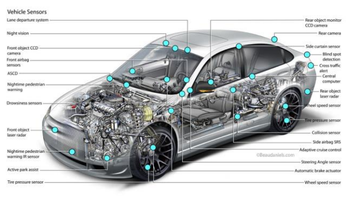
A Data-Centric Architecture for Pervasive Edge Computing in Heterogeneous Extensible Distributed Systems

PI: Yuanyuan Yang, Co-PI: Fan Ye, ECE Department, Stony Brook University
{yuanyuan.yang, fan.ye}@stonybrook.edu

1. Pervasive Distribution of Diverse Edge Devices

- Rich resources in sensing, communication, processing
- Phones/tables by customers in cafes, passengers at boarding gates
- IoT devices in homes, offices, shopping malls
- Vehicles around city streets

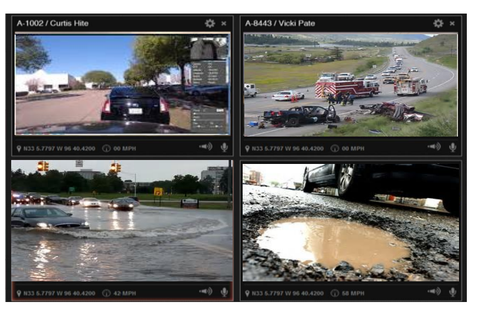


2. A New Computing Paradigm: Pervasive Edge Computing

- Novel application opportunities by data sharing/processing at the edge without backend cloud
  - Sports, traffic, VR/AR, Internet-of-Things, …
  - Zero barrier, low latency, backend oblivious, democratized creativity


Multi-angle game viewing

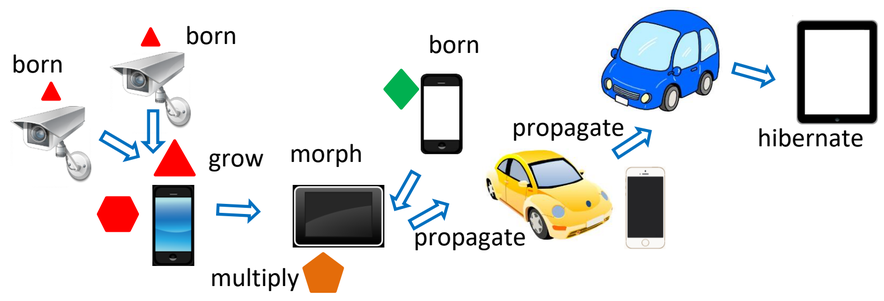


Live streaming among drivers

Interaction with physical and virtual objects

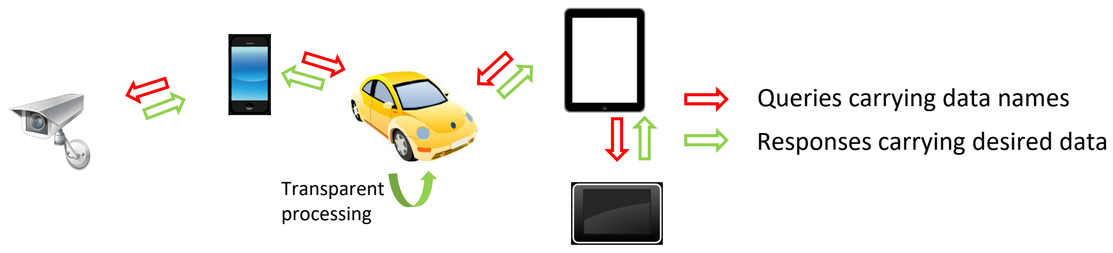
3. Solution: A Data-centric Architecture

- Data as first class citizens and living organisms
  - decoupled from any specific devices (e.g., their producers)
  - Lifecycle: born (gathered by sensors); grow (accumulated over space/time); morph (transformed in syntax/semantics after processing); multiply (information extracted by merging different data inputs); propagate (disseminate); hibernate/die (archived/eliminated)



4. An Exemplary Data-centric Architecture

- Naming structures
  - Formal handles to precisely describe/reference the data
- Discovery/retrieval
  - find out what data exist nearby and obtain interested ones
- Transparent processing
  - automatically process input data to produce desired final data

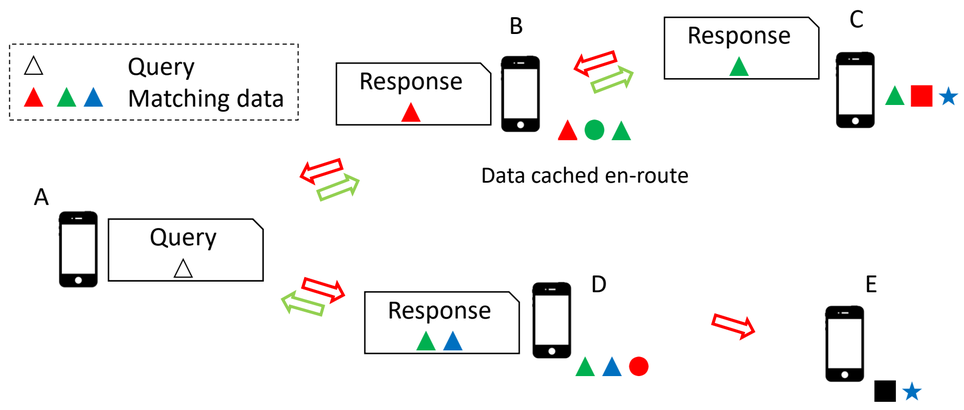


5. Data Descriptors

- Each data item is associated with a metadata entry (i.e., a descriptor)
  - Metadata is also a kind of data
    - Widely cached, possibly separately from respective data
  - All such entries together describe what data *may* exist in the environment (the menu)
- One possible form: key-value pairs
  - {key: value}
  - Example
    - Data Type: **NO_2** sample
    - Attributes: **time** and l**ocation** of sample
    - Namespace: **environment monitoring/atmosphere**

6. Query, Response and Caching

- The consumer propagates a query
- Devices respond matching data
- Responses flow back and their data cached en-route



7. Fair Caching among Edge Devices

- No central authority exists
  - devices belong to different owners; each decides its resource contribution
- Fairness metric: used/available
- Problem: given a network topology, which nodes should cache a copy
- Objective: minimize weighted sum of fairness and contention
- An integer programming formulation
  - Mapped to sum of Connected Facility Location (ConFL) problems
  - A centralized 6.55-approximation algorithm
  - A distributed algorithm based on peer message exchange

8. Applications Prototypes

- Internet-of-Things control and management
  - Wide caching of credentials among nodes: signed profiles, access tokens, certificates
  - Discover accessible devices and functions
  - Benefits: speed up the access; improve robustness/availability
- Others:
  - Smart navigation
  - Population density monitoring

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