Connected Vehicle Based Active Traffic and Demand Management

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Outline

- Introduction
- Challenges and Opportunities for Research
- Connected Vehicle ATDM Case Study
- Conclusion

What is Connected Vehicle?

- Definition
  - Connected Vehicle is a suite of technologies and applications that use ***wireless communications*** and ***multiple sensors*** to provide connectivity
- Objectives:
  - To improve Safety, Mobility and Environment
- Communications:
  - Vehicle to Vehicle (V2V)
  - Vehicle to Infrastructure (V2I)
  - Vehicle to Vehicle and Infrastructure (V2VI)

Introduction

- Connected Vehicle
  - Connected Vehicle is a **multimodal** initiative, and provides the feasibility to generate more **comprehensive** and **accurate** traffic state estimation
- Active Traffic and Demand Management
  - Active Traffic and Demand Management (ATDM) is the ability to dynamically manage **recurrent** and **non-recurrent** congestion based on prevailing traffic conditions.

Introduction

- Connected Vehicles based ATDM will build the wireless connectivity
  - **among vehicles** to enable crash prevention;
  - **between vehicles and infrastructure** to enable safety, mobility and environmental benefits; and
  - **among vehicles, infrastructure, and wireless devices** to provide continuous real-time connectivity to all system users.

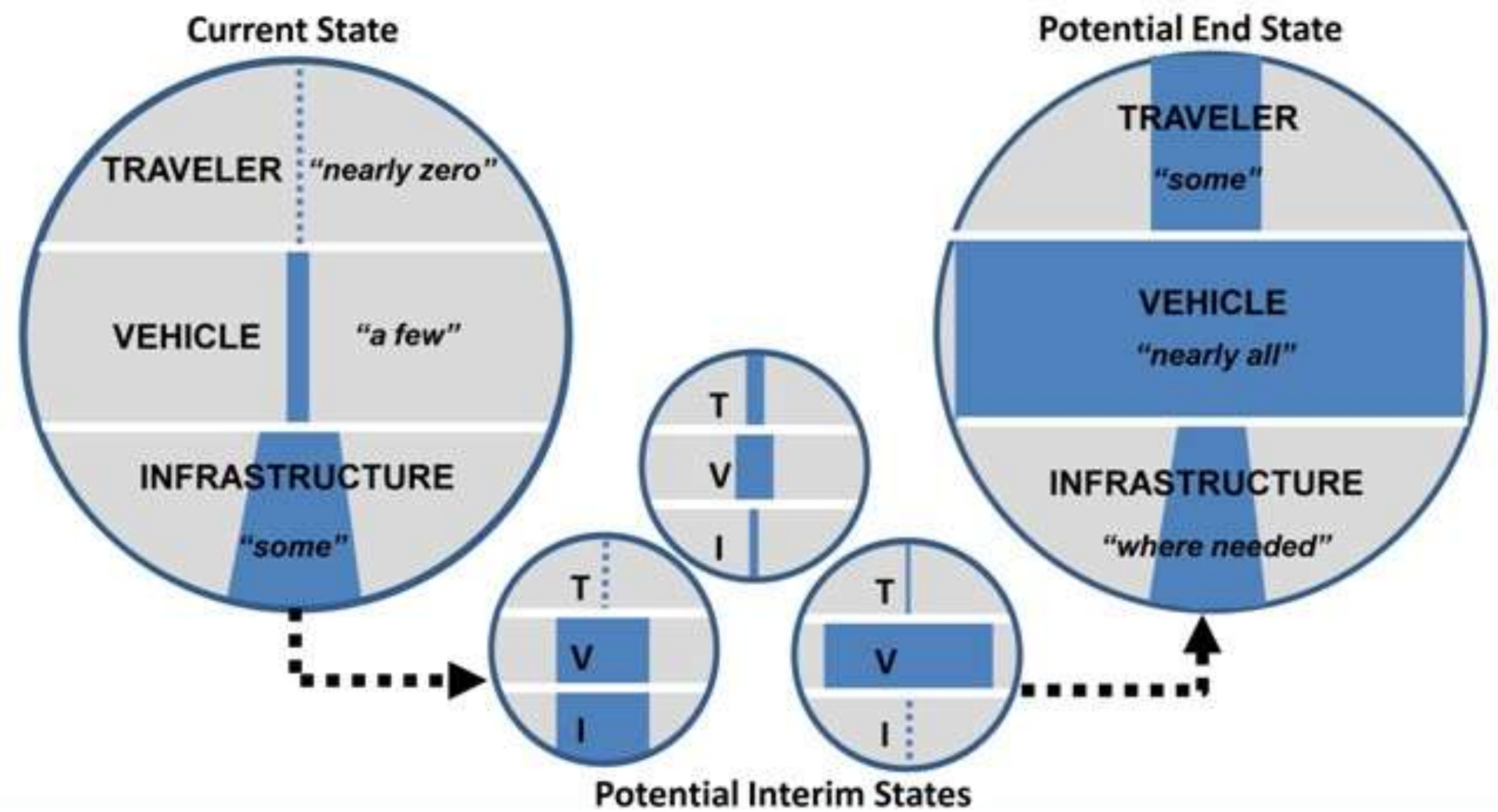
Connected Vehicle Development

- Three Major Steps

Connected Vehicle Development

- Dynamic Sensing (Upward-V2I, V2V)
  - Establish Data Sensing Environment (V2I, V2V)
  - Increase Market Penetration
  - New Application Development
- Active Control (Downward-I2V, V2V)
  - Establish Reliable I2V Control Environment
  - Active and Proactive Applications
- Integrated Coordination (Complete connection)
  - Complete upward/downward communications
  - Considering Interaction/Feedback/System Optimal
  - Integrated and System Application Development

Data Environment



Opportunities VS Challenges

Opportunities

- Data
  - Rich data environment
  - High resolution
  - Large sample size
- Control and Guidance
  - Bi-directional
  - Microscopic
  - User-specific
- Models
  - Real-time models
  - High-resolution models
  - Feedback models
  - System-optimal models
  - Integrated models

Challenges

- Data
  - Data noises
  - Multi-data sources
- Control and Guidance
  - High interaction
  - High sensitivity
  - User-specific
- Models
  - Changed nature of transportation system
  - Increased computation efficiency requirement
  - Interdisciplinary efforts

Opportunities VS Challenges

- Practice — Theory
- Next Generation Traffic Models
  - Transportation research made major advances since Greenshields’ fundamental diagrams model in 1935.
  - For young transportation researchers, it is easy to understand the details of a model than to understand the general trend and big picture of research.
  - We are at the edge of a new wave of transportation models with technological and theoretical advances in transportation.

Traffic Model Development

- The first wave (1950s – 1980s)
  - The completion of major freeway systems: US Interstate system, German Autobahn.
  - Models to describe and manage increased traffic flow.
- The second wave (1980s – 2000s)
  - The advances in information technologies.
  - Models taking the advantage of faster computers to collect, process, and use traffic data more efficiently.

Traffic Model Development

- New Generations of Traffic Models (2000s - Future)
  - Distributed and Cloud Computing, Smart Vehicle Technologies
  - Models to handle automated vehicles and user-specific control
  - Dynamic/Microscopic Traffic Control for Autonomous and Automated Vehicles

Evolution of Traffic Model

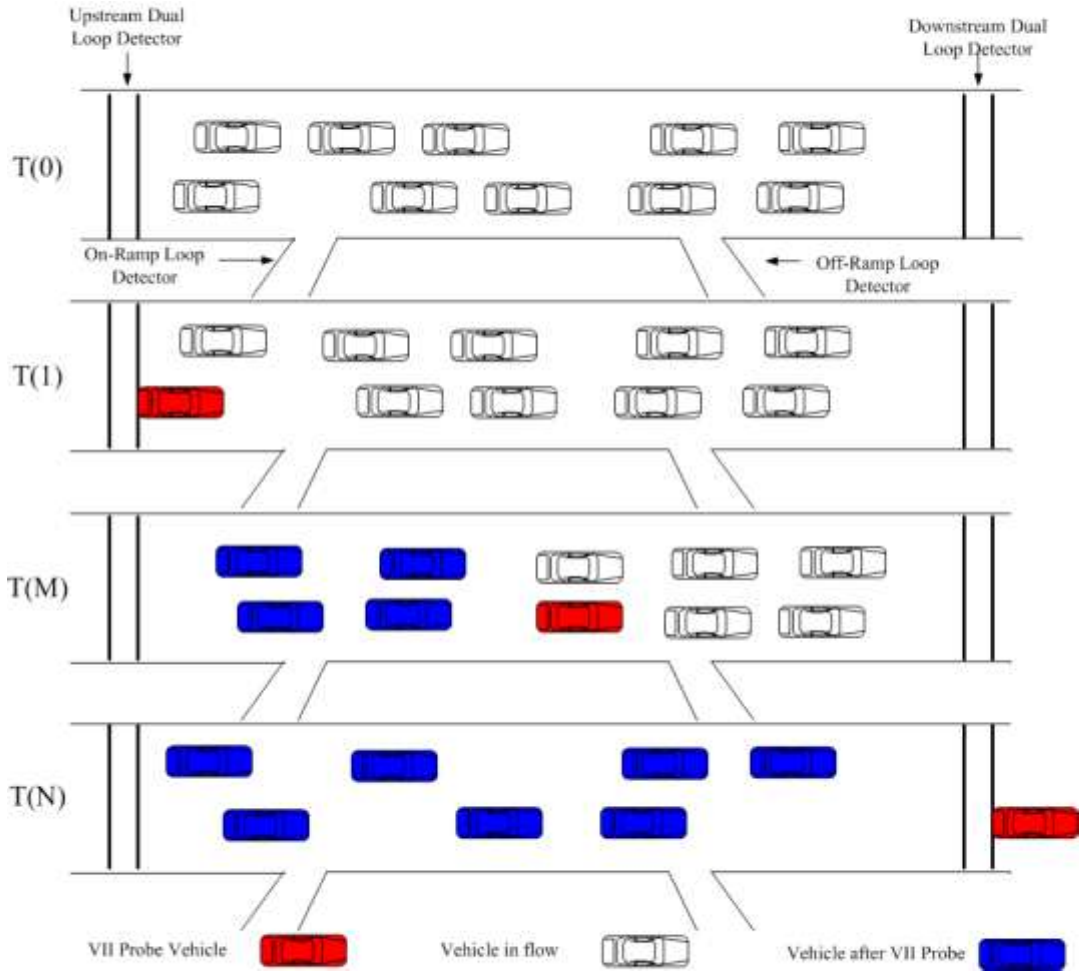
	1st Generation (1950s-1980s)	2nd Generation (1980s-2000s)	3rd Generation (2000s-?)	4th Generation (?-Future)
Background	Understand Basic Characteristics	Estimating Dynamic characteristics	Real-time characteristics and control	Automated driving and control
Key Characteristics	Empirical Static	Descriptive Dynamic	Real-time Interaction	Automated Integrated
Data Environment	Survey Experimental	24 hours/7 days Historical	24 hours/7 days High-resolution	24 hours/7 days Full information
Issues	• Labor-intensive data collection. • Not reliable for operations.	• Limited spatial/temporal coverage • Limited penetration rate	• Data reduction • Data fusion and integration • Strong interaction	• Integration with autonomous vehicles, • System reliability and security

Case Study: CV Based ATDM

- Macroscopic Traffic State Estimation
  - Density
  - Speed (space mean)
- Driver's Response to Traffic Control
  - On Board Unit (I2V)
  - Message Broadcasting (V2V)
- Measurement of Effectiveness
  - Reduce travel time
  - Increase total traffic flow
  - Reduce collision

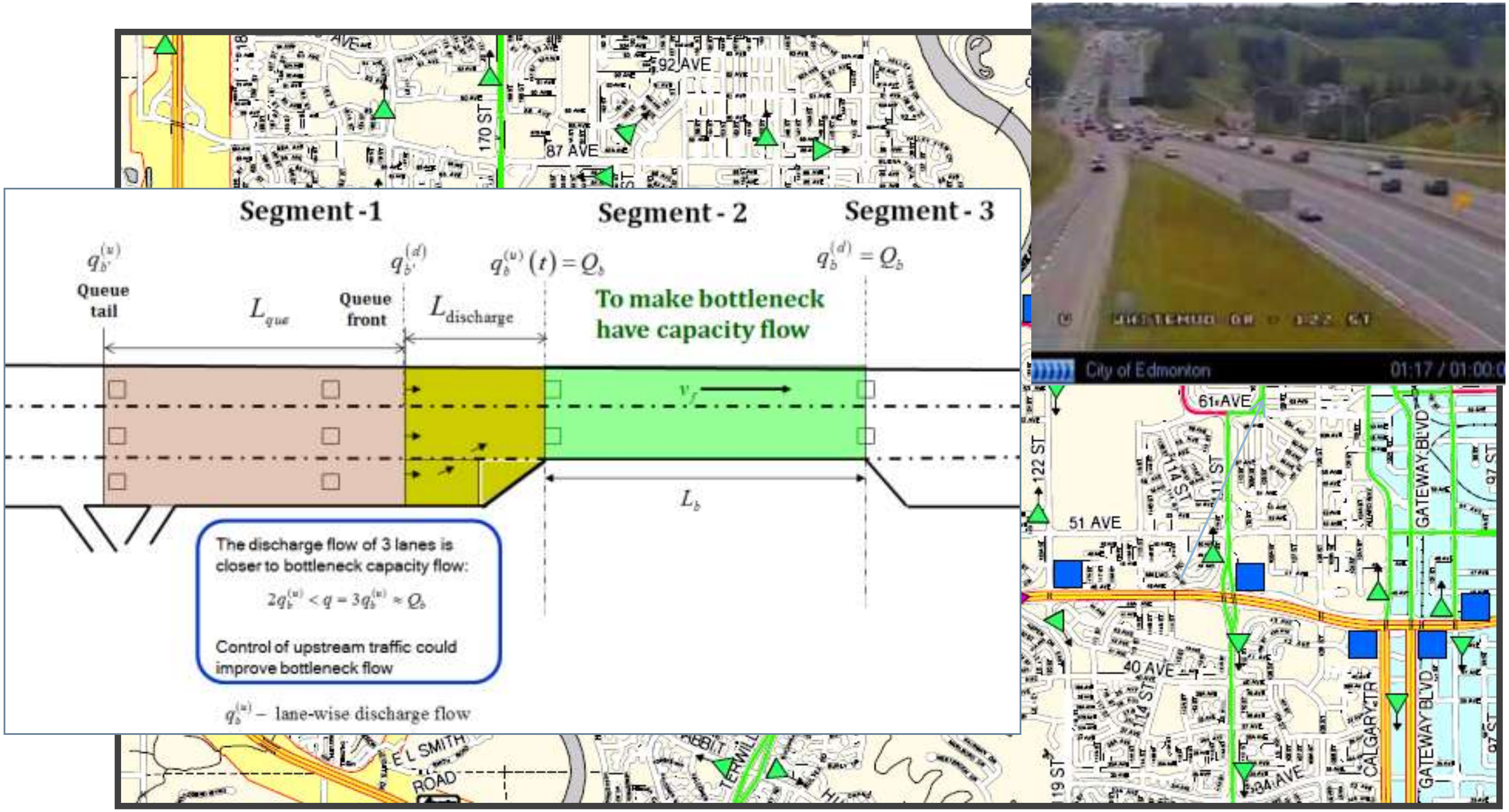
Case Study: CV Based ATDM

- Freeway Density Estimation



Case Study: CV Based ATDM

- Variable Speed Limit for Freeway Control



Whitemud Drive between 122 Street and 159 Street, Edmonton, Alberta

Model Prediction Control

Speed Dynamics

- 3 parameters

$\tau; \eta; \kappa$

$$v_{m,i}(k+1) = v_{m,i}(k) + \frac{T}{\tau}\Big(u_{m,i}(k) - v_{m,i}(k)\Big) + \frac{T}{L_m} v_{m,i}(k)\big(v_{m,i-1}(k) - v_{m,i}(k)\big) - \frac{\eta T}{\tau L_m} \frac{\rho_{m,i+1}(k) - \rho_{m,i}(k)}{\rho_{m,i}(k) + \kappa},$$

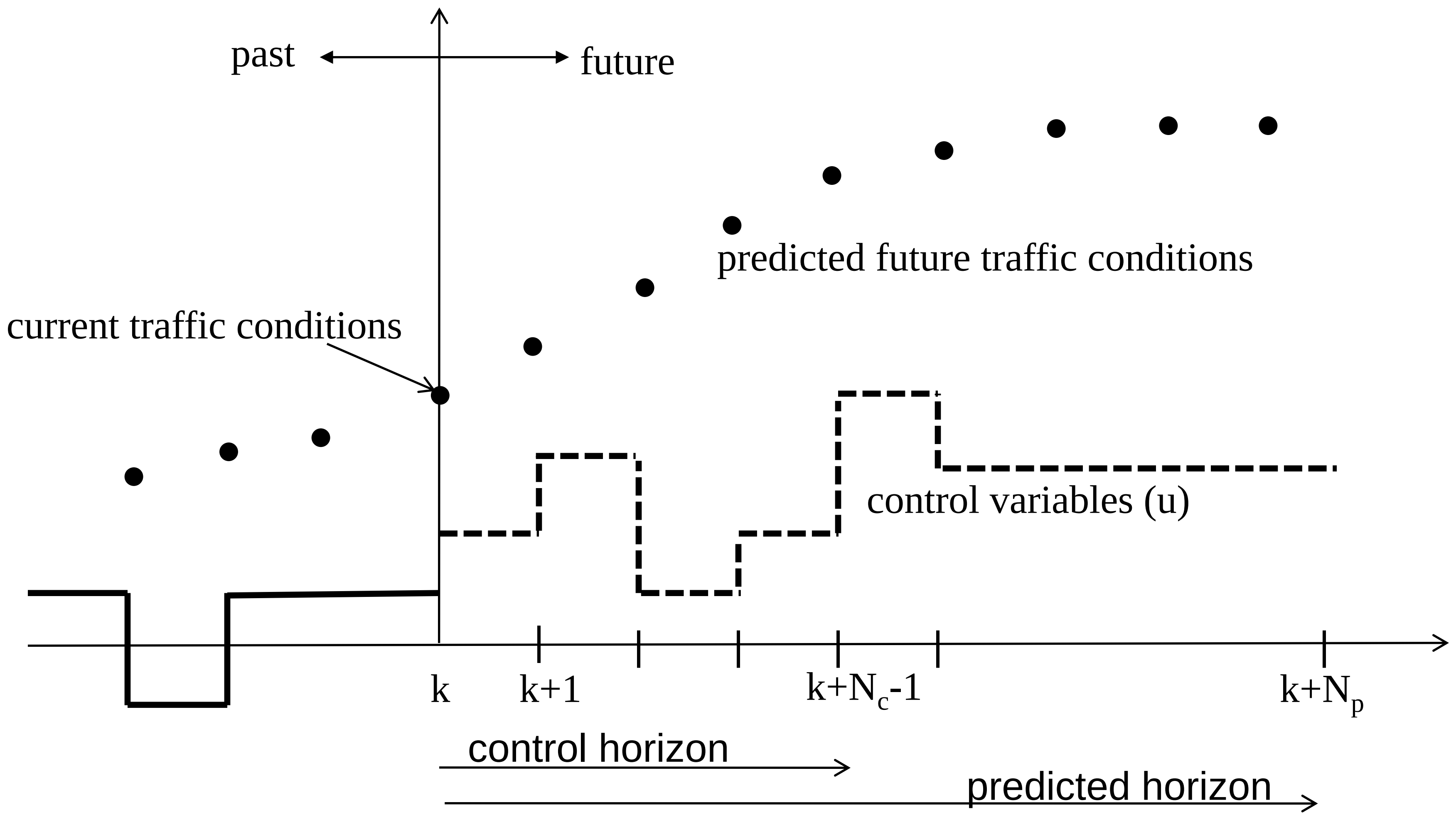
Density Dynamics

$$\rho_{m,i}(k+1) = \rho_{m,i}(k) + \frac{T}{L_{m,i}\lambda_{m,i}}\left(\rho_{m,i-1}(k)v_{m,i-1}(k) - \rho_{m,i}(k)v_{m,i}(k) + r_m(k) - s_m(k)\right)$$

Flow

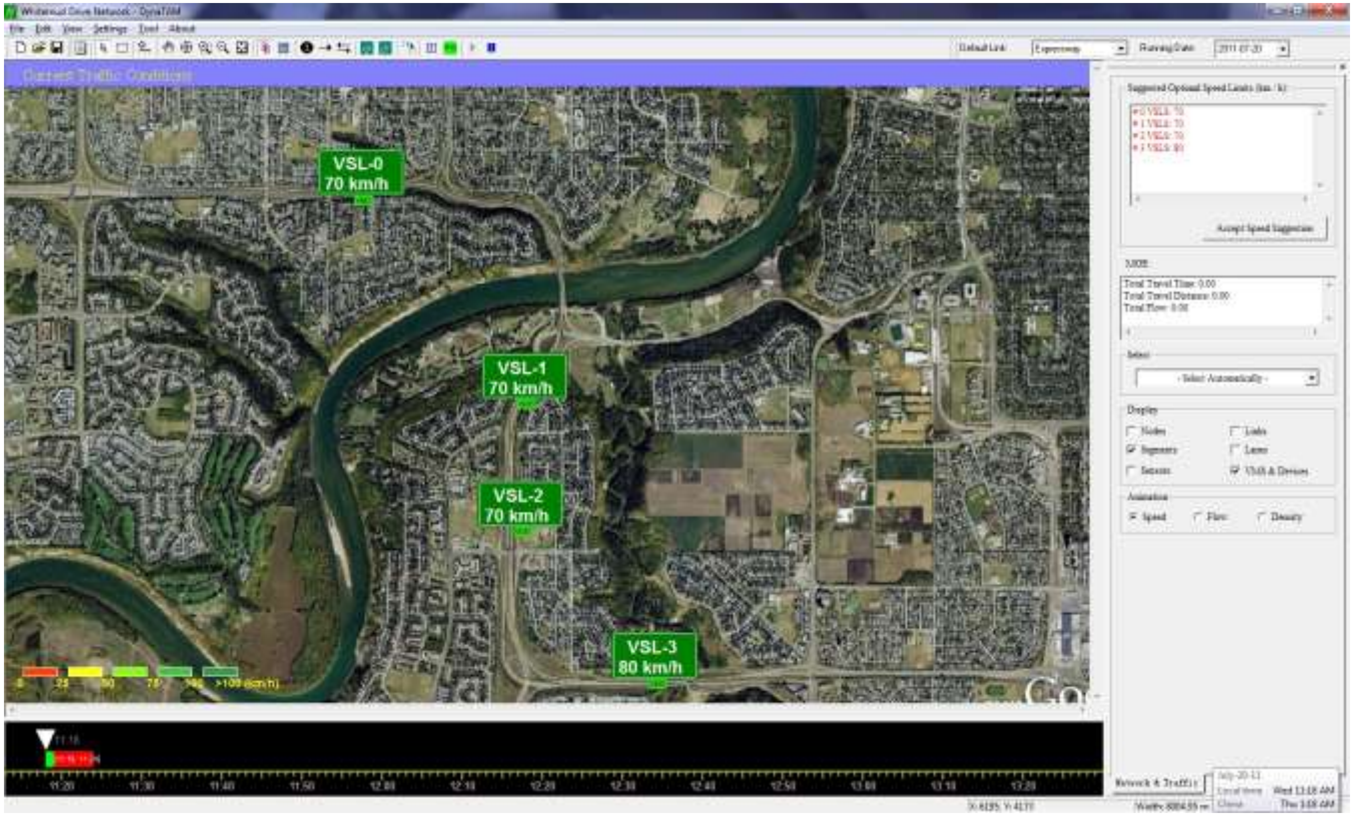
$$q_{m,i}(k) = \rho_{m,i}(k)v_{m,i}(k)\lambda_m$$

Model Prediction Control



Variable Speed Limit

- DynaTAM: Dynamic Tool for Active Traffic Management – used in Traffic Management Centre in City of Edmonton



CV Test Bed - ACTIVE

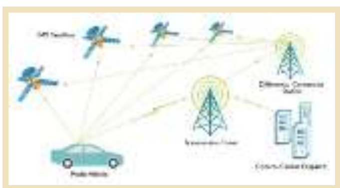
- ACTIVE: Alberta Cooperative Transportation Infrastructure and Vehicles Environment
- ACTIVE: Traffic Data and Control
- ACTIVE Partners
  - City of Edmonton
  - Alberta Transportation
  - Transport Canada
  - University of Alberta
  - Other Industry Partners

CV Test Bed - Applications

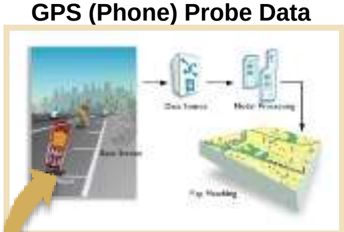
- Connected Vehicle Based Data Applications
  - Cellular Probe Based Speed Monitoring
    - Antoney Henday Drive
    - Other 4 corridors
  - Cellular Probe Based OD Estimation
    - Multimodal
    - Edmonton and Calgary, Edmonton airport
- Connected Vehicle Based Control Applications
  - Freeway Variable Speed Limit Control
    - Whitemud Drive
  - Adaptive Signal Control Considering Capacity Dynamics
  - Transit Bus Priority Control
  - Driver Guidance via Variable Message Signs
  - Enhance Winter Roadway Maintenance Efficiency

CV Based Traffic Monitoring

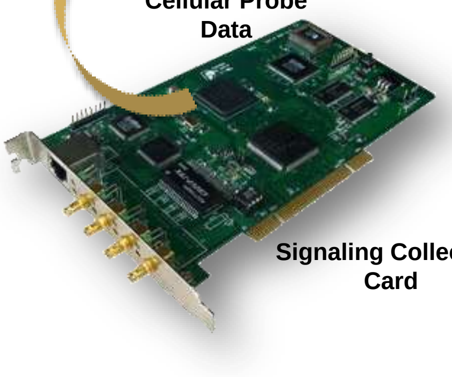
- Cellular Network



GPS (Phone) Probe Data



Cellular Probe Data

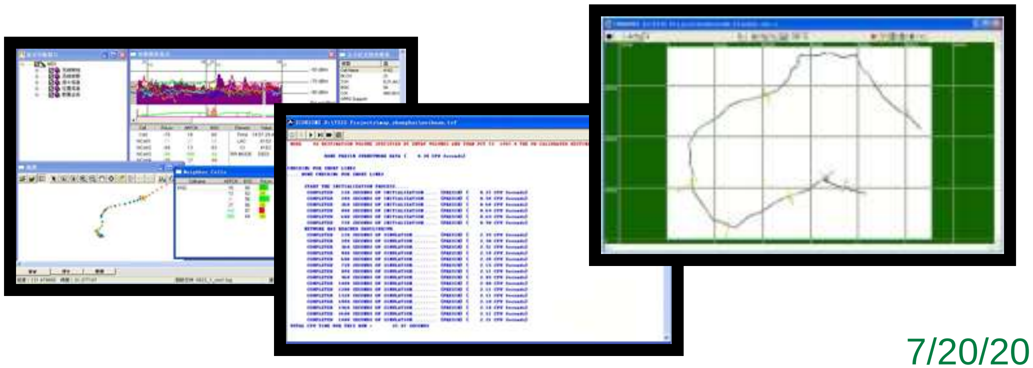


Signaling Collection Card

Traffic Modeling

- Map Match Engine
- Sample Filtering Engine
- Data Fusion Engine
- State Estimation Engine
- State Prediction Engine
- Parameter Calibration Engine

Real-time Traffic Data



CV Test Bed - ACTIVE

Phase 1: Anthony Henday Drive from Manning Drive NW to the Yellowhead Trail and the Whitemud *Drive from 156 Street to 122 Street (2012 July-2014 March)*

Phase 2: Anthony Henday Drive from Manning Drive NW to Yellowhead Trail, to Gateway Blvd from Yellowhead Trail to 170 street, Whitemud Dr. and 75 Street (2014 April-2016 March)

Phase 3: Cover most of the major roads in Edmonton Metro area. (2016 April -2018 March)

Conclusion

- Connected Vehicle is approaching us, and it potentially will make transportation smarter!
- The involvement of public sectors, private sectors and academic institutes are required!
- More challenges and opportunities in the ITS field!

THANKS

QUESTION?