Communication Hub Placement Driven by I2V Service Estimation

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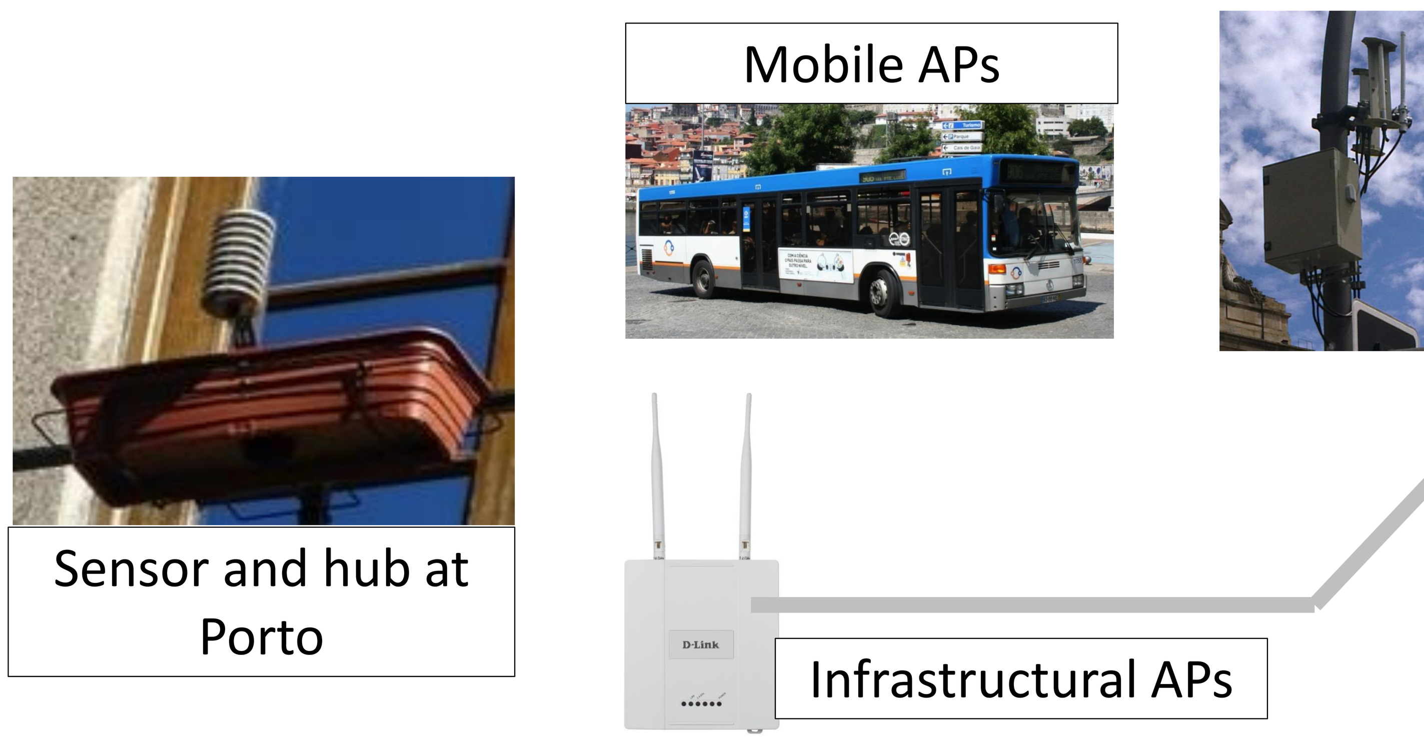
Motivation and Challenge

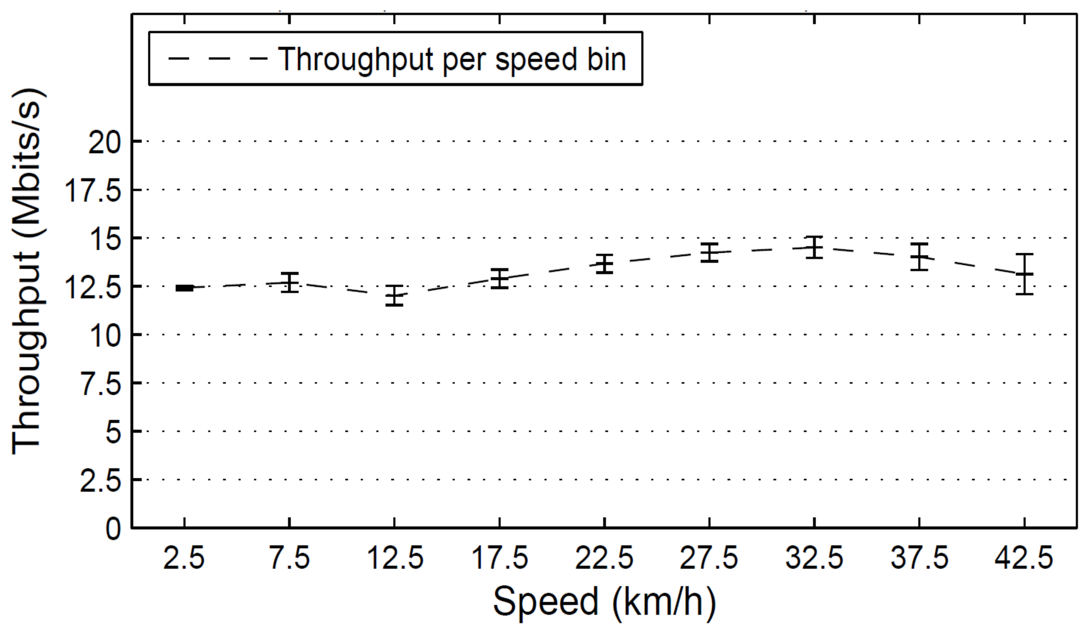
1. Sensors deployed at target area produce data that must reach a cloud backend
2. Sensor data is transported to the backend via wireless backhauls (fixed and vehicular)
3. **Communication hubs** bridge sensors and backhaul gateways.

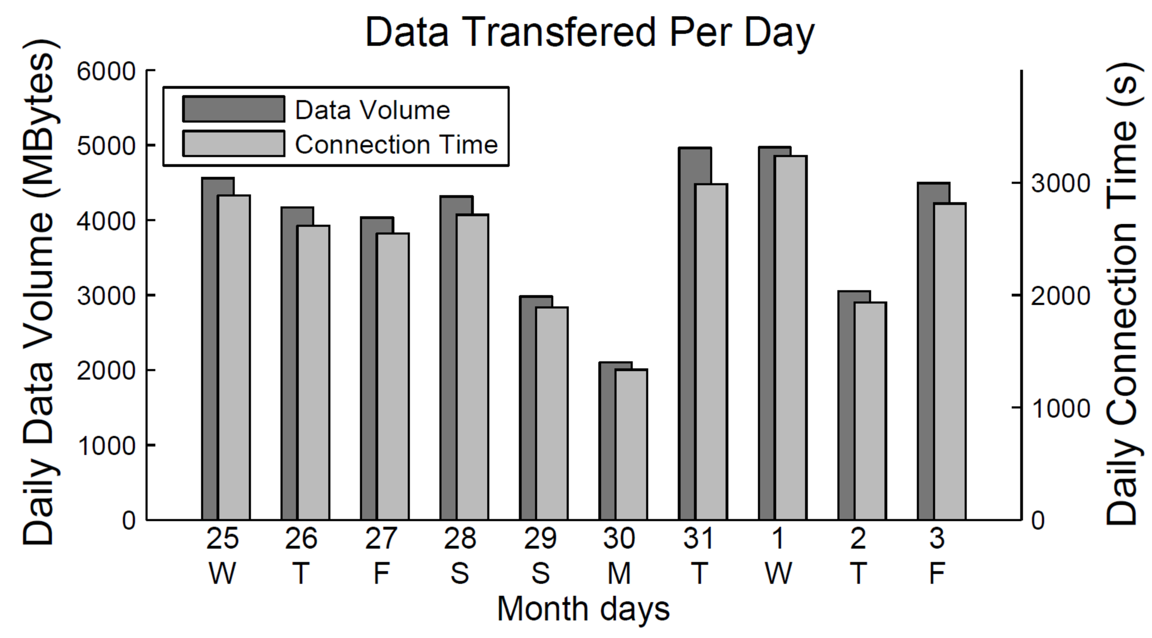


Challenge: **place hubs while ensuring sufficient service by vehicular nodes.**

1. I2V Service Characterization at a Single Location

- *Question1:* What throughput can be achieved in I2V links from road-side hubs to WiFi-equipped buses? Does speed play a significant impact?
- *Question 2:* How much data can be transfered from a hub to buses over the course of a day?
- *Measurements:* throughput, connection duration and vehicular position traces for a month





Answer to Q.1: Speed has little impact

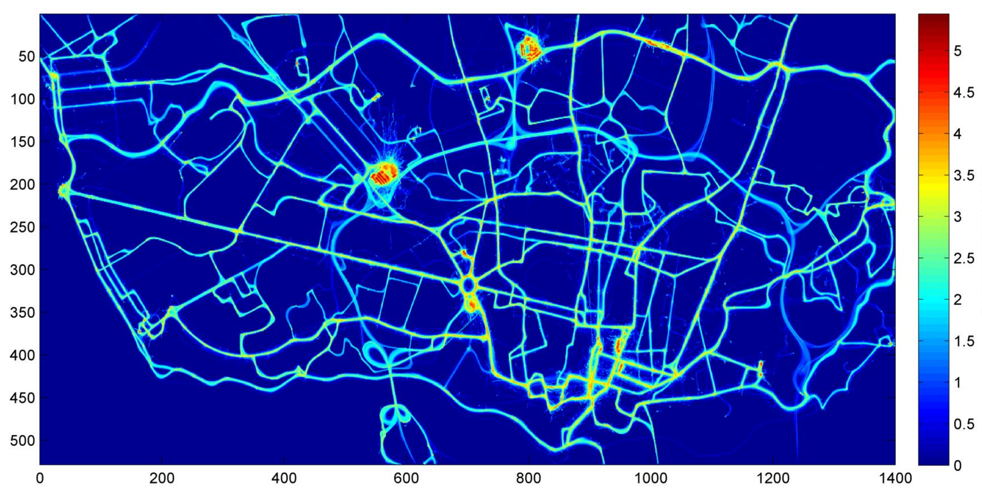
Answer to Q.2: Up to 5 Gigabytes/day

2. Large-Scale I2V Service Estimation

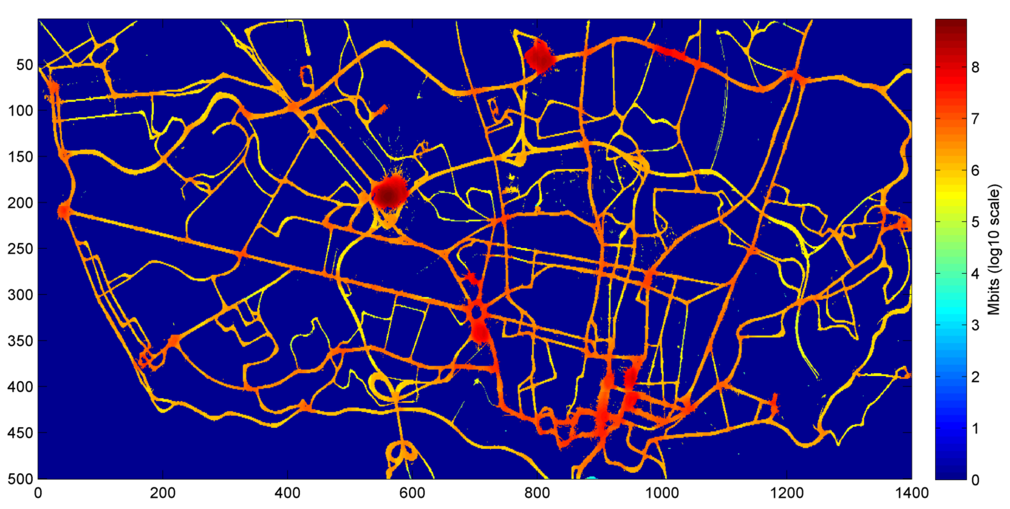
- ***Problem:*** how to estimate the data transfers to the vehicular backhaul that can be achieved at any given location in e.g. a city?
- ***Approach:*** develop estimation solution –

Map of I2V Transfers

- ***Solution strategy:***
  - *Data volume:* approximated by throughput times duration of connection
  - *Throughput-distance model:* from field measurements
  - *Connection duration:* from position traces of vehicles

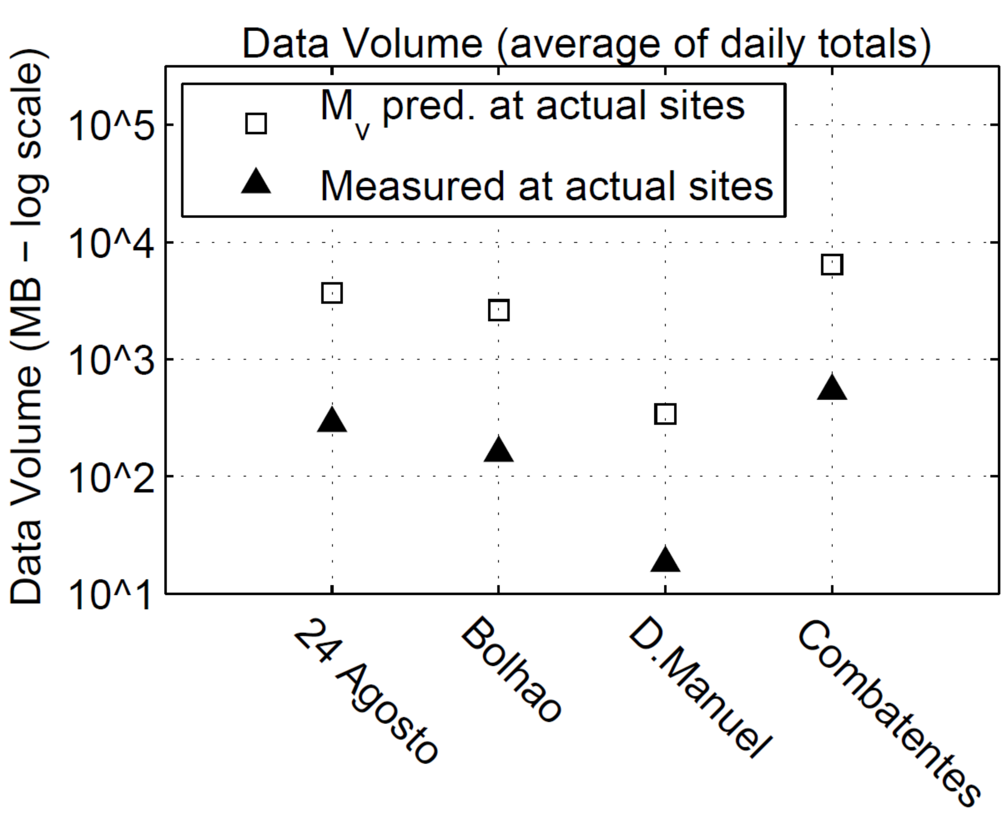


Mobility traces of buses



I2V data volume estimation

- ***Validating Estimates:***
  - *Experiments:* volume measured at 4 hubs
  - *Results:* estimated is 10x larger than measured; relative ordering is kept



3. Minimal Hub Placement Problem

- ***Problem:*** place hubs throughout city to serve pre-existing sensors
- ***Goal:*** as hubs can be shared by sensors, **minimize hubs**
- ***Approach:*** define optimization problem –

Min-Hub Problem

Min-DCU Problem Formulation:

$$\text{minimize} \quad \sum_{i}^{|\mathbf{U}|} c_i^f \cdot q_i^f + c_i^v \cdot q_i^v$$

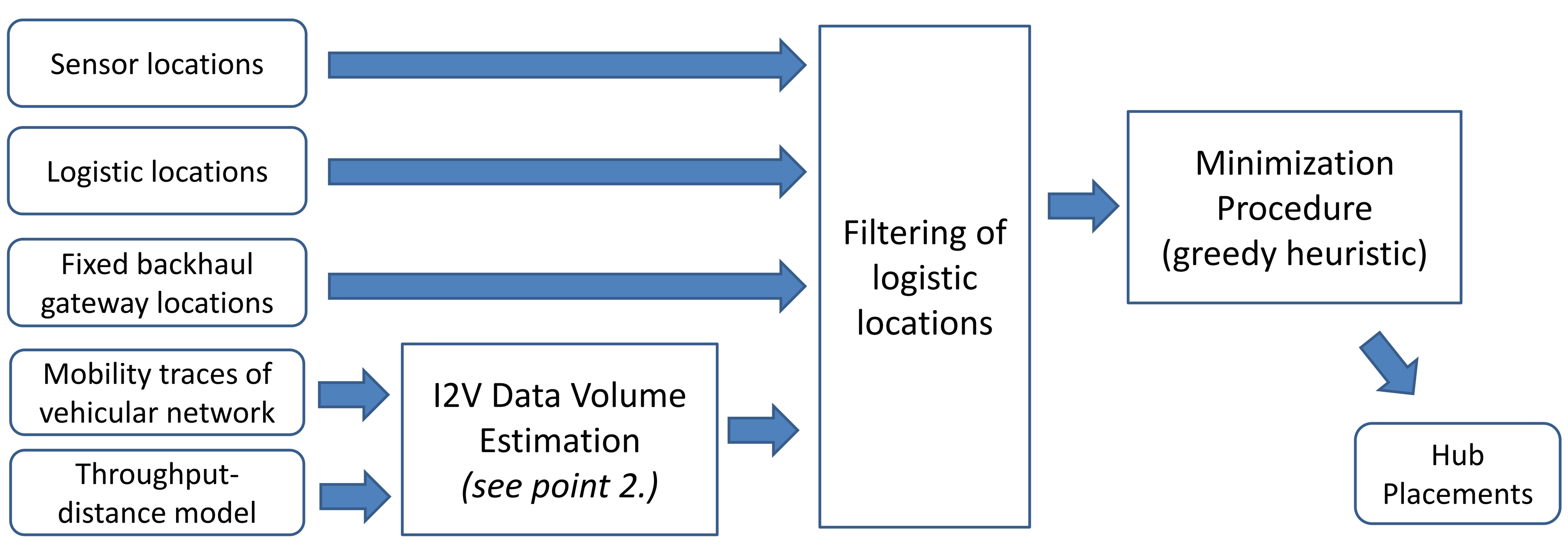
$$\begin{aligned}
\text{subject to:}\quad & v_i^s \geq v_{min},\ \forall\, i && \textbf{(c1)}\\
& |\mathbf{P}| \leq |\mathbf{S}| && \textbf{(c2)}\\
& x_i \in \mathbf{X}_u, d(x_i^s, x_i^u) < r_d\ \forall\, i && \textbf{(c3)}\\
& v_i \geq v_{min} \cdot |cover(x_i, x_i^s)|,\ \forall\, i && \textbf{(c4)}\\
& q_i^f = \begin{cases} 1, \text{if } \exists x^a \in \mathbf{X}^a : d(x_i, x^a) < r_c \\ 0, \text{otherwise} \end{cases} && \textbf{(c5)}\\
& q_i^v = \begin{cases} 1, \text{if } M_v(x_i^u) < v_{\min} \cdot |cover(x_i, x_i^s)| \\ 0, \text{otherwise} \end{cases} && \textbf{(c6)}\\
& c_i^f = f^f(\text{user-defined criteria}), c_i^v = f^v(\text{user-defined criteria}) && \textbf{(c7)}
\end{aligned}$$

Mathematical formulation of Minimal-DCU Placement Problem

- ***Constraints:***

Class	Description	Example (Porto)
Sensors	• Maximum range between hubs and sensors; • Sensor produce V bits/day	• UrbanSense sensing platform
Logistic	• Locations with power supply • Deployment authorized	• Traffic lights
Communication	• Fixed backhaul • Vehicular backhaul	• Porto Digital • STCP | Free WiFi

- ***Solution Strategy:***



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