Next Generation
Bus Signal Priority

Ed Alegre, PTP
Los Angeles County Metropolitan Transportation Authority
(LA Metro)
Program Background
Los Angeles Region

- 4,083 square miles
- 88 incorporated cities and unincorporated County areas
- Over 10,000 signalized intersections
- Diverse traffic control environment
- Other municipalities providing fixed route bus service
- Nearly 3,000 buses in service daily
Pilot Demonstration

* Crenshaw Boulevard
  * Smart-Bus and Wireless Communications
  * $4.3 Million
  * 10.5 miles
  * 51 signal priority equipped intersections

* Partners
  * Cities of Los Angeles, Gardena, Hawthorne, Inglewood, County of Los Angeles
Expansion of Metro Rapid Corridors Phase II:

- Atlantic
  - 25 Miles/128 Intersections /14 Jurisdictions

- Garvey-Chavez
  - 10.7 Miles / 52 Intersections / 4 Jurisdictions

- Manchester
  - 7.8 Miles / 45 Intersections / 3 Jurisdictions

Expansion of Metro Rapid Corridors Phase I:

- Long Beach Boulevard Line 760
  - 11.3 Miles / 59 Intersections / 6 Jurisdictions

- Florence Avenue Line 711
  - 7.6 Miles / 41 Intersections / 5 Jurisdictions

- Hawthorne Boulevard Line 740
  - 7.7 Miles / 39 Intersections / 5 Jurisdictions
CSP Expansion

- Foothill Transit (Line 187)
  - 42 intersections
  - 5 partners (Azusa, Arcadia, Duarte, Monrovia, Pasadena)

- Torrance Transit (Route 3)
  - 80 intersections
  - 5 partners (County of LA, Long Beach, Carson, City of LA, Torrance)
CSP Expansion

* Culver City Bus (Systemwide)
  * 103 intersections
* Gardena Transit - GTrans (Line 1)
  * 26 intersections
* Metro Rapid (Line 740)
  * 25 intersections in Pasadena
  * Conversion from loop and transponder to wireless
Current CSP Architecture and Technology
“Smart Bus” Approach

* On-Bus Hardware
  * On-Board Computer
    * Automated
    * Real-time vehicle location information (GPS)
    * Wireless radio transmitting priority request
      * 2.4Ghz spread spectrum
Wireless Communications

* Communication Infrastructure
  * IEEE 802.11b (Wi-Fi) Wireless local area network (WLAN)
  * Access Points
  * Bridges
  * Clients
Traffic Signal Interface

- Signal Control Hardware
  - 170E, 170ATC/HC11, 2070, ASC/2, ASC/3

- Signal Firmware
  - BiTran/McCain, Econolite, LA County (LACO-4), City of LA 2070, D4 (future)
Traffic Signal Timing Modifications

- Green Extension
  - Typically 8-10 seconds
  - Up to 10 percent of the cycle time
  - Typically not on back-to-back cycles
- Early Green
  - Typically 8-10 seconds
CSP System Architecture

Legend
- CAD/AVL: Computer-Aided Dispatch/Automatic Vehicle Location
- DTGP: Decision to Grant Priority
- DTRP: Decision to Request Priority
- MGR: Mobile Gateway Router
- OBU: On-Board Unit
- TOC: Transit Operations Center
- WLAN: Wireless Local Area Network

Signal Cabinet
- Wi-Fi Antenna
- 802.11 Radio
- Terminal Server
- Signal Controller
- DTGP

Bus
- Wi-Fi Antenna
- GPS Antenna
- 802.11 Radio
- BSP OBU
- DTRP
- CAD/AVL
- 508 MHz Data Radio

CSP WLAN

Agency-Owned 508 MHz Data Radio System
- TOC
- CAD
- Data Radio Antenna
Why Next Generation technologies?
Upgrades to Metro Buses

* Metro’s Advanced Transportation Management System (ATMS) Update
  * includes integration of transit signal priority
* Metro’s Bus and Rail Fleet Systems Strategic Plan
  * Mobile Gateway Router
Upgrades to CSP Network and Monitoring

* Migrate Central BSP Network to the Cloud
  * Phase 1 – Existing Network Improvements – Clean-up
  * Phase 2 – Cloud Infrastructure Setup – BSP Database
  * Phase 3 – Cloud Reporting Implementation – Remote Client Access for Metro, Torrance Transit, and Culver CityBus; Reporting Web Server
  * Phase 4 – BSP Web Service – Receive Request/DTGP Data
* Enhance the Cloud Reporting Software
New Central BSP Network

**Phase I**
- Internal and Field IP Re-Configuration
  - Field Terminal Servers
  - DCB Tunnel
  - Firewalls
  - New Router @ Iteris

**Phase II**
- Metro CSP Database (Legacy)
  - CSP Data Processor (Legacy)
    - Receive Request/DTGP Data
    - Insert into Database (AWS)
  - BSP Database
    - Most Recent (by bus/intersection)
    - Archive
    - Intersection (GPS/City/Int Code)

**Phase III**
- Reporting Web Server
  - CSP Analysis Reporting Web Server
    - User account
    - Reporting

**Phase IV**
- CSP Web Service
  - BSP Web Service (Data Processor)
    - Receive Request/DTGP Data
    - Insert into Database
    - Request Gateway (FUTURE)

**Future Deployment**
- BSP Request Messages
- BSP DTGP Messages
- Field BSP Networks
- Legacy – VPN Tunnel

**Legend**
- BSP Network
- BSP Field Network
- Iteris Enterprise Network
- Leased Services
- Local Transport

**Remote Users**
- Metro
- Torrance Transit
- Culver CityBus
- Foothill Transit
- Gardena (Future)

**Field**
- Cellular Modem
- DCB Tunnel
- Router

**Division**
- Cellular Modem
- DCB Tunnel

**Network**
- Field BSP Networks
- No VPN Tunnel

**City of Culver CityBus Monitor**
- BSP Data Processor
- Receive DTGP Data
- Mirror to Metro CSP Database
- Insert into Database
Next Generation BSP Study

- Original CSP architecture was developed and deployed over 15 years ago.
  - What other types of signal priority is being deployed nationwide?
  - Evaluate existing CSP approach
  - Evaluate new technologies that have advanced in the past few years
  - How we should evolve signal priority in the region?
Nationwide Evaluation of Current BSP Practices

* TriMet – Portland, OR
* AC Transit – East Bay, CA
* King County Metro – Seattle, WA
* Regional Transportation Authority (RTA) – Chicago, IL
* Metropolitan Transportation Authority (MTA) – New York, NY
* Los Angeles Department of Transportation (LADOT) – Los Angeles, CA
### Nationwide Evaluation of Current BSP Practices

<table>
<thead>
<tr>
<th>Attributes</th>
<th>TriMet (Portland)</th>
<th>AC Transit (East Bay)</th>
<th>King County Metro (Seattle)</th>
<th>RTA (Chicago)</th>
<th>MTA (New York)</th>
<th>LADOT (City of Los Angeles)</th>
<th>Metro CSP (Los Angeles County)</th>
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<tbody>
<tr>
<td><strong>System Design</strong></td>
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<tr>
<td>BSP Architecture:</td>
<td>Distributed, on-bus/intersection hybrid</td>
<td>Distributed, on-bus priority request</td>
<td>Distributed, off-vehicle priority logic</td>
<td>Distributed, on-bus priority request</td>
<td>Centralized, TMC priority request</td>
<td>Centralized, TMC priority request</td>
<td>Distributed, on-bus priority request</td>
</tr>
<tr>
<td>Wireless Comm. Technology:</td>
<td>Proprietary (Opticom IR)</td>
<td>Proprietary (Opticom GPS 2.4 GHz)</td>
<td>Licensed WiFi (4.9 GHz Public Safety)</td>
<td>Unlicensed WiFi (5 GHz)</td>
<td>Commercial cellular (Verizon 3G/4G)</td>
<td>N/A (Presence Detection Loops)</td>
<td>Unlicensed WiFi (2.4 GHz)</td>
</tr>
<tr>
<td>Size/Scope of Deployment:</td>
<td>7 corridors 275 intersections</td>
<td>3 corridors 270 intersections</td>
<td>6 corridors 192 intersections</td>
<td>(In construction)</td>
<td>10 corridors 474 intersections</td>
<td>9 corridors 654 intersections</td>
<td>7 corridors 400 intersections</td>
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<td><strong>Capabilities</strong></td>
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<tr>
<td>Priority Treatments:</td>
<td>• Early green</td>
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<tr>
<td>Monitoring Capabilities</td>
<td>Controllers log BSP requests</td>
<td>Central CMS logs and reports on BSP requests</td>
<td>Controllers log BSP requests</td>
<td>Controllers log BSP requests and status</td>
<td>Central system logs BSP requests and status</td>
<td>Controllers log BSP requests and action taken (early green/green extend)</td>
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<tr>
<td>Measured Benefits</td>
<td>• 5-12% reduction in travel time</td>
<td>Not yet collected</td>
<td>• 25-34% reduction in travel time*</td>
<td>Not yet collected</td>
<td>14-18% reduction in travel time</td>
<td>• 8% reduction in travel time</td>
<td>• 4-8% reduction in travel time</td>
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<td></td>
<td></td>
<td></td>
<td>• 35% reduction in travel time variability*</td>
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<td>• 12% reduction in intersection delay</td>
<td>• 14% reduction in intersection delay</td>
</tr>
</tbody>
</table>
Existing CSP Assessment
SWOT Analysis

On-Bus computer is antiquated and lacks computing power for additional future functions.

Current CSP bus is standalone, proprietary, and not easily integrated into other bus systems.

On-Bus equipment has some aspects of CV design but lacks the necessary enhancements to take advantage of full CV functionality.

TSP processes are not necessarily optimal due to limited resources.

CSP System needs better monitoring of bus priority performance through measures of effectiveness (MOEs).

Bus equipment, installation, and maintenance costs are high for each BSP system deployed.

Communication uses an unreliable UDP protocol and unlicensed frequency.

The current network access points are no longer sold or supported by manufacturer.

Current BSP message is not NTCP compliant.

Network security uses a weak security WEP protocol. This is a limitation of the equipment currently in service.

While simple and cost effective, BSP Adhoc capability does not fit into future connectivity of CV, which requires network infrastructure.

The PRS does not determine order of multiple BSP requests based upon higher priority conditions.

Transit agencies must pay a license cost to the controller manufacturer for each intersection that runs the BSP software.

Proprietary solutions limit interoperability.

Smart bus technologies are tending toward technologies such as Connected Vehicle, and architectural choices can lock Metro into a proprietary and non-USDOT solution.

Deviating from USDOT standards can dry up funds and cause interoperability problems with other agencies.

The DSRC standard is moving toward adoption, eventually USDOT may mandate as large scale demo projects are completed.

Industry could force the USDOT to give up the dedicated 5.9 spectrum, disrupting DSRC work.

Vendors may not deliver open standard compliant equipment, locking the system into multiple proprietary solutions.

Proven technology, consistent performance from BSP, GPS and PRS.

Self contained PRS, communication with central TMC and ATMS not needed.

Expansion of the DPS system requires the opening of new corridors, which is a well established process.

Accurate but limited monitoring of the use of signal priority, request and service as logs are collected at the roadside and uploaded to central TMC.

Wireless LAN is fully IP addressable and expandable using common access points along the corridor.

Proven reliable with good range and configurable to overlie coverage and avoid dead spots.

Adhoc capability allows the CSP system to communicate without the need for network infrastructure, reducing costs.

Traffic signal priority is distributed and independent of signal system type, and therefore, interoperable.

Agreements with other agencies in place, making cross jurisdiction operations possible.

Consolidating TSP and AVL into a single subsystem can save development, and maintenance costs.

Experience with CSP distributed architecture allows better decisions and opportunities for Federal CV programs.

Better fleet management through designs that address MOEs and the data required.

The CSP System has implemented a type of V2I, which is part of CV, and in better position to implement CV in full.

Multi-service routers can replace the current antiquated 802.11b radio and allow for an upgrade path to licensed frequencies while backward compatible.

Advances in center-to-center equipment will allow more complex calculations in determining PRS and who gets priority where multiple transit vehicles approach an intersection at the same time.

Recent advancements in Adaptive Transit Signal Priority pave the way for improving performance and integration with Dynamic Passenger Information.
Existing CSP Assessment
Strengths

- Proven technologies
- Wireless LAN is fully IP addressable and expandable
- Signal Priority is distributed and independent of signal system type
- Agreements with other agencies, and architecture is used county-wide.
Existing CSP Assessment
Weaknesses

- Pilot system was deployed over 15 years ago
- Aging CSP technologies and equipment (on-bus)
- Monitoring of performance through MOE’s
- BSP message is not NTCIP compliant
- Proprietary solutions limit interoperability
Existing CSP Assessment Opportunities

- Consolidating TSP and AVL into a single system
  - Metro is upgrading its ATMS to incorporate TSP
- Implementation of CV technologies
- Upgrade equipment on-bus (i.e. routers)
  - Metro completed its Bus/Rail Strategic Plan and includes the roll-out of mobile gateway routers
- Center-to-center equipment
Existing CSP Assessment Threats

- DSRC as a standard
- What is going to happen with DSRC?
- Vendors may not deliver open standard complaint equipment, locking the system into multiple proprietary solutions
Concept Exploration

* Goals:
  * Reliability, speed, and value of bus service

* Needs:
  * Cost effective
  * Rapidly deployable
  * Scalable
  * Adaptable and functional with traffic signal control and transit system management
  * Advanced priority functions
  * Performance measurement and data analysis
  * Standardized communications and messages
  * Not dependent on a particular vendor
Concept Exploration

- Vehicle-to-Infrastructure (V2I) Connected Vehicle
- Vehicle-to-Infrastructure (V2I) Cellular to Isolated Signal
- Vehicle-to-Center (V2C) Cellular to Centralized TMC
- Center-to-Center (C2C) Fully Centralized TOC and TMC
- BSP-as-a-Service (BSPaaS) Cloud Application
Vehicle-to-Infrastructure (V2I) Connected Vehicle

- On-bus priority request logic
- Intersection-based priority granting logic

Legend:
- CAD/AVL: Computer-Aided Dispatch/Automatic Vehicle Location
- DTGP: Decision to Grant Priority
- DTRP: Decision to Request Priority
- DSRC: Dedicated Short-Range Comm.
- MGR: Mobile Gateway Router
- PC: Industrial PC (Running CV apps)
- SIM: Subscriber Identity Module
- TOC: Transit Operations Center
- VLU: Vehicle Logic Unit

1. Local intersection PC is required only if controller is not an Advanced Traffic Controller (ATC). If traffic agency has upgraded to ATC the B5P application and DTGP can reside on the controller.
2. DTGP functionality may reside on either PC or controller, depending on architecture.
Vehicle-to-Infrastructure (V2I) Cellular to Isolated Signal

- On-bus priority request logic
- Intersection-based priority granting logic
Vehicle-to-Center (V2C) Cellular to Centralized TMC

- On-bus priority request logic
- TMC-based priority granting logic
Center-to-Center (C2C) Fully Centralized TOC and TMC

- TOC-based priority request logic
- TMC-based priority granting logic
BSP-as-a-Service (BSPaaS)
Cloud Application

- Cloud-based priority request logic
- Cloud-based priority granting logic
# Next Gen BSP Evaluation Summary

<table>
<thead>
<tr>
<th>Concept</th>
<th>Priority Request Logic Location</th>
<th>Priority Granting Logic Location</th>
<th>Support for Advanced Priority Functions</th>
<th>Maturity of Technology</th>
<th>Compatibility with Existing System</th>
<th>Cost Effectiveness</th>
<th>Maintainability</th>
<th>Expansion Potential</th>
<th>Overall Assessment (Near-Term)</th>
<th>Overall Assessment (Long-Term)</th>
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<tbody>
<tr>
<td>1. V2I Connected Vehicle</td>
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<td>2. V2I Cellular to Isolated Signal</td>
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<td>3. V2C Cellular to Centralized TMC</td>
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<td>4. C2C Centralized TOC and TMC</td>
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<td>5. BSP-as-a-Service Cloud Native</td>
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Ratings key:
- 1 (low)
- 2 (low-mid)
- 3 (medium)
- 4 (mid-high)
- 5 (high)
How should CSP evolve in the LA Region?

- Operate, maintain, and improve on the existing CSP system
- Consider Piloting V2I Connected Vehicle Concept
  - Deploy pilot on a small municipal operator/line
- Assess Readiness and Pilot for BSP-as-a-Service
  - Prepare industry white paper
  - Full deployment may take years on Metro Rapid service, therefore, small pilot may be more desirable to test out architecture
Thank You!

Questions?

Contact
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