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Towards Next Generation Public Transport Systems: Overview and some Preliminary results

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June 16, 2017 – ADAPT-IT Final Event, Stockholm, Sweden

The MobiLab Team at UL

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- **MobiLab Transport Research Group** established in mid-2012
  - Head: Ass. Prof. dr. Ing. **Francesco Viti**
    - MSc – Univ. of Naples 'Federico II', Civil Engineering degree
    - PhD – TU Delft, PhD in transportation planning and management
    - Post-doc – TU Delft (2007-2008) & KU Leuven (2007 – 2012)
  - 1.5 post docs
    - **Sebastien Faye**, computer scientist (0.5)
    - **Marco Rinaldi**, automation and control
  - 5 PhD students
    - **Francois Sprumont**, spatial planner
    - **Guido Cantelmo**, transport engineer
    - **Bogdan Toader**, computer scientist
    - **Giorgos Laskaris**, traffic engineer
    - **Giulio Giorgione**, transport engineer

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MobiLab

Overview of research at MobiLab

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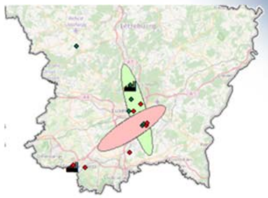


Data Scale

aggregate

Mobility analysis

Transport planning & mobility management

Big Data

Multimodal network modelling

MAMBA
MULTIMODAL MOBILITY

MobiLab Transport Research Group

Micro (Movements)

Macro (Flows)

Modelling scale

Activity-travel behavior

Mobile sensor networks

Traffic flow theory and control

ITS for Public Transport

Individual

Presentation Outline

1. Introduction and motivation

   A) Current PT systems and their prioritisation
   B) Trends in developing next generation PT systems

2. Cooperative ITS based support

   C) Integrated speed and dwell time control
   D) including opportunity charging for e-buses

3. Preliminary results

4. Conclusion

Next generation PT systems: trends and challenges

Trends

1: “greener vehicles”, e.g. hybrid/electric bus systems
2: improved ride comfort (less stops at signals)
3: improved bus performance and cost efficiency

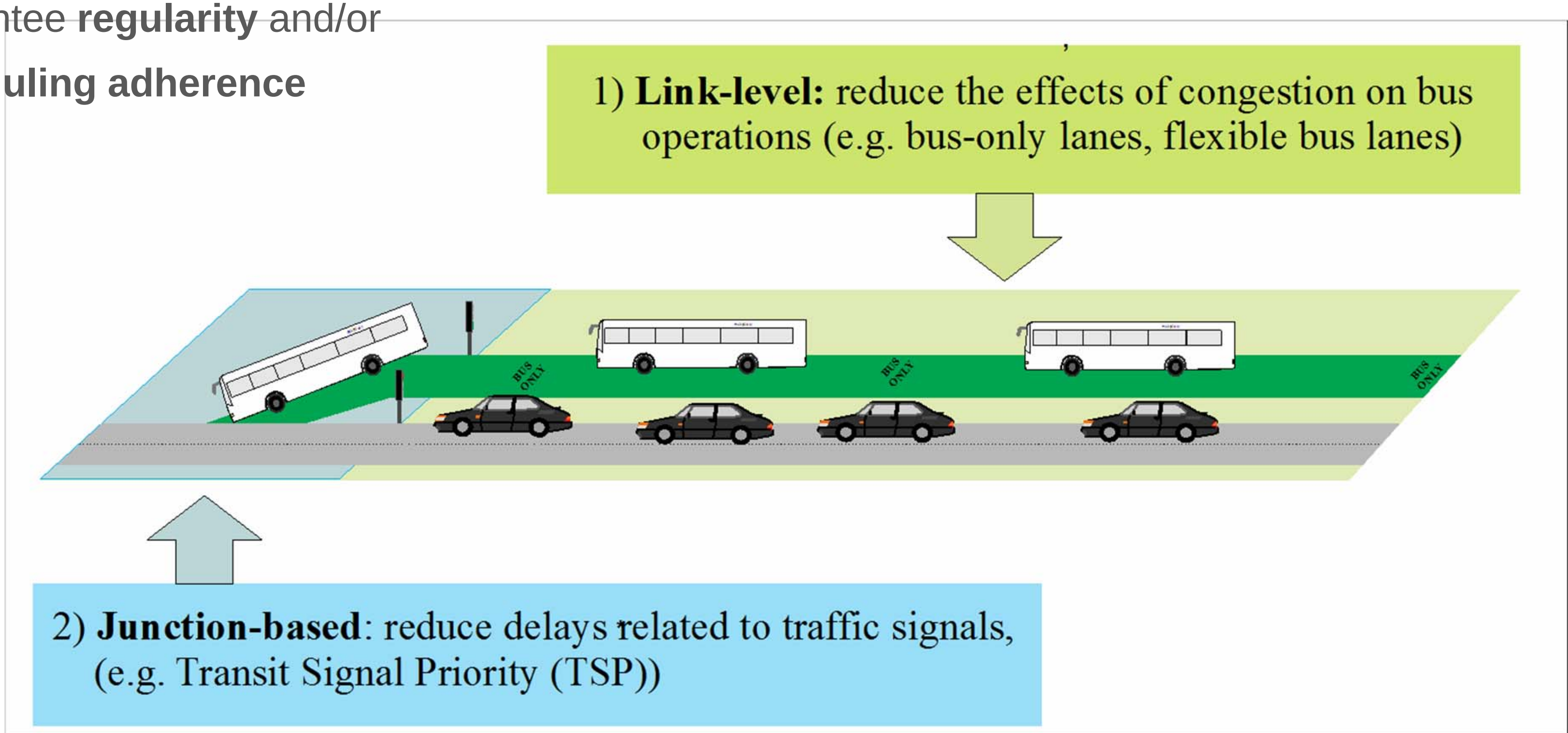
Challenges

1: Cost efficient control strategies – where, and when?
2: Reduction of stop-and-go at intersections without heavy use of TSP
3: Smart integration of e-mobility infrastructure

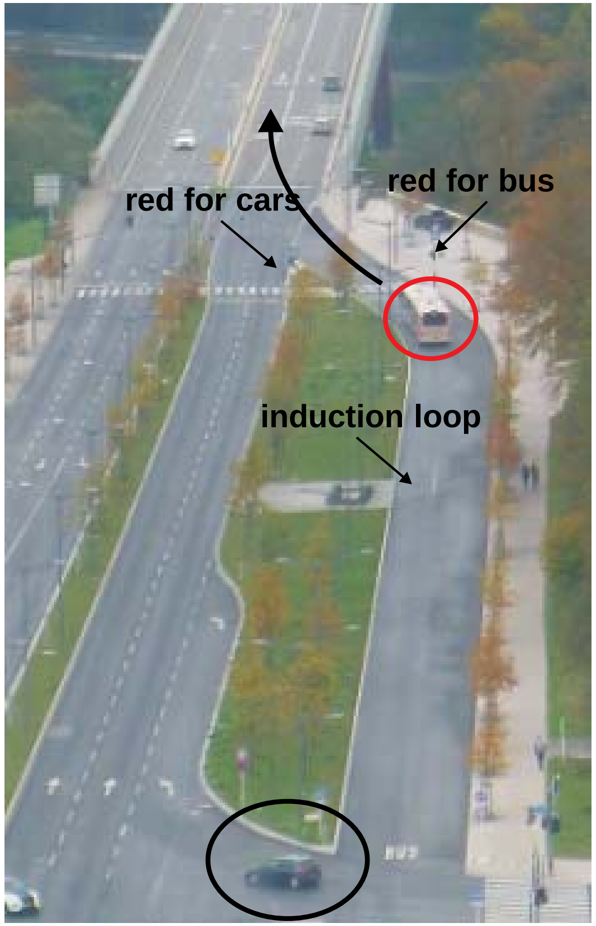
Current control of PT operations

- **Junction-based**: **Traffic controls** must guarantee **efficient traffic performances**
  - Signal policies adopted to **prioritise public transport** over car traffic
  - Generally private and public transport have **conflicting objectives**.

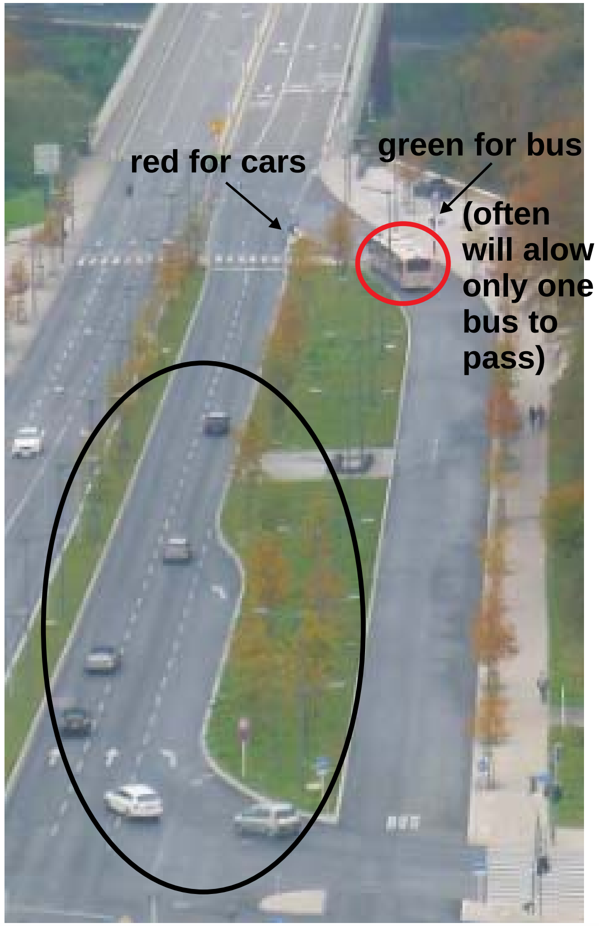
- **Link-based**: **Holding strategies** and **speed adaptations** used mainly to
  - guarantee **regularity** and/or
  - **scheduling adherence**



Example: impact of inefficient TSP control



t1



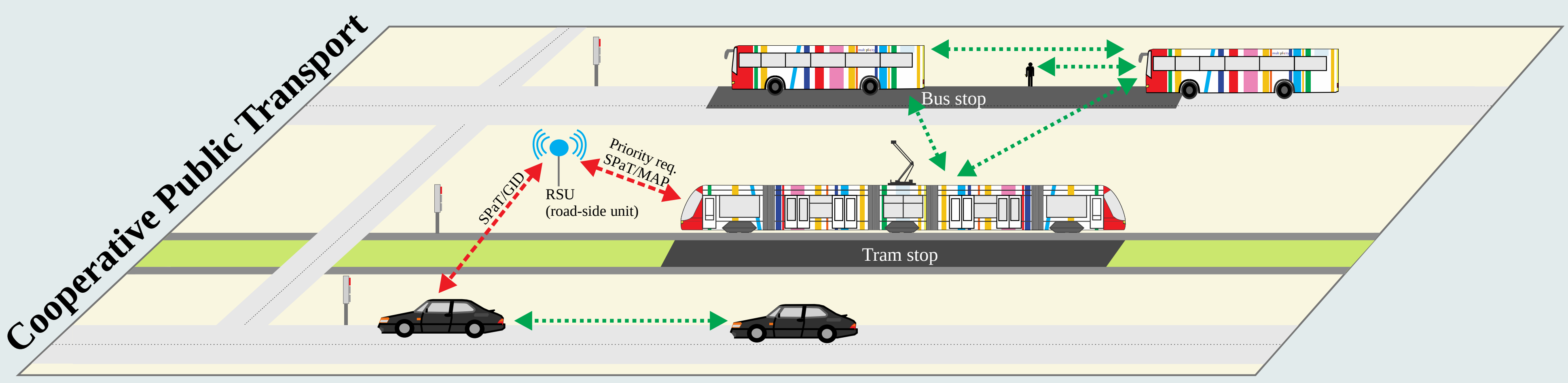
t2

t3

The added value of Cooperative ITS

Vehicles, road-side infrastructure, after market devices (e.g. smart phones) directly communicate using DSRC radio (Dedicated Short-Range Communications) to improve safety and mobility.

Communication patterns: V2I (vehicle to infrastructure) V2V (vehicle to vehicle)



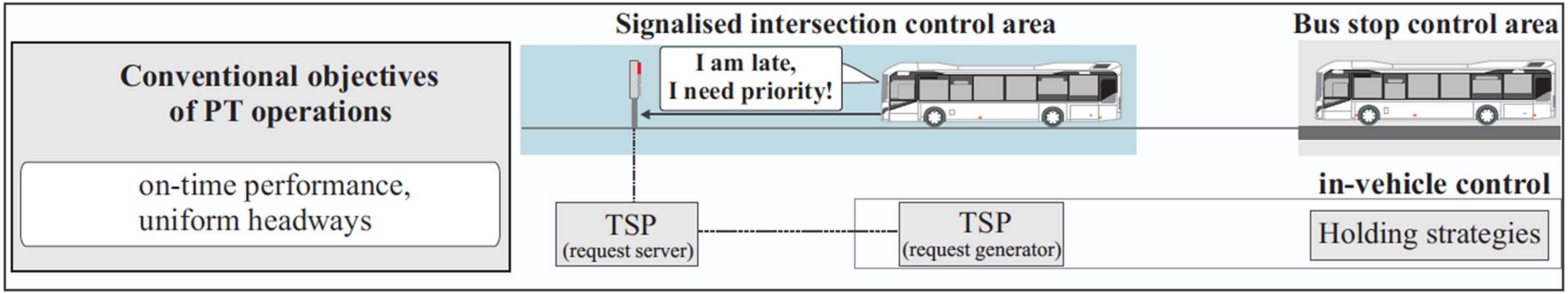
1) Each vehicle is now a sensor, thus **more data** available.
2) Possibility to transmit **complex data** (e.g. vehicle speeds, queue lengths, # of passengers).
3) Frequent **low-latency** message delivery (vs. traditional 30-90s pools).

Connected Vehicle Technology allows developing:

1) next generation **AVL/TSP*** (e.g. Metro Rapit service in LA, King County Metro in Seattle**),
2) new systems such as **flexible bus lanes** and **GLOSA**.

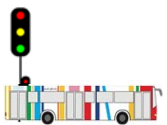
Integrated control of PT operations

TSP + DAS strategies



1: Conditional priority at traffic light – Priority Request Generation dependent on scheduling and/or headways

2: Real time holding strategies at stops and speed adaptation used to regulate headways and reduce TSP needs.

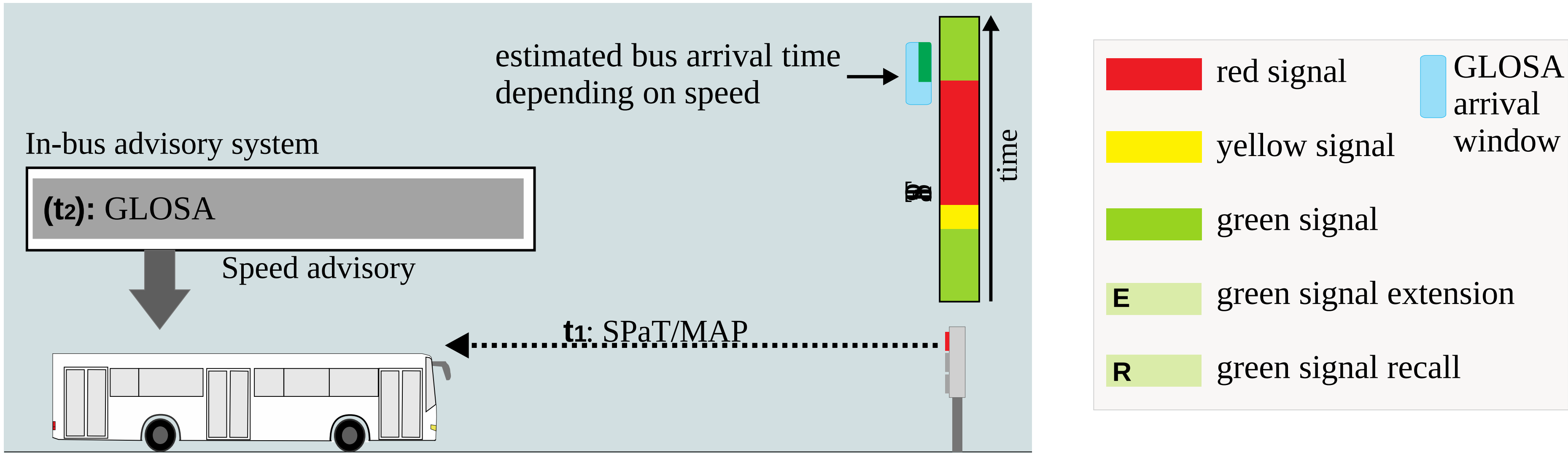


Green Light Optimal Speed Advisory (GLOSA)

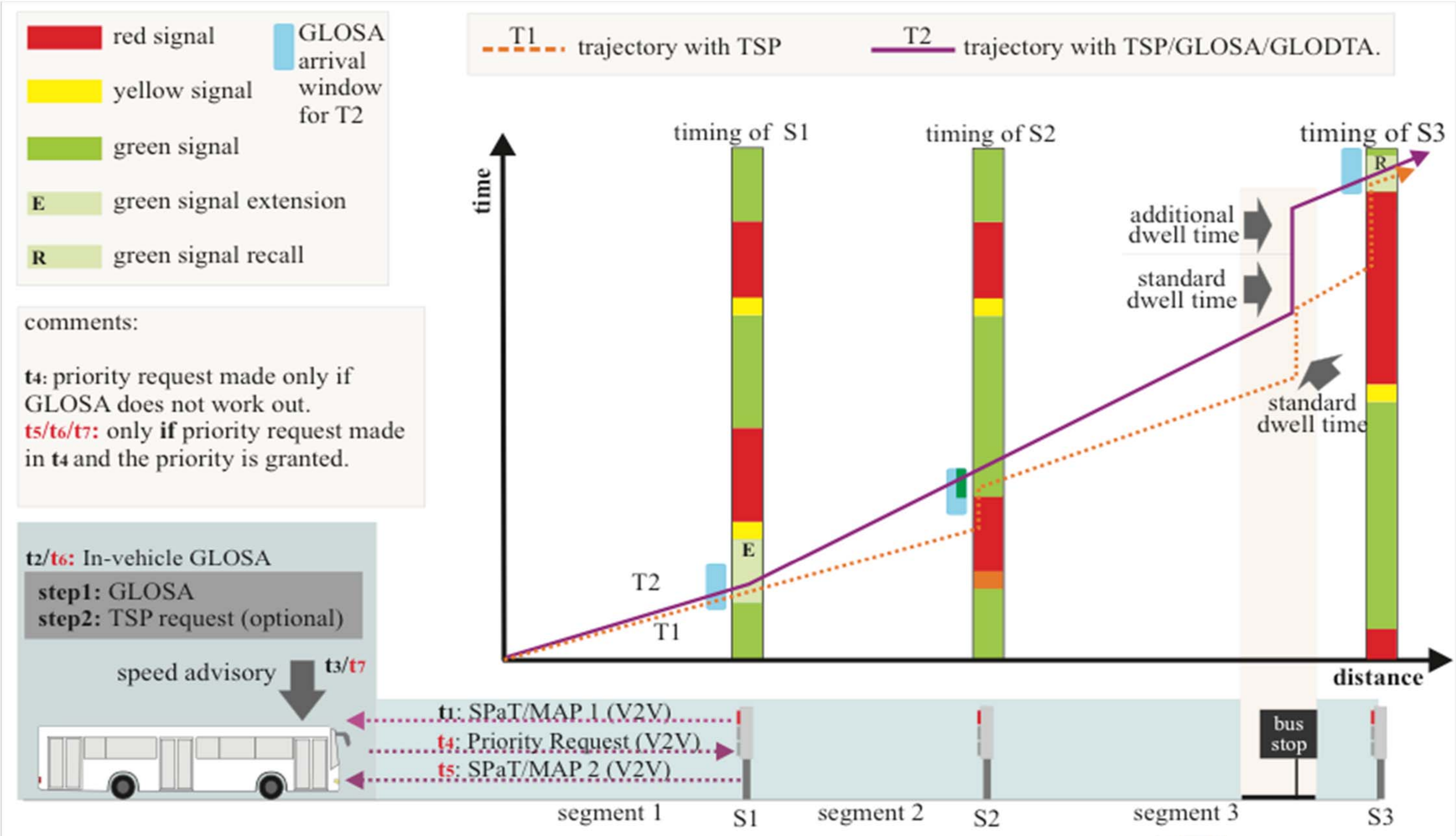
Information received from traffic signals:

SPaT – Signal Phase and Timing
MAP – description of physical geometry of the intersection

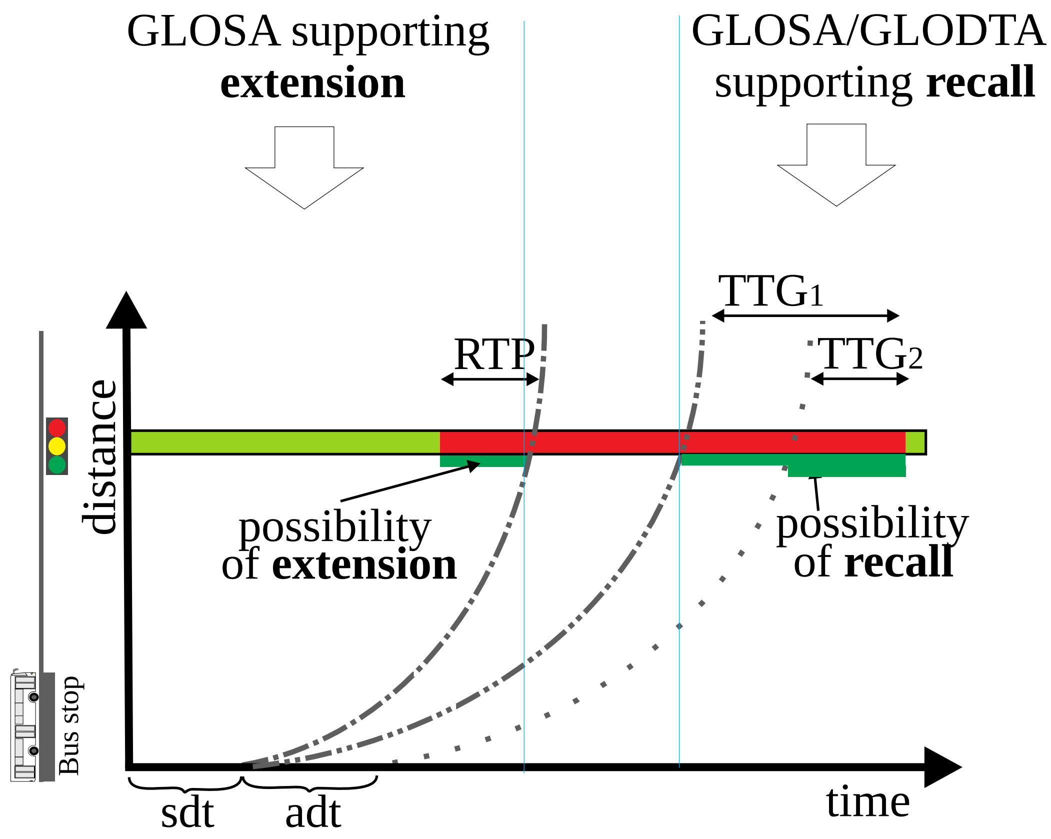
Upon reception of SPaT and MAP (via V2I) the in-bus GLOSA determines vehicle's optimal speed allowing to pass the next traffic signal on a green light.



Green Light Optimal Dwell Time Advisory (GLODTA)



TSP/GLOSA/GLODTA interplay



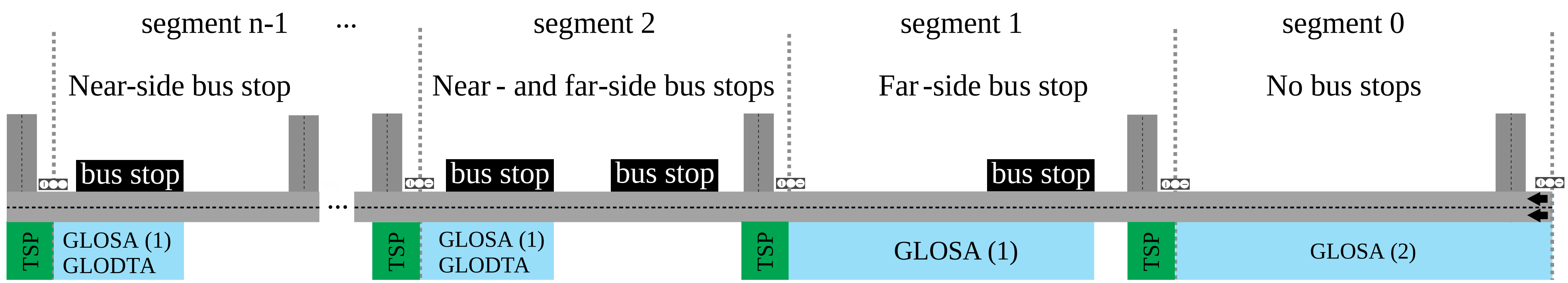
- fastest arrival ($v_{peak}==v_{max}$), no GLODTA
- slowest arrival ($v_{peak}==v_{min}$), no GLODTA
- slowest arrival ($v_{peak}==v_{min}$), GLODTA

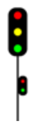
RTP– red time passed TTG– time to green

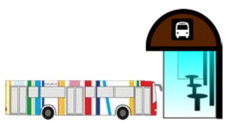
Problem instances: mix of near/far-side stops

Evaluation using various setups differing in segment length and setup of bus stops (near-side (NS), far-side (FS), both types (MIX))

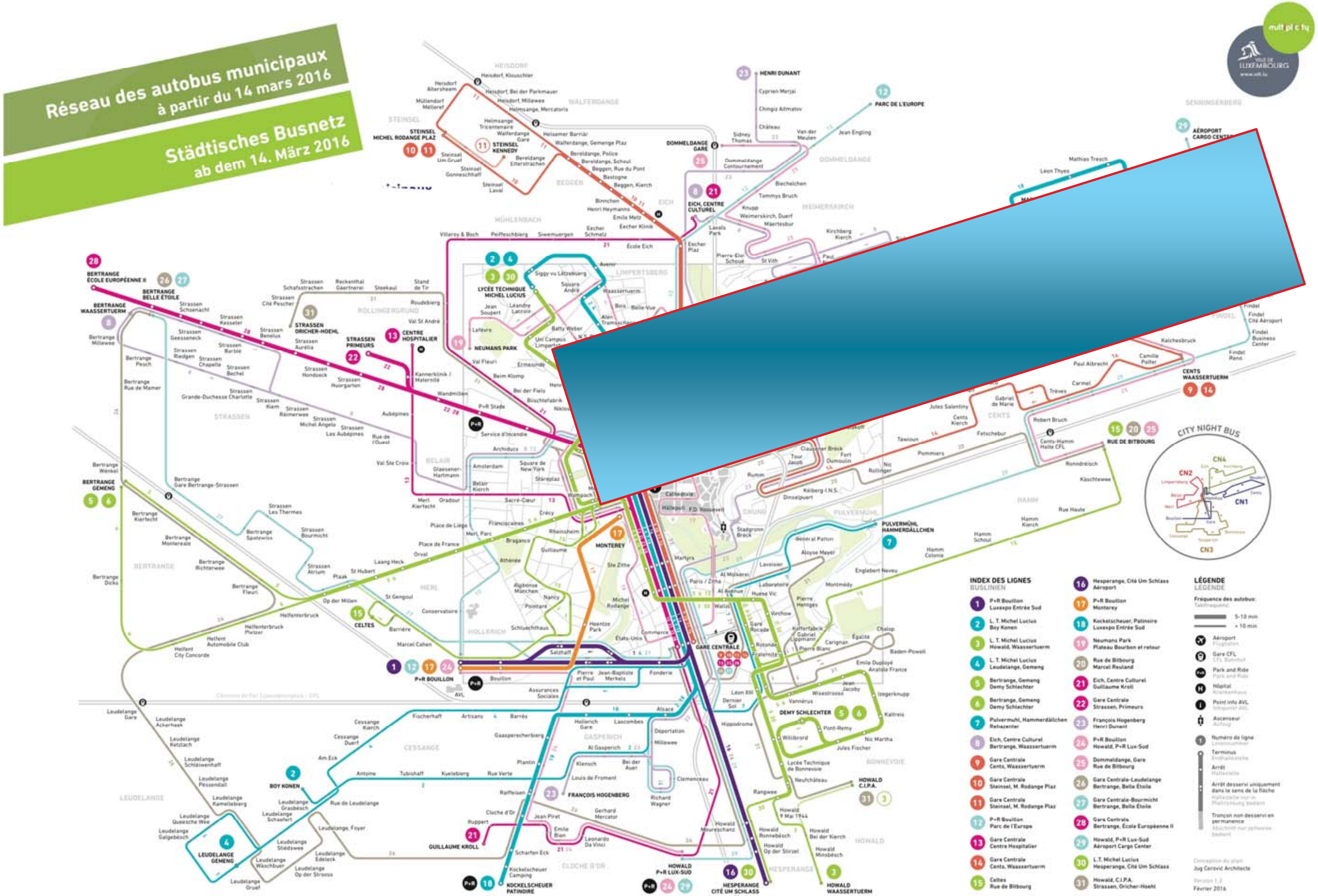
Different random distances for bus stop locations and link lengths and number simulated





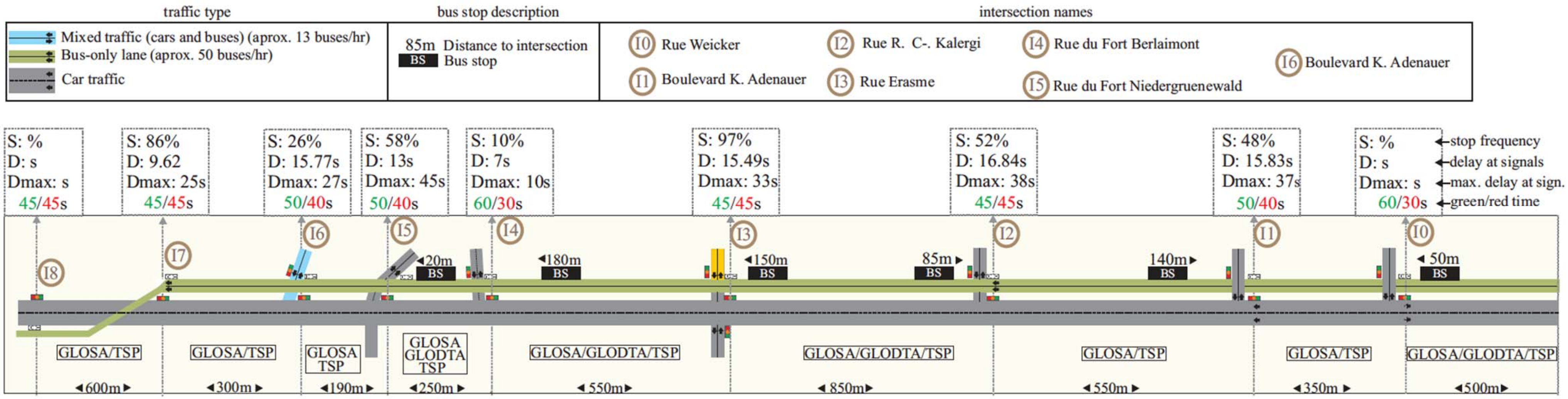


Real case: the ‘Spaghetti Monster’



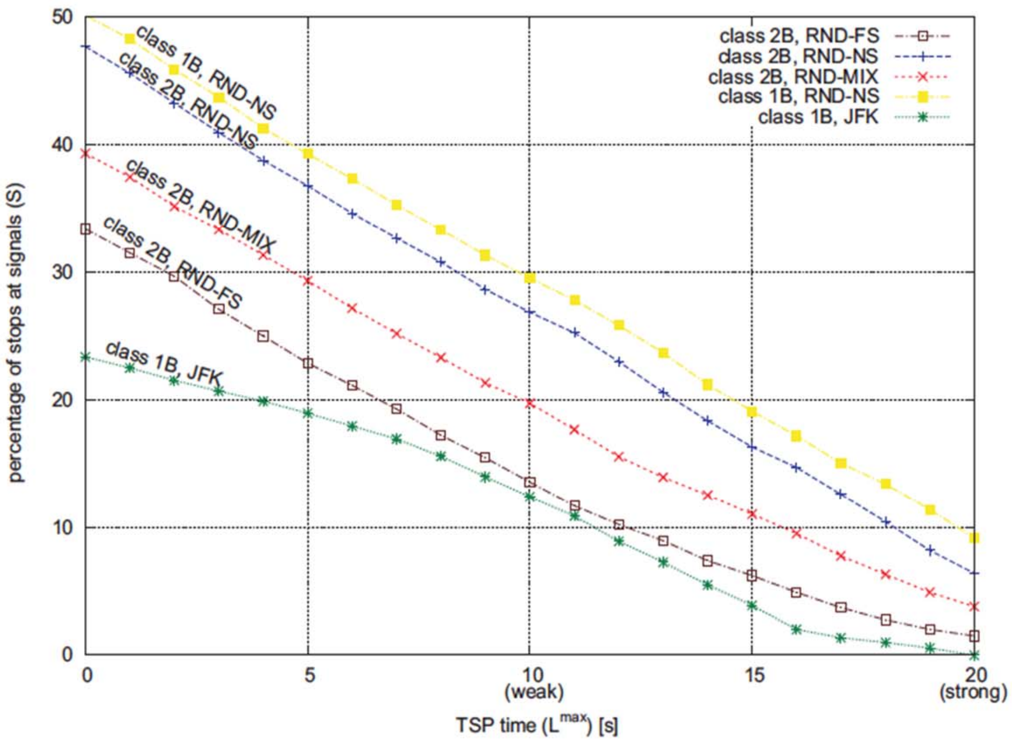
Problem instances: JFK realistic case study

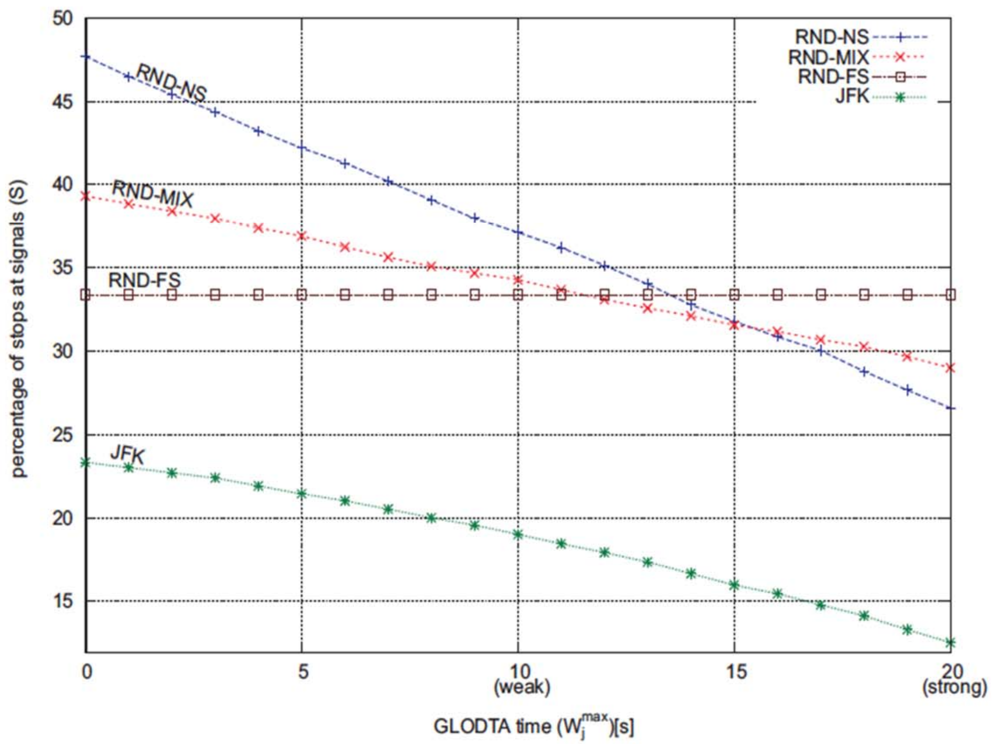
Realistic settings: operational conditions with systematic stops at major junctions; strong impact of TSP to car traffic performance



Selection of results (1/2)

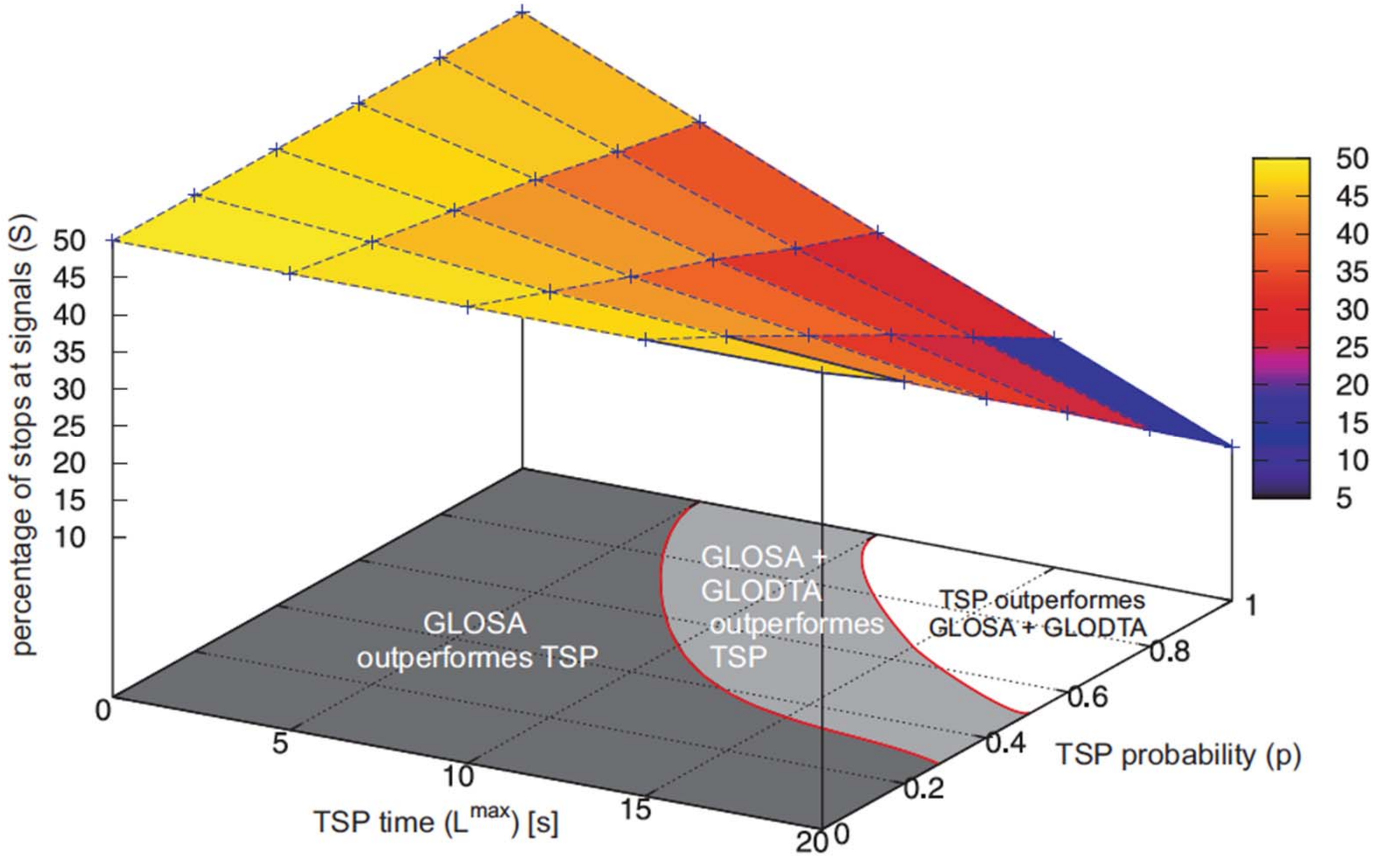
- Sensitivity analysis
  - GLODTA (obviously) ineffective with far-side stops
  - TSP effectively reducing stops but takes capacity away from car traffic





Selection of results (2/2)

- Interaction TSP + GLOSA + GLODTA



Next: eCoBus – electrified Cooperative Bus systems

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- **eCoBus** aims to design a system exploiting the potentials of the C-ITS to increase operating efficiency and comfort of next generation PT systems

- FNR-CORE project (2017-2020)

Electrified Cooperative Bus System

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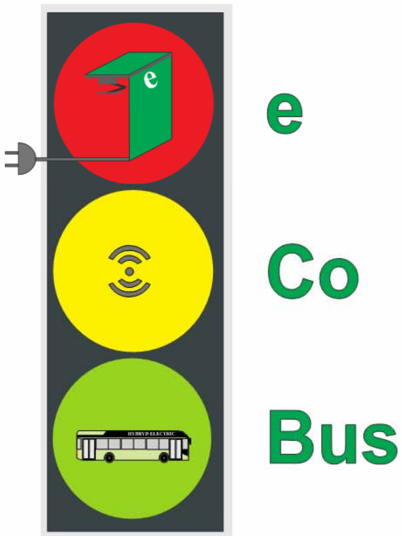


Partners

VOLVO BUSES

Sales-Lentz moving people

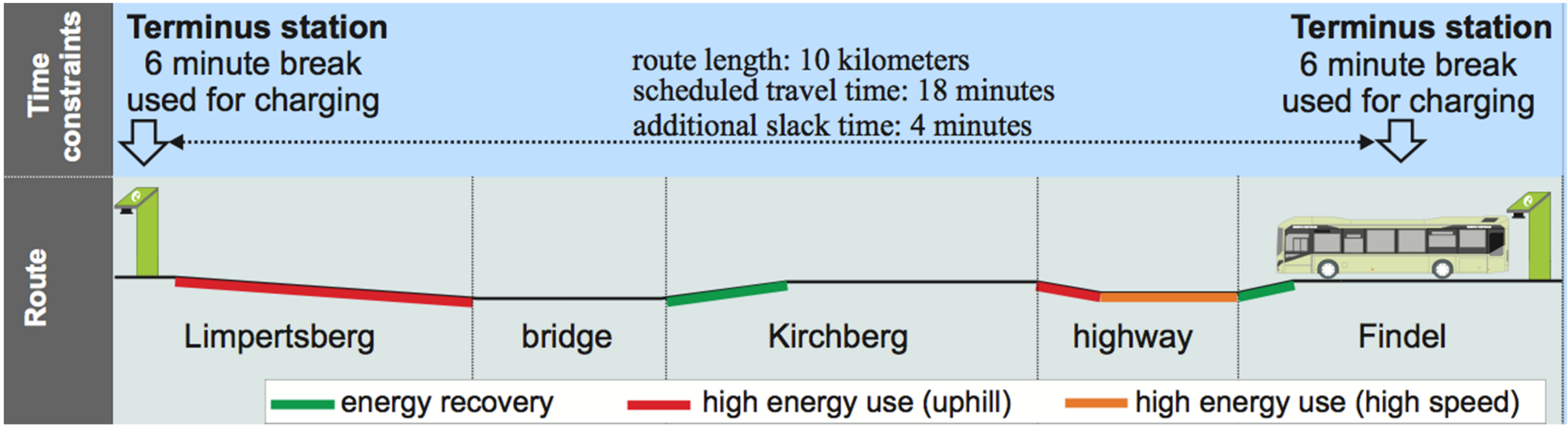
PTV GROUP

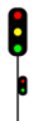
KU LEUVEN

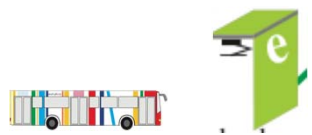
UCA Universidad de Cadiz

Opportunities and challenges brought by e-buses

Bus is charged on-route:
- Route end points (fast charging: 4-6 minutes)
- and/or selected bus stops (flash charging: 15 seconds)

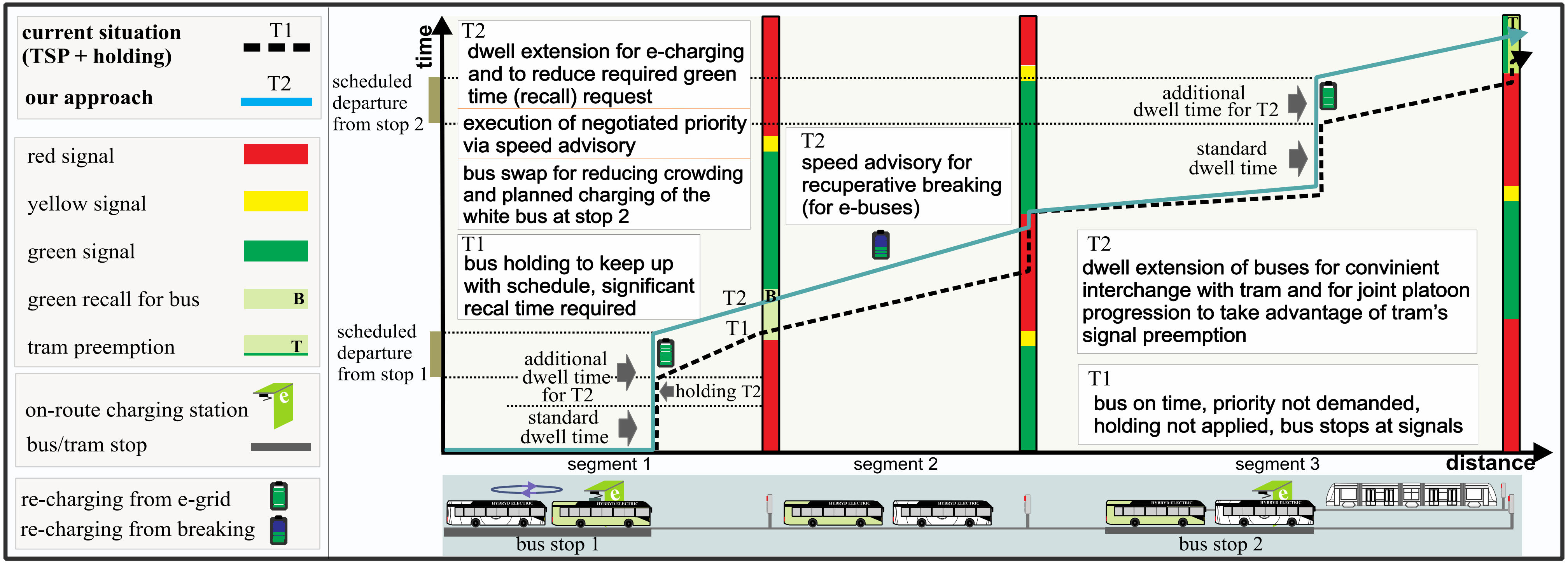






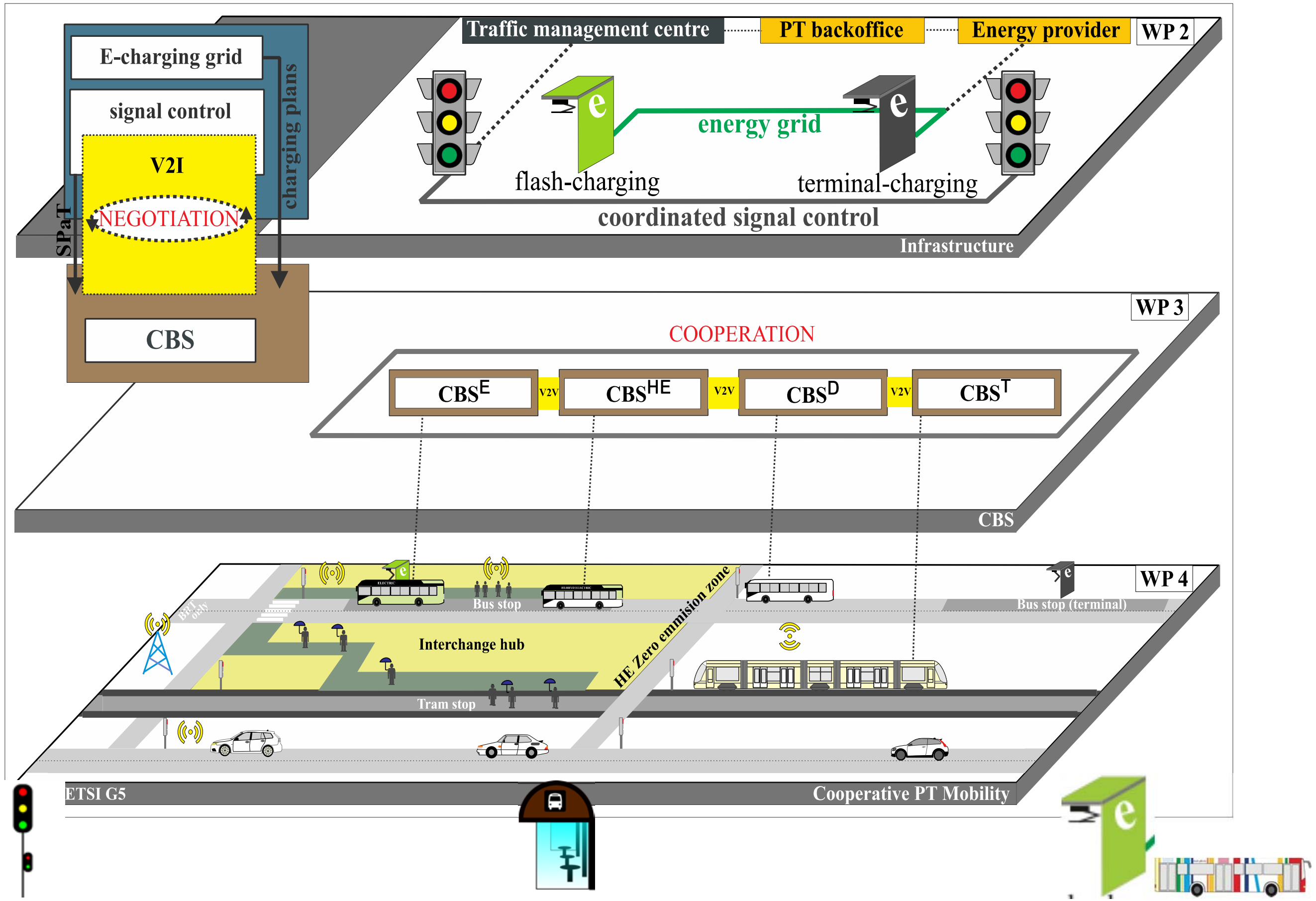
The idea in a simple example

- Optimisation of bus operations (Cooperative Bus System) integrated with traffic control and charging infrastructure
- Supporting in-vehicle controls C-PROG, C-SWAP and C-SYNC



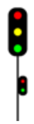
Multi-layered approach

- Traffic control level takes care of signal timing optimisation for general traffic
- PT vehicle level adapts vehicle trajectories and dwell times to optimise PT performance
- Communication level provides real time positioning of buses and estimated traffic control states



Expected contributions

- **CBS layer:** extend GLOSA/GLODTA to include capacity constraints and additional objective terms due to e-charging operations
- **Signal control layer:** extend current control systems (fixed, dynamic) with negotiation of optimal TSP strategies.
- **Charging layer:** PT design of charging station locations and real time use will be done according to given pricing schemes.
- **Communication layer:** C-ITS technology will be optimised for maximum performance and minimum infrastructure requirements.
- **Simulation and data:** commercial simulation tools (PTV-VISSIM, PTV-Balance and PTV-Epics) used to evaluate different rule-based heuristics.
- **Optimisation methods**: multi-actor decision-making & multi-objective optimisation heuristics using distributed control systems to deal with real time short-range data.
- **System evaluation and demonstration:** controlled experiments carried out to evaluate selected components of our solutions.




Laurent Bravetti

Project Leader Electro Mobility at Volvo Bus Corporation

4 d

An impressive moment : the inauguration of the first 4 Volvo full Electric buses in Differdange with a small version of 7900 Electric!

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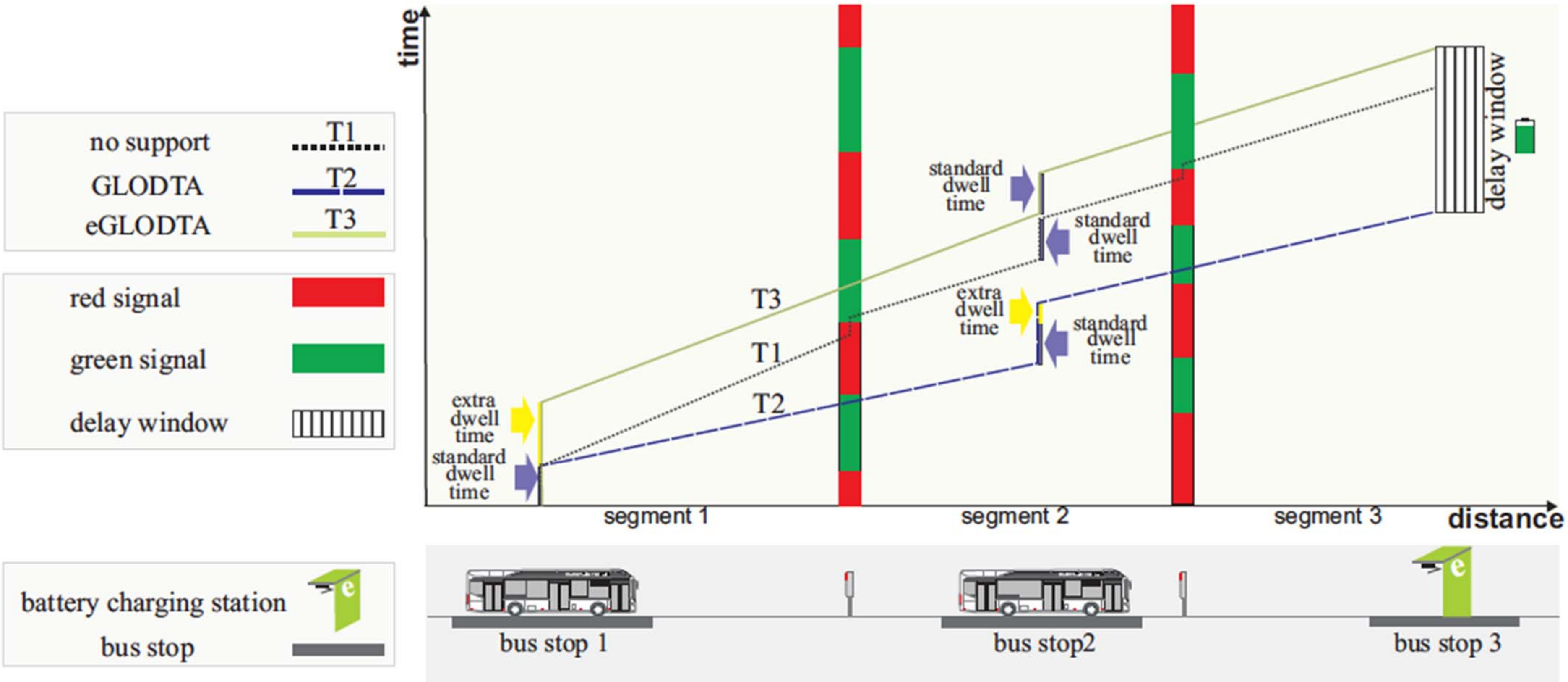
Research challenges

- Complex multi-objective and multiclass optimization problem
- Both design and operational constraints and variables
- Tram, hybrids, e-buses, traditional buses all have different requirements and operational characteristics
- E-infrastructure should be optimized to guarantee optimal use of e-buses
- C-ITS communication and real time operation will require fast heuristics
- Decomposed, decentralized and distributed optimization necessary
- Testing on (controlled) scenarios will not be straightforward



First steps: eGLOSA & eGLODTA

- C-ITS support with opportunity charging



Preliminary results: eGLOSA & eGLODTA

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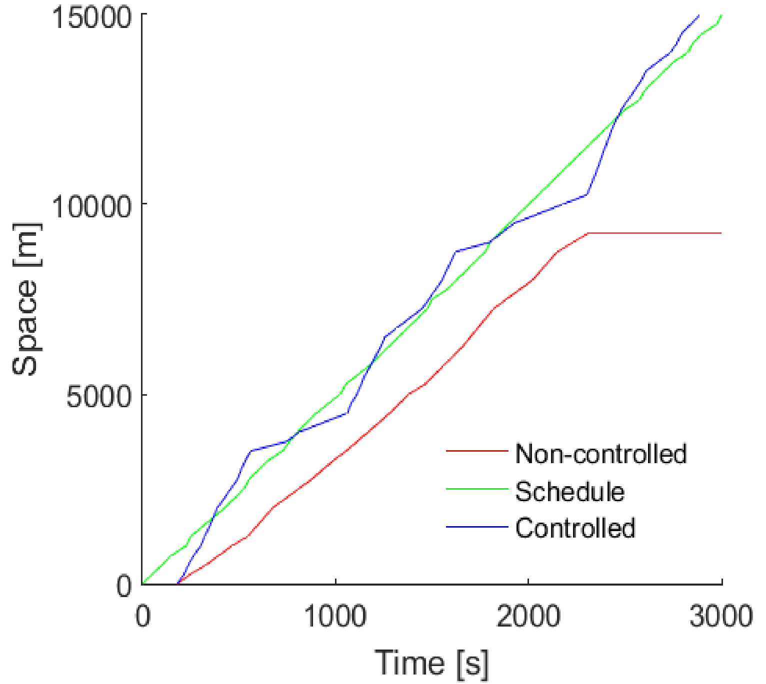
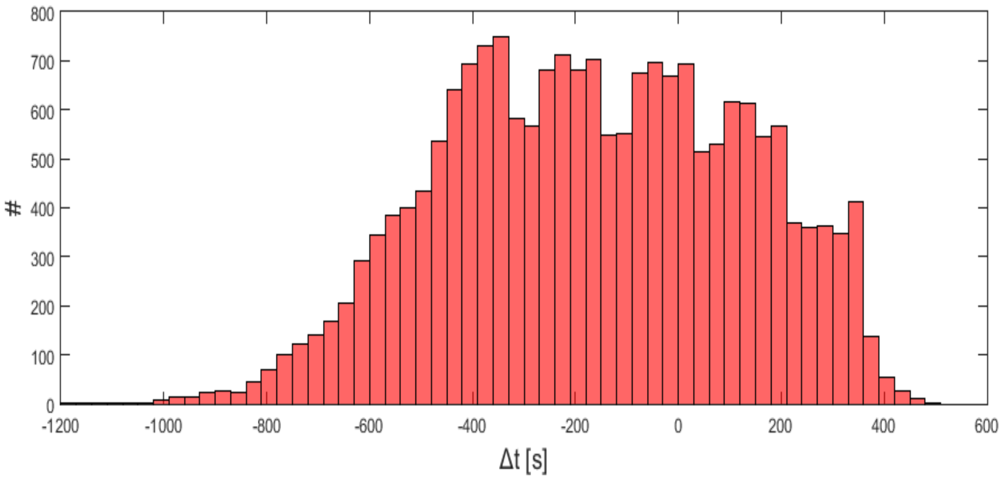
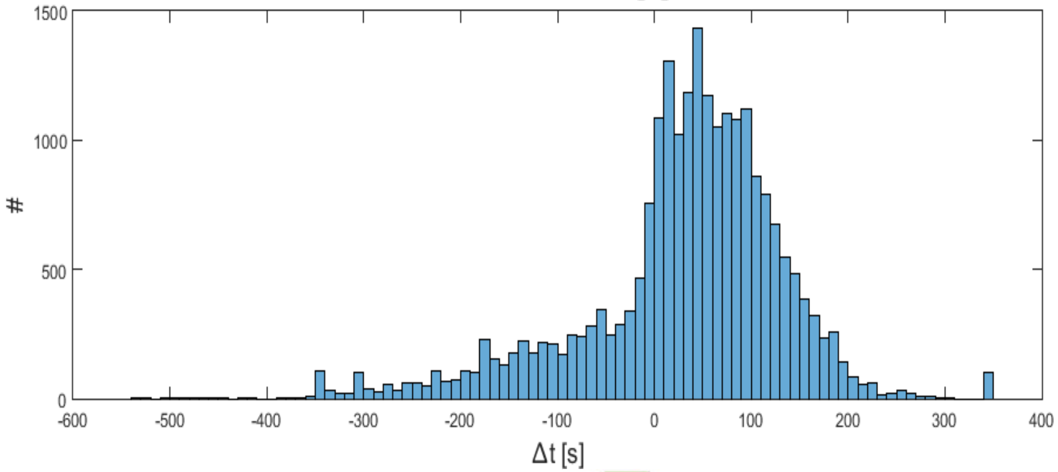
- **Three objectives**
  - Maximizing performance of on route battery charging at bus stops;
  - Minimizing power consumption by maximising probability of traversing signalized intersections without stopping at red lights;
  - Minimise deviations from schedules.







Conclusions

- Current prioritisation and PT control strategies are not jointly optimised. Clear opportunities for improvement discussed.
- Existing ITS support not sufficient. However, emerging cooperative ITS systems offer tools to support PT systems in real-time operations towards a fully integrated approach.
- We showed how cooperative ITS strategies can be used to support PT operations and reduced unneeded stops.
- Future e-mobility will bring additional complexities, i.e. where and when to charge, how to extend operational range in electric, how to deal with a mix of bus types,...
- A new project eCoBus will address some of the above additional complexities.

Thank you !

Src: http://www.williebus.com

Questions?

Visit http://mobilab.lu
http://ecobus.lu (coming soon!)