Vehicle-Infrastructure Communication for Traffic Management

Meng Lu, Dynniq Nederland B.V. The Netherlands

Twinning workshop: TransAID and US CAMP projects
25 July 2019, CAMP LLC, Farmington Hills, MI
Nettenbouw was founded by H. Keyser.

- 1936: Nettenbouw was responsible for the first sodium lighting in the Netherlands.
- 1970: Traffic related activities were added.
- 1972-1973: Internatio acquired full ownership of the company.
- 1993: Founding Intech.
- 1997: The acquisition of WPS added parking to the solution portfolio whilst extending the geography to the USA and Canada.
- 2004: Intech Traffic & Infra expanded its activities into Belgium.
- 2007: Acquired YSP and SSR to develop a stronger position in Scandinavia.
- 2010-2012: The company was acquired by private equity company Egeria.
- 2015: Dynniq, energising mobility.
Dynniq footprint

### Dynniq footprint

**Dynniq footprint**

**UNIQUE in Energising Mobility**

**as Market Leader or in Strong Position**

<table>
<thead>
<tr>
<th>Position</th>
<th>Market Leader</th>
<th>Controllers maintenance</th>
<th>The Netherlands, with 600 Employees and being Dynniq’s home country, is playing a key-role while leading the world into a promising and bright Future.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 2</td>
<td>Highway management</td>
<td>Employees ± 1,800</td>
<td>Employees ± 1,800</td>
</tr>
<tr>
<td>No. 2</td>
<td>Urban traffic controllers</td>
<td>Around the world market shares grow. Sustainable profitability growth</td>
<td>Around the world market shares grow. Sustainable profitability growth</td>
</tr>
<tr>
<td>20%</td>
<td>Public lighting columns</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Strong Market Position mission critical connectivity in Belgium**

<table>
<thead>
<tr>
<th>UK/Ireland</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Market Leader SCOOT</td>
</tr>
<tr>
<td>- 35% market share in supply and installing TLCs</td>
</tr>
<tr>
<td>- 35% market share in supply and installing signal heads</td>
</tr>
</tbody>
</table>

**Finland:** Market Leader infra control and main contractor on largest ongoing motorway projects

- > 7,500,000 parking visits handled each month by WPS worldwide

**Market Leader:**

- Brazil

**Top 3 position:**

- Netherlands, Belgium, UK/Ireland

**Netherlands**

- Knowledge & execution partner first public direct current networks
- 1,000,000 kilometres underground cable accommodated in 2016
- 60% of light rail traction
- Middle voltage/High voltage automated (sub)stations design & construct

**UNIQUE in Energising Mobility**

**as Market Leader or in Strong Position**

- Employees ± 1,800

**Around the world market shares grow. Sustainable profitability growth**

**Position**

- Market Leader
- No. 2
- No. 2
- 20%
Managing Automated Vehicles Enhances Network

- Management regimes for automated driving in urban areas
  - increase safety with collective perception (alternative: very slow driving)
  - increase efficiency by exploiting possibilities of automated driving
- Monitoring, support and orchestration of movements of road users to guide vehicles at signalised intersections
- Further enhancement for ADAS and C-ITS applications
MAVEN use cases overview

- **I2V interactions**
  - ✓ V2I “explicit” probing + I2V speed/lane advisory + V2I feedbacks on compliance to advisories

- **Traffic controllers optimization**
  - ✓ Signal optimization, priority management, queue estimation, green wave

- **Platoon management**
  - ✓ Forming, joining, travelling in, leaving, breaking a platoon

- **Inclusion of conventional traffic and VRUs**
  - ✓ Detection/reaction in presence of non-coop cars & VRUs

MAVEN is funded by the EC Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727
## Use cases and new data elements

### Managing Automated Vehicles Enhances Network

<table>
<thead>
<tr>
<th>Cluster/platoon phases</th>
<th>Movement</th>
<th>Flow optimisation</th>
<th>Disruptive</th>
</tr>
</thead>
<tbody>
<tr>
<td>initialisation</td>
<td></td>
<td></td>
<td>priority</td>
</tr>
<tr>
<td>joining</td>
<td></td>
<td></td>
<td>queue length estimation</td>
</tr>
<tr>
<td>travelling</td>
<td></td>
<td></td>
<td>local routing</td>
</tr>
<tr>
<td>leaving</td>
<td></td>
<td></td>
<td>network coordination</td>
</tr>
<tr>
<td>break-up</td>
<td></td>
<td></td>
<td>signal optimisation</td>
</tr>
<tr>
<td>termination</td>
<td></td>
<td></td>
<td>intersection negotiation</td>
</tr>
<tr>
<td>speed change advisory</td>
<td></td>
<td>priority</td>
<td>non-cooperation</td>
</tr>
<tr>
<td>lane change advisory</td>
<td></td>
<td>queue length estimation</td>
<td>emergency situations</td>
</tr>
</tbody>
</table>

### New data element

<table>
<thead>
<tr>
<th>New data element</th>
<th>Applicable scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of occupants</td>
<td>Intersection priority management.</td>
</tr>
<tr>
<td>Distance to following vehicle</td>
<td>Queue estimation. This information can improve queue model accuracy, leading to more optimal solutions for GLOSA negotiation and signal timing</td>
</tr>
<tr>
<td>Distance to preceding vehicle</td>
<td></td>
</tr>
<tr>
<td>Plaotuning state</td>
<td>Signal optimization and intersection priority</td>
</tr>
<tr>
<td>Desired speed</td>
<td>Queue estimation and GLOSA negotiation</td>
</tr>
<tr>
<td>Current lane</td>
<td>Lane advice, multiple lanes for a certain direction</td>
</tr>
<tr>
<td>Route information</td>
<td>Queue estimation, signal optimization and GLOSA</td>
</tr>
</tbody>
</table>

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Message sets

Managing Automated Vehicles Enhances Network

- Extended CAM (Cooperative Awareness Message) for automation and negotiation
- Profiled MAP/SPaT for lane specific GLOSA
- New LAM (Lane Advice Message)
- Extension to CPM (Collective Perception Message)
  - RSU detections can be included
  - possibility to link to MAP message topology for efficiency

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Queue modelling - data fusion

Managing Automated Vehicles Enhances Network

- Automated vehicles have more data available
  - intended turn direction (6% better traffic efficiency)
  - desired speed
  - number of occupants (priority input)
  - compliance to advice

- Information enabled more accurate queue modelling

- Direct positive effect on several MAVEN systems
  - lane advice
  - signal optimization
  - route advice
  - speed advice

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AGLOSA

Agent-Aware Green Light Optimal Speed Advice

- Combination of vehicle-actuated control and GLOSA
- bi-directional communication
- Possible detection, e.g.
  - V2X communication
  - video capturing
  - laser scanning
  - wireless in-road detectors
  - loop detectors

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Green wave

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ImFlow BL</td>
<td>Current adaptive traffic plan in operation</td>
</tr>
<tr>
<td>ImFlow SA</td>
<td>Current adaptive traffic plan with speed advice, 23km/hr and 18km/hr between intersection 101 and 102</td>
</tr>
<tr>
<td>Static BL</td>
<td>Static traffic plan with no speed advice</td>
</tr>
<tr>
<td>Static SA</td>
<td>Static traffic plan with speed advice, 23km/hr and 18km/hr between intersection 101 and 102</td>
</tr>
</tbody>
</table>

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Traffic signal control methods

- **Static control / Fixed-time control**
  - based on a fixed time control plan
  - switching can occur between a configured min/max time

- **Actuated control**

- **Semi-fixed time control**
  - based on a fixed time control plan
  - switching can occur between a configured min/max time

- **Adaptive control**

- **Enhanced adaptive control**

### Table: Scenario Comparison

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Impact(s)</th>
<th>Delay(s)</th>
<th>Stops</th>
<th>GLOSA(%)</th>
<th>MSE(s²)</th>
<th>MRE(%)</th>
<th>PC(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>43.2</td>
<td>36.7</td>
<td>0.81</td>
<td>25</td>
<td>0</td>
<td>2.35</td>
<td>0.91</td>
</tr>
<tr>
<td>Semi-fixed</td>
<td>37.4</td>
<td>31.0</td>
<td>0.80</td>
<td>27</td>
<td>62</td>
<td>41.89</td>
<td>3.82</td>
</tr>
<tr>
<td>Actuated</td>
<td>36.3</td>
<td>29.6</td>
<td>0.84</td>
<td>19</td>
<td>182</td>
<td>84.67</td>
<td>7.62</td>
</tr>
<tr>
<td>Stabilized50</td>
<td>35.6</td>
<td>29.7</td>
<td>0.73</td>
<td>51</td>
<td>22</td>
<td>7.95</td>
<td>2.66</td>
</tr>
<tr>
<td>Stabilized</td>
<td>32.7</td>
<td>27.0</td>
<td>0.71</td>
<td>53</td>
<td>17</td>
<td>15.01</td>
<td>3.52</td>
</tr>
<tr>
<td>Adaptive</td>
<td>32.7</td>
<td>27.0</td>
<td>0.72</td>
<td>46</td>
<td>46</td>
<td>25.86</td>
<td>5.76</td>
</tr>
<tr>
<td>AdaptiveNG</td>
<td>33.7</td>
<td>27.0</td>
<td>0.83</td>
<td>6</td>
<td>47</td>
<td>26.90</td>
<td>5.54</td>
</tr>
</tbody>
</table>
Enhanced/Stabilised adaptive control

Plan stabilisation for adaptive control

- **Problem definition**
  - classic green wave only works with fixed time control; adaptive control can offer green wave based on high priorities for specific traffic; both approaches result in increased delay for all other traffic; traditional actuated or adaptive control is too unpredictable for a green wave or speed advice

- **Dynniq solution**
  - increase stability of adaptive control plan; give speed advice and show countdown at large distance to bicycles; limited extra delay for other traffic; high success rate for green wave
Greenwave results

Plan stabilisation for adaptive control

- Speed indication at long distance

- Plan stabilisation in ImFlow

For more information, see: http://maven-its.eu/ www.xcycle-h2020.eu/
Use cases (examples)

TransAID - Transition Areas for Infrastructure-Assisted Driving

- Roadworks/ bus lane usage
- Motorway merging
- No automation zone, TOC (Transition of Control) spread
Ramp metering: perception area

TransAID - Transition Areas for Infrastructure-Assisted Driving

- New ramp metering algorithm
- New C-ITS application to assist safe merging at on-ramp
- Modelling tools for simulation of motorway on-ramp situations
- Extended message sets for providing advice for traffic merging situations to cooperative and automated vehicles
Ramp metering: scenario
Ramp metering: interactions

TransAID - Transition Areas for Infrastructure-Assisted Driving

- Non-cooperative vehicles
  - monitor at entry detector and with the tracking camera
  - turn ramp meter to green near gaps

- Cooperative vehicles
  - CAM (Cooperative Awareness Message) gives regular speed and position update
  - possibility to send lane and speed advice with app

- Automated vehicles
  - report distance to leader vehicle
  - more precise instructions
Ramp metering: algorithm and result

TransAID - Transition Areas for Infrastructure-Assisted Driving

- **Restrict return to rightmost lane**
  - more space for merging
  - increase model accuracy

- **Speed advice**
  - find first acceptable gap for vehicle when entering on-ramp

- **Transition of control fallback**
  - as soon as possible conclude whether merge is possible
  - more time for human driver to adjust

- **Create gap with another cooperative or automated vehicle**

- **Turn on ramp meter**
Recent results - summary
Vehicle-Infrastructure Communication for Traffic Management

- At low traffic required ToC (Transitions of Control) dropped from 50% to 4%
- Higher traffic volume also demonstrated improvement from 90% to 54%
- Baseline model clearly needed improvement for more realistic merging behaviour, especially in high traffic scenarios
- Number of stops also reduced significantly by up to 87% and a CO₂ reduction of up to 7%
- High traffic volume scenarios are expected to improve further with main road speed advice and ramp metering
- The final goal is to have no stops at all at a saturation flow that is higher than with only human drivers in the network
References

Vehicle-Infrastructure Communication for Traffic Management

Thank you for your attention.

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