UNIVERSITY OF TEXAS ARLINGTON | DEPARTMENT OF CIVIL ENGINEERING

An open-source arterial performance monitoring system based on multiple traffic data sources

- ***High-resolution traffic signal events***
- ***Wi-Fi/Bluetooth***
- ***GPS trajectories***

Presenter: Pengfei (Taylor) Li, Ph.D., P.Eng.

Assistant professor in civil engineering at University of Texas Arlington

Self introduction

- **Highest Education:**
  - **Ph.D. in Civil Engineering from Virginia Tech**
- **Previous appointment:**
  - **Assistant Professor in Civil Engineering at Mississippi State University**
- **Current appointment:**
  - **Assistant Professor in Civil Engineering at University of Texas Arlington**
- **Years of industrial experiences before returning to academia**

Background

- Arterial performance is critical for urban traffic mobility
  - Monitoring arterial performance is a major task for most public agencies
- Traditional arterial performance monitoring is to measure arterial speed as opposed to posted speed limit (HCM LOS)

Travel Speed as a Percentage of Basic Free-Flow Speed (%)	LOS by critical Volume-to-Capacity ratio	
	≤ 1.0	>1.0
>85	A	F
>67-85	B	F
>50-67	C	F
>40-50	D	F
>30-40	E	F
≤30	F	F

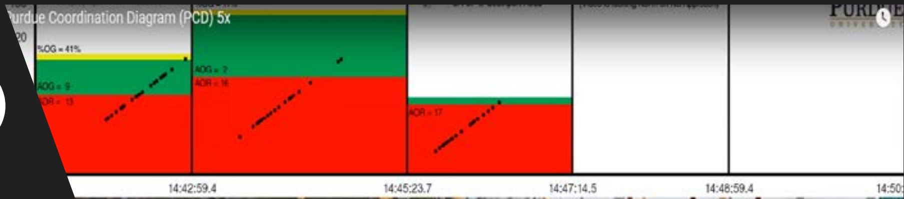
High-resolution signal events data and new arterial MOEs

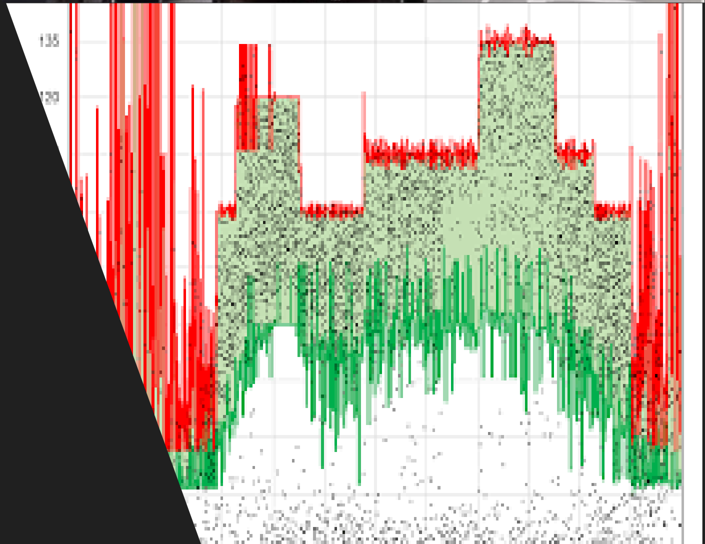
- Traffic signal controller is a discrete state machine
  - Driven by events (vehicle arrivals, veh/ped calls, phase transitions, etc.)
  - Each event include time stamp, event type and event index
    - E.g. "vehicle placed a *vehicle call* on *phase 8* at *7:01:02.2 AM, May-02-2019*"

- Logging such events data has become a standard function for most traffic signal controllers

- These events can be used to develop novel arterial performance MOEs
  - Purdue University has been working on this topic since 2000
  - Popular new MOEs: Purdue Coordination Diagram
  - Utah DOT contributes an open-source system to visualize the proposed new MOEs

- FHWA is strongly promoting this new method



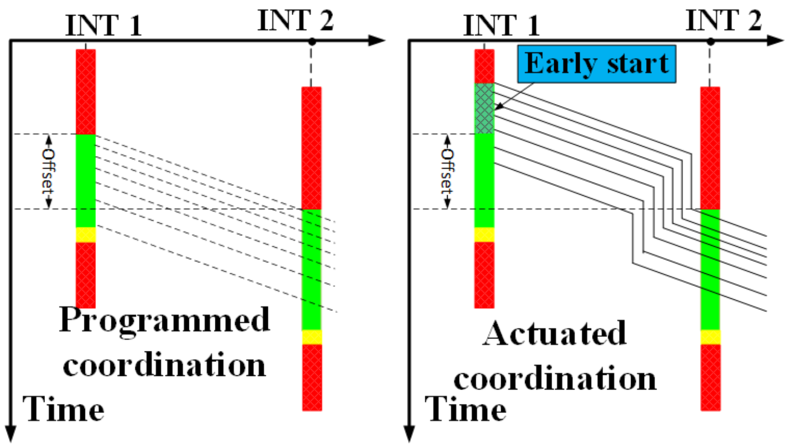


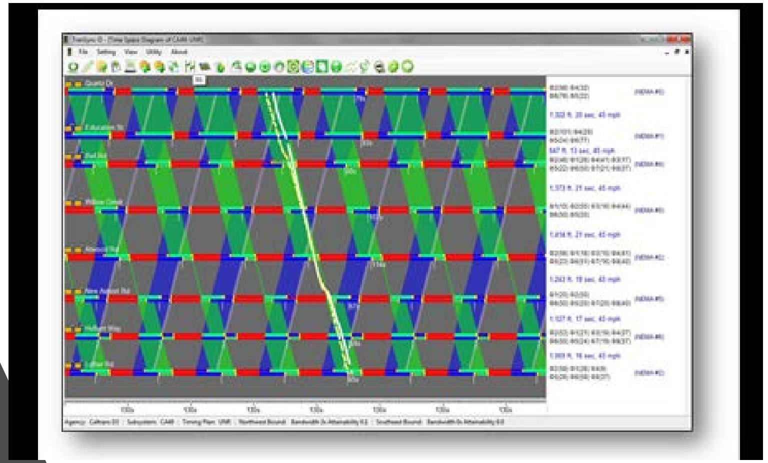
New puzzles for public agencies

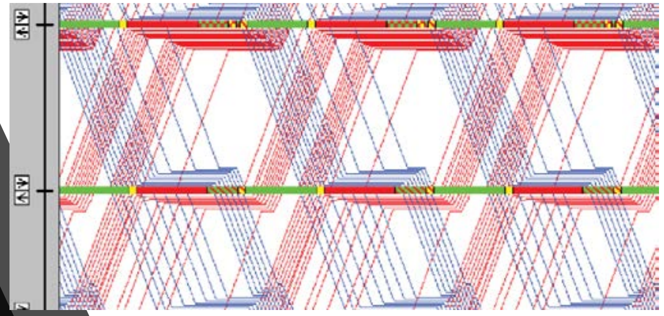
- **Open question 1: Arterial speed v.s. coordination diagram**
  - *Which arterial MOE should be preferred?*
  - *Or should we use them together?*

- **Open question 2: How to conduct green-band analysis?**
  - Green-band analysis is the foundation of traffic signal coordination
  - However, the common approach is valid for fixed traffic signal coordination
  - Many traffic signal coordination systems are actuated. The standard band analysis barely holds because of the “Early return to green”.
    - The effective green bands vary cycle by cycle.
  - Can we do better to measure the effective green-bands *for actuated traffic signal systems*?

- **Open question 3: we want additional new MOEs to see full-spectrum arterial performance**
  - *Traditional MOEs: speed, delay, queue length*
  - *Novel MOEs: Arrivals on Green, etc.*
  - *Wish list: new MOEs*





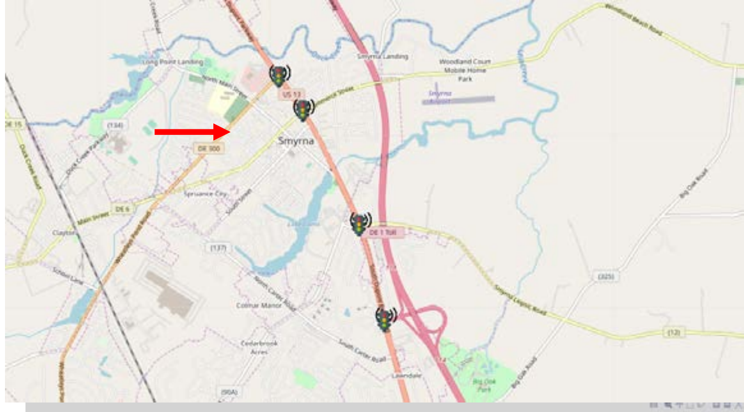


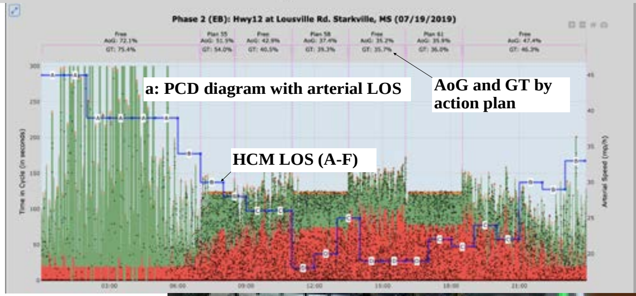
Some facts of our open-source arterial performance monitoring system

- The complete system **is *<u>an integral hardware-software solution</u>***
  - For on-line arterial performance monitoring (update every 5-15 min), customized field sensors are needed to collect raw Wi-Fi/Bluetooth and raw traffic signal events
  - The system reaches the industrial grade
- Deployed at 4 intersections in Starkville, MS, in July 2018
  - The complete hardware-software option
  - Exceed the requirements for Technological readiness level (TRL) 8 by FHWA
- Visualized 4 intersections for Delaware DOT (3rd party data)

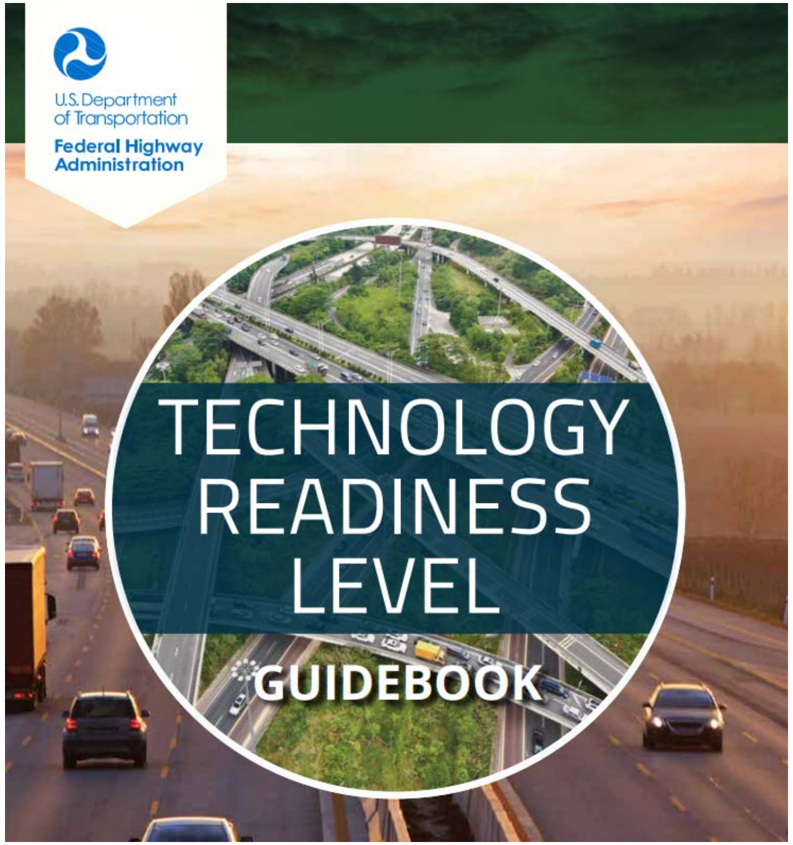
- The central system can be used alone to evaluate the arterial performance in an off-line manner
  - Take 3rd party signal events data and Wi-Fi/Bluetooth travel time samples and visualize

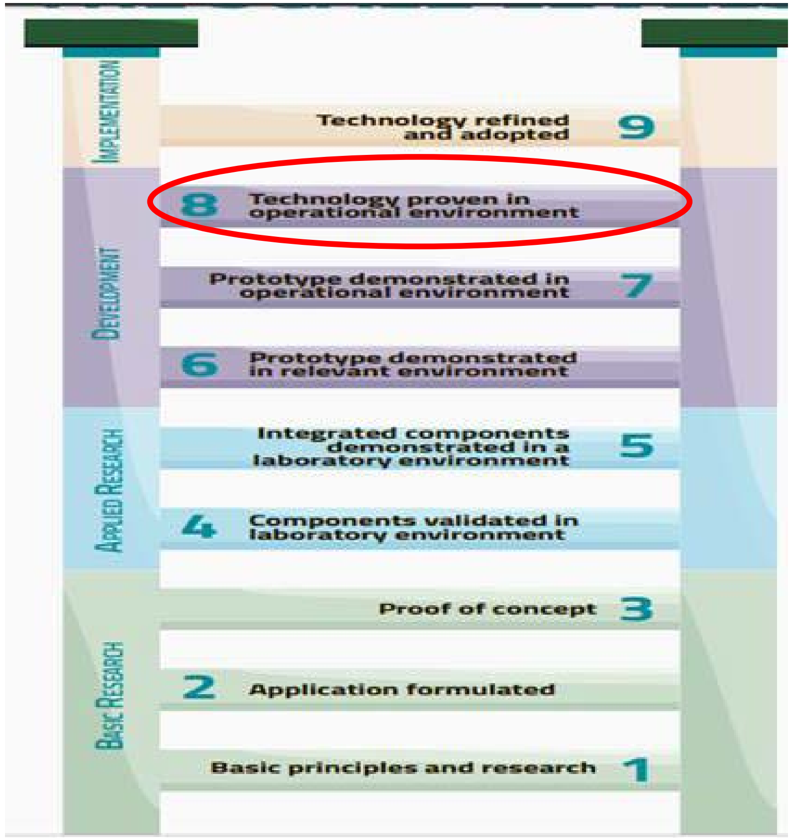
4 Locations in Delaware

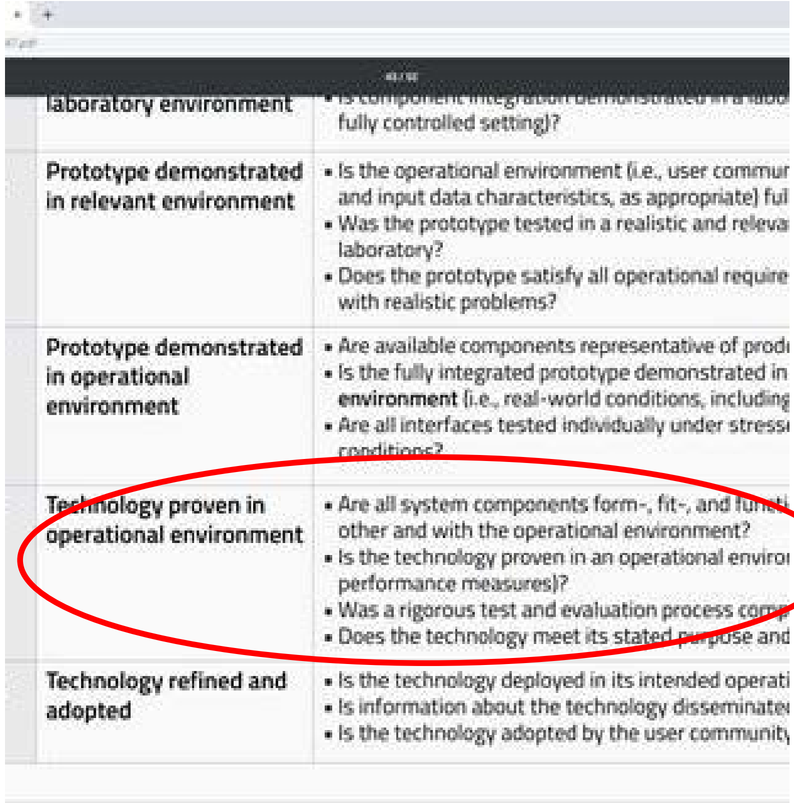




Technology Readiness Level Guidebook (Federal Highway Administration)

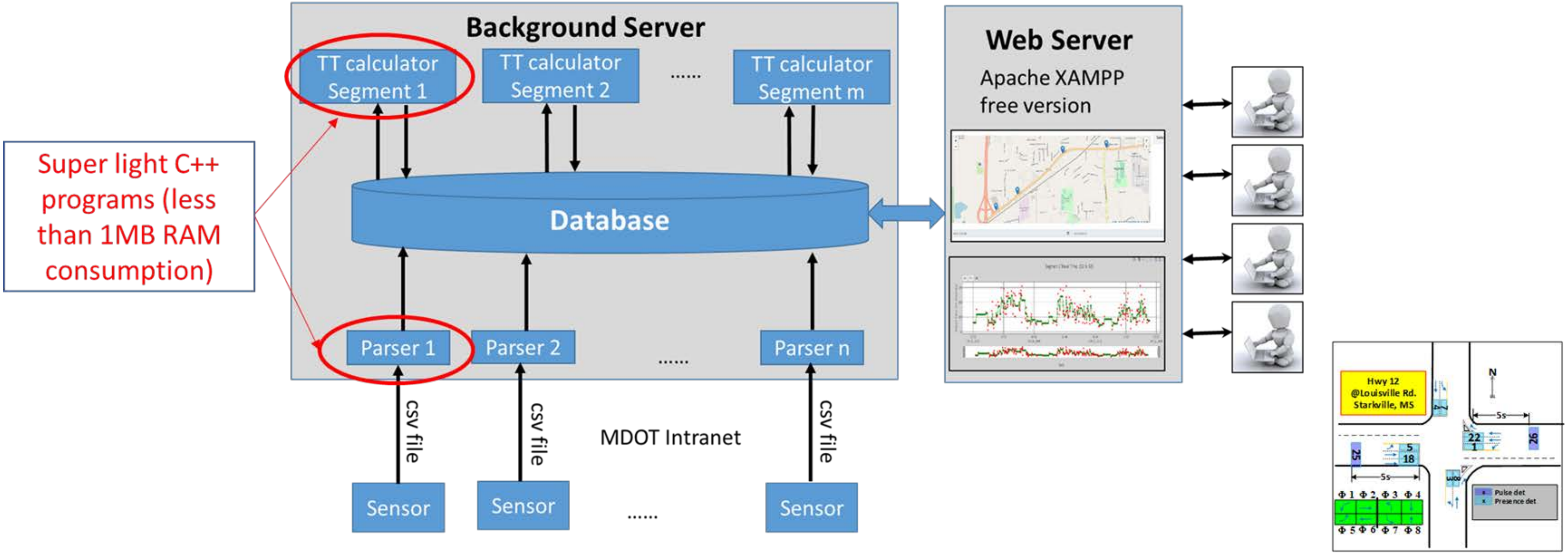






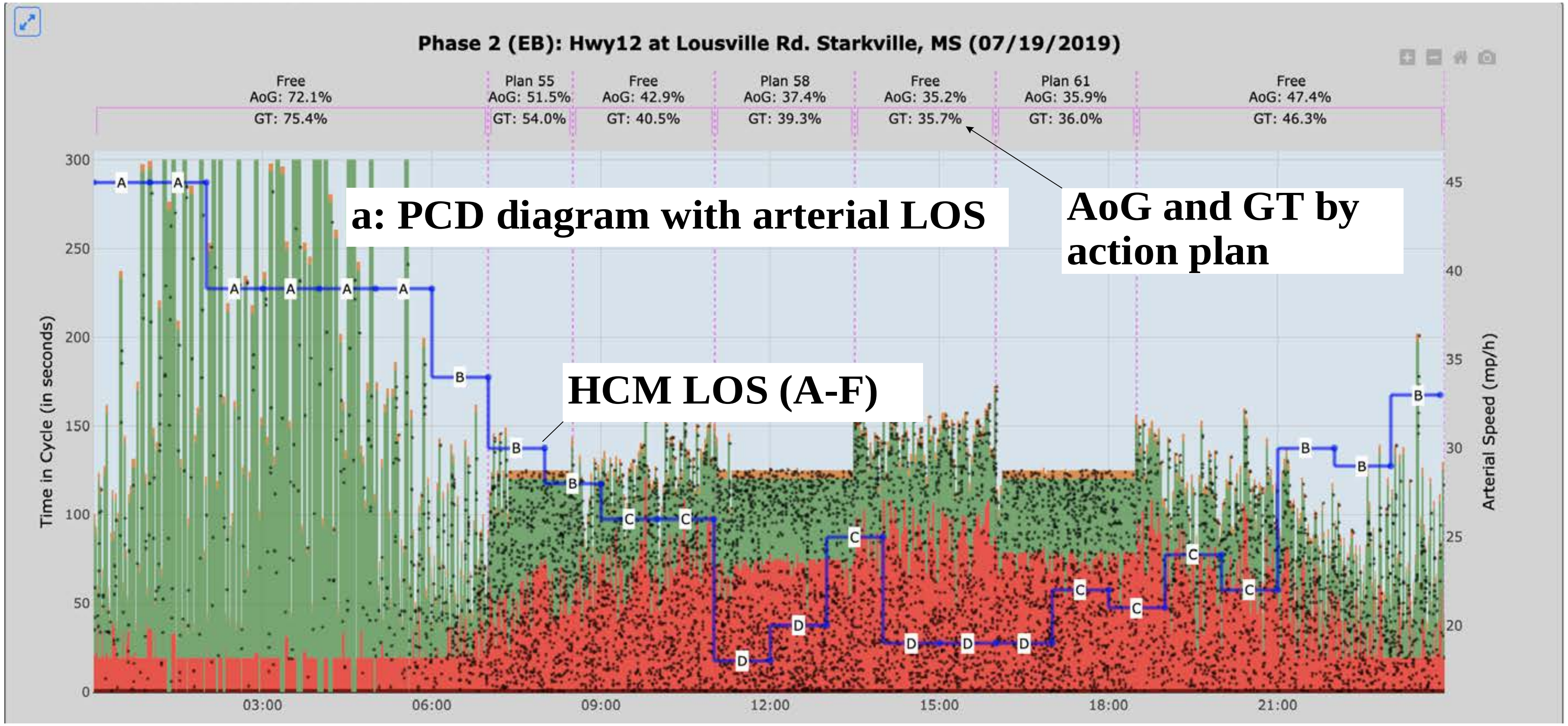
Scalable System architecture

suitable the large-scale applications



MOE1 at one intersection: Purdue coordination diagram and Time-of-day arterial travel speed

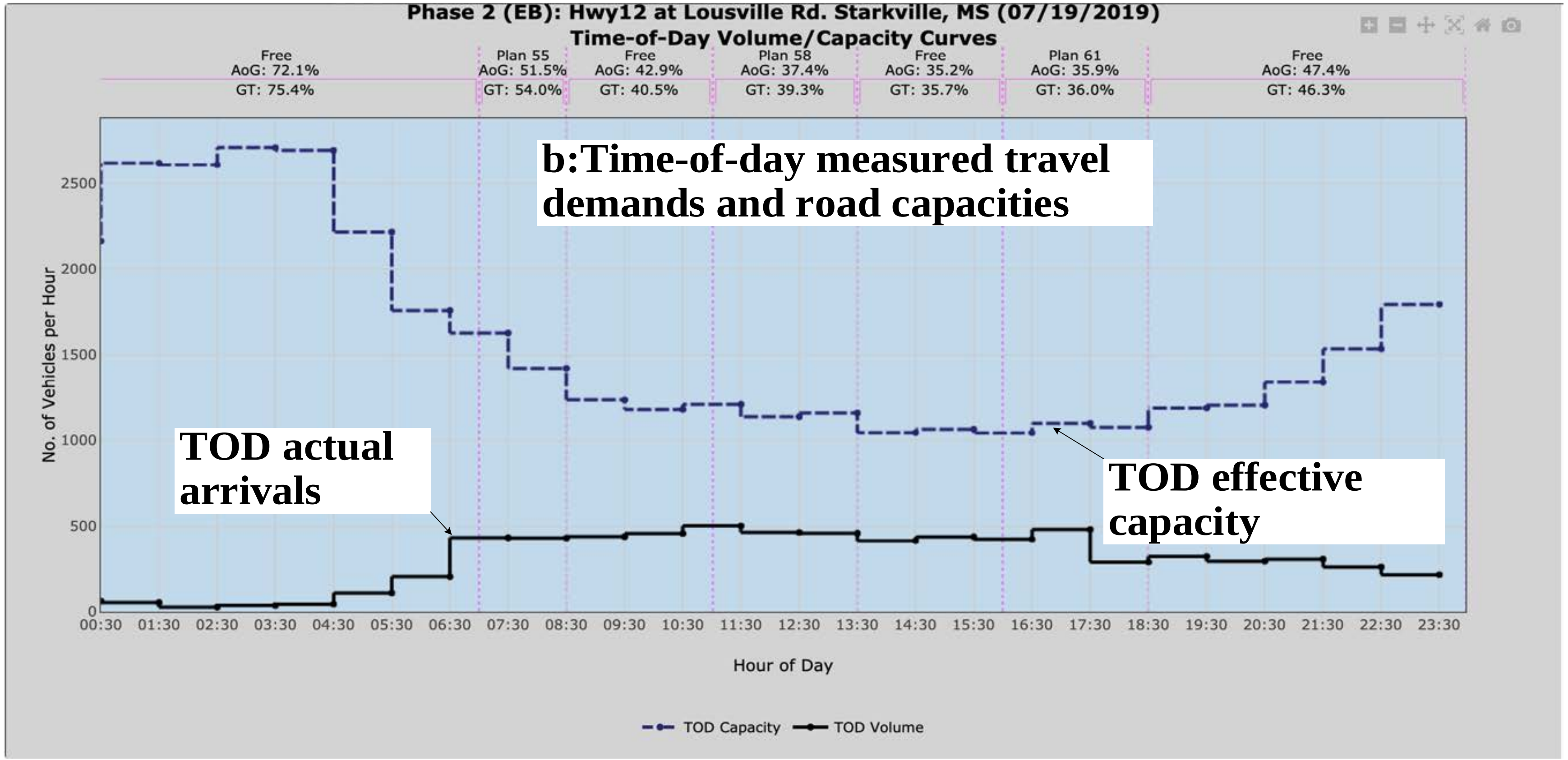
An enhanced coordination diagram including both PCD and HCM LOS for arterials



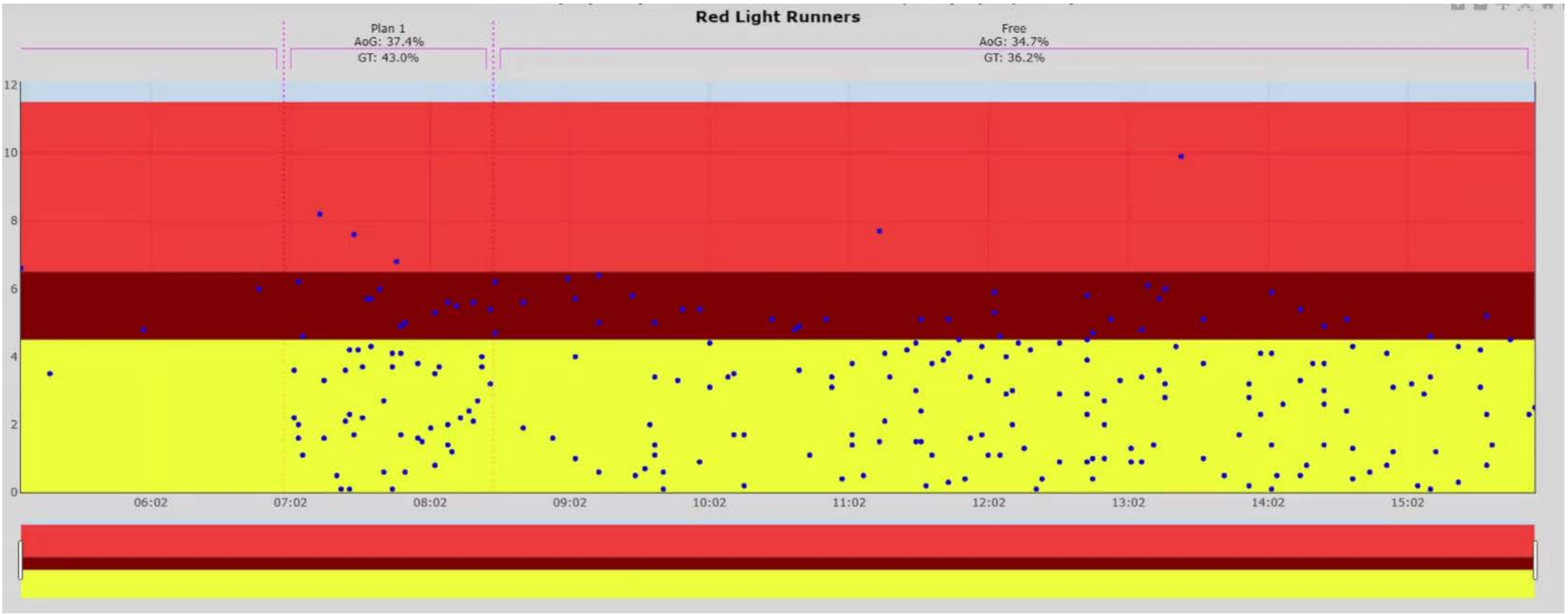
MOE2 at one intersection : Mainline approach congestion identification

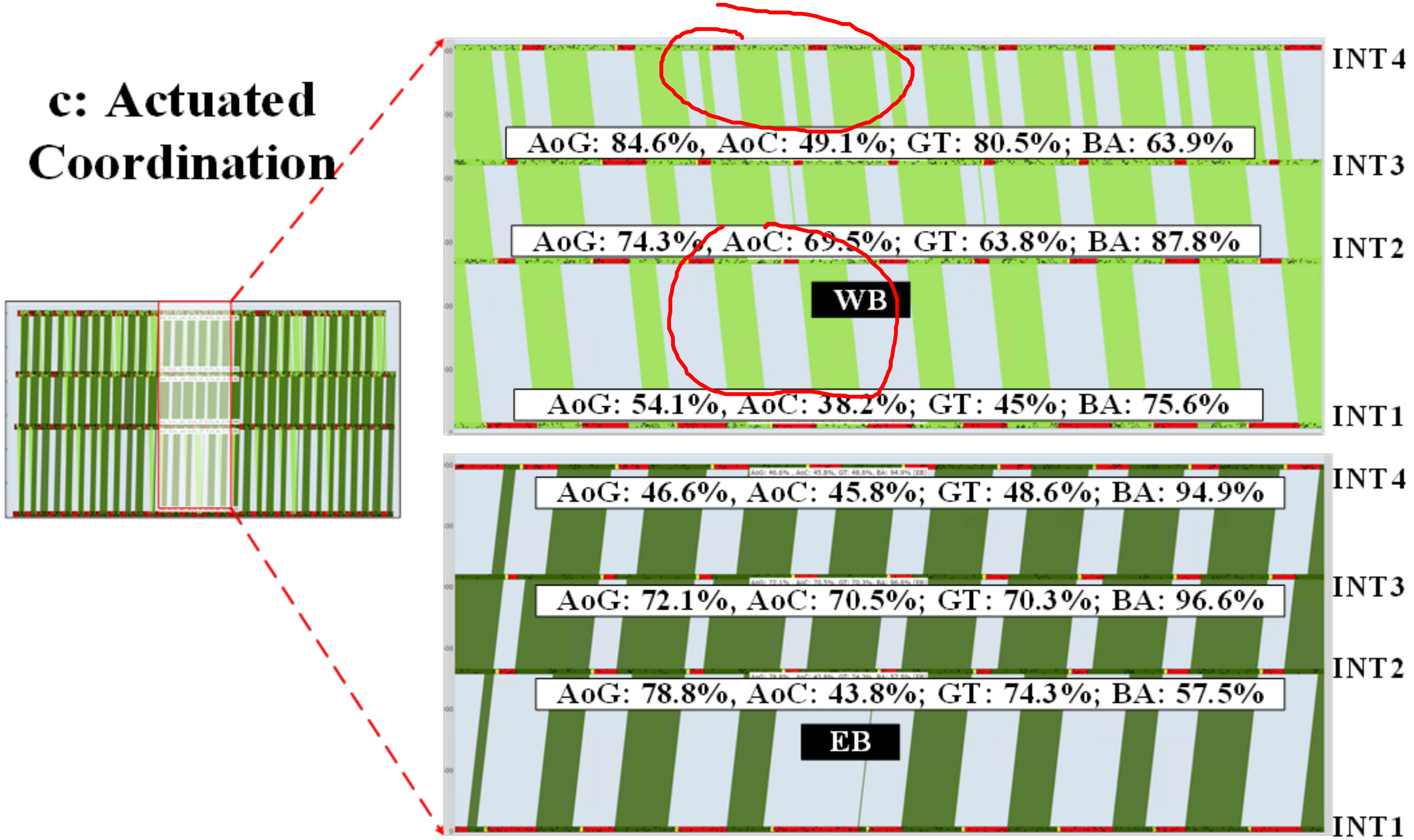
Measured arrivals via advance detectors (demand) v.s. actual road capacity (green%*saturation rate)

(Capacity curve should be always higher than the actual arrival curve)



MOE3 at one intersection: Yellow light and red-light running



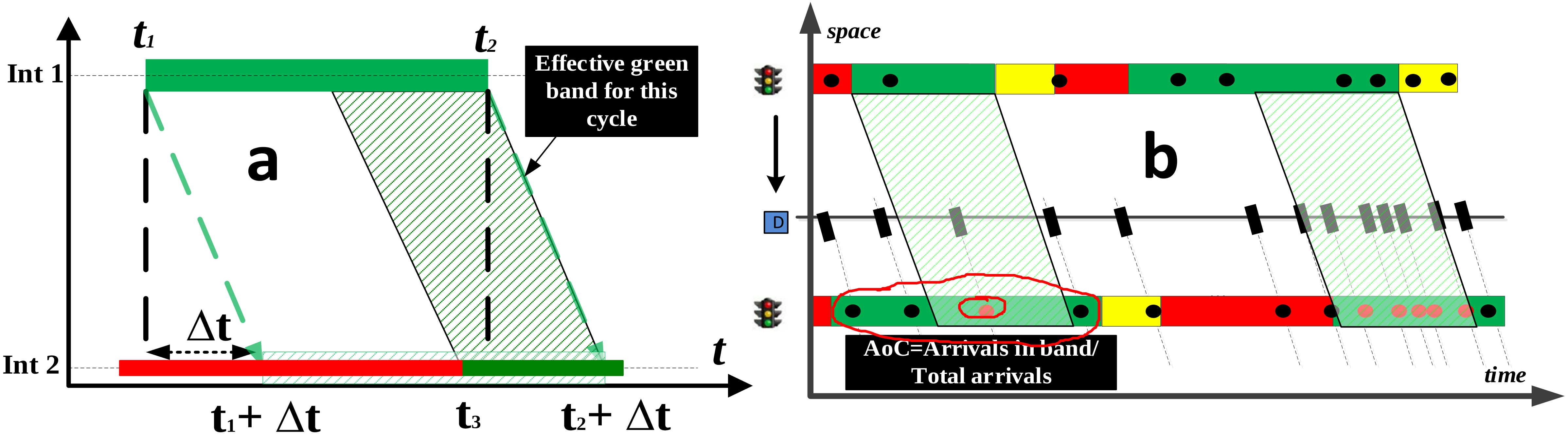


Greenbands visualization in time space diagram for actuated traffic signal coordination

- One of the most desirable diagrams by practitioners
- Greenbands are established cycle-by-cycle according to the actual phase transitions

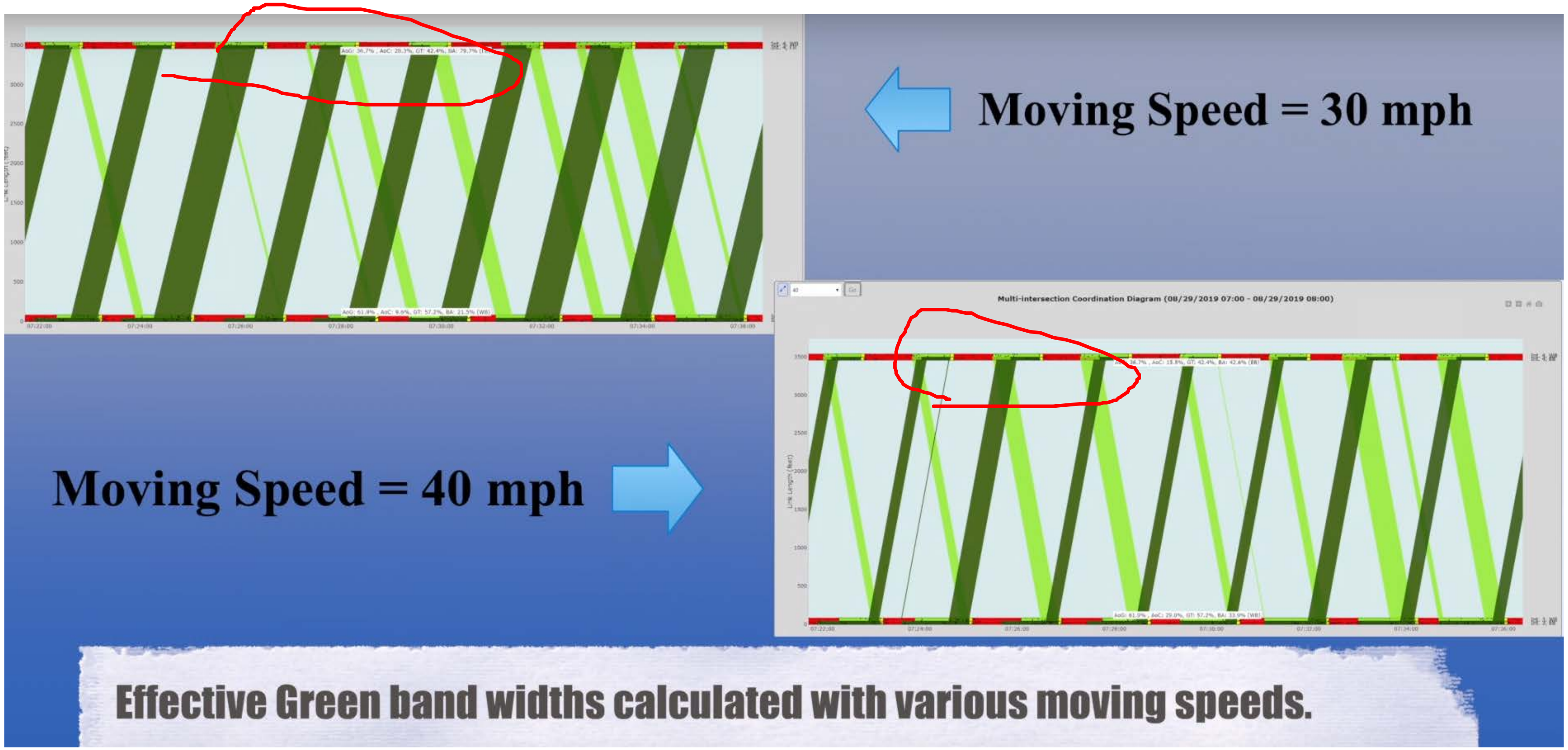
MOE4 for multiple intersections: Arrival on Coordination

To distinguish the arrivals during coordination and otherwise

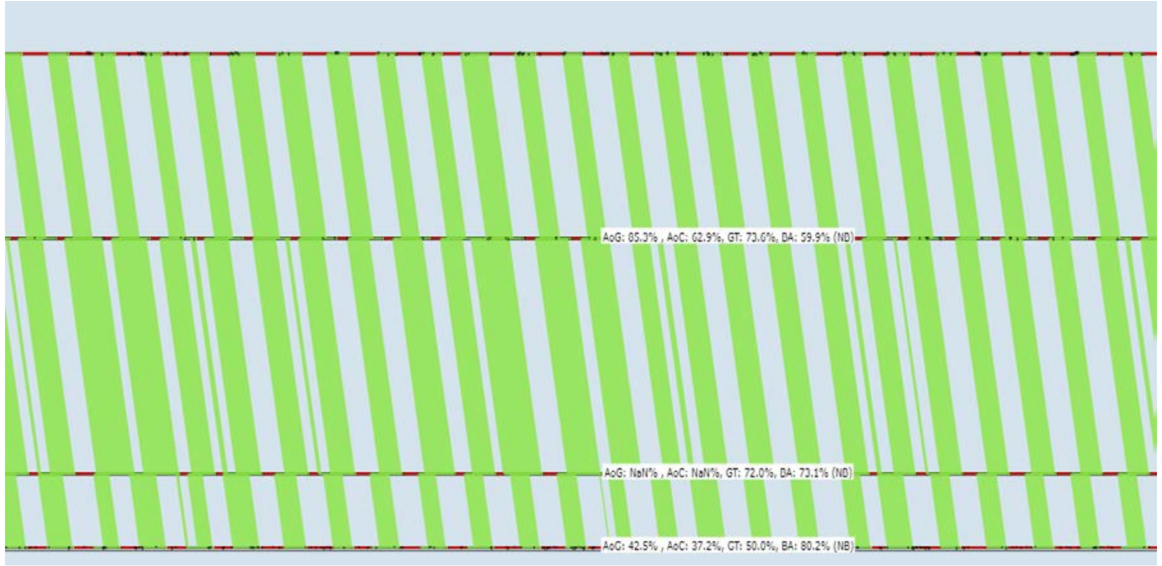


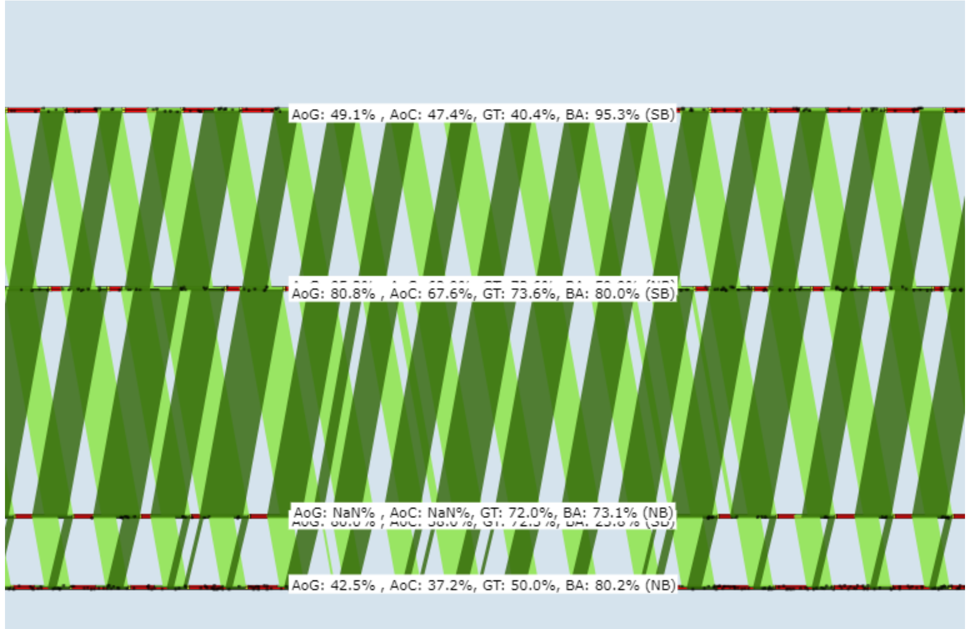
MOE5: Greenband Analysis based on observed moving speed

Greenband establishment is highly sensitive to the choice of vehicle speeds, especially when vehicles are slow due to congestions. **An important finding!**



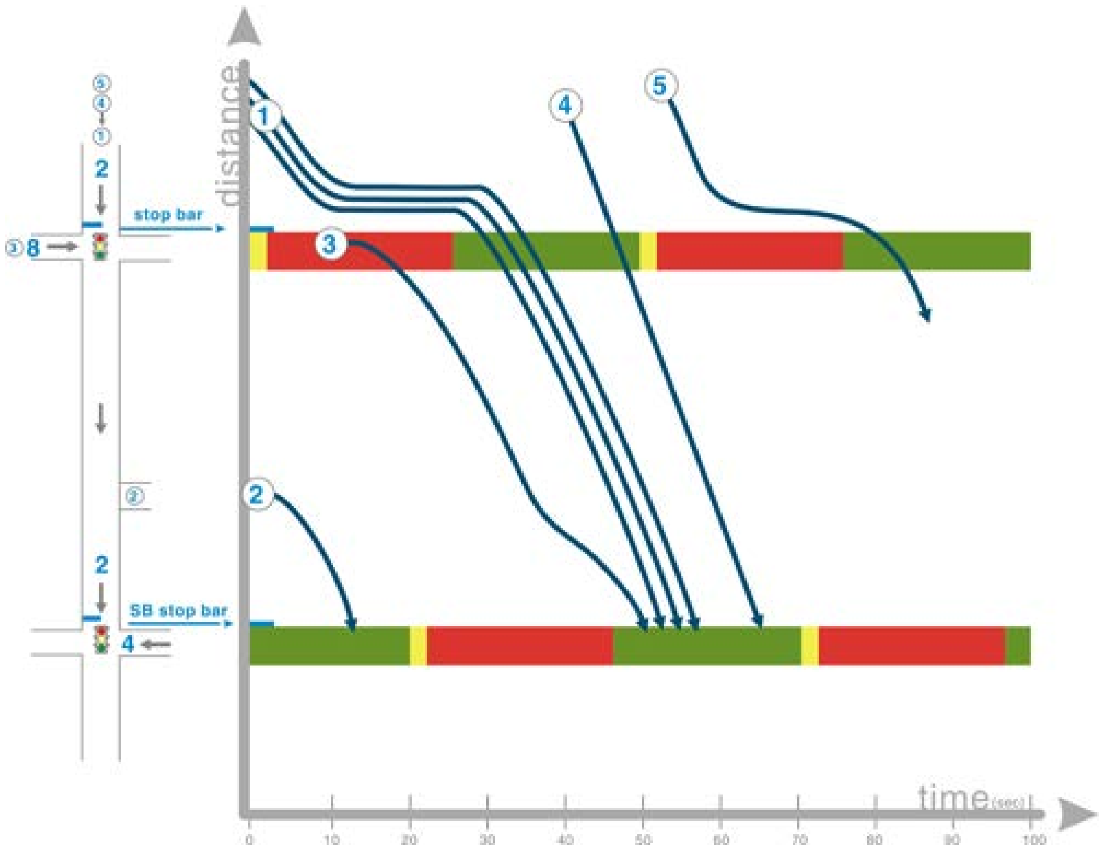
Coordination Diagrams of four intersections in Delaware





MOE6: Vehicle trajectories in actual time-space diagram

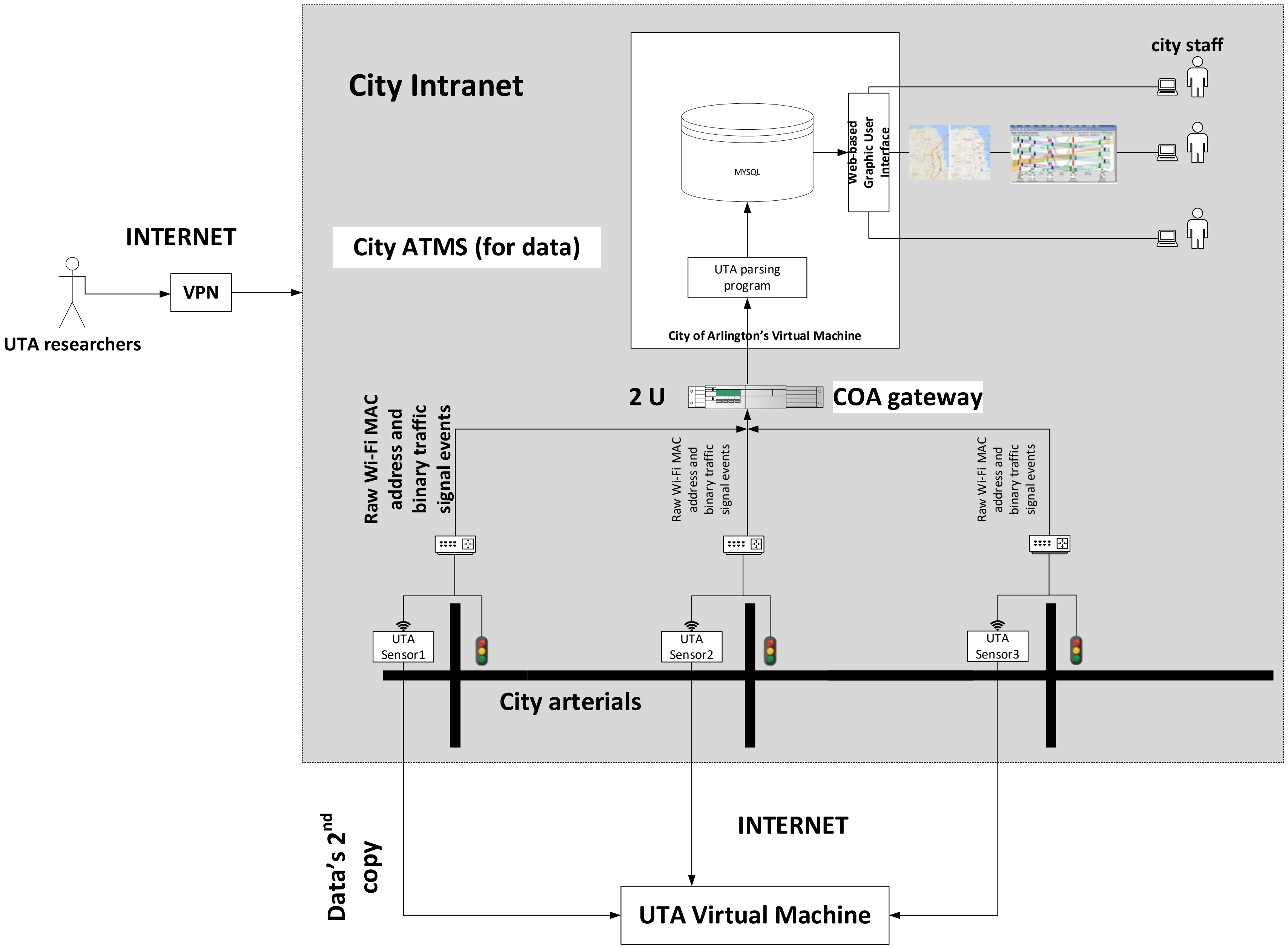
Visualize GPS trajectories in actual time-space diagram



(illustration)

When it is deployed…

Proposed Network Architecture for the arterial performance monitoring system



Future work

Explore integrate the 3rd party vehicle trajectories (e.g., INRIX, Wejo)

Explore the next generation database engine for data retrieving

- Without vehicle trajectories: easily 500,000 new records per day archived into the database at each intersection
- With 3rd party vehicle trajectories: easily reach billions of records per day
- Current relational database cannot tackle this magnitude of data, new database techniques must be investigated
  - e.g., GPU database, NOSQL database engine
  - No cheap database solutions, but it may be paid off if urban traffic congestions can be really avoided

Explore automated arterial optimization with machine learning

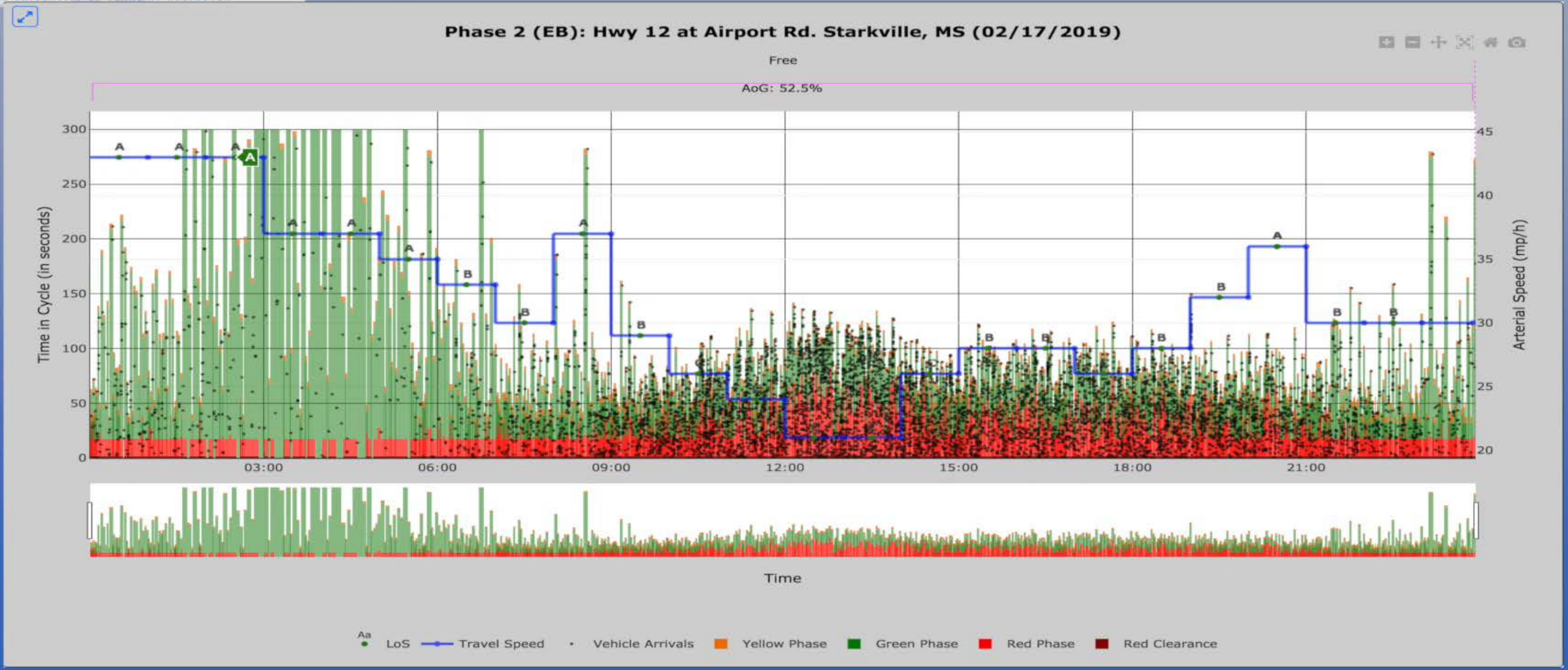
- New MOEs, big data sets, why not?
- The current practice is basically a trial-and-error methods.

Please enjoy the show…

CIVIL ENGINEERING
THE UNIVERSITY OF TEXAS AT ARLINGTON

WiFi

MDOT
MISSISSIPPI DEPARTMENT OF TRANSPORTATION



Thank you

If you wish to try out or deploy this system, please contact Taylor Li:
pengfei.li@uta.edu