Development of Network Signal Timing Methodology in SIDRA INTERSECTION

Direct Elements of Network Signal Timing

- Lane-based platoon model (using signal offsets)
- Network Cycle Time and Site Phase Time calculations
- Offset calculations (Route based)
- Common Control Groups
Development of Network Signal Timing Methodology in SIDRA INTERSECTION

- **PLATOON MODEL**
  - Lane-based model
  - Platoons by Movement Class (Special MCs for downstream turning movements)
  - Second-by-second arrival and departure patterns
  - Platoon dispersion
  - Output: Percent Arriving During Green, Platoon Ratio, Arrival Types
Indirect Aspects of the Network Model

- **Lane Blockage**  
  (upstream saturation flow rates are reduced)

- **Capacity Constraint**  
  (downstream arrival flow rates are reduced)

- **Lane Movements at intersections**

- **Midblock lane changes**
Version 6.0 released in April 2013 and improved significantly after release.

Biggest changes in the 30-year history of the software
- Network Model
- Movement Classes

Version 6.1 released in Feb 2015

Version 7.0 expected to be released during late 2015 / early 2016

Over 7700 Licences (1836 Organisations) in 84 Countries
SIDRA INTERSECTION recent developments related to Network Signal Timing (Versions 6.1 and 7)

Version 6.1

• New model for signal coordination effects using SIGNAL OFFSETS and lane-based second-by-second platoon patterns including lane changes and platoon dispersion

Version 7

• Network CYCLE TIME calculations
• SIGNAL OFFSET calculations
• Common Control Groups (multiple Sites controlled by a single controller)
• ROUTES for signal Offset calculations
• More User Movement Classes
Lane-based model for intersections

**LANE-BASED MODEL**

More realistic and reliable analysis compared with approach-based and lane group (link) - based methods (various UK models and US HCM).

- **General**: Unequal lane flows, de facto exclusive lanes, short lanes, slip/bypass lanes (give-way/yield, continuous, signals).
- **Roundabouts**: Circulating lane use; Dominant and subdominant lanes.
- **NETWORK Model** (lane queues, lane blockage, signal platoon arrival and departure patterns).

- Individual lanes have different characteristics
- Try defining “links” and “lane groups”!
- Short lane analysis (flaring)
- Slip / Bypass lanes
Movement Classes

Combined with the lane-based method, new Movement Classes allow modeling of Bus Priority Lanes, Bicycle Lanes, and so on ...

Site Origin-Destination Movements by Movement Class as a basis of all data and modelling

- Light Vehicles
- Heavy Vehicles
- Buses
- Bicycles
- Large Trucks
- Light Rail / Trams
- Two User Classes for special treatment
SIDRA NETWORK Model

Unique lane-based NETWORK model

All intersection types (signals, roundabouts, sign control)

Paired Intersections

Easy to CONFIGURE SIDRA INTERSECTION Sites

Easy to compare a large number of scenarios quickly.
Lane-based model for NETWORKS

LANE MOVEMENTS

Approach lane number

Lane Movement: South Lane 1 to West Lane 2

Exit lane number

Origin – Destination (OD) Movements

OD Mov. S-E

OD Mov. E-W

OD Mov. E-S
Departure patterns at upstream lanes

Backward spread of congestion (reduced upstream capacity)  

Capacity constraint (reduced downstream arrival flows)

Backward spread of congestion and capacity constraint are highly interactive with opposing effects.

SIDRA INTERSECTION uses a network-wide iterative process to find a solution that balances these opposing effects.
Lane-based Model for Networks

Departure patterns per lane are split by OD movements and by Movement Classes

Platoons move to downstream intersection

Midblock lane changes

- Exit Short Lane flows merge into adjacent lanes
- Net Inflows allocated to available lanes equally and as uniform patterns
- Net Outflows reduced from midblock patterns in all lanes proportionally
- Midblock lane changes for upstream flow rates to match downstream approach lane flow rates according to OD-MC movements and lane disciplines
- Arrival flows diverge to Approach Short Lanes

Figures in next two slides
Midblock Lane Changes

Second-by-second platoon patterns move accordingly.
Lane-based model for NETWORKS

Example with Net Inflow

Second-by-second platoon patterns move accordingly

- Upstream flow rates at entry to the approach
  - Total upstream flow rate at entry = 800

- Upstream flow rates at midblock virtual connection
  - Midblock net inflow rate = 100

- Downstream flow rates at the approach stop line
  - Total arrival flow rate = 900

- Upstream lane flow rates after short lane
- Upstream lane flow rates at midblock connection adjusted for inflow
  - Lane change = 550 - 450 = 100

- Approach lane flow rates
Modelling of departure patterns at upstream lanes takes into account

- **capacity reduction due to lane blockage** by downstream queues (reduced saturation flow rates affect required movement times)
- **reduced arrival flows** at downstream lanes due to capacity constraint at oversaturated upstream lanes
- **lane movement flow proportions** (these determine exit lane flow rates).
The modelling of PLATOON ARRIVAL PATTERNS at downstream approach lanes takes into account:

- **Platoon Dispersion**
- **Midblock LANE CHANGES** based on matching of upstream and downstream lane flow rates. These are different from lane changes for entry into short lanes included in the model.
- Any midblock inflow and outflow rates (including uniform arrival flow patterns for inflow) implied by turning volume specifications are also taken into account.
- **Movement Classes** (Light vehicles, Heavy Vehicles, Buses, Large Trucks, etc.) due to different lane use and approach cruise speeds.

The model improves assessment of signal coordination quality and optimisation of signal offsets.
The second-by-second arrival patterns determined by the program as a function of signal offsets are used to calculate Percent Arriving During Green, $P_G$ and Platoon Ratio, $P_A$ for each approach lane for use in performance calculations.
Platoon Dispersion Model

No platoon dispersion in short distances ...

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{pf}$</td>
<td>0.80</td>
<td>0.50 - 1.50</td>
</tr>
<tr>
<td>$f_{pmin}$</td>
<td>1.00</td>
<td>1.00 - 1.50</td>
</tr>
<tr>
<td>$f_{pmax}$</td>
<td>1.25</td>
<td>1.00 - 2.00</td>
</tr>
<tr>
<td>$L_{min}$ (m / ft)</td>
<td>60 m</td>
<td>0 - 200 m</td>
</tr>
<tr>
<td>$L_{max}$ (m / ft)</td>
<td>300 m</td>
<td>100 m - 2000 m</td>
</tr>
</tbody>
</table>

Maximum platoon dispersion occurs at distance $L_{max}$. A platoon factor of $f_p = 1.25$ means a 1.25 increase in platoon time length.
NETWORK SIGNAL TIMING - OFFSETS

SIGNAL OFFSETS

Offset Definition: Phase Start
Reference Site / CGG 3-E [Signal 1 Intersection (East)]
Cycle Time (sec): 100

Signal Offsets
- Site ID: 3-E
- CGG ID (if applicable): NA
- Offset (sec): 0
- Program / User: P
- Reference Phase: B
- Route ID: 1

Route Offset Calculation Results
- Route ID: 1
- Route Name: WB Through
- Offset Priority: 1
- Offset Method: Start of Green (Leading)
- Movement Class: Light Vehicles

Route Layout
- Route: 1 [WB Through]
Analysis of closely-spaced intersections can be enhanced by using **SPECIAL MOVEMENT CLASSES** based on **User Classes** in SIDRA INTERSECTION.

When the Network OD flows are known, external approach movements that continue as turning movements on internal approaches can be treated as **Special Movement Classes**.

These movements can then be assigned to upstream and downstream lanes according to their downstream destinations. This was found to improve the lane-based modelling of second-by-second platoon patterns further.
**Common Control Groups**

**Common Control Group (CCG)** is used for Sites that form a group of signals controlled by a single signal controller.

This is relevant to the modelling of **paired (closely-spaced) intersections** such as staggered T intersections, freeway interchanges, intersections with median storage and fully signalised roundabouts.

All Sites in a Common Control Group will have the **same phase sequence with same Phase Times**, and there will be a **single Offset** relevant to the group.
Network Example: Freeway Diamond Interchange

Through traffic in different lanes have different destinations downstream

Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements

Common Control Group

Doncaster Road - Eastern Freeway, Melbourne
Network Examples: Diverging Diamond Interchange

Diverging Diamond Interchange

Through traffic in different lanes have different destinations downstream

Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements

Templates will be available

Common Control Group
Network Example: Fully Signalised Roundabout

Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements

Through traffic in different lanes have different destinations downstream

Network Displays

Common Control Group

Cemetery Road East - Swanston Street, Melbourne
Network Example: Staggered T intersections

ARRB Conference 2014 paper

A detailed example is presented using various analysis scenarios to investigate basic aspects of the lane-based network model in relation to signal platooning.

Staggered T intersections with 180 m distance between them.

Detailed description is presented in the ARRB Conference 2014 paper (available for download on www.sidrasolutions.com/Resources/Articles).
Network OD flows that match the Site OD flows perfectly are used for analysing differences between analysis scenarios with and without knowledge of Network OD flows.

The analysis scenarios are used to investigate the differences between signal platooning and the resulting performance estimates according to the assumptions about approach lane use and exit lanes chosen in departing from an intersection.

The differences between the analysis scenarios are identified according to differences in midblock lane change implications for internal approach lanes.
Analysis Scenario (i) with Special Movement Classes

- Network OD flows are known in addition to the Site OD flows.
- Lane Movement Flow Proportions for Site 1 West Right and Site 2 East Right movements are specified based on known Network OD flows.
- Equal lane use for all Through approach lanes. This results in implied midblock lane changes.
### Comparison of results for Through LANES on Site 1 South internal (Northbound) approach

<table>
<thead>
<tr>
<th>Approach Lane</th>
<th>Arrival Flow (veh/h)</th>
<th>Capacity (veh/h)</th>
<th>Degree of Saturation (v / c)</th>
<th>Per cent Arriving During Green (%)</th>
<th>Platoon Ratio</th>
<th>Average Delay (s)</th>
<th>95th %ile Back of Queue (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis Scenario (i) with Special Movement Classes for downstream turns</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Lane 2</td>
<td>635</td>
<td>988</td>
<td>0.643</td>
<td>86.5%</td>
<td>1.664</td>
<td>5.2</td>
<td>65</td>
</tr>
<tr>
<td>Lane 3</td>
<td>635</td>
<td>988</td>
<td>0.643</td>
<td>75.8%</td>
<td>1.457</td>
<td>10.7</td>
<td>102</td>
</tr>
<tr>
<td>Analysis Scenario (ii) without Special Movement Classes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Lane 2</td>
<td>635</td>
<td>988</td>
<td>0.643</td>
<td>68.0%</td>
<td>1.227</td>
<td>16.0</td>
<td>132</td>
</tr>
<tr>
<td>Lane 3</td>
<td>635</td>
<td>988</td>
<td>0.643</td>
<td>75.8%</td>
<td>1.457</td>
<td>10.7</td>
<td>102</td>
</tr>
</tbody>
</table>
Concluding Remarks

The Lane-based platoon model used in SIDRA INTERSECTION differs from the use of "links" or "lane groups" in traditional network models.

The new lane-based method derives second-by-second downstream lane arrival patterns from upstream lane departure patterns with midblock lane changes.

In the traditional network models using links or lane groups:

- individual lane conditions are aggregated
- insufficient information about queue lengths, lane blockage probabilities, backward spread of queues, and so on as these need lane level of detail.
A complete LANE-BASED model with

- lane-based input
- lane-based capacity and performance calculations, and
- lane-based output

as used in SIDRA INTERSECTION is particularly important in evaluating

- closely-spaced intersections
- high demand flows
- cases where vehicles have limited opportunities for lane changing between intersections.
Thank you!

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