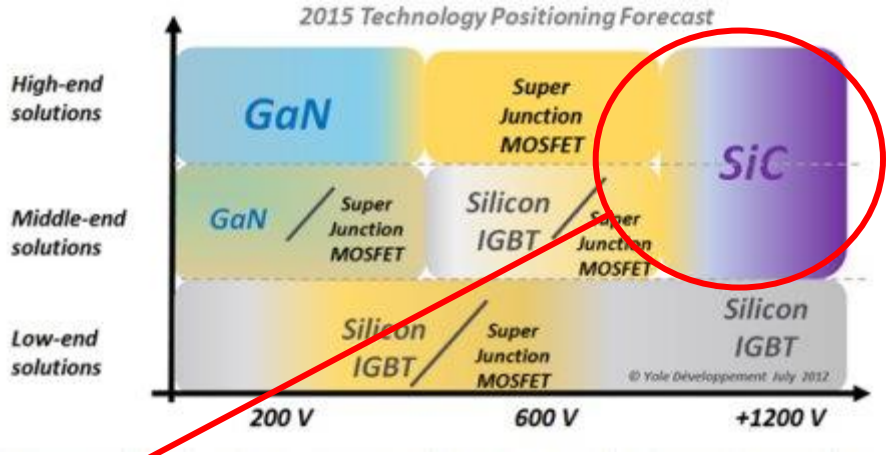
- Information collection
  - Specialized sensors and sensor networks
    - Distance, velocity, acceleration
      - Small form factors
      - Combination with transmission/broadcasting circuits
    - 3D chip stacking
    - Sensor platforms
      - → More-than-Moore integration

EU FP7: MultiSensorPlatform, Foundry service for Outdoor Environmental Monitoring (ams)

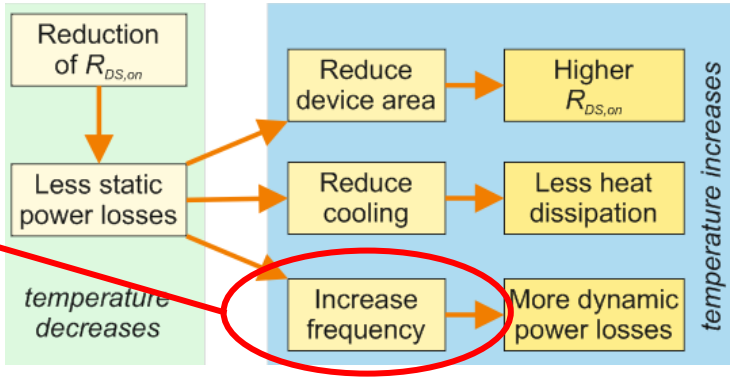


Energy “transmission”

- High power application
  - Low volume, weight
  - High efficiency
    - → High switching frequencies required
      - Vehicle traction and power supplies
        - SiC devices
          - » Bill-of-materials!
        - Modules (Assembly)
          - » Technologies!



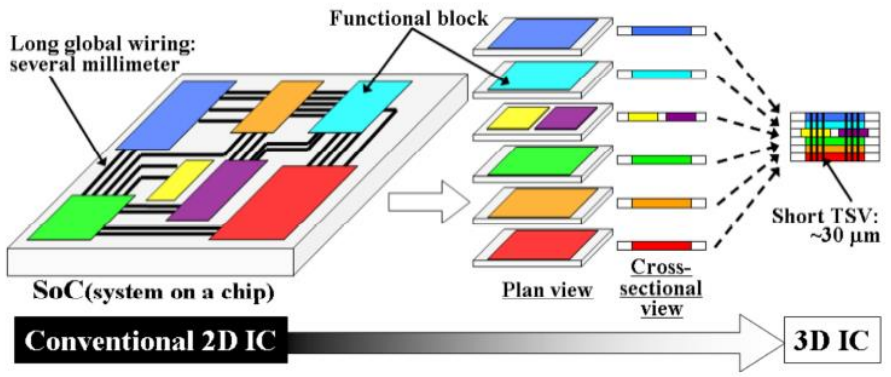
Power semiconductor device materials for future power electronic systems



Potential benefits of using SiC / GaN power devices

Energy “transmission”

- Low power application
  - Low volume, weight
  - High efficiency
    - → High switching frequencies required
    - Integrated power converters
      - Integration density
        - » 3D-stacking
        - » Integrated passives
      - → More-than-Moore integration



EU FP7: ATHENIS_3D
High-voltage automotive technology platform

Conclusion

- Application-pull for Mobility in Smart Cities
  - Traffic prediction and optimization yields benefits
    - Individual traffic: “Fastest way through the city”
    - Public transportation: Efficient last-mile transportation
    - The City: Less traffic, less pollution, more sustainability
  - High technology demands for “best-in-class” solutions
    - Sensor networks with high data transmission
    - Connectivity to Internet-of-things, “Big data” handling
    - Combination with ICT: Safety – Reliability – Robustness

→ Typical Mobility demands: Synergy with Smart Cities