Research Works on Sensor Networking Technologies

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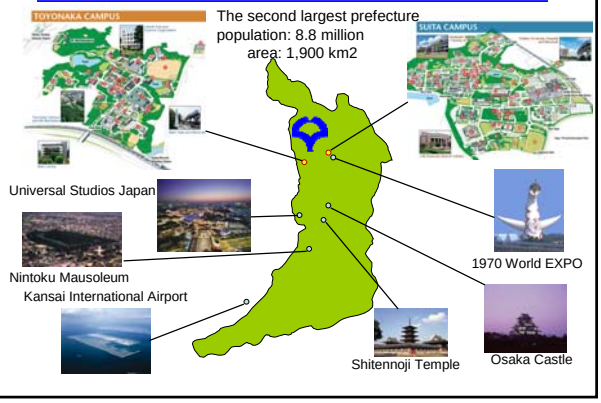
Osaka University



Osaka University

- established in 1931 as the sixth imperial university
- has
  - 12 faculties/schools
  - 14 graduate schools + 1 law school
  - 5 research institutes
  - 15 joint-use facilities
  - 2 nationwide joint-use facilities
  - 3 university libraries
  - 2 hospitalsGRADUATE
- 4,500 staff and 20,000 students
  - undergraduate 12,000 + graduate 8,000

Bio-inspired Network Technologies

Symbiosis

"New Information Technologies for Building a Networked Symbiosis Environment" in The 21st Century Center of Excellence Program (COE) of the Ministry of Education, Culture, Sports, Science and Technology of Japan.

New Network Paradigm

- Networks constituting of end nodes
  - Overlay networks
  - Ad-hoc networks
  - Sensor networks
- We need technologies (protocol, algorithm, mechanism)
  - scalable to the size of a network
  - robust to failures of nodes and links
  - adaptive to changes in network conditions
  - fully distributed and self-organizing

Getting Inspiration from Biology

Swarm Intelligence

- The emergent collective intelligence of groups of simple agent.
  - Ant trail (foraging behavior of ants)
  - Cemetery organization and brood sorting
  - Colonial closure
  - Division of labor and task allocation
  - Pattern forming
  - Synchronization in flashing fireflies
- A group exhibits an intelligent and organized behavior without any centralized control, but with local and mutual interactions among individuals (**stigmergy**)
- The behavior is adaptive to changes in environments
- A group keep working even if a part fails

Bio-inspired Networking

- Overlay Network Symbiosis
  symbiosis of different cells, organisms, groups, and species

- Waveform Synchronized Data Gathering
  synchronized flashes in a group of fireflies
- Reaction-Diffusion based Control Scheme for Sensor Networks
  pattern formation on the surface of the body of an emperor angelfish

Scalable Ant-based Routing Scheme
foraging behavior of ants

Waveform Synchronized Data Gathering in a Sensor Network

synchronized flashes in a group of fireflies

Sensor Network

- Sensor node:
  - Sensor: Temperature, Humidity, Acceleration,…
  - Processor: limited computational capability
  - Memory: limited capacity
  - Wireless Transceiver: 802.11, IrDA, bluetooth,…
  - Battery: sometimes with power supply

MOTE2
Crossbow Technology, Inc.

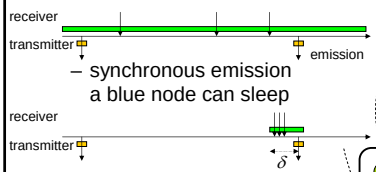
- Application:
  - Health and Welfare: vital sign monitoring, safety check
  - Crime Prevention and Security: protect daily life
  - Disaster Prevention: monitor and predict fire, hurricane, earthquake, floods, landslide, collapse of structure,…
  - Environment: surveillance of weather, water pollution, air pollution,...
  - Others: Plants, factory, farm, transportation, distribution

Requirements

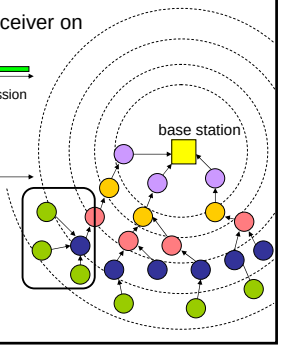
- Sensor nodes
  - are many (hundreds to thousands)
  - are deployed in an uncontrolled and unorganized way
  - are added, removed, and moved
  - halt due to depletion of the battery or failure
- Therefore, a control mechanism must be
  - fully-distributed and self-organizing
  - adaptive to changes
  - robust to failures of nodes
  - scalable to the size of a network
  - energy-efficient

Energy-Efficient Periodic Data Gathering

- Turning off unused components contributes very much
  - asynchronous emission
    a blue node must keep a receiver on



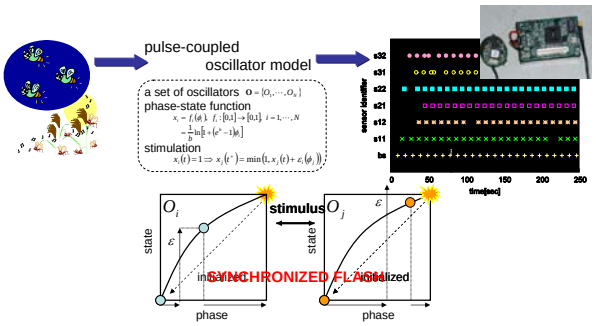
  - synchronous emission
    a blue node can sleep



- Sensor nodes on the same circumference must be SYNCHRONIZED

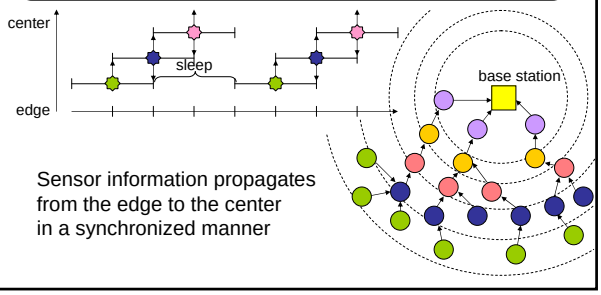
Bio-Inspired Synchronized Data Gathering

- A group of fireflies flash in synchrony
- **Fully-distributed and self-organizing**



Characteristics of Synchronized Data Gathering

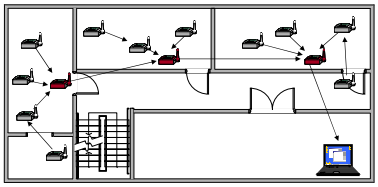
It can collect sensor information from a large number of randomly distributed sensors at regular intervals in an energy-efficient way



Sensor information propagates from the edge to the center in a synchronized manner

Data Gathering in a Building

- Unstable and unreliable radio communication
- Components
  - monitoring PC: collects sensor information, a sink
  - parent node: with power supply, wired connection to monitoring PC
  - child node: with battery, wireless connection

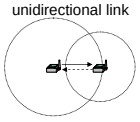


Unstable and Unreliable Radio

- Find a stable path to a parent node
  - introduction of a cost function
    - RSSI and the ratio of successful reception

$$\text{cost} = \text{round}\left(\left(S + \left(1 - \frac{R - R_{min}}{R_{max} - R_{min}}\right)\right) \times 10\right) + C_p$$

- Avoid collisions of wireless communication
  - among child nodes with the same next-hop node
    - regulate timing of packet emission by RSSI
  - among parent nodes with overlapping radio ranges
- Eliminate unidirectional links
  - detection by received packets



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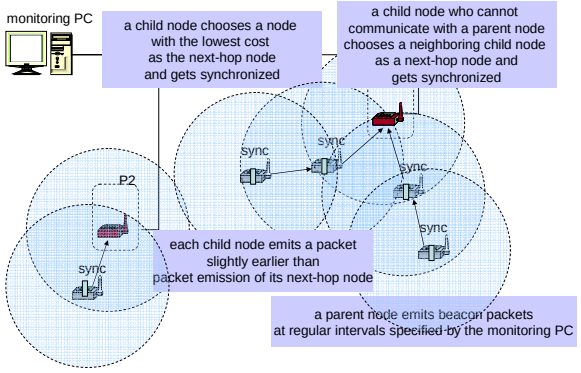

Distribution of Packet Emission

- Synchronized emission causes severe collisions

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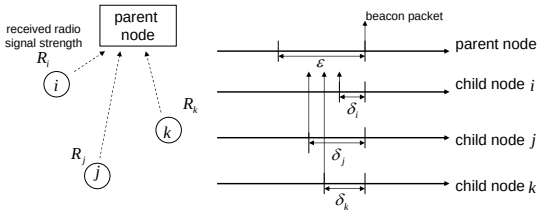
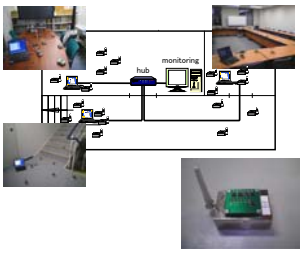
- Regulate timing of packet emission based on RSSI

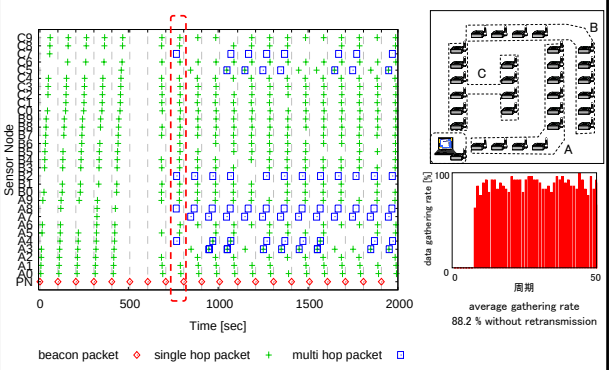


Prototype System

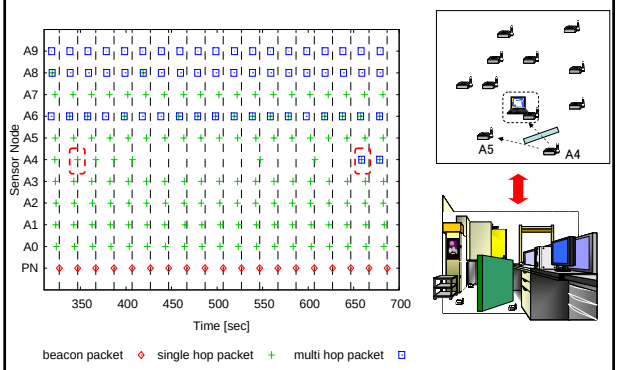
- Sensor node
  - Oki Electric Industry
  - MAC protocol
    - IEEE 802.15.4
  - transmission range 5 m
    - max 100 m
  - AAA battery x3
- Experiments
  - basic behavior
    - addition, removal, movement of child nodes
    - changes in communication environment
    - overlapping radio ranges among parent nodes
  - practical test



Basic Behavior

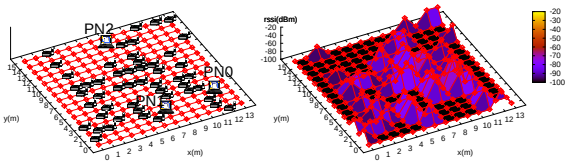


Changes in Radio Environment



Practical Experiment

- Parent node x3, child node x50
- obstacles and moving people
- RSSI is used as sensor information

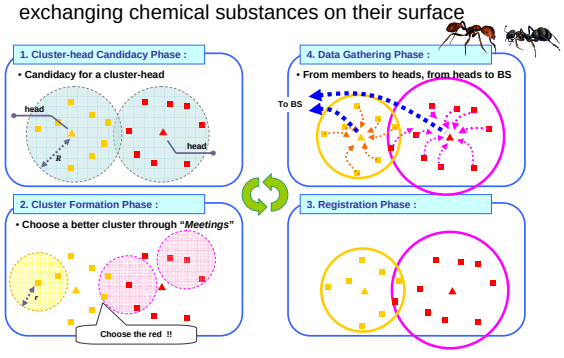


average gathering rate 81.6 %w/o retrans

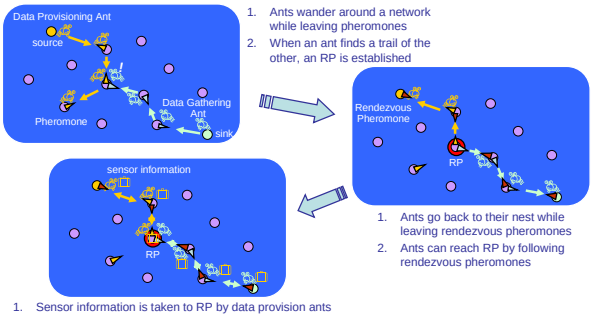
Other Research Topics

Clustering Mechanism for WSN

- Colonial Closure: An ant distinguishes its nestmate by exchanging chemical substances on their surface



Data-Centric Communication Protocol for WSN



1. Ants wander around a network while leaving pheromones
2. When an ant finds a trail of the other, an RP is established

1. Ants go back to their nest while leaving rendezvous pheromones
2. Ants can reach RP by following rendezvous pheromones

1. Sensor information is taken to RP by data provision ants
2. Sensor information is taken from RP by data gathering ants

Sensor Network Technologies for Safe and Secure Life

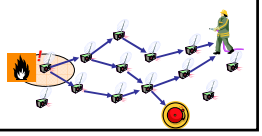
- Prolong the lifetime of a sensor network

  +

- Certain detection of emergency and fast and reliable transmission of urgent information

- A combination of
  - normal operation preparing for emergency
  - emergent operation for fast and reliable communication

  is needed taking into account heterogeneity in sensor information and sensor nodes



For Safety of Children

(1) Reliable data gathering from hundreds of children
(2) Secure data communication to protect personal information
(3) Data mining for fast detection of emergency and tracking a misbehaving child