A Networked Remote Sensing System for On-Road Vehicle Emission Monitoring

中国科学技术大学

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Low-cost, Large-scale Monitoring Is Key to Control Vehicle Emissions

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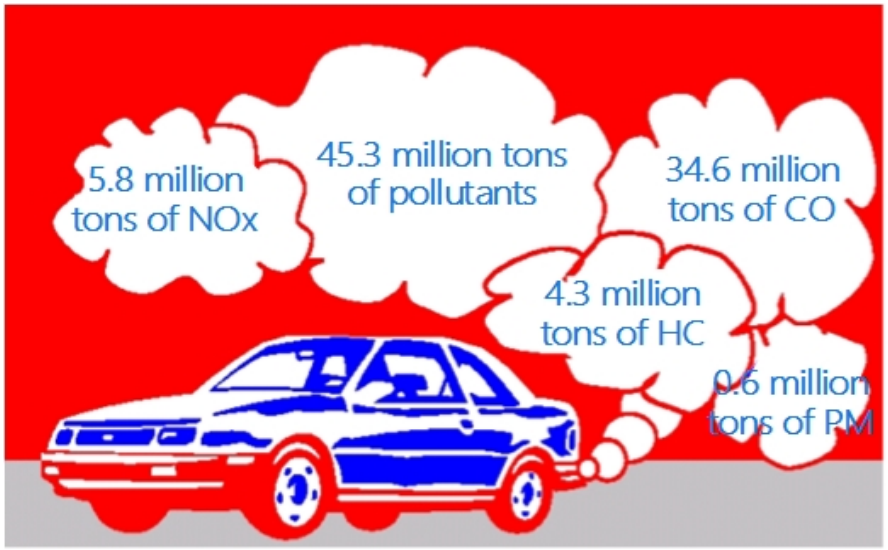
Air pollution is one major concern for China's future

- **78.4% of all cities in China exceed the air quality standards.** -- 2015 Report of the State of the Environment in China

- **7 million premature deaths annually linked to air pollution.** -- WHO, 2014

Vehicle emissions is one major source to air pollution



- **NOx emitted by vehicles account for 30% of the total quantity.**
- **Vehicle emissions contribute about 30% of all particulate matters. In extreme weather condition, the ratio can rise to 50%.** – 2016 China Vehicle Environmental Management Annual Report

The government dominates the battle against vehicle emissions

- **The battle against vehicle emissions can never be market dominated**
  - **Emission reduction causes additional cost to vehicle manufactures**
  - **The government is dominant: Reward the good and punish the bad**

- **The government has already taken actions**
  - **"Build supervision system of motor vehicles and fuel oil standards of environmental protection"** --The 13th Five-year Plan for National Economic and Social Development
  - **"Focus on developing the regional environmental quality monitoring and early warning technology, break through the key technology of urban air pollution control"**--National Outline for Medium and Long Term S&T Development
  - **"Develop mobile source emissions testing technology for conventional pollutants and key precursor of compound and non-conventional pollutants recognition and detection technology"** --National environmental protection S&T Development in the "13th Five-Year"

Low-cost, large-scale monitoring is key to the government dominated battle against vehicle emissions

- **Monitoring the emissions is the foundation to the policy "reward the good and punish the bad"**

- **The requirements of the monitoring**
  - **Large scale**: ideally for all vehicles
  - **Low cost:** since there are so many vehicles
  - **Automatic:** otherwise it can never be of low cost
  - **Friendly to vehicle owners:** they should not be asked to do the test at specific time and location, etc.
  - **Friendly to data users (the government):** they should be able to access to the real-time data of all interested area in a friendly format

Traditional methods do not meet the requirements

Idle speed test

Driving mode test

Small scale

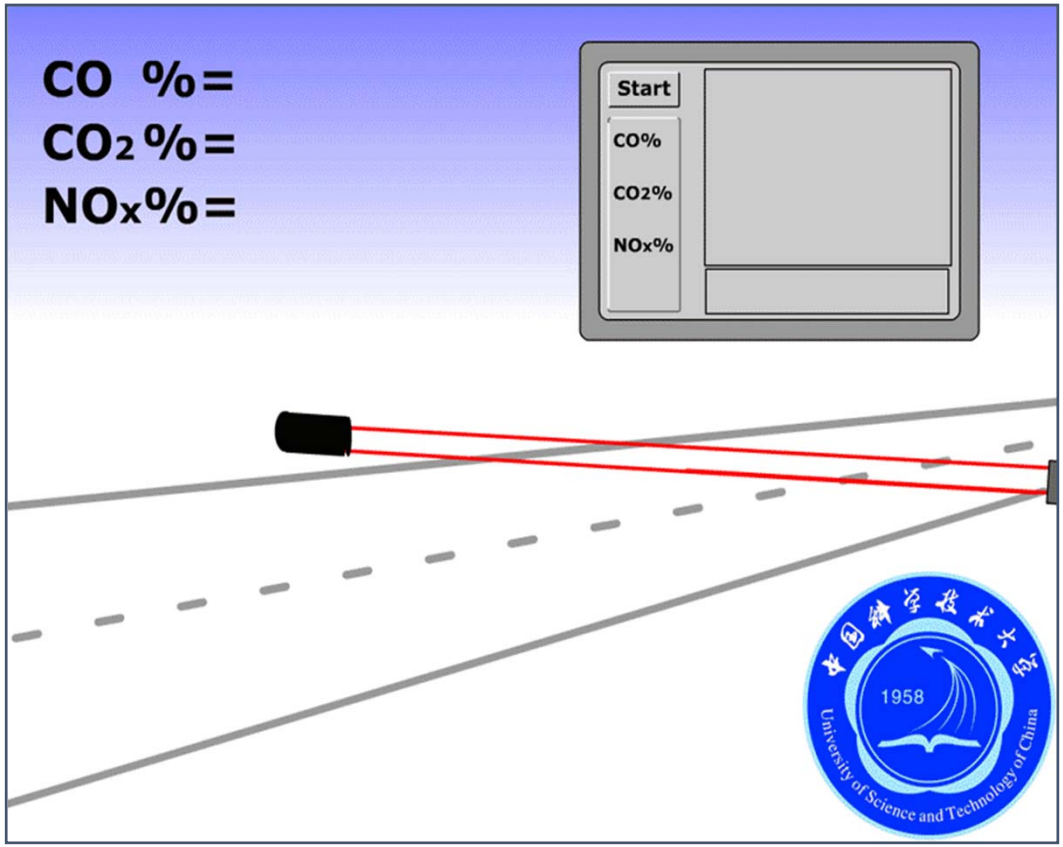
High cost

Non-automatic

Non-friendly

Remote sensing may be a promising technique

- Using remote sensing to detect vehicle exhaust has a long history
- How remote sensing works:
  - **The equipment: :** Infrared and ultraviolet light emitter and receiver mounted on both roadside.
  - **The measurement:** Light signal after being attenuated by emissions of passing vehicles
  - **The calculation:** based on the strengths of two light signals



Existing remote sensing technique needs reformation for our purpose

- Existing remote sensing is
  - Low cost
  - Automatic for a single vehicle
  - Friendly to vehicle owners
- Existing remote sensing is NOT
  - Large scale: it is only for single-point detection
  - Automatic at the large scale
  - Friendly to data users (the government)

A Solution Based on A Networked Remote Sensing System (NRSS)

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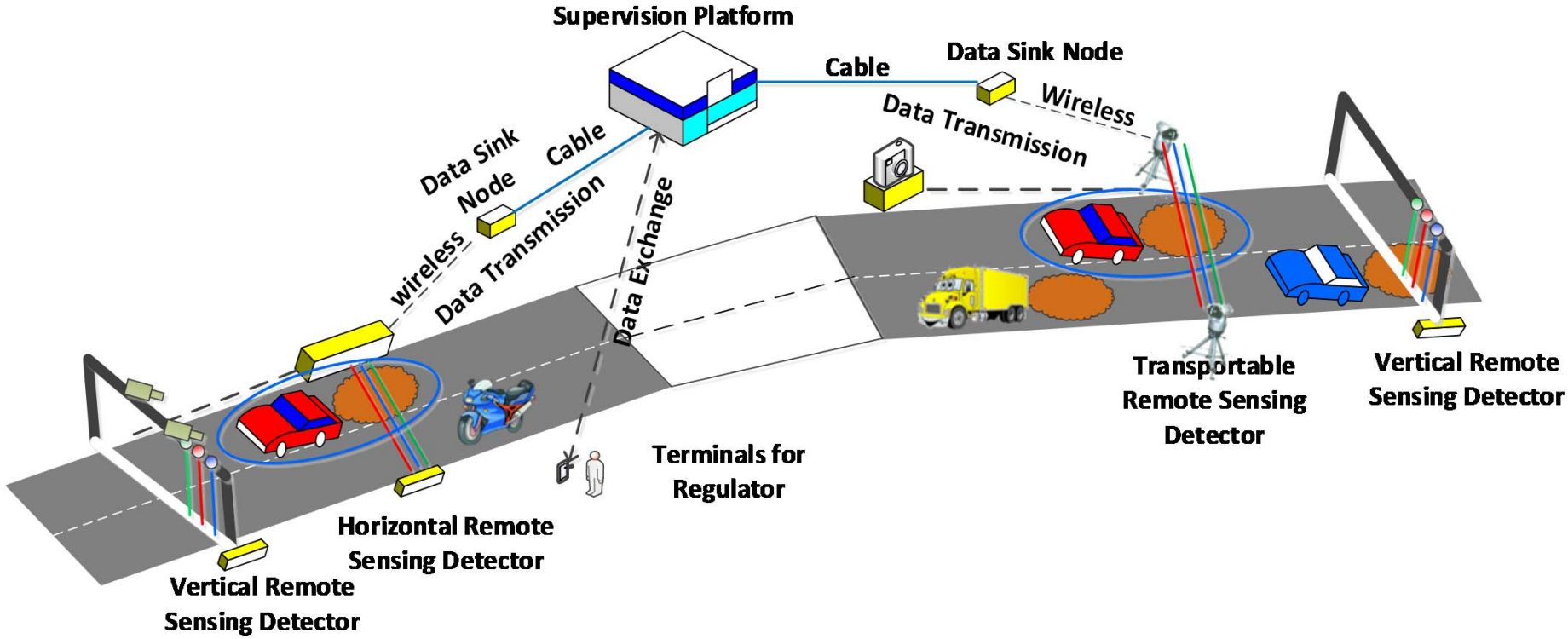
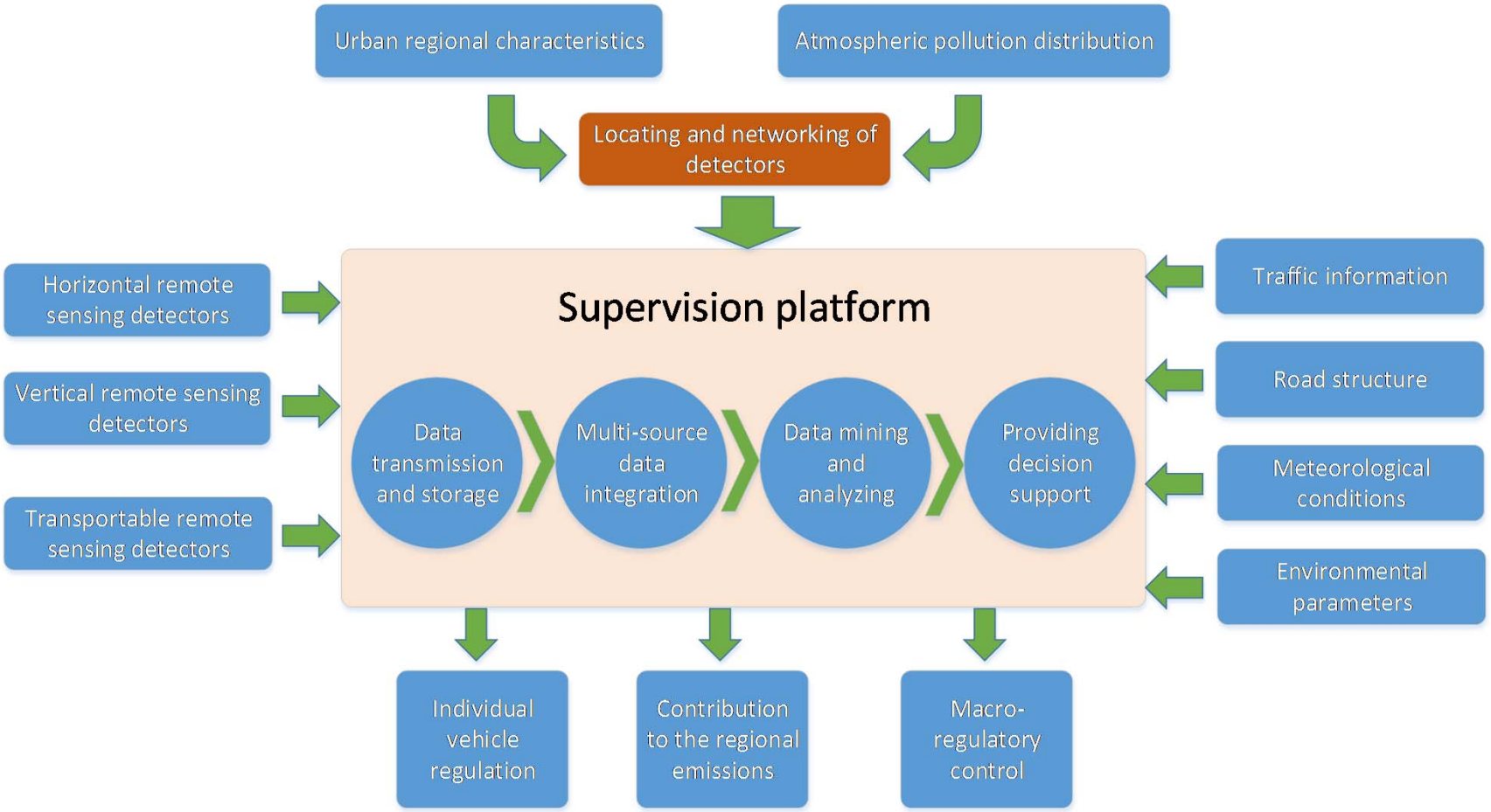
Conceptual model of NRSS: remote sensing, networked



Four parts: remote sensing detectors (including fixed remote sensing detectors and transportable remote sensing detectors), detection data sink nodes, the supervision platform and terminals for regulator.

Technical framework of NRSS



Key technique of NRSS: graph theory based location strategy

- Urban traffic net topological structure is the only requirement
- Traffic flow independent
- Adaptive and flexible

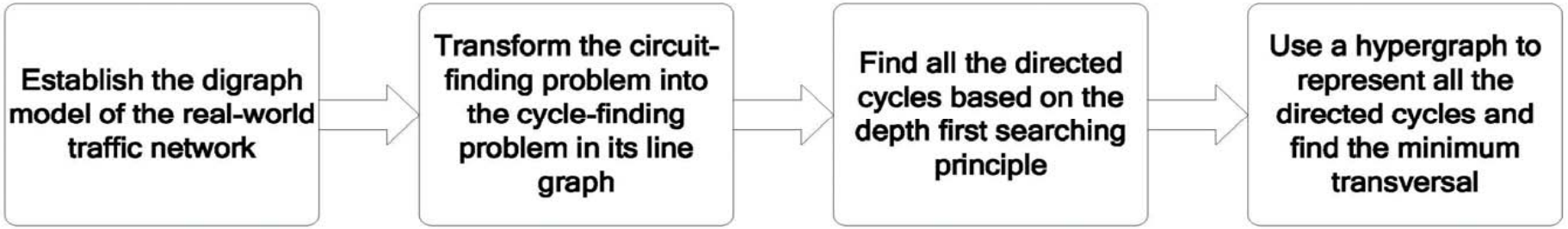
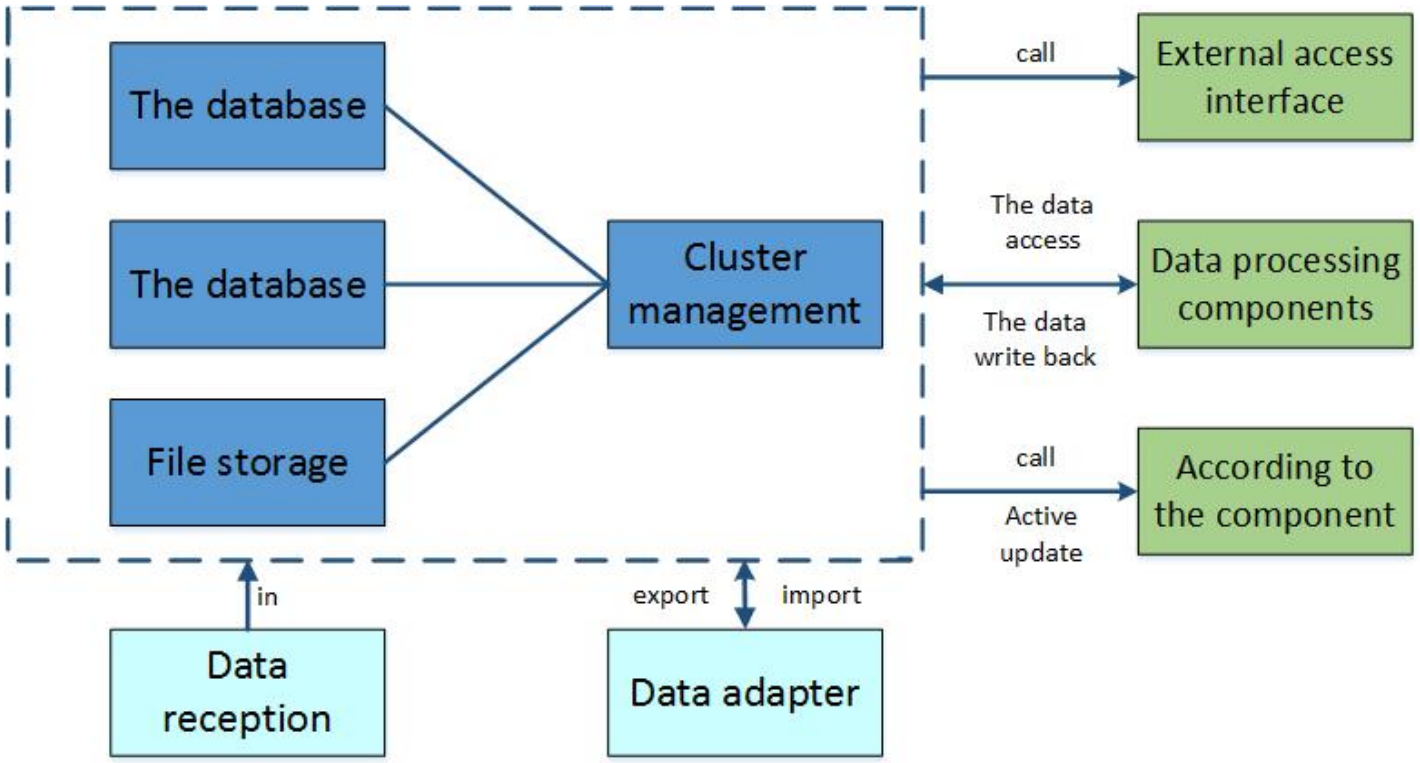
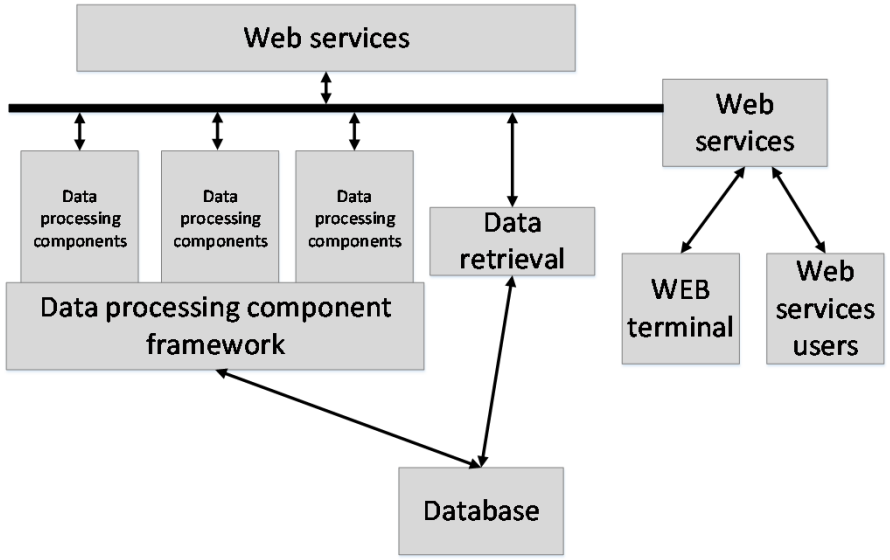


Illustration of the location strategy

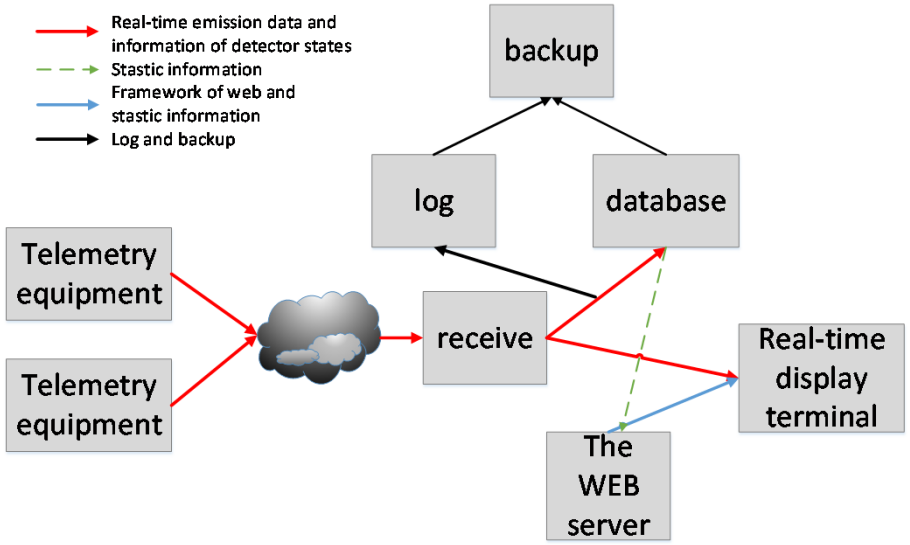
Key technique of NRSS: cloud based data transmission and storage



Key technique of NRSS: big data based data processing and visualization



Data processing module

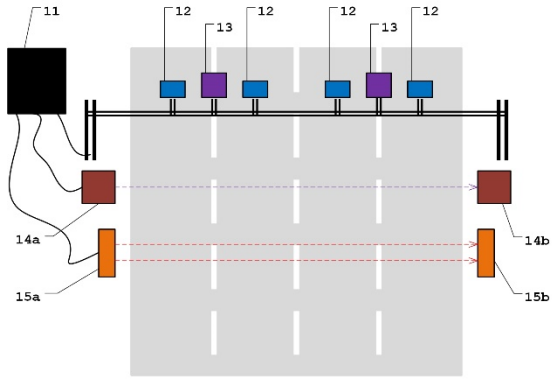


Real-time data storage and visualization

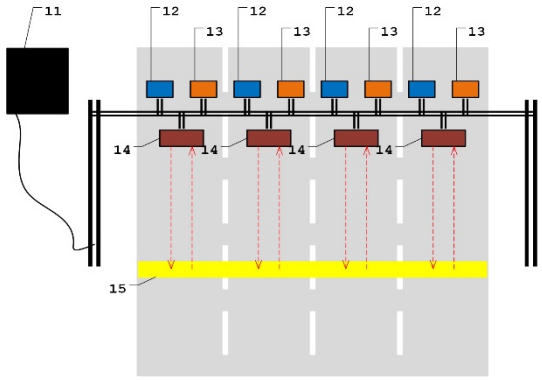
Preliminary Verifications

Implement of NRSS (Yanqing, Beijing，2015)

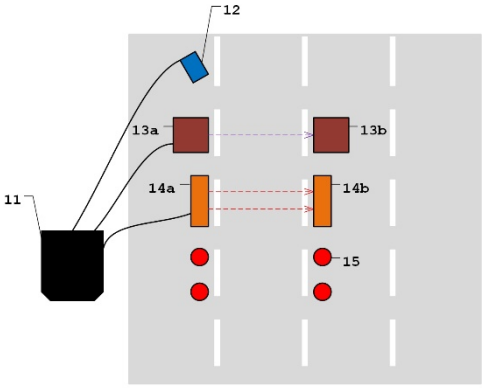
Horizontal remote sensing detector (HRSD)

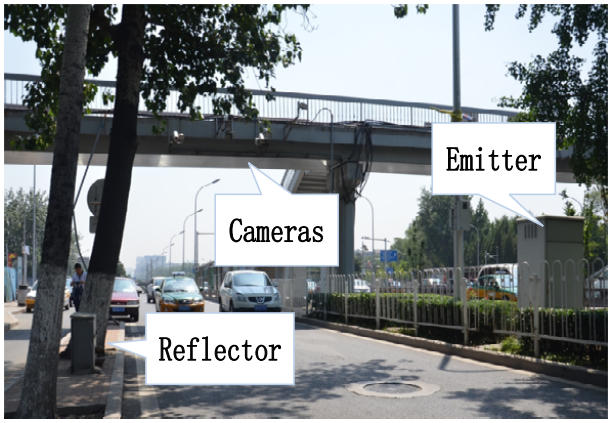


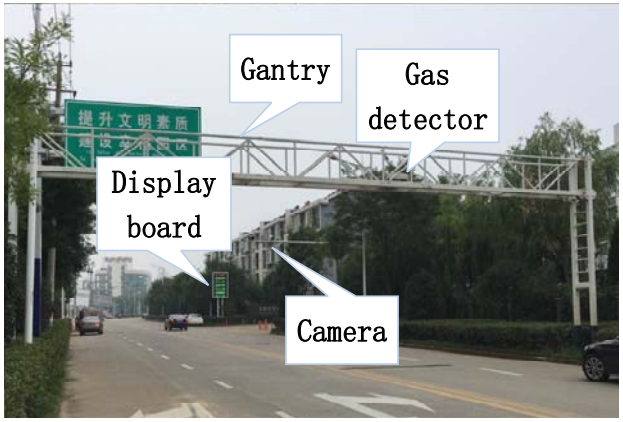
Vertical remote sensing detector (VRSD)

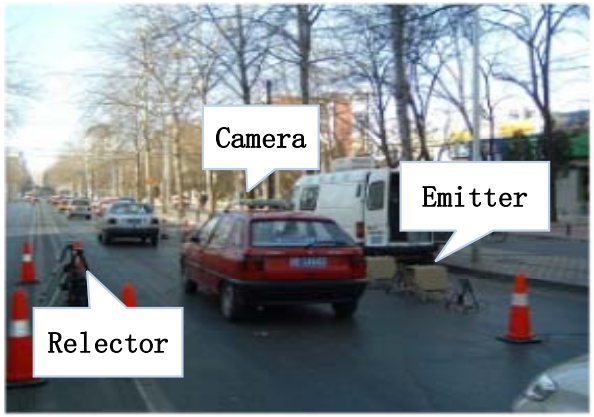


Transportable remote sensing detector (TRSD)









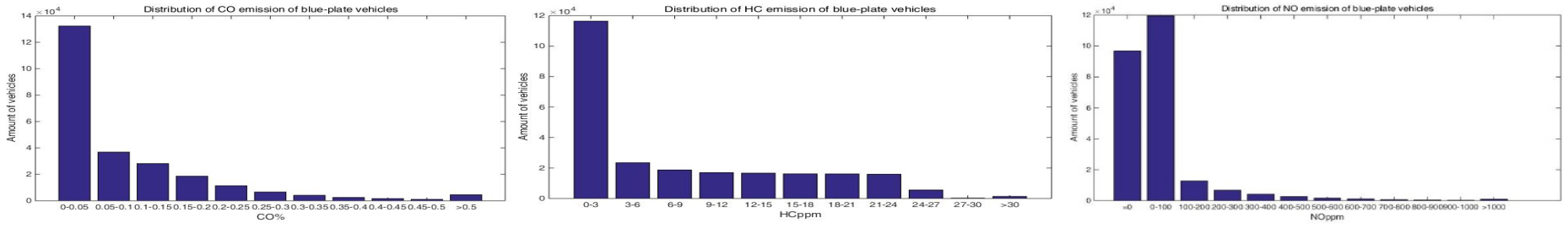
Comparison of detectors

Detector type	Total data	Valid data	Blue-plate data	Yellow-plate data	White-plate data
single-lane HRSD	109776	87821	79853	7115	853
multi-lane HRSD	156105	102330	97048	4456	826
TRSD	97392	76288	70802	4578	908

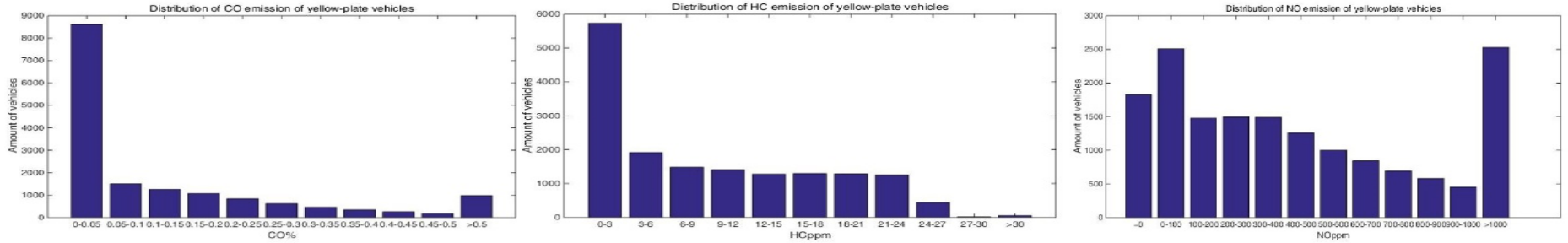
Comparison of single-lane HRSD、multi-lane HRSD and TRSD

- **Multi-lane HRSD can obtain more total measurements**
- **Multi-lane HRSD has a significantly lower valid ratio**
- **Vehicles with blue plates are the major part on roads**

Data analysis 1: general statistical results



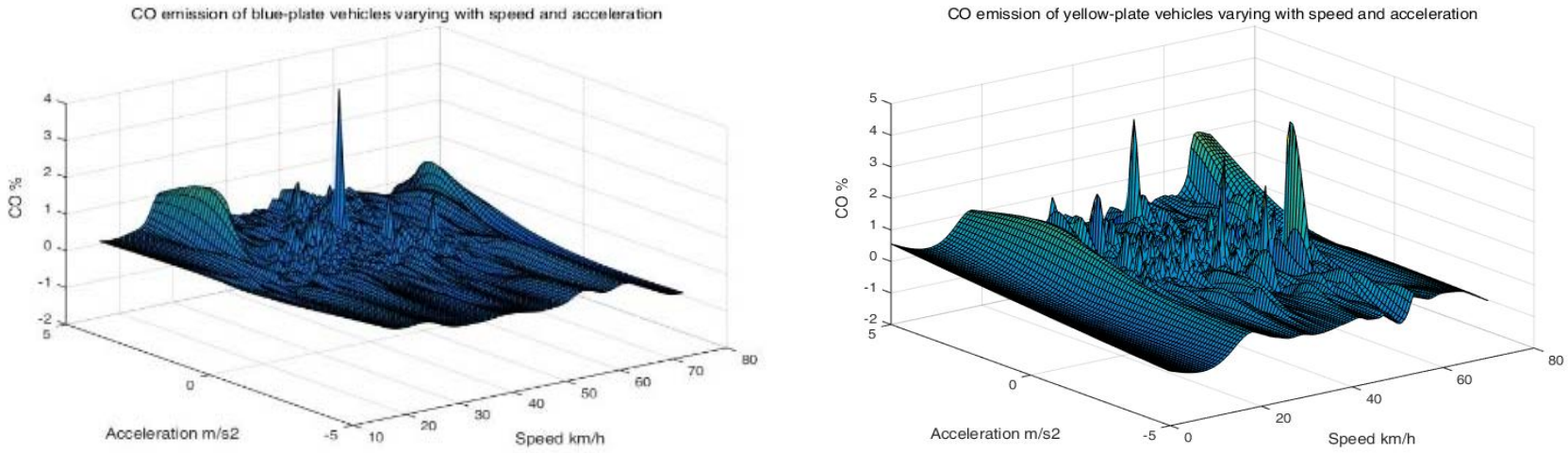
Distribution of CO, HC and NO emissions of blue-plate vehicles



Distribution of CO, HC and NO emissions of yellow-plate vehicles

- **Similar tendencies of CO are found for blue-plate and yellow-plate vehicles**
- **Most vehicles emit 0-0.05% CO or 0-3ppm HC**
- **Yellow-plate vehicles emit much more NO than blue-plate ones.**

Data analysis 2: relationship between emission and speed/ acceleration



CO emission varying with speed and acceleration of blue-plate and yellow-plate vehicles

- **CO concentration of decelerating is less than that of accelerating**
- **CO concentration increases with acceleration increasing**
- **The emission of CO has an notable increase when the speed is within the range of about 20km/s or 70km/s**

NRSS: A Clear Sky for Future

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