Sensor Coordination using Active Dataspaces

Steven Cheung

NSF NOSS PI Meeting

October 18, 2004

SRI International®

Outline

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Characteristics of sensor networks

- Resource constraints
  - Energy reserve
  - Computation power
  - Memory
- Unpredictable communication links
  - Intermittent connectivity
  - Asymmetric links and radio directionality
- Node failure
  - Exposed to harsh environment and attacks
  - Battery depletion
- Possibly large number of nodes
- Possibly difficult deployment environment

Techniques for building sensor network applications

- General resource conservation
  - In-network processing
  - Localized algorithms
  - Hibernation (e.g., sentry service)
- Optimizations for key communication patterns
  - Tree-based aggregation scheme (many-1)
  - Firecracker protocol (1-many)
- Adaptive protocols
  - Protocols that adaptively optimize communication based on local information and feedback (e.g., directed diffusion and PARC's CB-LRTA*)
- Exploiting redundancy and broadcast medium

Why sensor network programming hard?

Deploying new or additional sensors

Applications

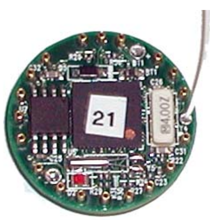
Intermittent end-to-end connectivity

Limited CPU power and memory

Hibernation

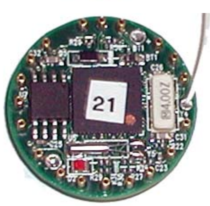
Attacks

Scalability



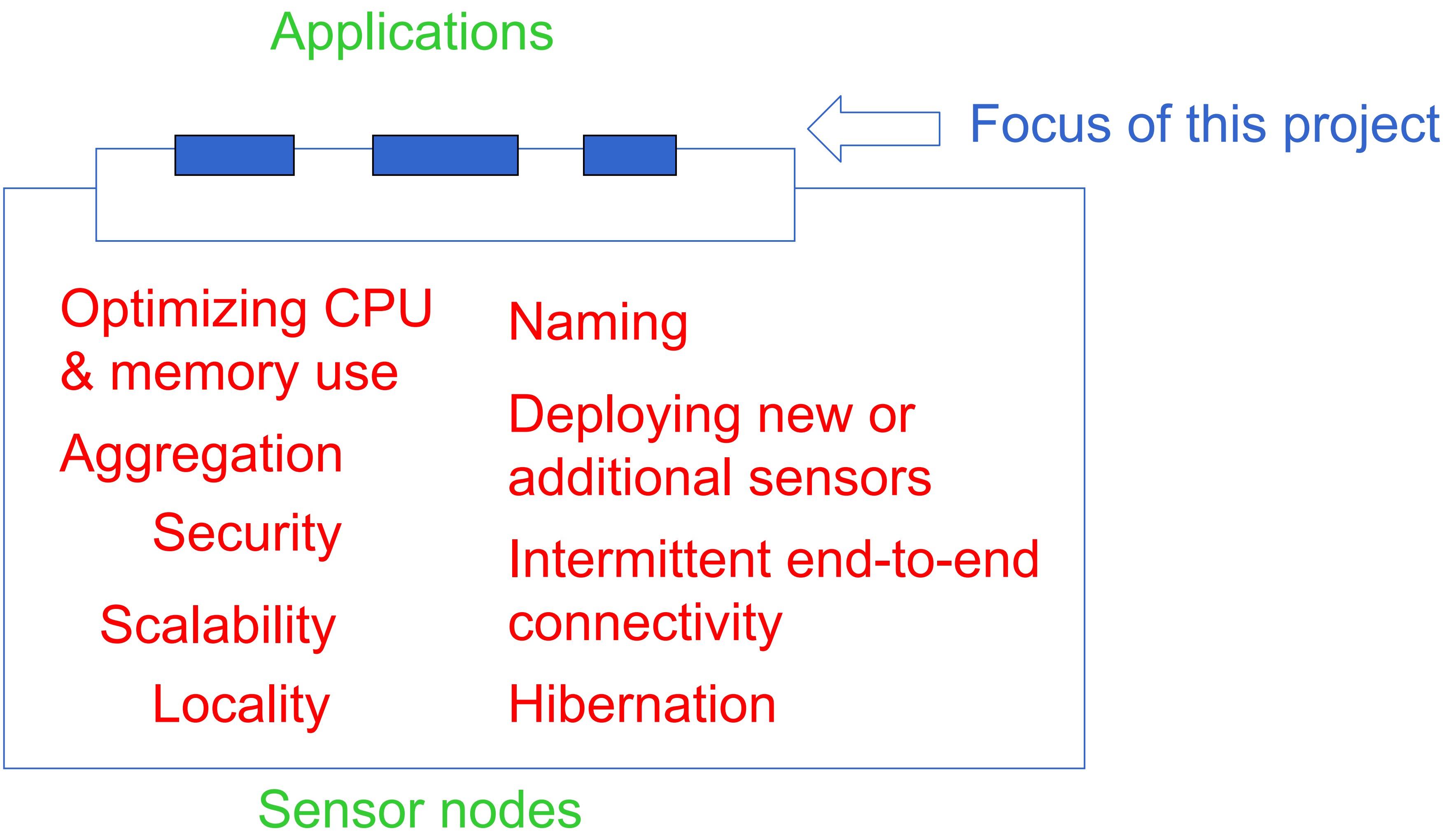
Locality

Data aggregation



Sensor nodes

Need: High-level programming abstraction



Active dataspace (ADS)

- ADS is an active data repository that provides associative operations for data access
- Inspired by the tuple space model [Gelernter 85], developed for parallel computing
- Every data tuple (or record) contains a list of fields
- Basic TS operations:
  - *in* is used to remove tuples from TS
  - *rd* to read tuples
  - *out* to create data tuples
  - *eval* to create “active” tuples

Features of ADS

- Data-centric model
- Time-uncoupling: Data consumers and producers do not need to be active at the same time
- Identity-uncoupling: Endpoints do not need to know each other's identities
- Stable network paths between endpoints need not exist
- *Virtual tuples* support data generation on demand
- Tuple set operator and *cardinality constraint* to facilitate in-network aggregation
- *Search constraint* for specifying the scope and preferences for tuple selection to exploit locality

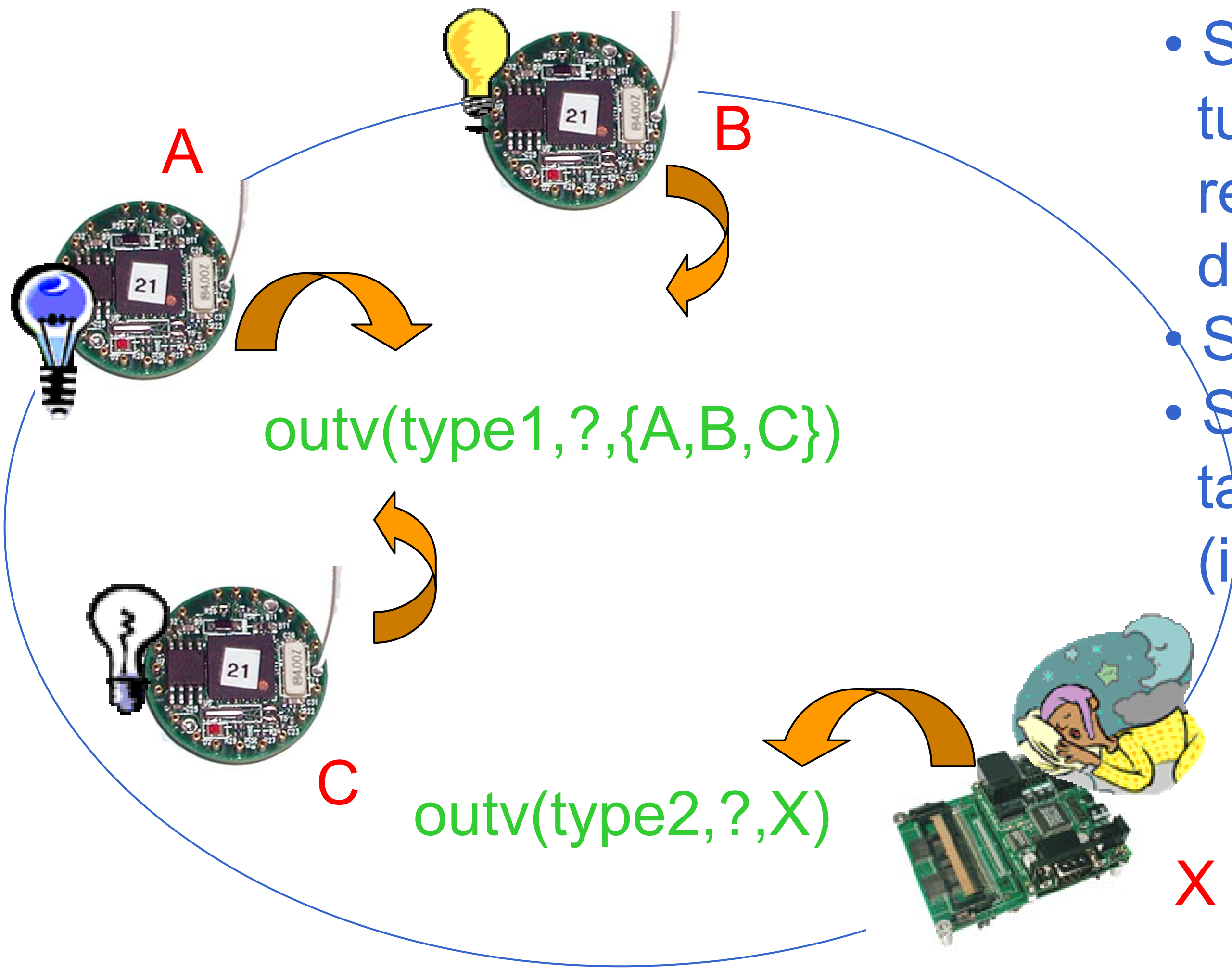
Tuples on demand

- Motivation: To enable sensor nodes to conserve energy and other resources during time intervals in which their work is not needed
- A virtual tuple represents the capability of a node to generate a certain type of tuple specified by the virtual tuple
- When a tuple request matches a virtual tuple, the corresponding node will be contacted to produce the data on demand
- Use of virtual tuple is transparent to data consumers

Vehicle detection: Setup

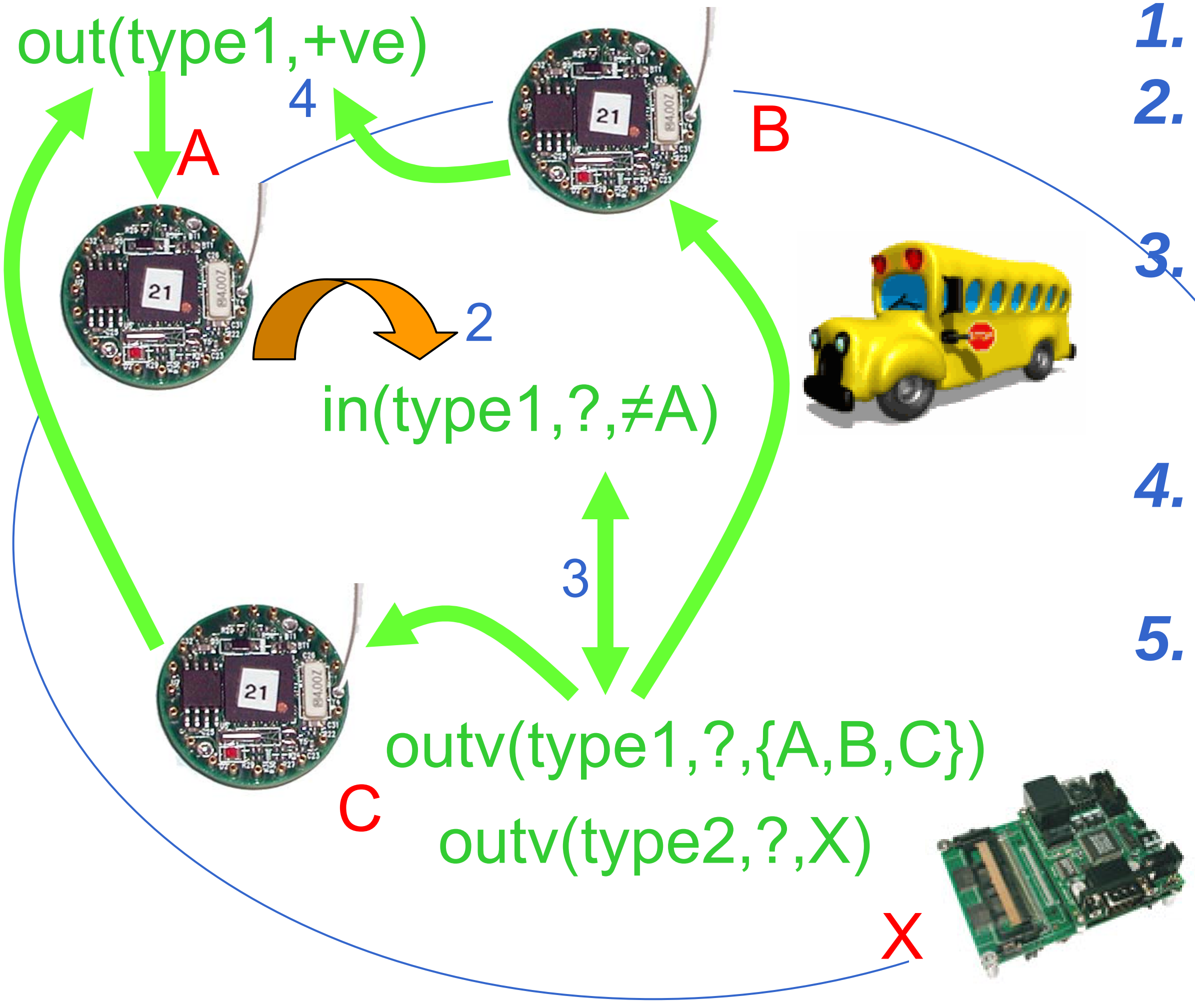
- Sensors deployed in a region for vehicle detection
- 2 types of sensor nodes
- Type 1 (Sensors A, B, and C) :
  - Low-cost to operate
  - less accurate
  - has a shorter range
  - cannot classify vehicles
- Type 2 (Sensor X):
  - Expensive to use
  - more accurate
  - have a longer range
  - can distinguish different classes of vehicles

Event sequence: Bootstrapping



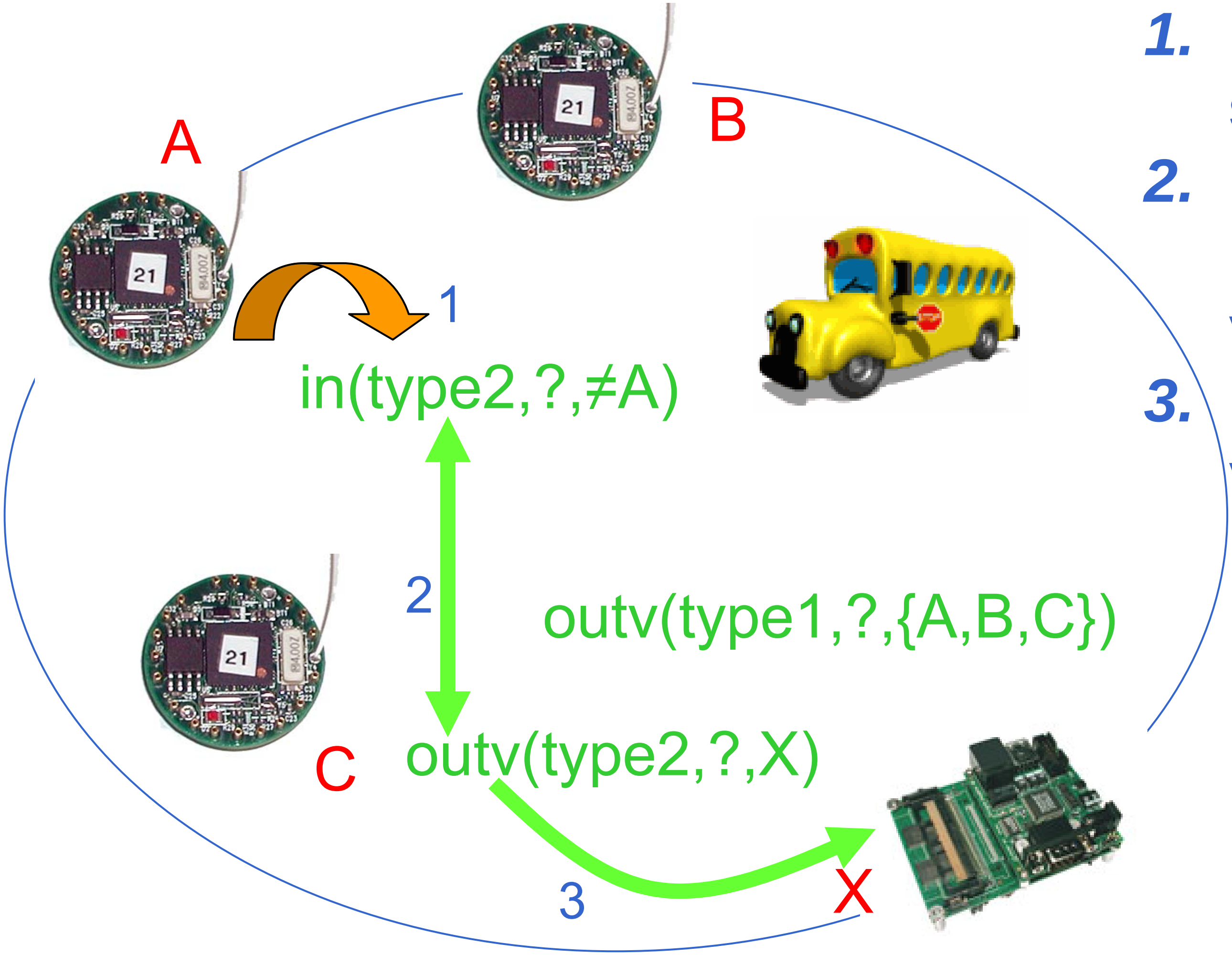
- Sensors put virtual tuples in ADS, which represent their detection capabilities
- Sensor ***X*** hibernates
- Sensors ***A***, ***B***, & ***C*** take turn being active (i.e., the sentry)

Event sequence: Detection phase (1)



1. ***A*** detects a vehicle
2. ***A*** requests other type1 sensor data
3. ***ADS*** matches the request with ***B***'s and ***C***'s virtual tuples
4. ***B*** and ***C*** produce sensor reading tuples
5. ***A*** confirms detection with ***B***'s and ***C***'s input

Event sequence: Detection phase (2)



1. ***A*** requests type2 sensor data
2. ***ADS*** matches the request with ***X***'s virtual tuple
3. ***X*** is awaken for vehicle detection

Expected results

- High-level programming model and language to ease sensor network programming for a wide range of application domains
- Architecture and techniques to implement a resource-efficient, adaptive, and trustworthy ADS system