Integrated Data System Structure for Active Traffic Management - Planning and Operation

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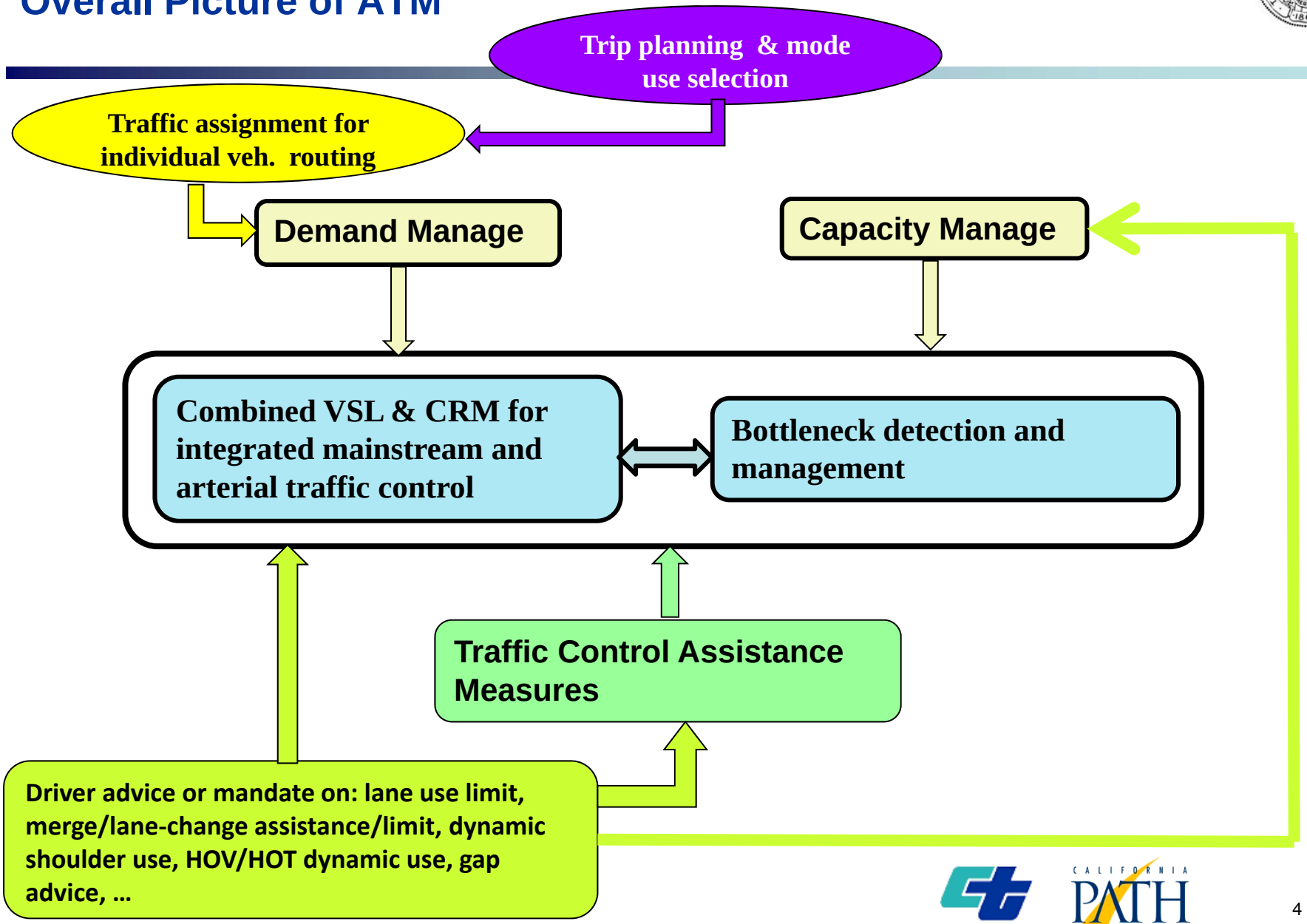
Outlines

- **Active Traffic Management (ATM)**
- **Towards Integrated Traffic Data Systems**

Active Traffic Management

- Overall Picture of ATM
- Demand Manage
- Capacity Management
- Freeway Traffic Control
- Bottleneck Detection and Handling
- Coordination between Freeway and Arterial Traffic Control

Overall Picture of ATM



Demand Manage

- **Demand manage - Semi-global (corridor or network) range – dynamically assigning traffic according to *predicted demand* and *practical capacity***
  - **Routing**
    - **Network wide**
    - **Routing through arterial/surface street (using alternate onramp and off-ramp)**
  - **Diverging (using alternate onramp and off-ramp)**
  - **Integrated manage for freeway connections**

Capacity Manage

- Real-time operation (practical) capacity estimation
- Mainline capacity flow is determined by bottleneck capacity flow
- Capacity of a corridor with multiple bottlenecks is determined by the bottleneck with the minimum capacity unless diverging road is available
- Planning: revise recurrent bottleneck to improve physical capacity
- Operation: maximally use capacity for highest mobility
  - Active (dynamic or temporary) shoulder use if necessary
  - Active (dynamic or temporary) HOV/HOT lane manage

Freeway Traffic Control - Coordinated VSL and RM

- **RM:**
  - **Local traffic responsive RM directly control average density for the immediate downstream**
  - **Corridor wide Coordinated RM control balances the main lane flow and demands from onramps**
  - **Only indirectly affecting speed passively**

- **VSL:**
  - **To control driver behavior in mainline**
  - **To reduce speed variance in the same lane and between lanes**
  - **To smooth traffic and delay/avoid shock wave including *Stop&Go***
  - **To control mainline traffic flow when RM switched off due to onramp length limit and/or equity issues**

Freeway Traffic Control - Coordinated VSL and RM

- **Combined VSL & CRM**
  - **To control traffic in different aspects and complementary**
  - **To control main line traffic to a large extent for given demand, capacity and current traffic situation**
  - **To homogenize/stabilize traffic flow**
  - **To control density distribution**
  - **To achieve higher density (thus flow) for the same speed**
  - **To delay congestion start time**
  - **To achieve maximum possible flow (not necessarily free-flow) under congested condition**
  - **Two legs of a person**

Freeway Traffic Control – Other Measures

- **Local Active Traffic Management to smooth traffic**
  - **Merging manage – assisting onramp merging**
  - **Weaving manage**
  - **Maximizing off-ramp flow**
  - **Dynamic Lane Use Manage**

Bottleneck Detection and Handling

- **Needs traffic data immediate upstream as well as within the bottleneck**
  - **Demand over capacity–lane drop due to geometry or road work zone**
  - **Off-ramp spills back: case-by-case based on traffic & road geometry**
- **Needs on-ramp and off-ramp data**

Bottleneck Detection and Handling

- **Non-recurrent – detection and assessment are crucial**
  - **Demand over capacity**
  - **Incident/accident**
  - **Driver behavior or slow vehicle: moving bottleneck**
  - **Off-ramp spill back**
  - **Other causes**
  - **Weather/visibility (capacity reduction)**

- **Challenge:**
  - **To quickly identify the type of bottleneck, its location**
  - **To quantitatively estimate/predict its impact on traffic**

Coordination between Freeway and Arterial Traffic Control

- **Objectives:**
  - **To relieve the conflict between high demand to freeway and traffic congestion in arterials to optimize the traffic systematically.**
  - **To avoid/minimize traffic spills back into arterial/surface street**
  - **Balance the efficiency of moving in peak hours**
  - **Optimization in a system level**
- **The problem: subsystems interact with each other needs coordination**
  - **Arterial traffic control**
  - **Freeway Traffic Control**

Coordination between Freeway and Arterial Traffic Control

- **Possible solution: systematic coordination**
  - Optimize w. r. t. an integrated system performance measure
  - Slow down arterial multiple intersection traffic flow if necessary
  - Diversion to adjacent street if necessary
- **Planning:**
  - Onramp length for adequate storage capacity for peak hours
  - Smart road geometry design
- **Issues for integration**
  - Equity among multiple onramps subject to length limit
  - Technical:
    - Integration of data system
    - Integration of different traffic control system
  - Institutional: close cooperation of state DOT, county & city

Towards Integrated Traffic Data Systems

- Data Requirement for ATM
- Current Traffic Data Systems Structure
- New Technologies and Information Available
- Next Step Data Systems Structure
- Function of VII
- Data System Examples
- Data Quality and ATM Performance
- How to Maximally Use Current Data System
- Integrated Traffic Data System for Planning and Operation

Data Requirement for ATM

- **Low Goal for local traffic responsive or coordinated RM**
  - **Distance mean speed**
  - **Average density**
  - **Data aggregation level:**
    - **Time: 30~60s**
    - **Space: 200~300m**
- **High Goal: Accurate and reliable traffic state parameter estimation over time and space**
  - **Spatial-temporal (distance mean) speed estimation**
  - **Spatial-temporal density distribution**
  - **Traffic prediction over certain period of time**
  - **Data aggregation level:**
    - **Time: 10 ~ 20s**
    - **Space ~ 150m**

Data Requirement for ATM

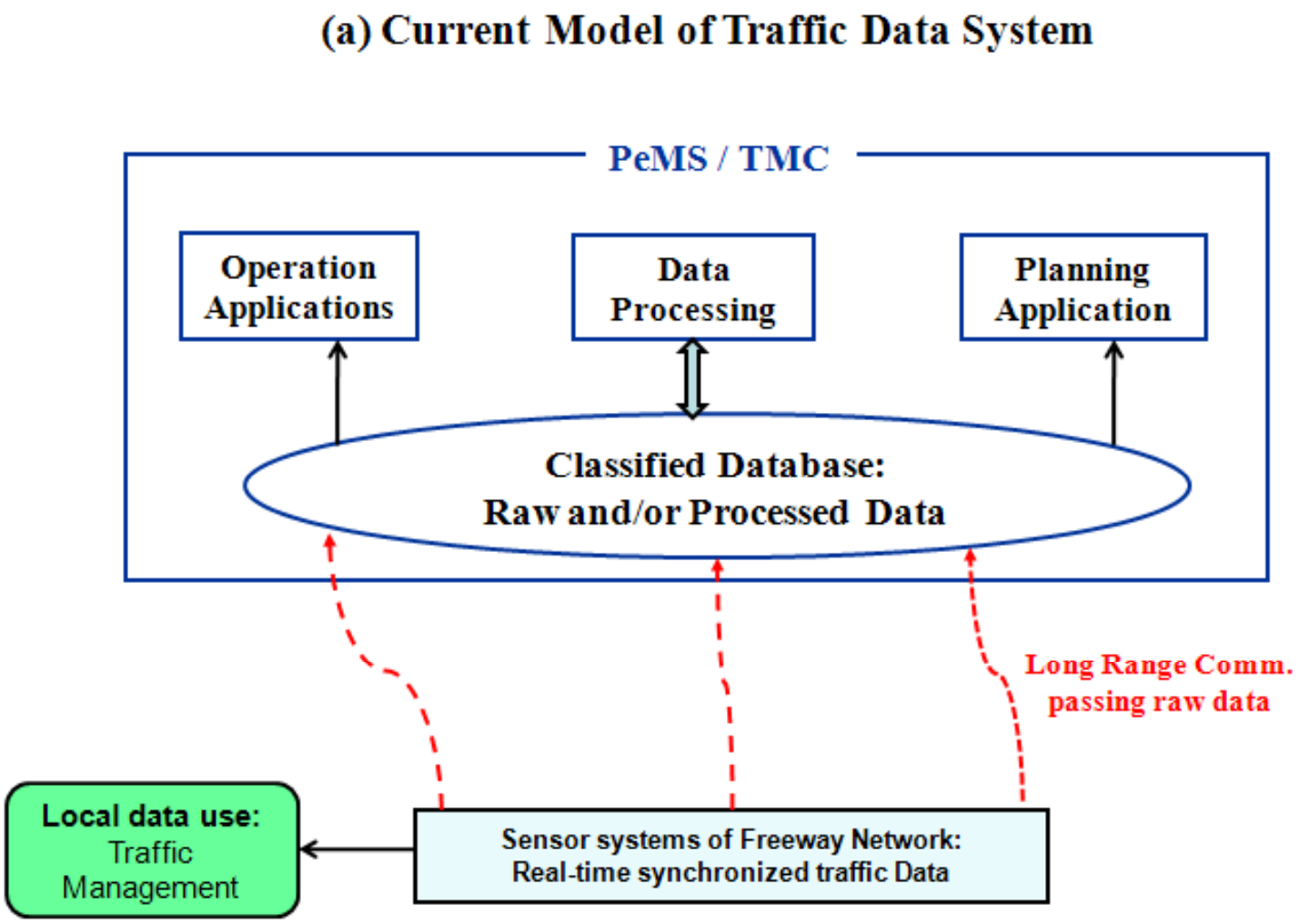
- **OD for a given set of modes:**
  - **Only possible if**
    - **VII is available for individual vehicle**
    - **Traffic assignment conducted network wide**
    - **Dynamic rerouting in case of incident/accident**

- **VSL and RM have to be coordinated instead of local**
  - **Real-time capacity estimation**
    - **Recurrent bottleneck: influence zone**
    - **Non-recurrent bottleneck: influence zone**
  - **Integration with arterial and surface street traffic control**
  - **Dynamic reconfiguration through wireless or cable**

Data Requirement for ATM

- **Coordinated RM Needs:**
  - **Minimum Requirement**
    - **Onramp queue length measure**
    - **Off-ramp flow**
  - **Medium Goal: in addition**
    - **Density distribution**
    - **Synchronized data along a corridor**
  - **High Goal: in addition for *merging assistance***
    - **Individual vehicle movement**
- **VSL Needs:**
  - **Spatial-temporal speed estimation**
  - **Spatial-temporal density estimation**

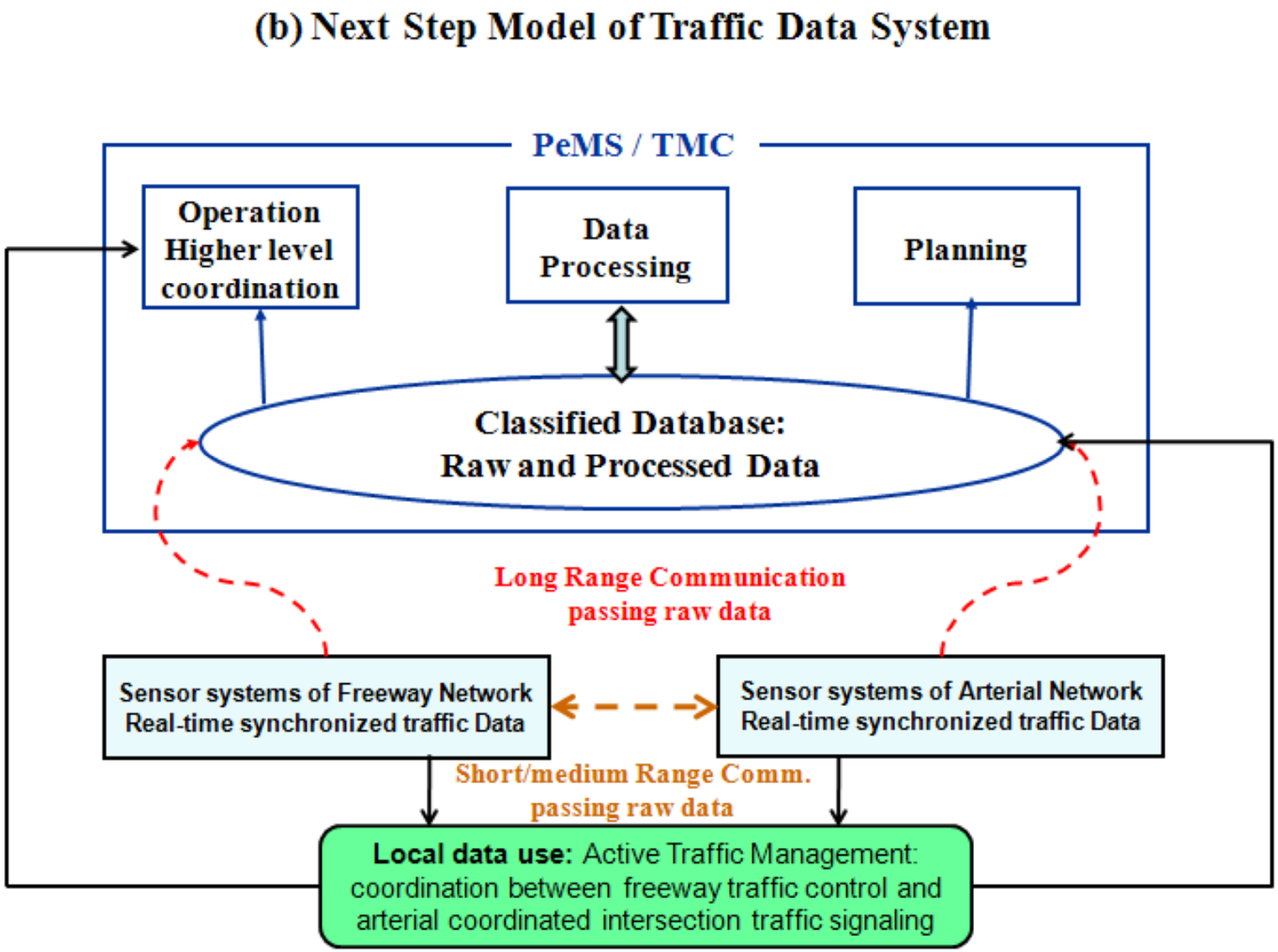
Current Traffic Data Systems Structure



New Technologies and Information Available

- **Computer technologies-miniature and used in almost all corners**
- **Road sensors: smart cards for inductive loops, magnetometer, lidar, microwave radar, digital video camera, infrared radar, acoustic sensor, piezoelectric (WIM), light beam, …**
- **Vehicle Information: J-Bus, onboard and remote Sensors, GPS, …**
- **Communication System**
  - **Wireless (GPRS, Cell-phone, DSRC – VII radio, WiFi, Bluetooth,)**
  - **Fiber-optics cable**
  - **Telephone line - DSL**
- **Information System**
  - **Internet, GIS, iPhone**
  - **Video, Radio**
  - **VMS, Traffic signs: Real-time feedback to the driver**
  - **Individual vehicle feedback**

Immediate Next Step Data Systems Structure



Function of VII in Active Traffic Management

- **VII Vehicle include: probe vehicles; vehicle equipped with VII DSRC; vehicle equipped with combined cell-phone and GPS**

- **VII Vehicle Info:**
  - **Continuous measure over time**
  - **High market penetration of VII provides data continuous in both time and space**
  - **Single VII vehicle providing narrow moving distance-window measure**
  - **Certain percent of market penetration VII vehicles provide traffic measurement continuous over time and distance**

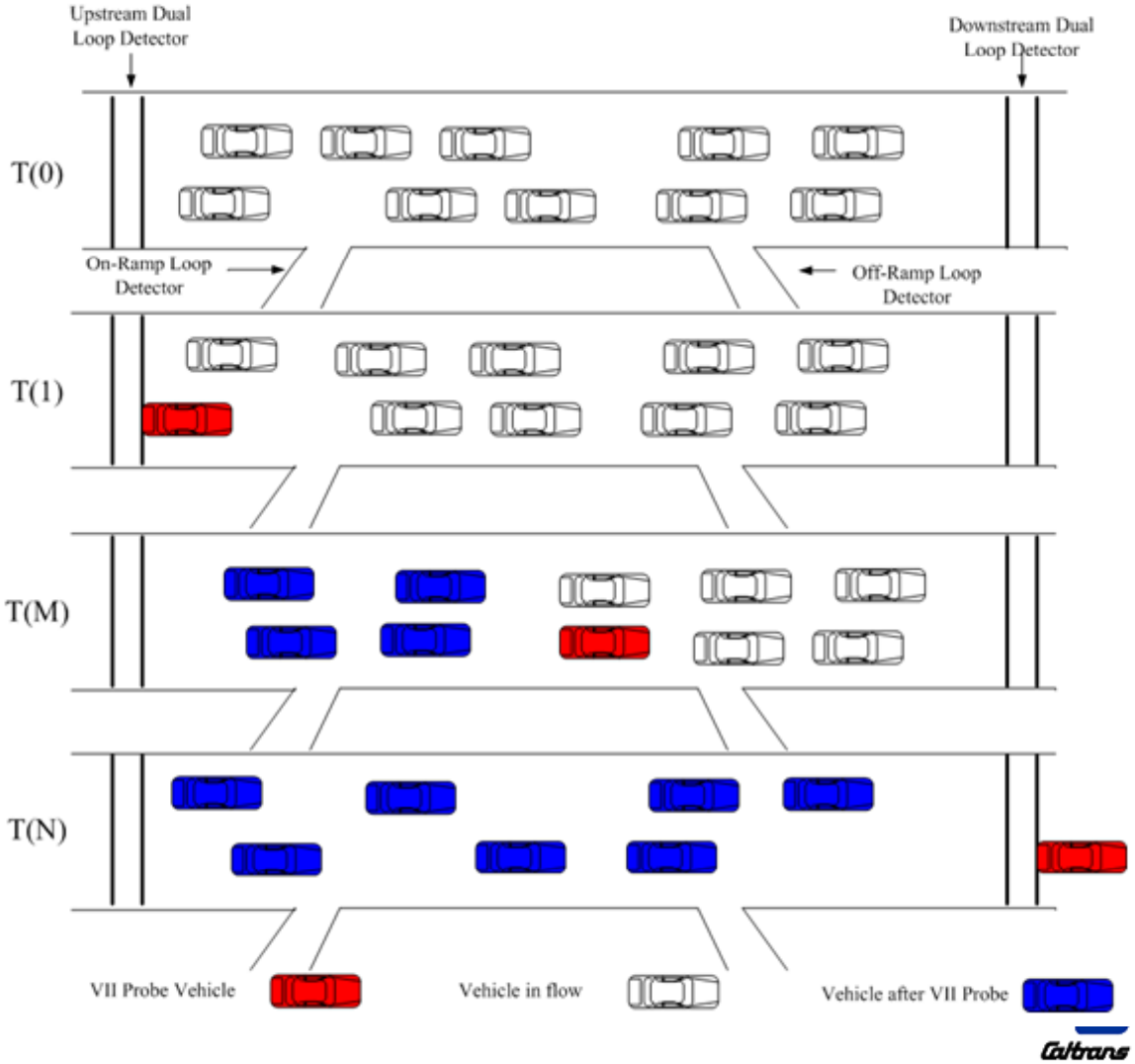
- **Road sensor only provide point/short range measure: heavily depends on sensor type, location, density, measurement accuracy, reliability, …**

Function of VII in Active Traffic Management

- **Application:**
  - **Traffic state estimation/prediction;**
    - **OD estimation**
    - **Spatial and temporal speed and density estimation**
    - **Retrieving microscopic traffic data**
    - **Refined RM, merging assistance,…**
  - **Congestion onset detection and management;**
  - **Active safety**
    - **Collision warning and avoidance**
    - **Intelligent intersection**
- **Future Trend:**
  - **VII data directly routed to control cabinet**
  - **Gradual merging/fusing point sensor data with VII data**

Function of VII in Active Traffic Management

- **Fusion of BHL loop & VII data for accurate speed and density estimation**



Data System Examples:

- PeMS
- Netherlands NDW (National Data Workhouse)
- POTAL
- Berkeley Highway Lab (BHL)

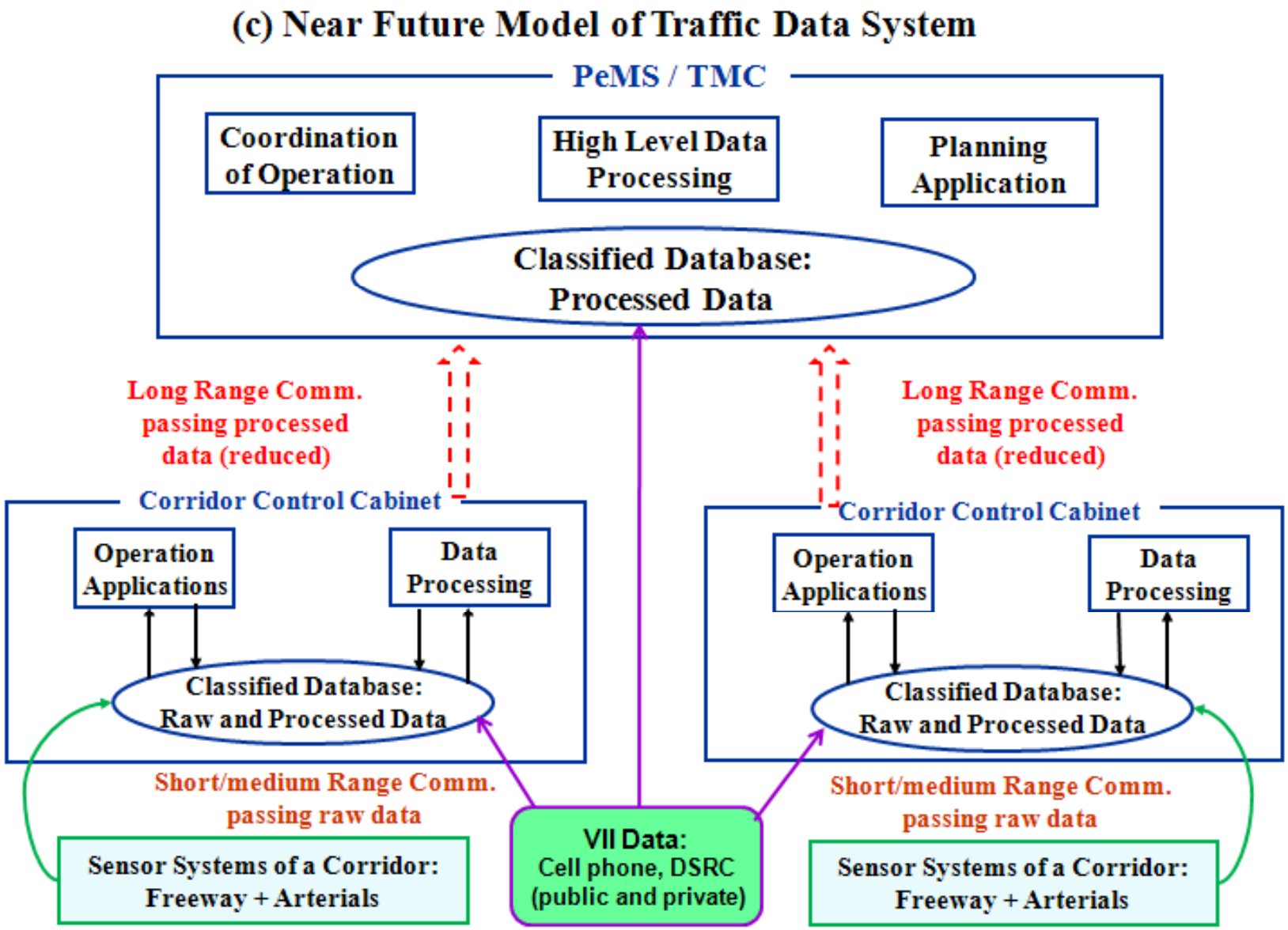
Data Quality and ATM Performance

- **Data quality determines traffic control performance**
  - **Most RM methods very simple; mostly determined by data quality**
  - **Quantitatively sensitivity analysis of the control system**
- **Data quality**
  - **Measurement noise and error (discrepancy)**
  - **Reliability**
  - **Time delay**
    - **from sensor**
    - **from communication for data passing**
    - **from data processing (such as aggregation)**
    - **from data aggregation**
- **Improving data quality in different level**
  - **Microscopic (sensor reading) - essential**
  - **Mesoscopic – a section of freeway & arterial**
  - **Macroscopic – corridor level (PeMS/TMC)**

Data Quality and ATM Performance

- Systematic Sensor Fault Detection and Management
- Systematic data correction in different level, but critical in even data level
- Developing Reliable Communication Systems for data passing

Integrated Traffic Data System for Planning and Operation



Integrated Traffic Data System for Planning and Operation

- **Systems approach for supporting ATM**
  - Integrated and system wide performance measurement
  - Integrated freeway and arterial data system
  - Synchronized data in time and unified coordinate in space
  - Private and public data, from road-side and on-vehicle sensors
  - Optimal combination of sensor types and locations
- **Minimizing data storage and maximizing data utility**
  - Local data fusion and traffic parameter estimation for operation
  - ATM; ATIS; corridor level and system wide strategic planning
  - Processed and classified database at PeMS or TMC level
- **Improving data quality**
  - Systematic sensor fault detection, remedy and maintenance
  - Developing reliable communication systems for data passing
  - Systematic data correction and filtering in application

Thank You!

Please send questions and comments to: ***xylu@path.berkeley.edu***