Data Science and Communication in Smart Cities

Day 1: Smart Cities & Data Communication

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Outline

Basic concepts of data communication

- Purpose: bring information from one location to another
- Why?
  - Sensing: collect needed information both from environment and from machines/users therein
  - Actuating: send control command to machines and/or users
  - Logging: exchange operation information between machines
  - Notification: let people know that something has happened or is going to happen (e.g., incoming seismic wave)
- Data communication is an inherent part of the technologies that enable smart city applications. Software-hardware design and implementation for data communication is part of the critical infrastructure of any smart city.

Data communication models

- A *model* is a description of
  1. some specific properties of the subject we have interest in, and
  2. how those properties drive the behavior of the subject.
- Modeling the semantics of data communication applications
  - One-to-one (unicast)
  - One-to-all (broadcast); all-to-one
  - One-to-some (multicast); some-to-one
- Modeling the service for data communication pairs
  - Direct communication
  - Broker-based communication

Quick exercise

Match the following application scenarios and models:

- Application scenarios
  1. City residents want to receive air-quality reports in their living area
  2. City governer want to dim street light when there is no pedestrian
  3. City visitors want to find parking spots during their travel
- Models
  1. one-to-all data communication (broadcast)
  2. one-to-some data communication (multicast)
  3. brokerless service
  4. broker-based service

Data communication requirements

- Functionalities
- Performance
  - dependability
  - scalability
  - sustainability
  - cybersecurity
  - quality-of-service (QoS)
  - timeliness
  - fault tolerance
  - user privacy
  - interoberability

Data communication challenges

- One challenge: how to meet the requirements?
- Some examples
  - Scalability: how would a data communication infrastructure support city-scale volume of data transport?
  - Sustainability: how would we make the insrastructure energy-efficient and easy-to-maintain?
  - Timeliness: how would the infrastructure ensure that data items are delivered before some specified deadline?
  - User privacy and cybersecurity: how would the infrastructure protect sensitive data from leaking or tampering?
  - Interoperability: how would different machines, devices, and people exchange information over different networks (Wi-Fi, 5G, Bluetooth, Zigbee, LoRa, etc.)?

A survey for smart city applications

- Wolniak, Radosław, and Kinga Stecuła. "Artificial Intelligence in Smart Cities—Applications, Barriers, and Future Directions: A Review." Smart Cities 7.3 (2024): 1346-1389. (link to the paper)
  - A survey paper based on 157 articles published in 2021–2024.
- Six aspects:
  1. Smart governance
  2. Smart economy
  3. Smart mobility ⟵ our focus for now
  4. Smart environment
  5. Smart living
  6. Smart people

Example: smart mobility in modern cities

- Objective: provide safe and convenient means to move about in a city
- Inter-related applications
  - Personalized route recommendation
  - Ride/bike-sharing
  - Smart parking solutions
  - Traffic orchestration
  - Public transportation infrastructure maintenance
  - Internet of Vehicles
- Roles of data communication
  - Large-scale data collection (context)
  - Cloud-edge data transport (integration)
  - On-demand event notification (usability)
  - Emergency response (safety)
  - Data communication for human and AI (co-pilot)

Smart mobility potentials illustration