Transit-Hub

An Extensible and Smart Decision Support System

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Overview of the project

- **Challenge**:
  - Create a solution that improves engagement and efficiency of public transport system.
- **Approach:**
  - A smart phone application and a backend system that enables
    - Riders to compare and choose between available transit options.
    - Provides real-time feedback and prediction of performance
    - Gathers data and provide simulation based analytics for MTA planners.
- **Broad Impact:**
  - Several high-visibility demonstrations in the city.
  - We are exploring other city-specific CPS projects.
  - The project will be made available to commuters in January. The system is already in beta test.
  - Active participation of undergraduate students in the project. They are interested in the project because of its direct impact to the city.

Problem Context

Nashville - the Music City,
is a fast growing metropolis

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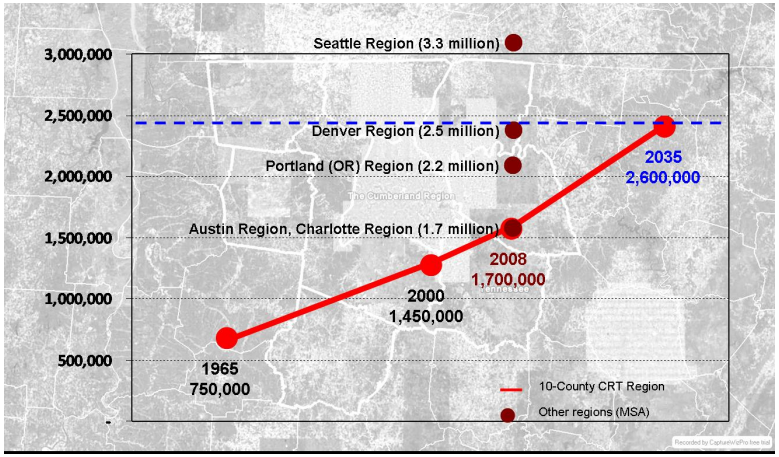

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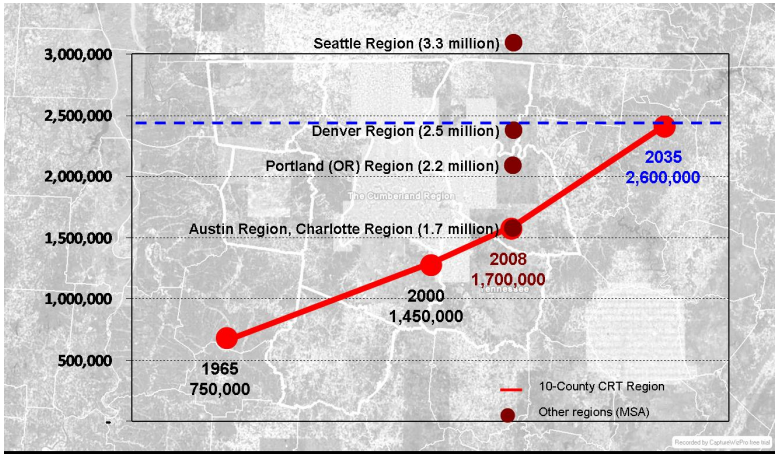

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public transit is essential to servicing the current and future traffic needs, but …

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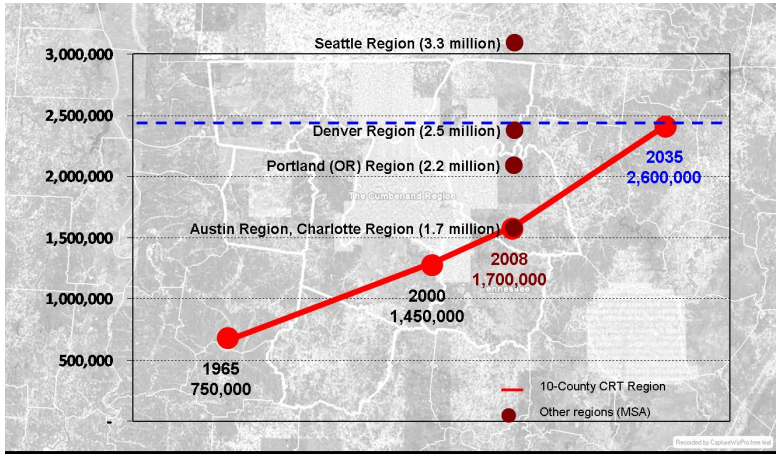

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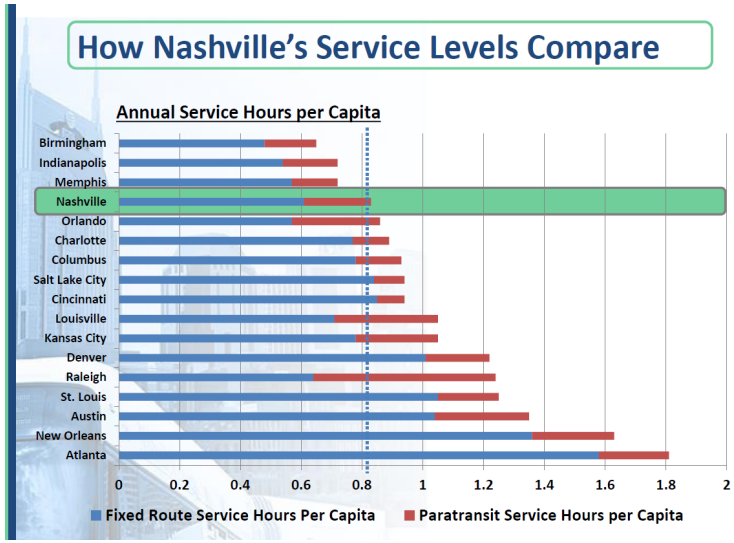
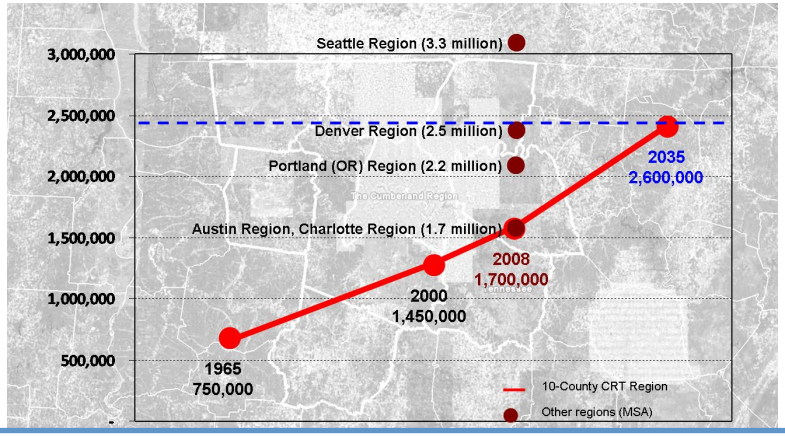


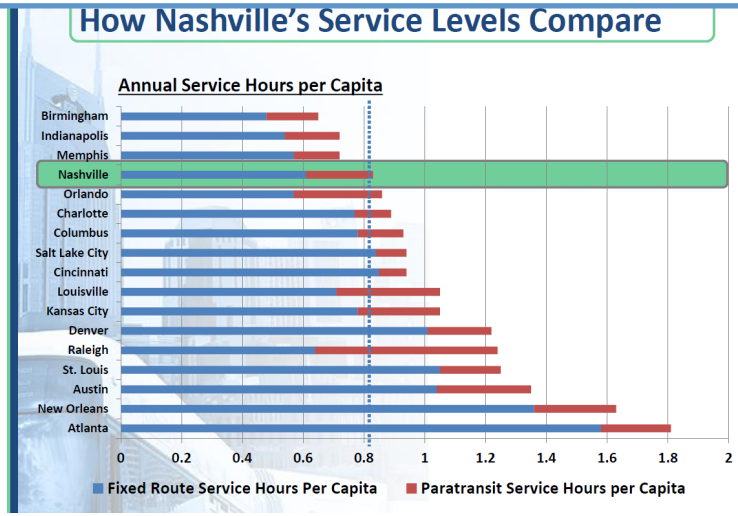
But public transport services and usage both lag behind comparable cities

Problem Context



Increasing the usage of public transit services and reducing personal vehicle trips is important to reduce traffic congestion in Nashville.

Nashville already has 11th worst traffic in US



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Transit Hub Approach

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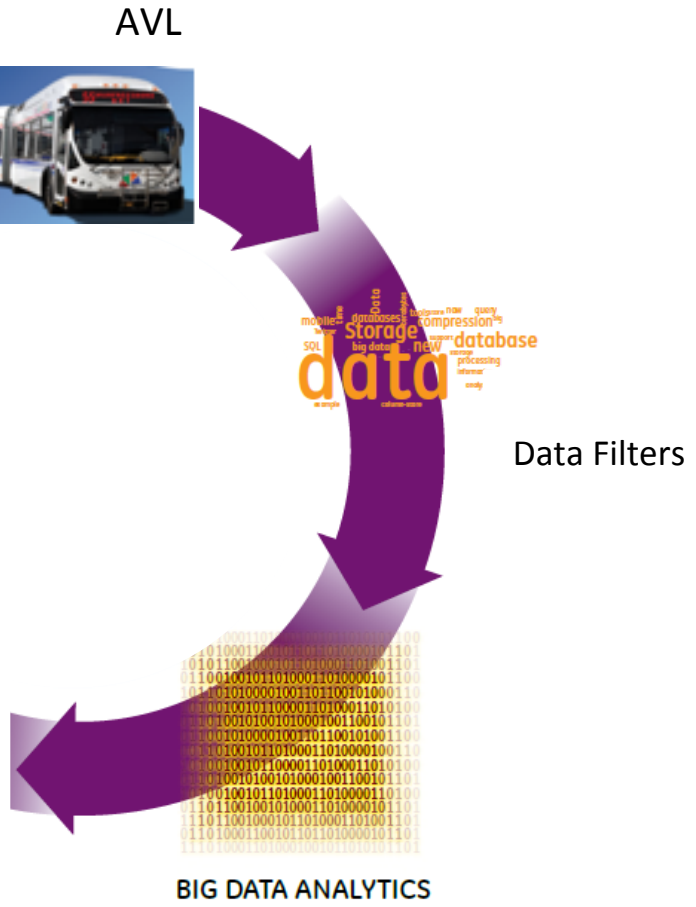
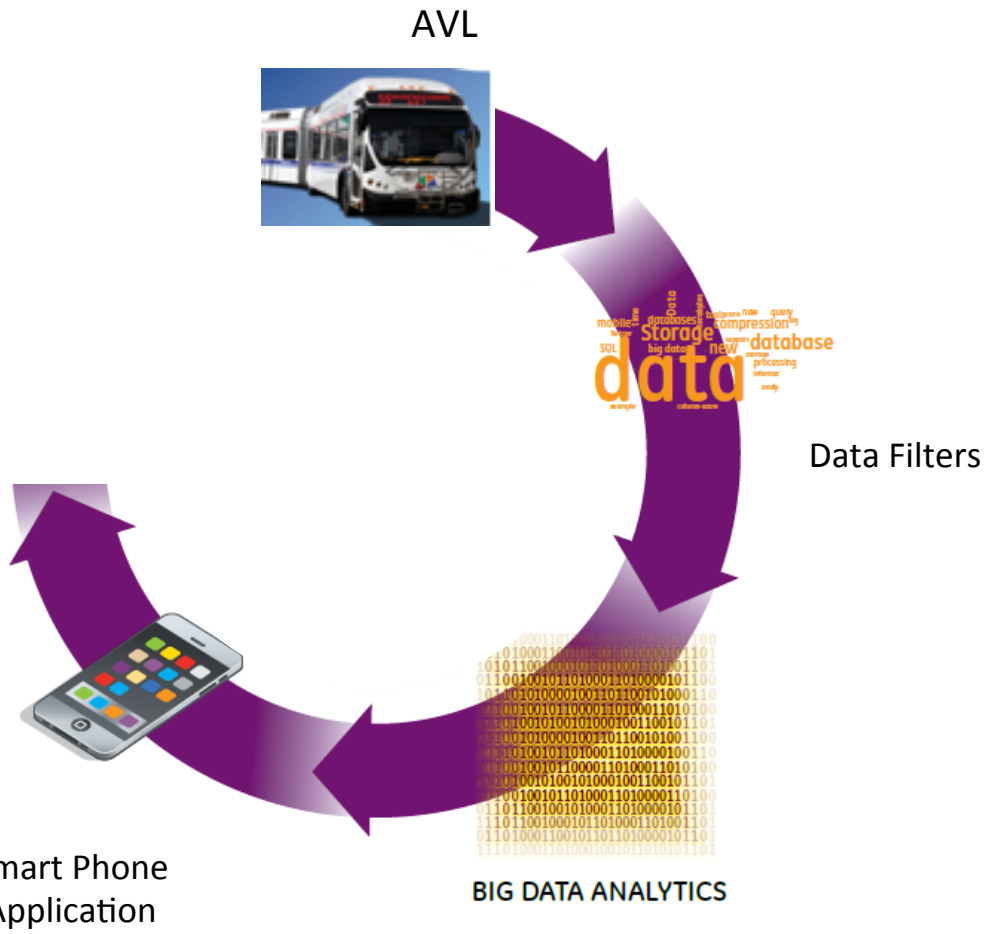


Transit Hub Approach

- Get real-time data update from the vehicles.
- Use data analytics and models to create a decision support system
- Use the information to provide contextual service with improved alerts and predictions to riders



Transit Hub Approach

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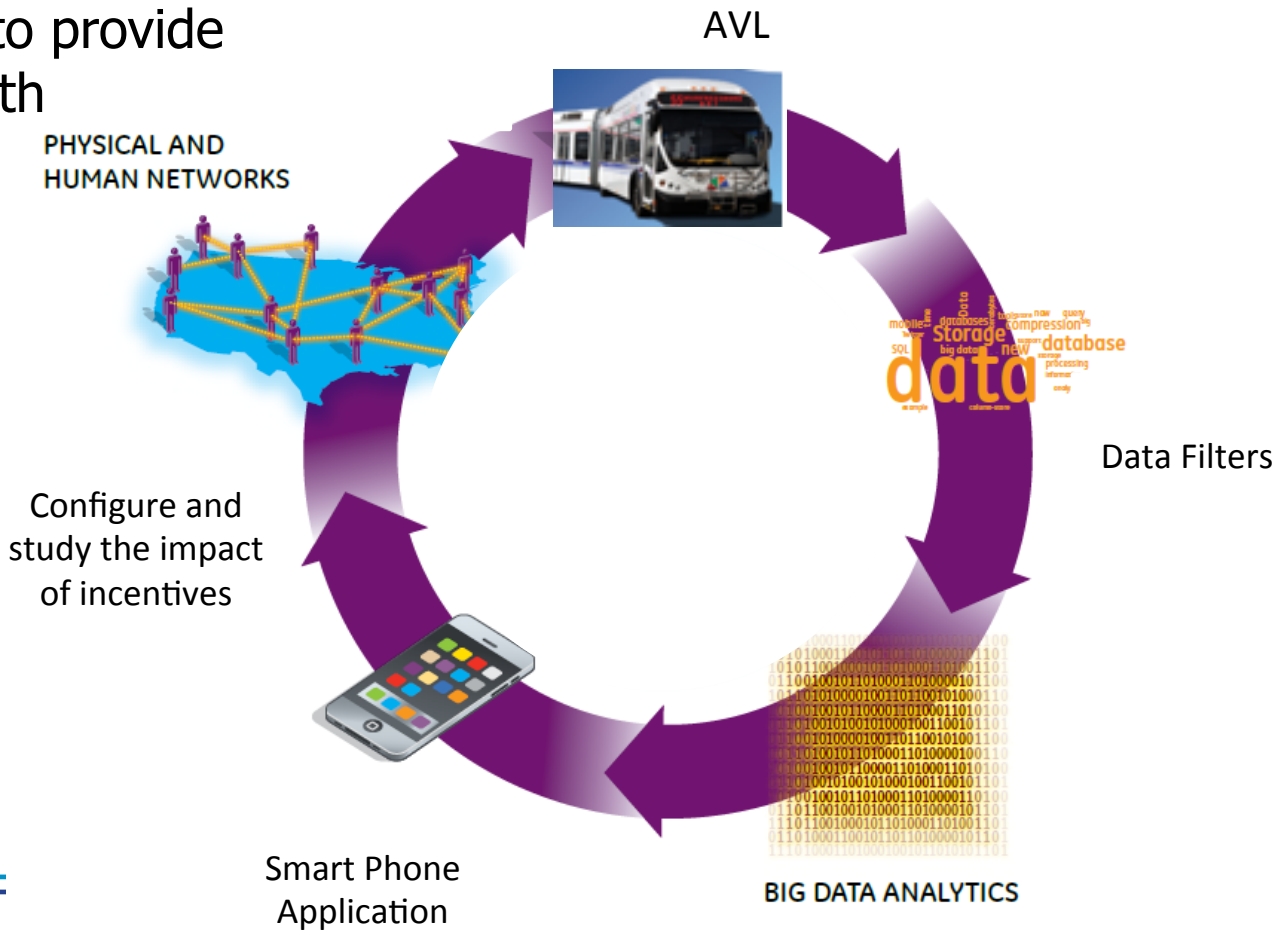
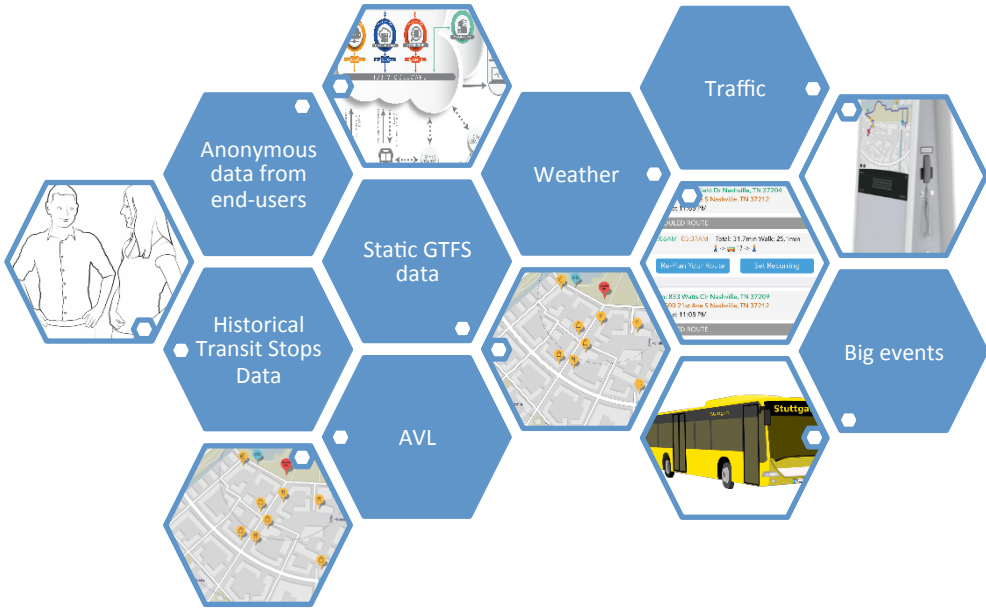
- Use data analytics and models to create a decision support system
- Use the information to provide contextual service with improved alerts and predictions to riders
- Collect usage information to improve the service



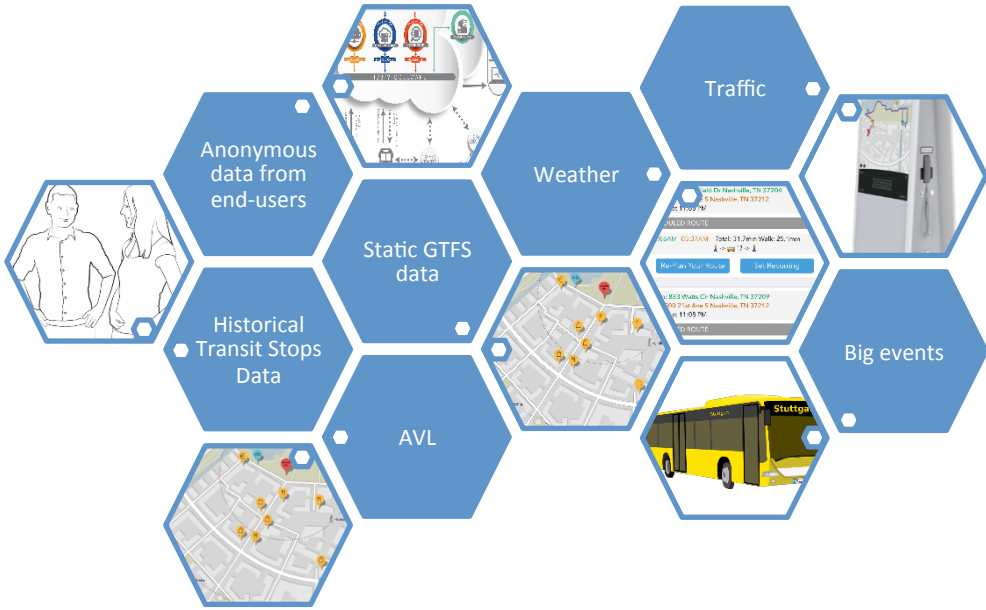
Data Sources

- Data from Automatic vehicle locators (AVL) on buses
- Static transit schedule data in General Transit Feed Specification (GTFS)
- Transit trip plans, walking distances, real-time transit data, etc.
- Weather, traffic data, big events in the city, etc.

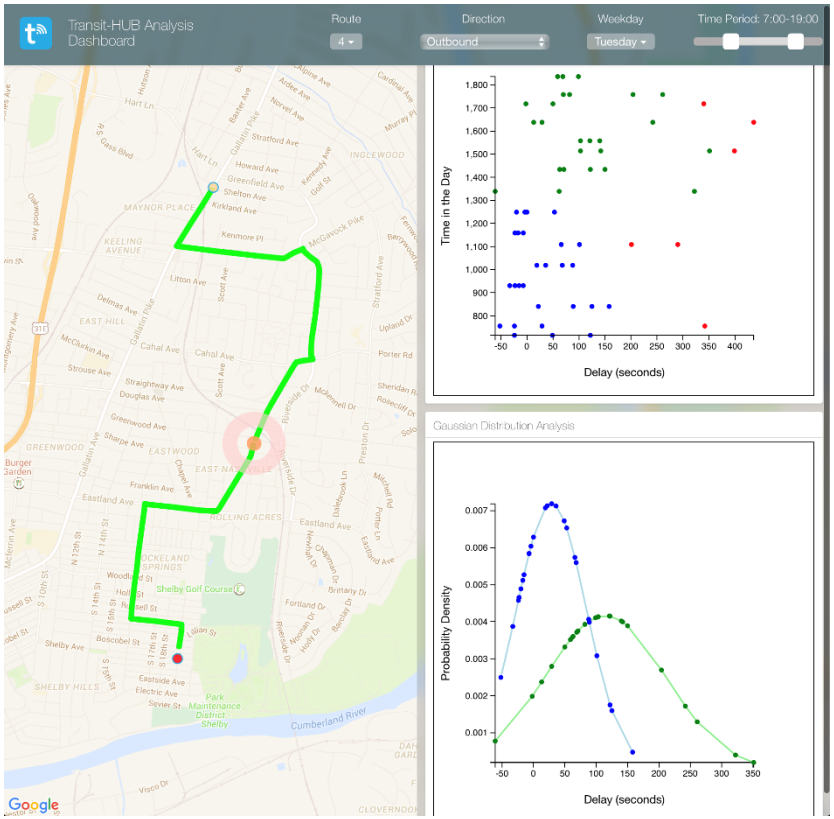


Data Analytics

- Feature Identification
- Model Generation
- Anomaly Identification
- Gaussian Distribution Analysis



Example - Analysis and Prediction of Schedule Adherence



Blue curve: Cluster 1

Between 7 AM to 1 PM

- The 95% confidence interval of delay: 18.2 sec to 89 sec
- Mean value is 53.6 sec

Green curve: Cluster 2

Between 1 PM to 7 PM

- The 95% confidence interval of delay: 94.8 sec to 193.8 sec
- Mean value is 144.3 sec

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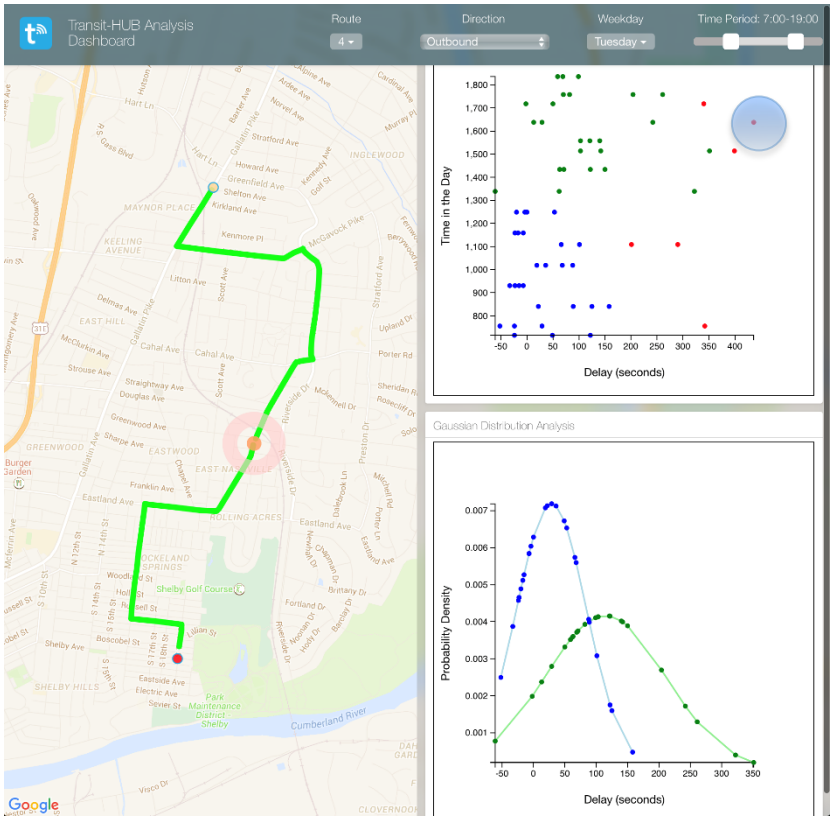
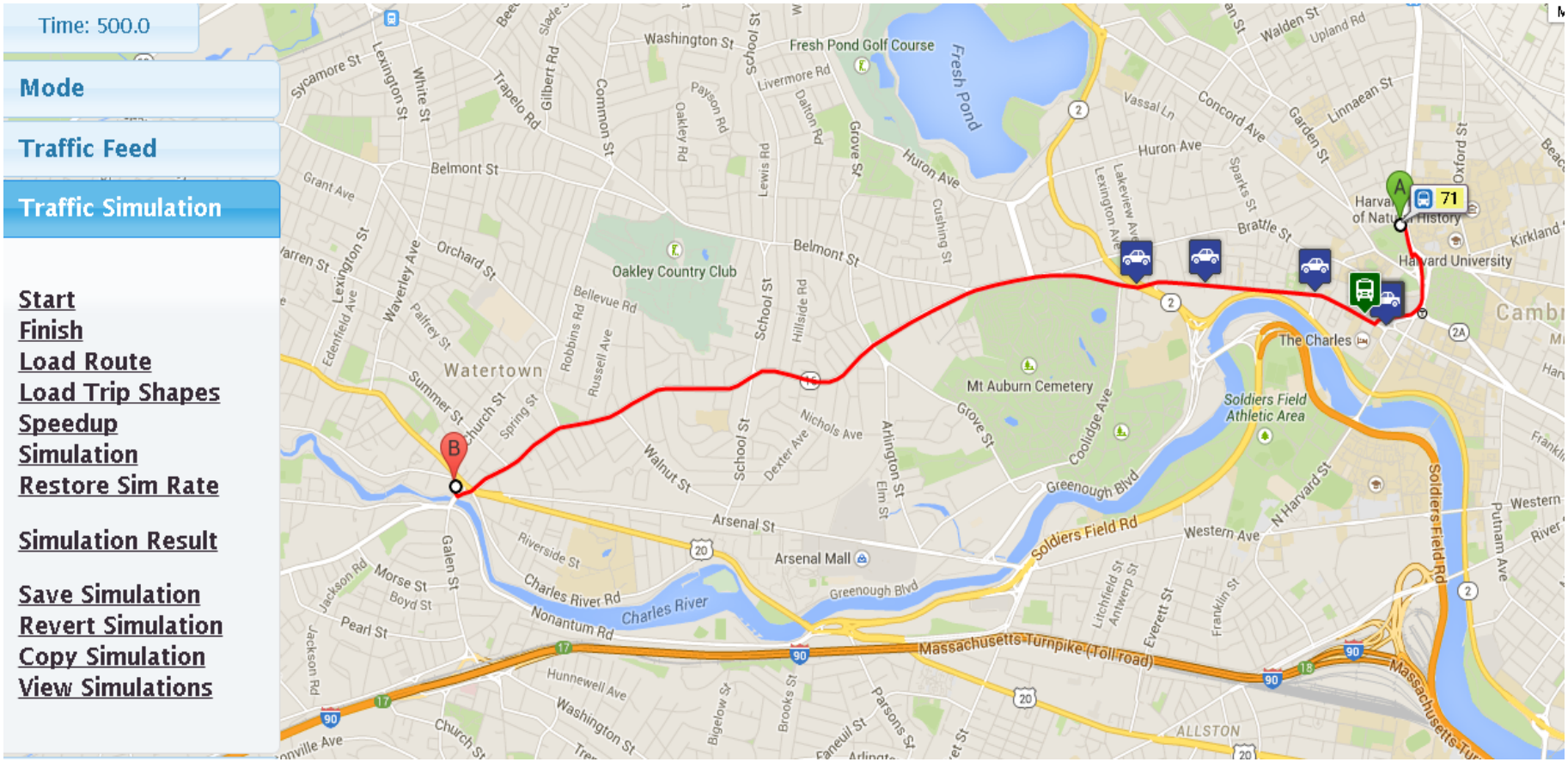


Observations:

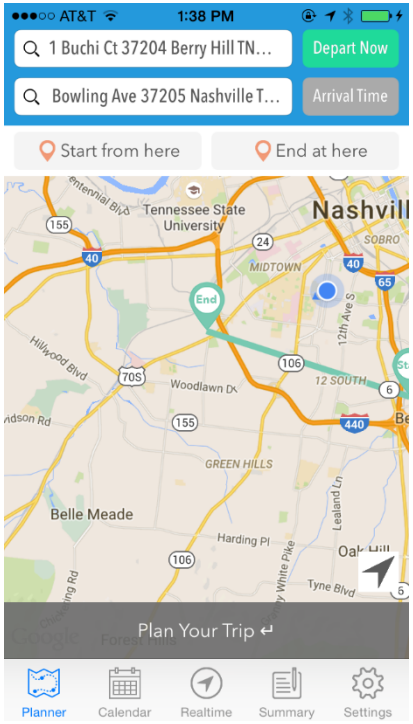
- If the current data fits in the distribution, then we use the historical data for prediction.
- If the current data is anomalous then we use other data points to generate hypothesis for explaining the anomaly.
- And, use simulation based estimation for prediction

Simulation based Estimation



Vehicles simulated in SUMO displayed using Google Maps

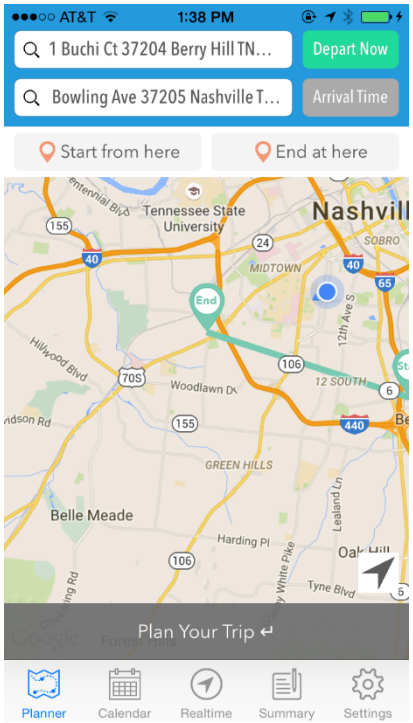
Companion Smartphone Application



Trip Planning

In Beta Testing

Companion Smartphone Application



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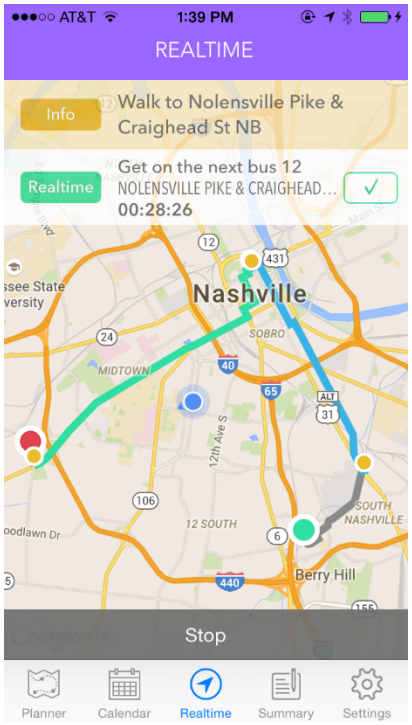

Real-Time View

In Beta Testing

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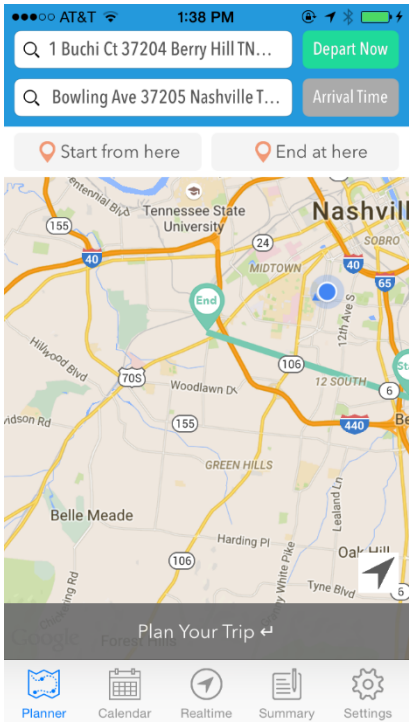

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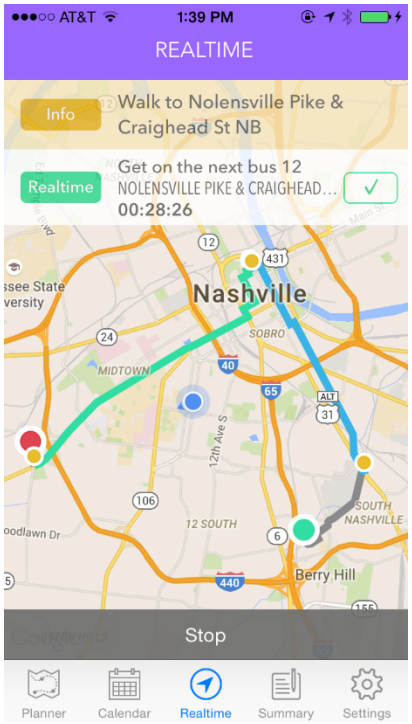

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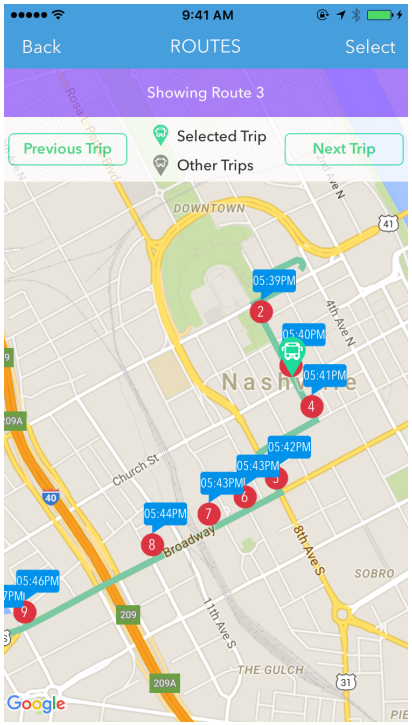

Route Update View

In Beta Testing

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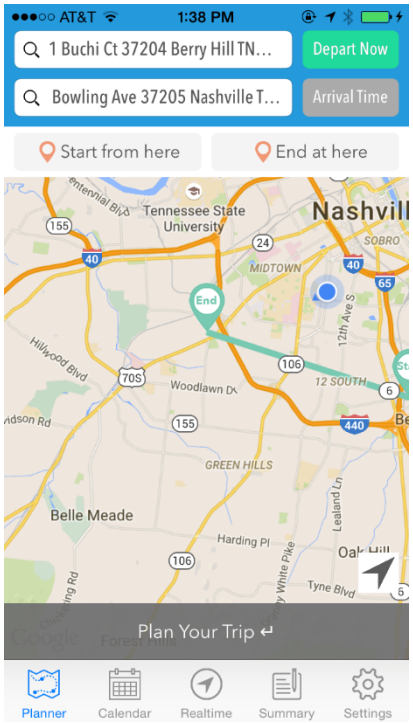

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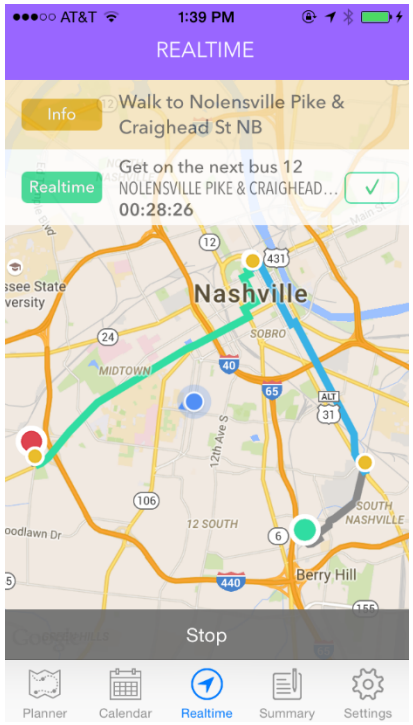

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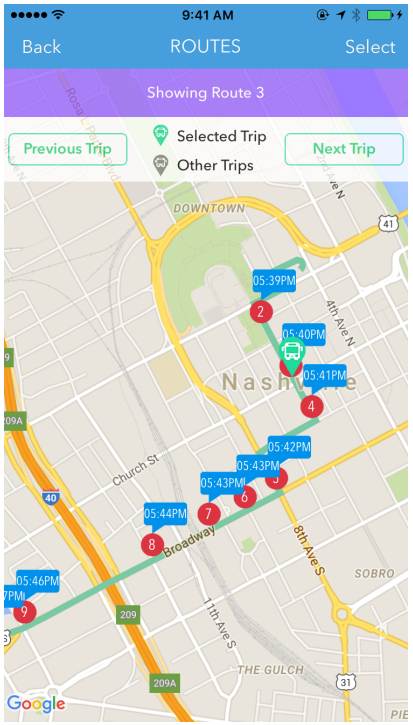

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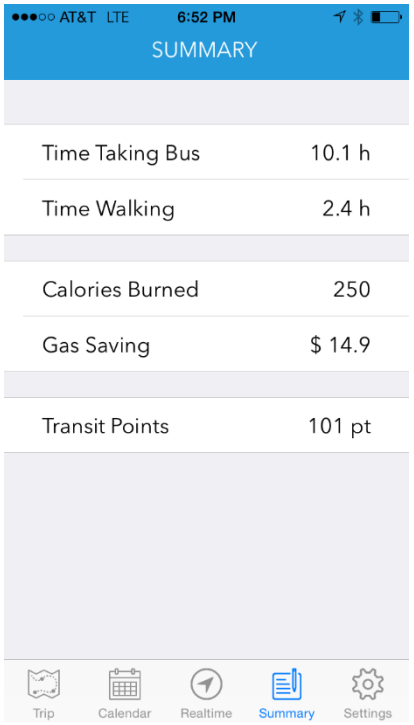
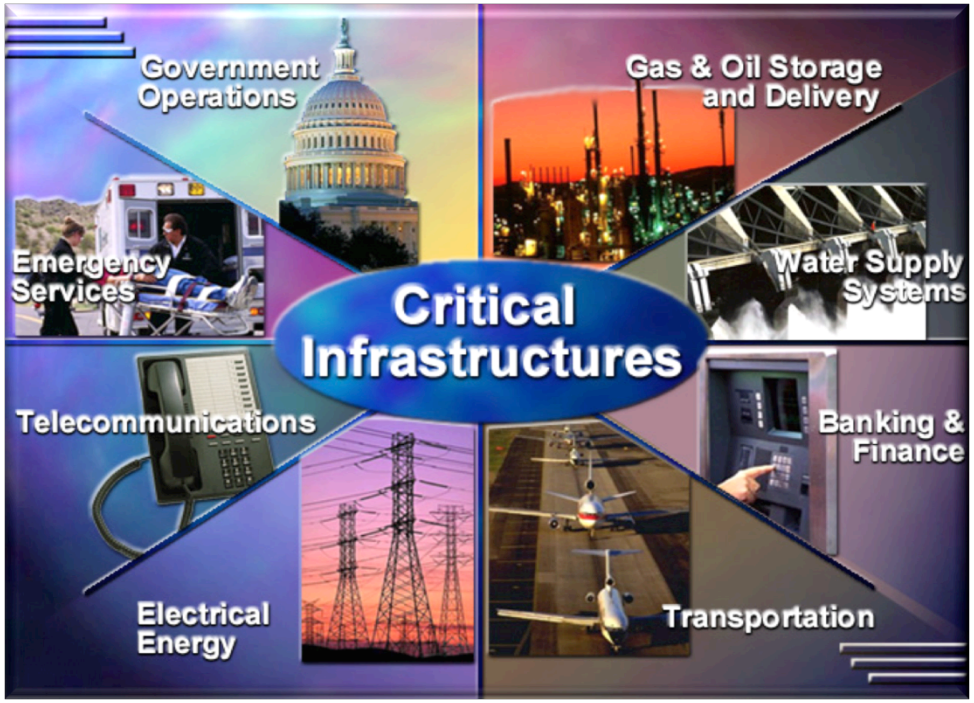


Incentives

In Beta Testing

Extending the Framework



Key problem space challenges

- Highly dynamic behavior
- Transient overloads
- Time-critical tasks
- Context-specific requirements
- Resource conflicts
- Interdependence of (sub)systems
- Integration with legacy (sub)systems

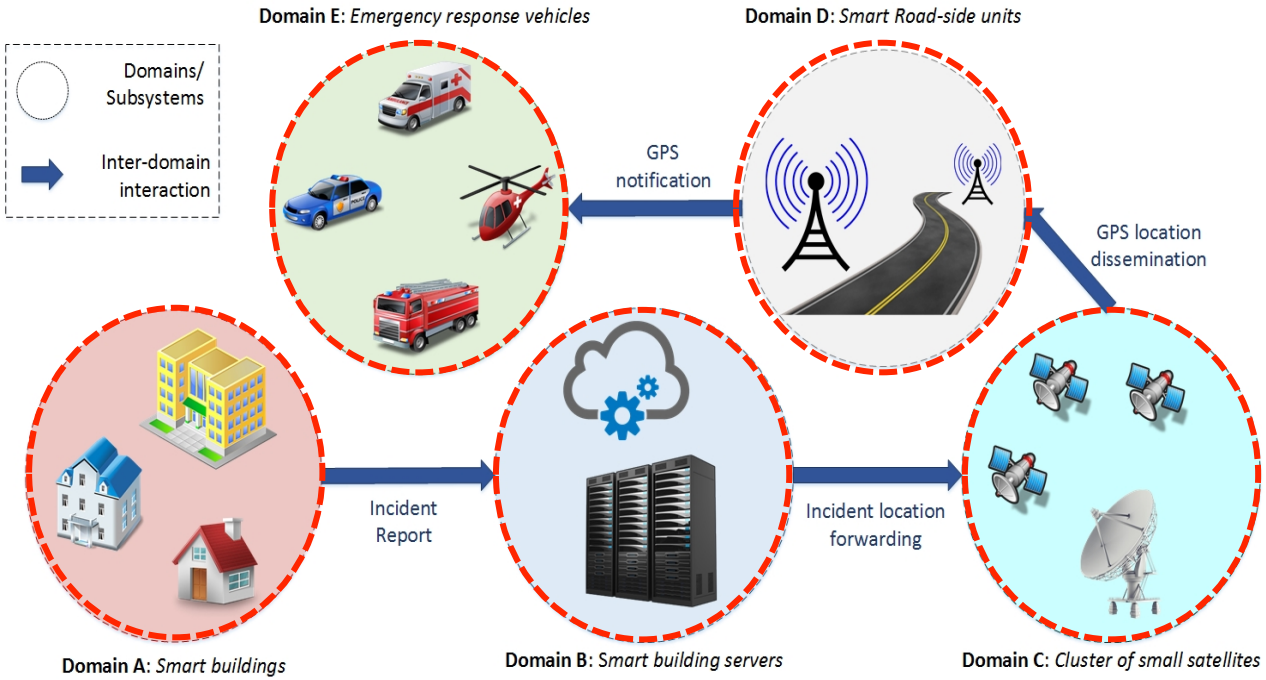
Key solution space challenges

- Enormous accidental & inherent complexities
- Continuous evolution & change
- Highly heterogeneous platform, language, & tool environments

Extending the Framework

Common middleware & data models that can integrate large-scale Industrial Internet deployments

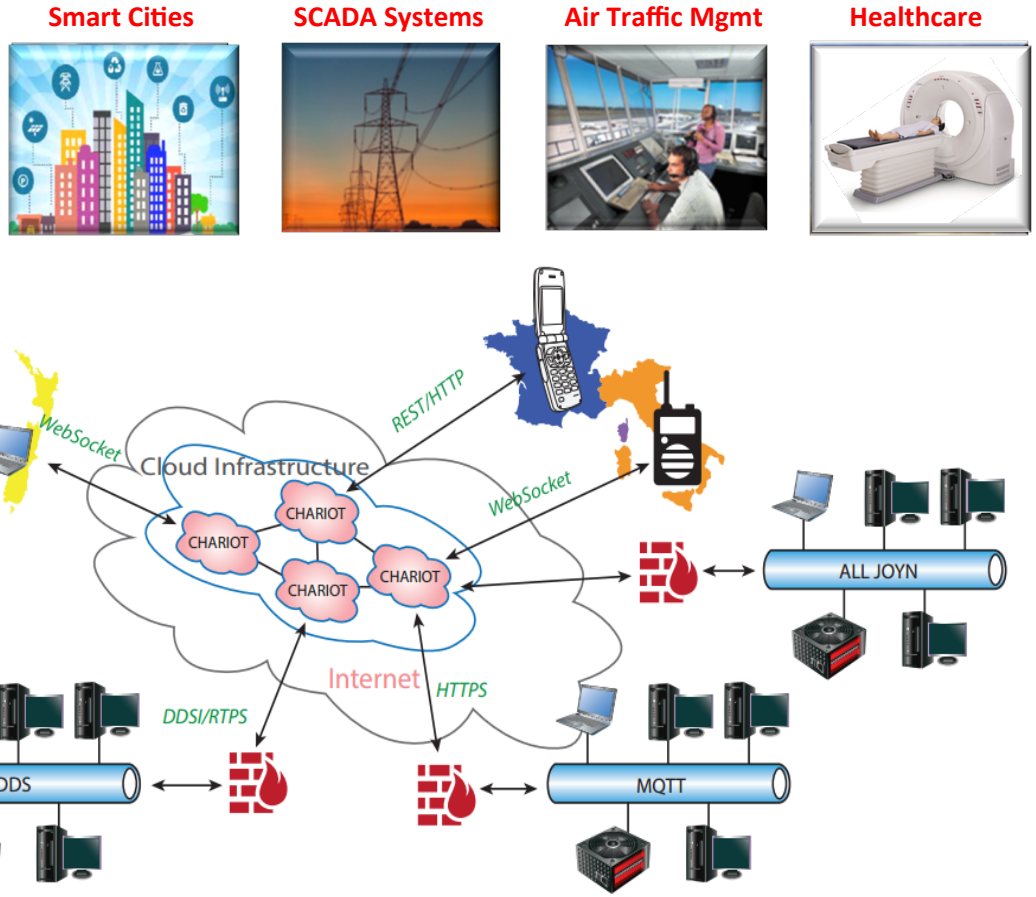
- These large-scale systems often span multiple domains



Extending the Framework

Common middleware & data models that can integrate large-scale Industrial Internet deployments

- These large-scale systems often span multiple domains
- Cross-domain interaction must therefore support heterogeneous
  - APIs & protocols



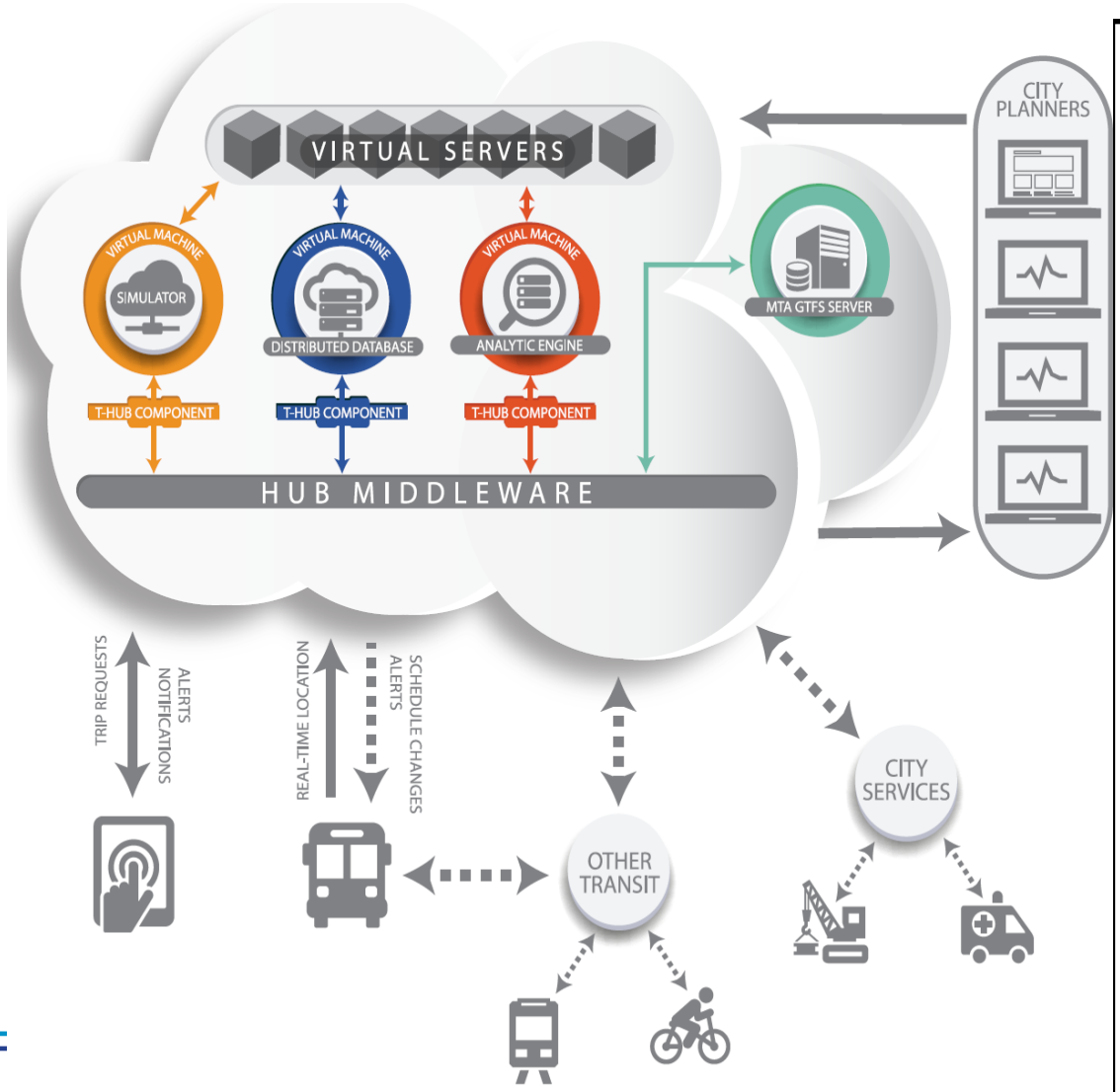

Multi-core Chips


Symmetric Multiprocessors


Blade Clusters


Public/Private Clouds

Summary



- **Real-time data ingestion**
  - –MTA Real-time GTFS feed
  - –Real-time current traffic feed using Nokia HERE APIs
- **Advanced decision support**
  - –Advanced trip planning
  - –Notifications and alerts
  - –Rescheduling
  - –City services planning
- **Incentive-based ridership promotion**
  - –Integrated health monitoring
  - –Cost and gas savings
  - –Carbon credit calculations
  - –Integration with city incentives

Broader Impacts

- Several high visibility demonstrations all over Nashville including the chamber of commerce, and Mayor's office.
- Initial research results have encouraged us to set up a center focusing on smart city research.
- Transit Hub will be deployed next year in Nashville.
- We are in discussion with the city to extend this framework to include parking management services.

Integration Platform for Human Cyber-Physical Systems In Smart Cities

Social Challenge:

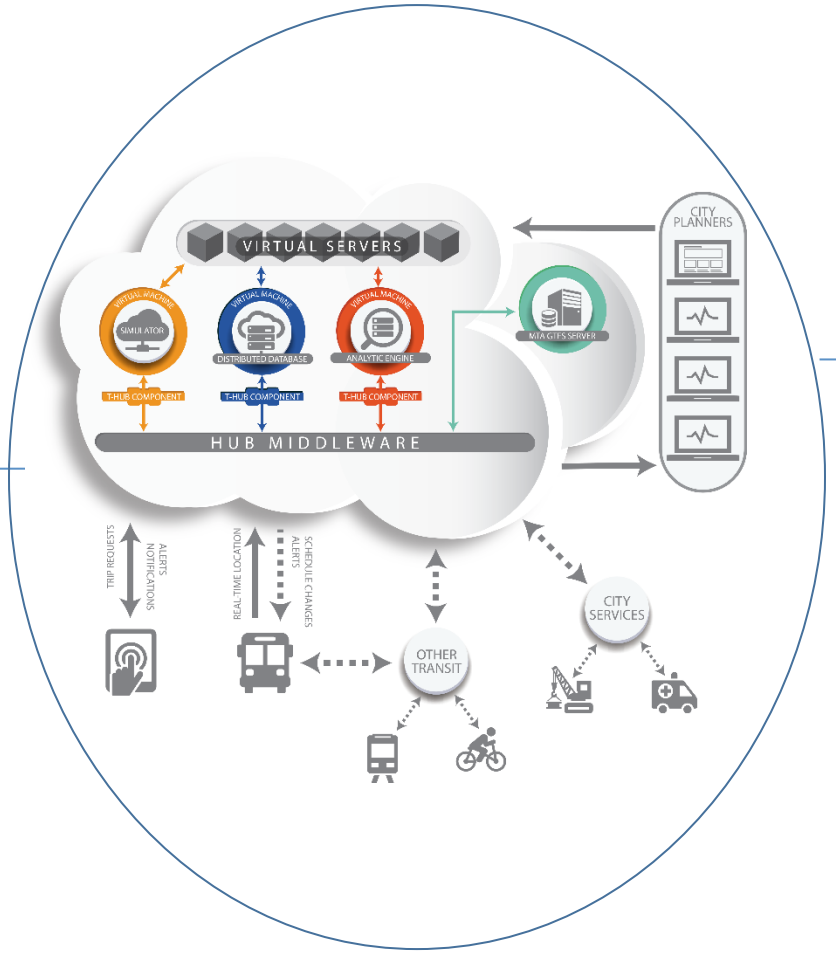
- Public Transit System is currently significantly underutilized in Nashville.
- Making transit services easier to use is important

Technical Challenge:

- Data-Driven Decision Support System
- Integrating heterogeneous sources of data
- Making the service extensible

Solution:

- HUB Middleware - New data, middleware, platform services are added using adapters at runtime.
- A smart phone based application that provides
  - Real-time planning
  - Service Alert Integration
  - Incentive Campaigns
- A decision support system
  - Data-driven analytics
  - Integrated Simulation based approach for "what-if" analysis



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Award # 1528799

Scientific Impact:

- An extensible middleware framework that can be used to integrate other city services e.g. parking management
- Framework to combine historical data-driven analytics with simulation-based real-time analytics within a H-CPS
- Understanding how decision support systems and incentive campaigns affect human engagement with the system

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