Real-time Big-Data Management Architecture for Adaptive Traffic Signal Control

Presented by

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Agenda

- Background
- Big-Data Challenge
- System Development
- Implementation and Application
Background

- Adaptive Control in a Nutshell
  - The years of 1903, 1912, 1914, 1917, 1918
  - The 1920’s-1930’s witnessed introduction of fixed-time control and later actuated signal control
  - Major paradigm shift in the 1950’s – 1960’s
  - Adaptive signal control, concepts, systems, and implementation
Background cont’d

- Sources of “big data” for real-time control
  - Conventional data collected at higher resolution
  - Cost-effective technology enables previously prohibitive data
  - Data originally intended for other domain application
  - Controller status, and log data
  - High-resolution event-based data
  - Low-cost traffic sensor network, with high-bandwidth communication
  - Crowd-sourced data
System Context

Real World Infrastructure
- Other Multi-Source Data
- Traffic Sensors (Detection)
- NTCEP-compatible Controllers
  - Adapative Control Object (Cycle, Offset and Split)
  - Controller Status Object

Traffic Management Center Communication Layer
- IP Network

Central Traffic Management System (e.g., TransSuite TCS)

Adaptive Control Web Service Interface
- High-level Interface for Data and Control
- SOAP/HTTP (Web Service Protocol) Data/Control

ACDSS - System Kernel
- Data Processing Engine
- Signal Optimization Engine

Multi-Source Data Fusion and Management
- Detection Data
- Signal Status Data
- System Log Data
- GPS/ANR/AWAN Data
- Crowd-Sourced Data
- Real-time Database
  - In-Memory
  - On Disk

Operator Interface

Operator Terminals

Arterial Progression
Queue Management
Congestion Management
Grid Network Control
Diamond Interchange
Script-based Algorithm

Intranet...

University Transportation Research Center
Big Data Challenges

- **Acquire** - Acquiring multi-source data (AWAM, RFID, traffic sensor data, controller status data etc.) involves accessing various data sources and retrieving the data using appropriate protocols.

- **Integrate and Organize** - Heterogeneity in data formats, the different data transmission protocols, and the fact that new types of data keeps emerging.

- **Analyze and Action** – Historical and real-time time series analysis and low-latency action.
Acquisition of Data

- Data source that publishes data in XML format via a public accessible HTTP URL (AWAM data, and other XML-based data);
- Data source that publishes data using Telnet protocol (RFID data);
- Data source that publishes data using the ACDSS Adaptive Control Web Service Interface (detector data, controller status data);
Integration, Analysis and Action

Acquisition of Multi-Source Data
- Adaptive Control Web Service
  - Detector/Controller Data
- XML Data Feeds
  - Bluetooth/AWAM Data
- Telnet Data Feeds
  - RFID Data

Unified Data Fetcher Interface for Acquiring Multi-Source Data

Integration of Multi-Source Data
- Real-time Database
  - In-Memory
  - On Disk
- Database Tables/Records

Unified Interface for Accessing the Real-time and Historical Data

Analyze and Action
- ACDSS - System Kernel
  - Data Processing Engine
  - Signal Optimization Engine

Signal Optimization Algorithm Repository

Optimized Control Decisions
Data Fetcher Service

Web Service Server URL:
https://example.com/services/adaptive_if

Web Service Login Settings:
- Web Service Proxy IP and Port: 127.0.0.1:8085
- Use local embedded ACI web service proxy

ACI SystemID: [Enter value]
ACI OperatorID: [Enter value]

Web Service Data Pooling Intervals:
- Sensor Pooling (sec): 20
- Controller Pooling (sec): 5
Implementation and Sample Applications
Victory Blvd. – Staten Island
New York City

- Dense grid network
- >12000 intersections
- > 300 under real-time control
- Oversaturated
- > 500 RTMS sensors
- > 100 roadside EZ-Pass tag readers collecting large-scale per-trip travel time data (4.5 million records daily), from 8 million commuters
Big-Data for Real-time Control

Level 1 – Strategic Area Wide Control
- Implemented by avenues
- Rebalance traffic being delivered to the target control area
- Real-time selection from a library of pre-designed congestion management plans

Level 2 – Tactical Control
- Implemented at critical intersections
- Complimentary to Level 1 with splits dynamically optimized
- Balance queuing and minimize the gridlock potential
Travel Time

- Per-trip travel times are processed and analyzed, to derive measure of congestion levels
Level 1 Control

- Trigger conditions based on real-time travel time data

<table>
<thead>
<tr>
<th>Travel Time</th>
<th>Area Wide Control Plan</th>
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<tbody>
<tr>
<td>2 Stops</td>
<td>Network Balancing Plan (NBP)</td>
</tr>
<tr>
<td>3 Stops</td>
<td>Access Control 1 (AC1)</td>
</tr>
<tr>
<td>3+ Stops</td>
<td>Access Control 2 (AC2)</td>
</tr>
</tbody>
</table>

- NBP – Simultaneous offset, minimal green tapering
- AC1 – Simultaneous offset, increased green tapering
- AC2 – Simultaneous offset, higher green tapering
Level 2 Control

- Robust queue control at critical intersections

- A local congestion index called Severity Index (SI) is derived from flow/occupancy

- Splits are dynamically optimized to minimize the grid lock potential

<table>
<thead>
<tr>
<th>SI</th>
<th>Condition</th>
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<tbody>
<tr>
<td>1</td>
<td>Q &lt; L/3</td>
</tr>
<tr>
<td>2</td>
<td>L/3 &lt; Q &lt; 2L/3</td>
</tr>
<tr>
<td>3</td>
<td>2L/3 &lt; Q &lt; 3L/4</td>
</tr>
<tr>
<td>4</td>
<td>Q &gt; 3L/4</td>
</tr>
</tbody>
</table>
Thank you