DAI-Labor
TU Berlin

Towards Realizing Autonomous Driving Based on Distributed Decision Making for Complex Urban Environments

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on behalf of Prof. Dr. Dr. h.c. Sahin Albayrak

Digital Mobility – Our vision

Intelligent vehicle is good …

But

Intelligent environment is better …

Digital Mobility – Our vision

DIGINET PS

Make the road talk to vehicles

- Equip the roads with different sensors
- Enable the vehicles to communicate with each other
- Computation resources for decision making

- Vehicles equipped with different sensors
- Decision logics for assistance system
- Communication mechanisms

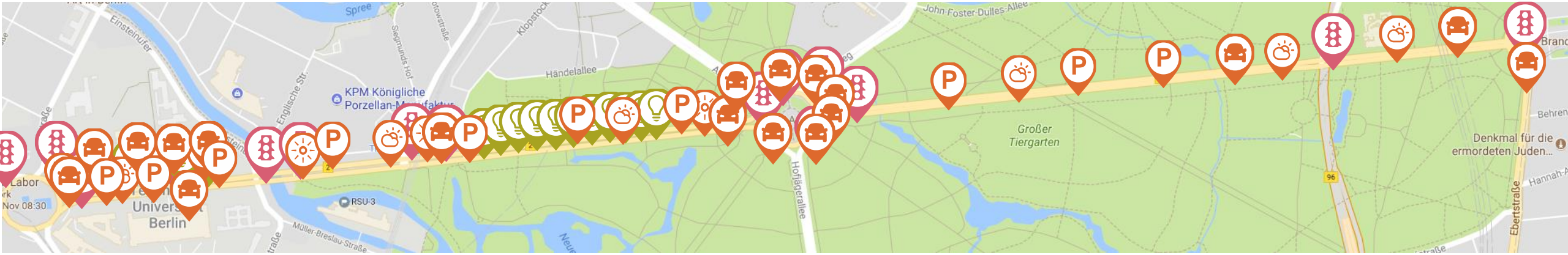
Open & Urban is

DigiNet-PS Aims at Achieving …

- Open & Distributed Intelligent Solutions for Autonomous Driving in Urban Environment

Ernst-Reuter-Platz

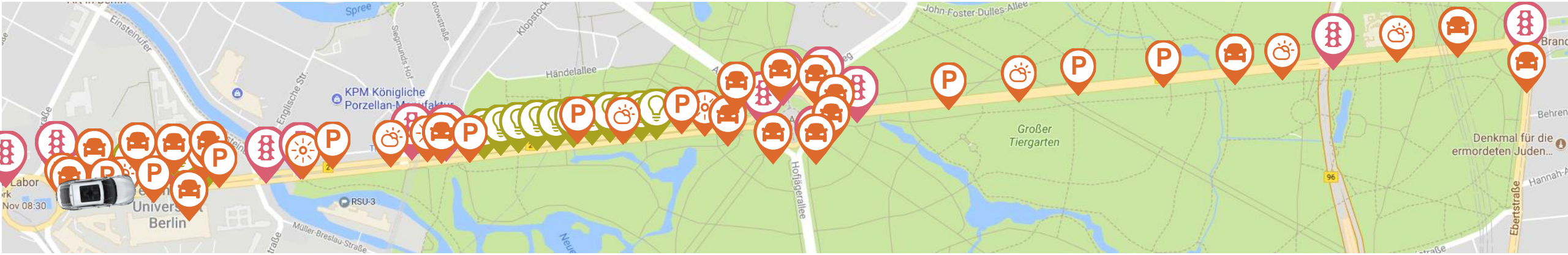
Brandenburger Tor



Digitized Environment

sensors

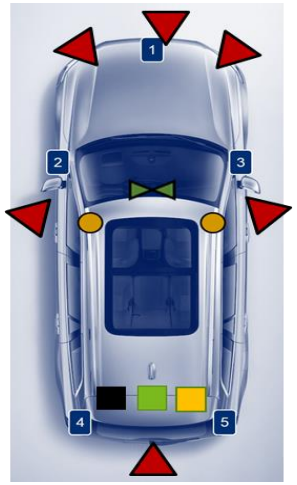
- Open & Distributed Intelligent Solutions for Autonomous Driving in Urban Environment



Digitized Environment

Intelligent Vehicle

sensors



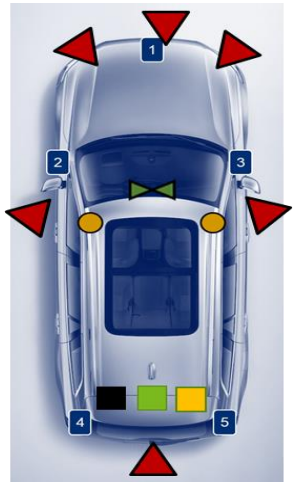
- Stereo Kamera
- 1 Kameras für 360° Vision
- LIDAR
- RADAR
- Application Unit
- Communication Unit
- Vehicle Device Provider

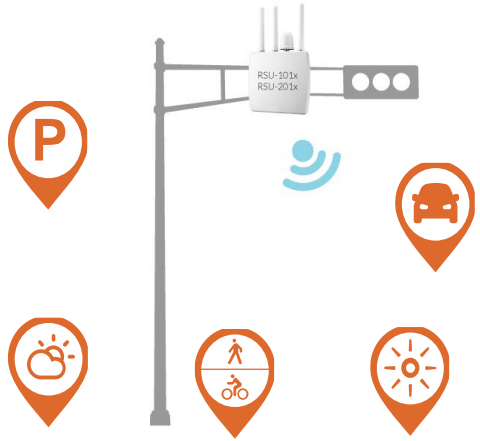
➢ Open & Distributed Intelligent Solutions for Autonomous Driving in Urban Environment

Digitized Environment

Intelligent Vehicle

Intelligent Infrastructure





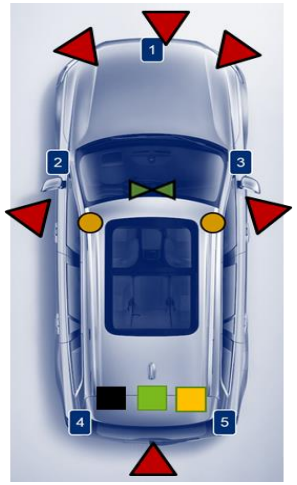
➢ Open & Distributed Intelligent Solutions for Autonomous Driving in Urban Environment

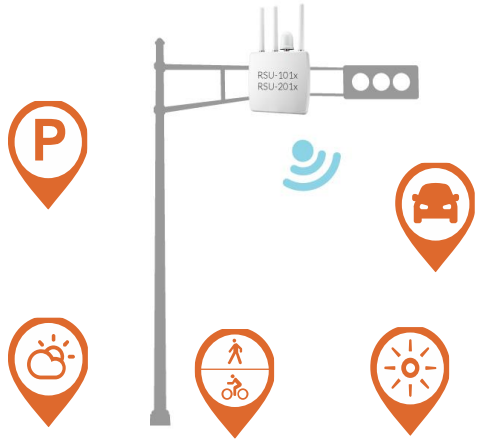
Digitized Environment

Intelligent Vehicle

Intelligent Infrastructure

Intelligent Cloud & Datacenter





➢ Open & Distributed Intelligent Solutions for Autonomous Driving in Urban Environment

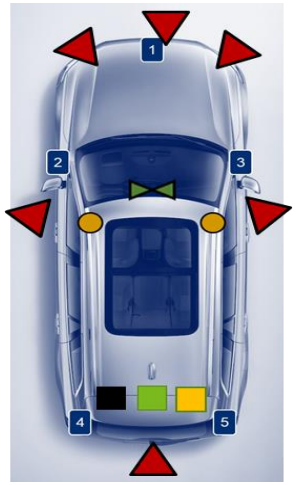
Digitized Environment

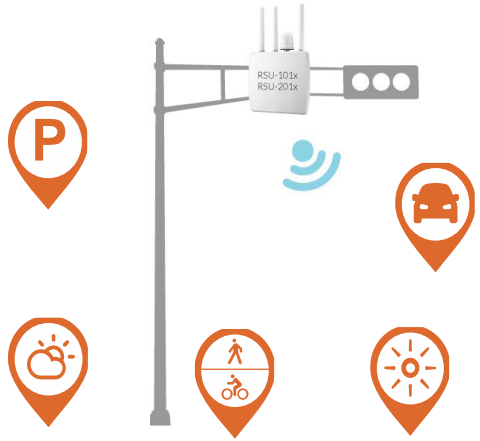
Intelligent Vehicle

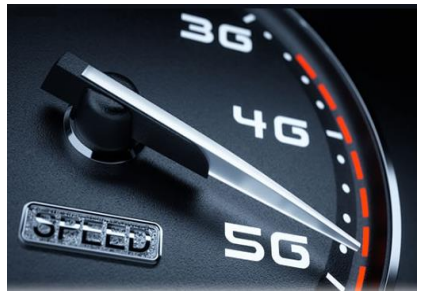
Intelligent Infrastructure

Intelligent Cloud & Datacenter

Intelligent Communication







➢ Open & Distributed Intelligent Solutions for Autonomous Driving in Urban Environment

DigiNet-PS Impacts on Vehicle Manufacturers

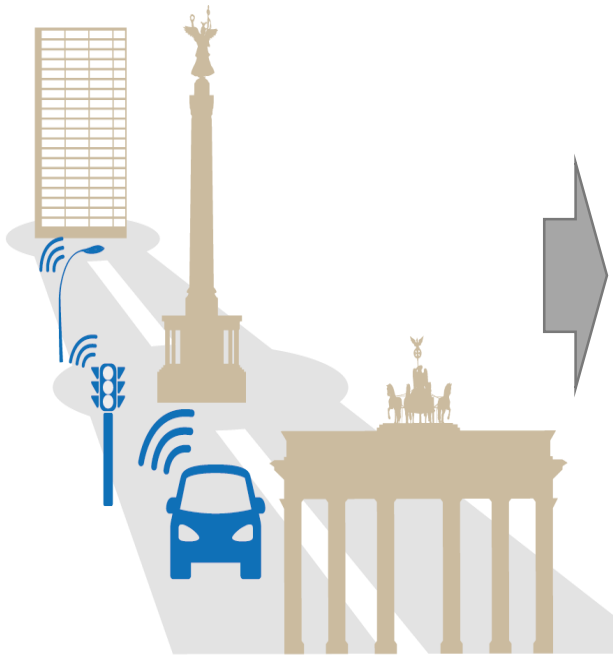
Audi

PORSCHE

Many others …

Can we test the impacts of our envisioned evolution path ?

Create use cases for the testing?



DIGINET PS

Analyze the outcome

00 No Automation

Driver is in complete and sole control of brakes, steering, throttle, and motive power at all times.

01 Driver Assistance

Vehicle can assist the driver or take control of either vehicle's speed, its lane position

02 Occasional self-driving

Vehicle can take control of both vehicle's speed and lane position in some situation

03 Limited self-driving

Automation that takes over all safety-critical functions under certain traffic conditions. Driver is available for occasional control.

04 Full self-driving in some conditions

Vehicle is in full control for the entire trip in these conditions such as urban ride sharing

05 Full self-driving under all conditions

Vehicle can operate without human driver

DigiNet-PS Impacts on Government and Citizens

Government

Citizens

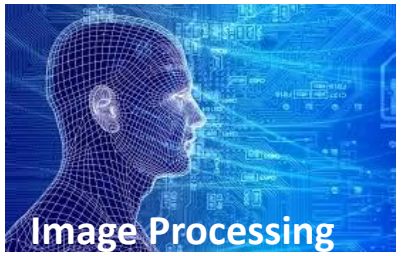
Faced with

Analog cities /
Traditional cities

Digital cities /
Smart cities

- Study the impact of autonomous driving on citizens
- Predict major changes to urban landscape
- Study citizens' perception by realizing various use case scenarios

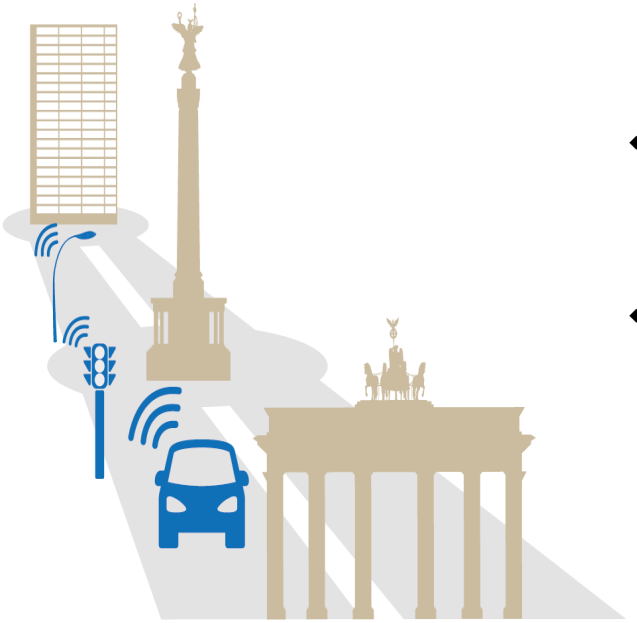
DigiNet-PS Impacts on entrepreneurs and startups



Many others …

- Ecosystem
- Business models for future transportation

Data



DIGINET PS

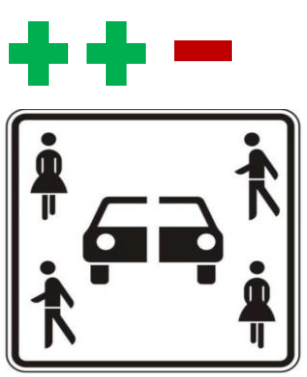
- ❖ Study and inputs for the business model shifts
- ❖ Enable the entrance of new entrants in the market

DigiNet-PS Impacts on existing markets

License holder intelligent car

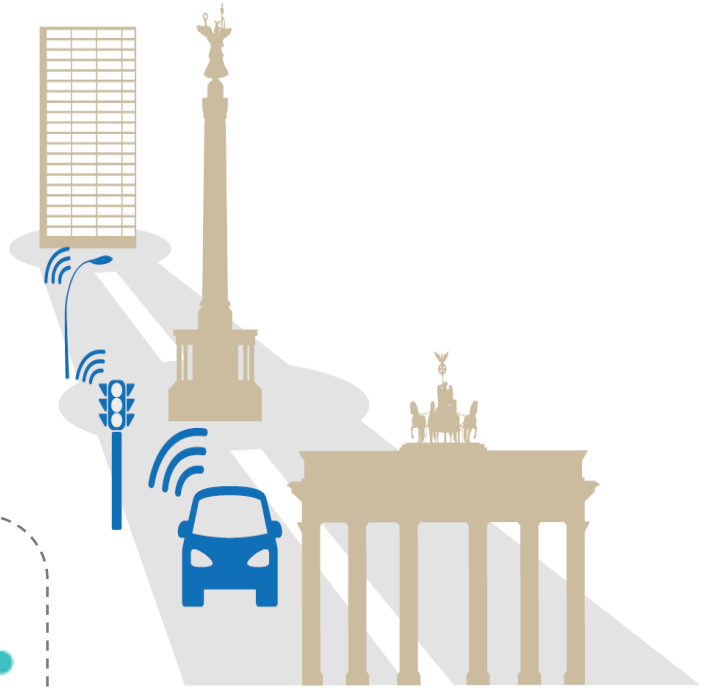
VS

New Markets



Car Sharing

Taxi services



- Study the co-existence models
- Study the new business models

DigiNet-PS Route Overview

Complex Roundabouts

Ernst-reuter-platz

3,65 km,
three-lane each direction,
with road markings

Brandenburget To

DigiNet-PS Route Overview

- Complex parking situations,
- marked and non-marked,
- parallel and slanted parking (about 1000 parking spaces),
- center island parking (about 600 parking spaces),
- separate parking areas

Ernst-reuter-platz

3,65 km,
three-lane each direction,
with road markings

Brandenburget To

DigiNet-PS Route Overview

- 15 traffic control systems with group control for vehicles, bicycles, pedestrians and handicapped, each having a different topology
- Complex traffic situations, rush hour traffic, governmental convoys

Ernst-reuter-platz

3,65 km,
three-lane each direction,
with road markings

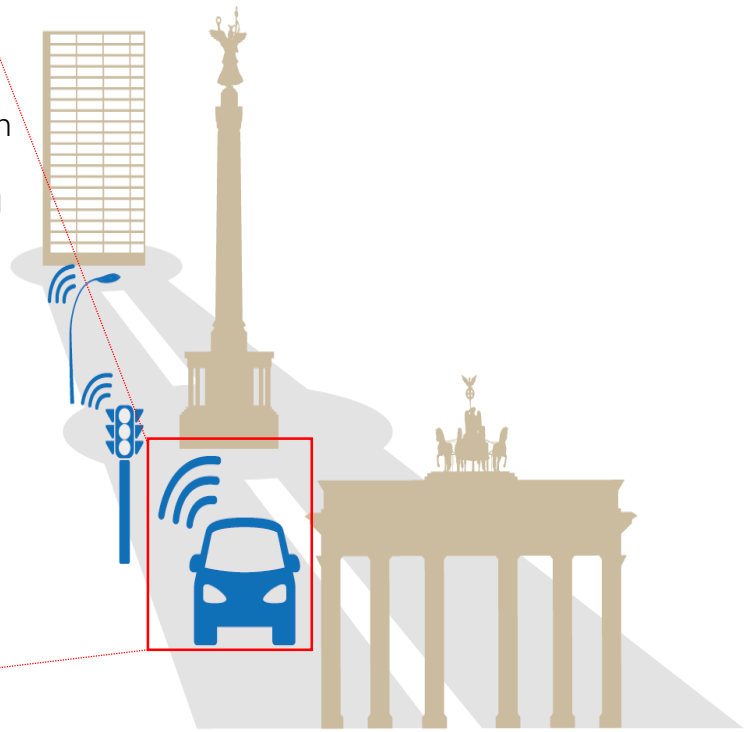
Brandenburget To

DigiNet-PS Vehicle Solution Suite

Test Vehicles
- Q5
- ....

Additional functions & sensors
- New sensors
- New functions

Intelligent Decision Making Platform
- Machine learning
- Proactive / Reactive
- Local decisions



DIGINET PS

Roadside Unit Solution Suite

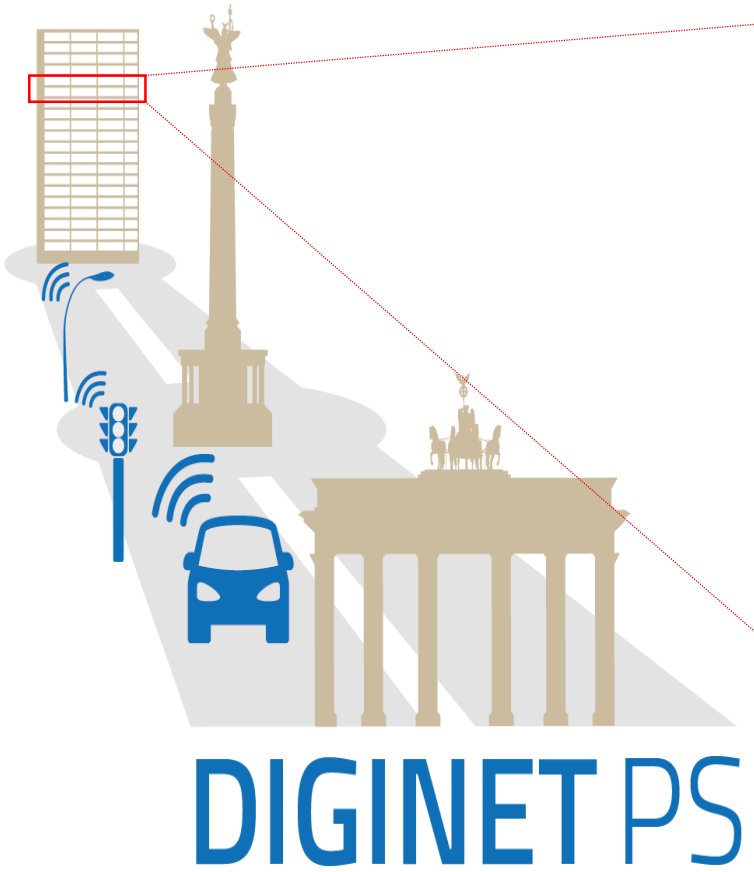
Intelligent Decision Making Platform
- Machine learning
- Proactive / Reactive
- Edge Computing

Sensors
- Parking
- Road condition
- Traffic Analysis
- Weather
- Environmental
- Traffic
- Light

Roadside Units
- Router
- DSCRC
- WiFi/5G
- Microwave

DIGINET PS

DigiNet-PS Cloud Solution Suite



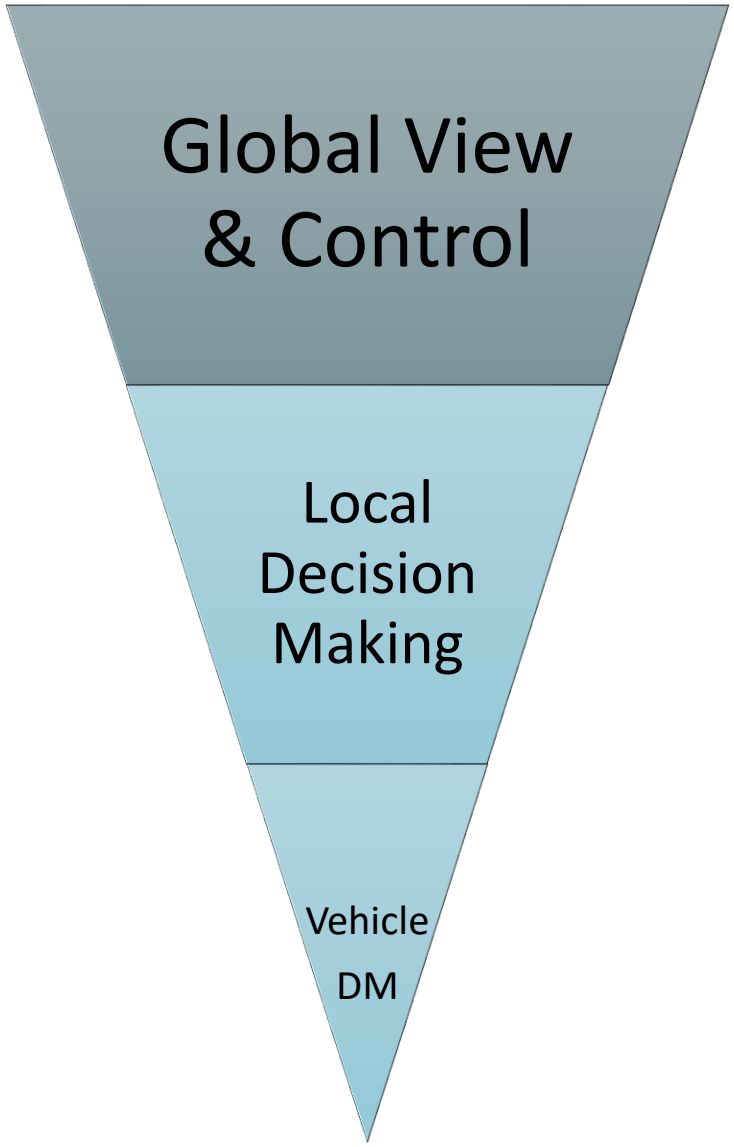
Intelligent Decision Making Platform
- Machine learning
- Reactive
- Prediction Engine

Control & Visualization Center
- Facilitates in implementation of use cases
- Visualization of KPIs

Cloud infrastructure
- Hyperflex
- GPUs
- Transport Network
- Aggregation Network

Intelligent Core Network
- SDN, NFV, SON, etc.

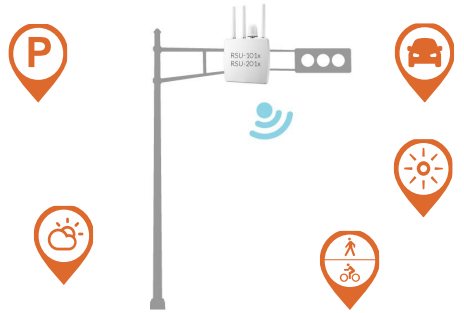
DigiNet-PS Decisions Hierarchy



- Machine learning
- Proactive decisions
- Integrating stakeholders & huge heterogeneous sensory data

Cloud Solution

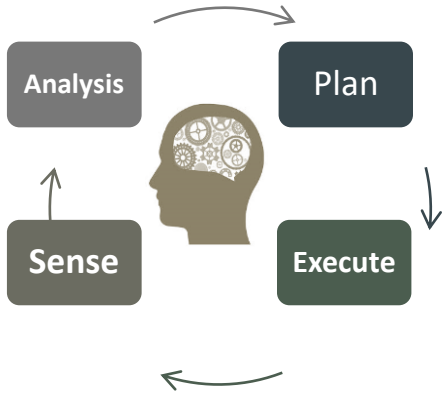
- Edge computing
- Time critical decisions

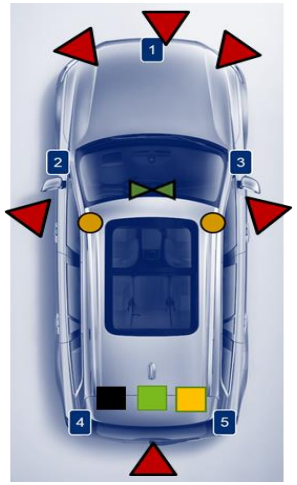


Wide-range Backhaul

Cellular Communication (LTE)

Short Range Communication





Stereo Kamera

Kameras für 360° Vision

LIDAR

RADAR

Application Unit

Communication Unit

Vehicle Device Provider

DigiNet-PS Key Outcomes

Intelligent Cloud

- Machine learning approaches for proactive DM
- Autonomic network Management
- Control & Management applications
- Development APIs for different stakeholders
- Applications & logic for co-existing with traditional vehicles

Use Cases

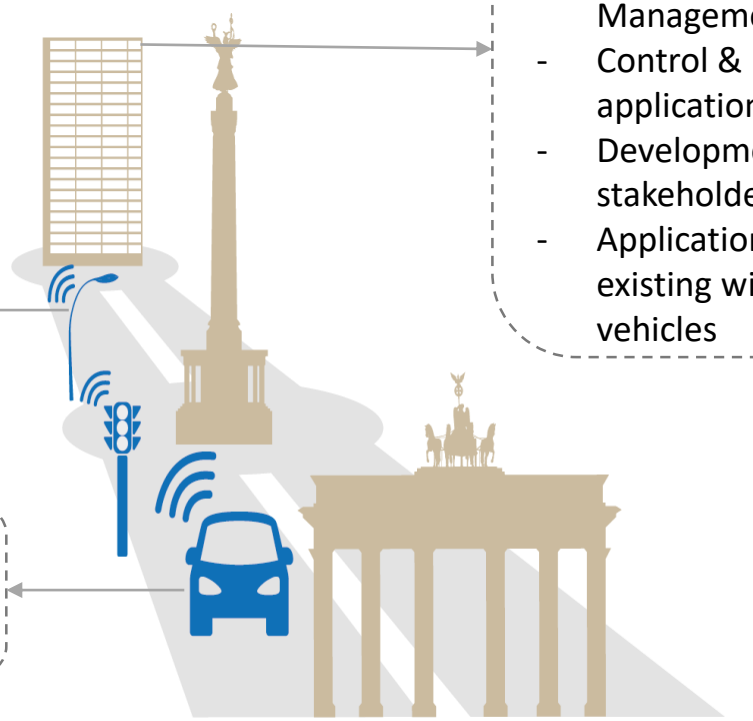
- Vehicle Testing
- Protocol Road
- Navigator App
- Uni Shuttle
- Application Development
- Control Center
- Environmental Friendly Driving

Roadside Unit

Edge Processing & Decisions

Vehicle

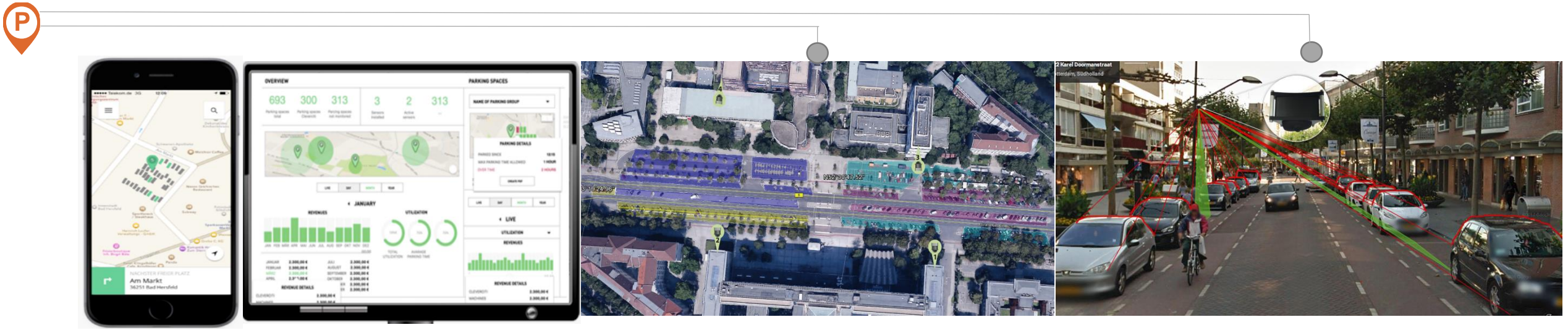
Vehicle Software Stack + new functions



DIGINET PS

- **Sustainability**
  - Reduce fuel consumption and pollution
    - Avoiding search for parking spaces
    - Avoiding congested routes
    - Avoiding stop & go by choosing suitable speed and lane (green wave)
- **Safety**
  - Reduce accidents
- **Efficiency**
  - Reduced travel time

Infrastructure for Street Digitization



Infrastructure for Street Digitization

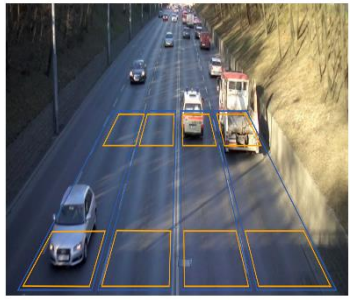
Parking Sensors

Traffic Analysis

Activity Analyzer

- Visualizes motion and dwelling time
- Objective measurement of hot spots
- Compiles statistical evaluations
- Adjustable duration and intervals of evaluation

Traffic Analyzer



- Automatic counting of vehicles (passenger cars, trucks, motorbikes)
- Classification into two-wheel, passenger car and bus/truck
- Up to four lanes
- Output in minutes, hours, days, weeks and months

Queue Detection

- Alarm if a defined queue length is reached
- Crowd analysis & crowd density estimation
- Analyzing the speed of the flow
- Estimation of the average waiting time

Infrastructure for Street Digitization

Parking Sensors

Traffic Analysis Sensors

Infrastructure for Street Digitization

Parking Sensors

Traffic Analysis Sensors

Weather Sensors

- Temperature,
- Relative humidity,
- Precipitation intensity,
- Precipitation type,
- Precipitation quantity,
- Air pressure,
- Wind direction,
- Wind speed

Infrastructure for Street Digitization

Parking Sensors

Traffic Analysis Sensors

Weather Sensors

Infrastructure for Street Digitization

Parking Sensors

Traffic Analysis Sensors

Weather Sensors

Road Condition Sensors

- Layer thickness of water, snow and ice,
- Surface conditions (dry, damp, wet, snow, ice),
- Friction,
- Road surface temperature

Infrastructure for Street Digitization

Parking Sensors

Traffic Analysis Sensors

Weather Sensors

Road condition Sensors

Infrastructure for Street Digitization

Parking Sensors

Traffic Analysis Sensors

Weather Sensors

Road condition Sensors

Environmental Sensors

- NO,
- No2
- O3,
- PM1,
- PM2.5,
- PM10

Infrastructure for Street Digitization

- Parking Sensors
- Traffic Analysis Sensors
- Weather Sensors
- Road condition Sensors
- Environmental Sensors

Infrastructure for Street Digitization

- Parking Sensors
- Traffic Analysis Sensors
- Weather Sensors
- Road condition Sensors
- Environmental Sensors
- Intelligent light sensors

Infrastructure for Street Digitization

- Parking Sensors
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- Intelligent Light Sensors

Infrastructure for Street Digitization

- Parking Sensors
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- Intelligent Light Sensors
- Traffic Light Sensors

Infrastructure for Street Digitization

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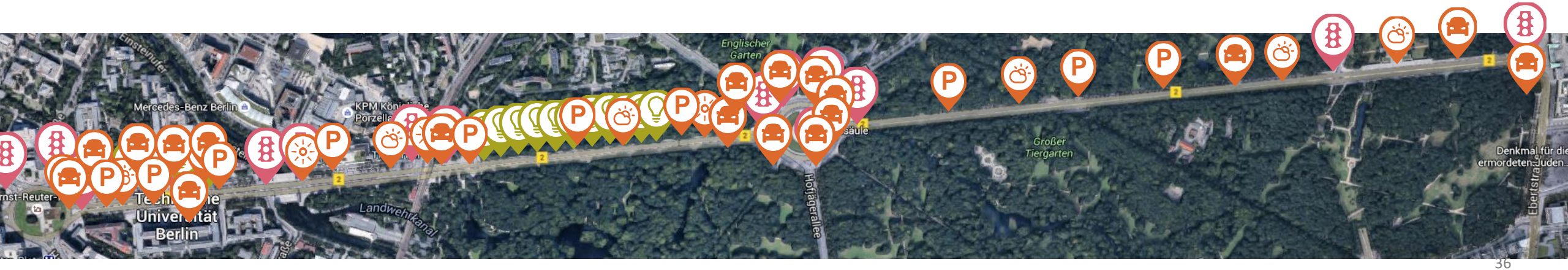

Infrastructure for Street Digitization

- Parking Sensors
- Traffic Analysis Sensors
- Weather Sensors
- Road condition Sensors
- Environmental Sensors
- Intelligent Light Sensors
- Traffic Light Sensors

Intelligent Communication Infrastructure

1 Access Network Node 2 Backhaul Network Node
3 Transport Network Node

- Connectivity of RSUs
- Backbone design

Unique Standpoint of DigiNet-PS

Urban

Open / Mixed traffic

Intelligent Vehicle

Intelligent Networks

Distributed & autonomous decisions

DigiNet-PS will help achieve

Intelligent Vehicle with **human driver like perception**

New Eco-systems & Business Opportunities

Digital Urban Environment

Improved Quality of Life

Project Consortium

DAI-Labor
Distributed Artificial Intelligence Laboratory

TU berlin

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