A Distributed and Self-organizing Data Gathering Scheme in Wireless Sensor Networks

Yoshiaki Taniguchi
Osaka University, Japan
y-tanigu@ist.osaka-u.ac.jp

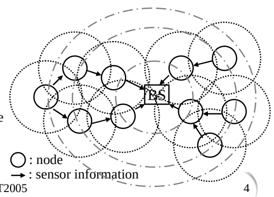
Contents

Background

- A data gathering scheme for sensor networks must be
  - energy-efficient
    A sensor node is typically powered by a battery that cannot be easily replaced
  - fully-distributed
    Sensor nodes are often deployed and distributed in an uncontrolled way

Previous work

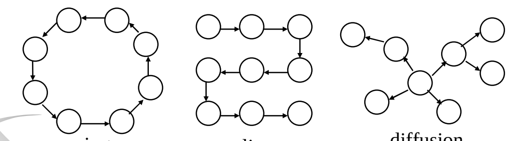
- Synchronization-based data gathering [2]
  - Fully-distributed, self-organizing, robust, adaptable, scalable, and energy-efficient
  - Sensor information is periodically propagated and aggregated from the edge of a sensor network to the base station
    → Concentric circles



[2] N.Wakamiya, M. Murata, "Synchronization-based Data Gathering Scheme for Sensor Networks", IEICE Trans. on Comm., vol. E88-B, pp. 871-881, Mar. 2005.

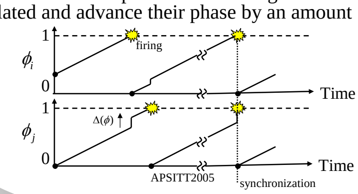
Research Target

- Generate a variety of patterns of data gathering
  - Different applications need different types of traveling waves
  - Adopt a pulse-coupled oscillator model



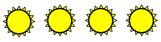
Pulse-coupled oscillator model

- Based on biological mutual synchronization
  - Pacemaker cells, fireflies, and neurons
- Each oscillator *i* has phase $\phi_i \in [0,1]$
- When the phase reaches 1, the oscillator *i* fires and the phase jumps back to 0
- Other oscillators coupled with the firing oscillator are stimulated and advance their phase by an amount $\Delta(\phi)$

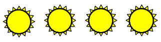


Two types of synchronization

- Depending on the initial conditions, a set of oscillators reach:
  - Global synchronization
    - They keep the same phases and fire all at once

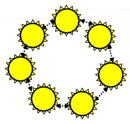


  - Phase-lock condition
    - Phases are kept constant and different

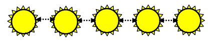


Variety of traveling waves

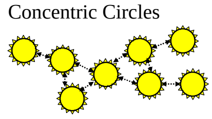
- Ring



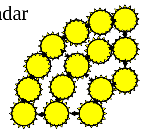
- Line



- Concentric Circles



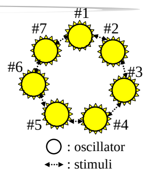
- Radar



- Assumptions
  - An oscillator ignores all stimuli at the moment of firing
  - An oscillator identifies multiple stimuli received at the same time as one stimulus

Generation of traveling waves Ring (1)

- A ring of N oscillators [4]
  - An oscillator is stimulated by its two neighboring oscillators
  - Oscillators fire at constant phase-difference τ



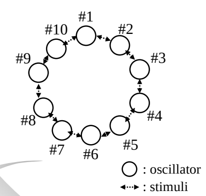
- Condition for the existence of traveling waves

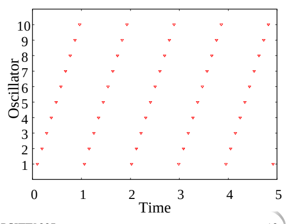
$$F((N-2)\tau + F(\tau)) + \tau = 1$$

with $F(\phi) = \phi + \Delta(\phi)$

Generation of traveling waves Ring (2)

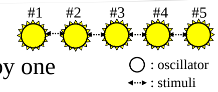
- Simulation results
  - N=10, τ =0.0964





Generation of traveling waves Line (1)

- A line of N oscillators

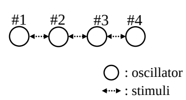


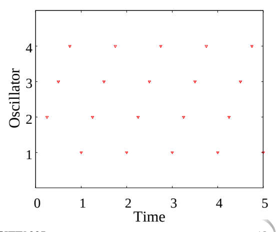
  - An oscillator is stimulated by one or two neighboring oscillators
  - Oscillators fire at constant phase-difference τ , and oscillator *1* fires after T units of time from a firing of oscillator N
- Condition for the existence of traveling waves

$$F((N-3)\tau + T + F(\tau)) = 1 - \tau$$
$$F((N-2)\tau + T) = 1 - \tau$$
$$(N-2)\tau + F(\tau) = 1 - T$$

Generation of traveling waves Line (2)

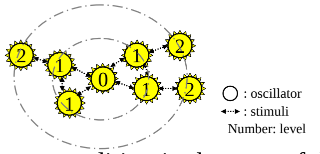
- Simulation results
  - N=4, T=0.25, τ=0.25





Generation of traveling waves Concentric circles (1)

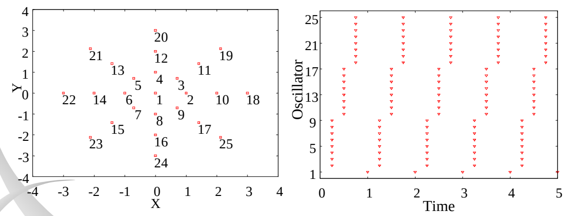
- Concentric circles as in [2]



- Apply the same condition in the case of the line
  – Defining the same initial conditions for oscillators on the same level

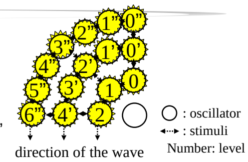
Generation of traveling waves Concentric circles (2)

- Simulation results
  – 25 oscillators, T=0.25, τ=0.25



Generation of traveling waves Radar (1)

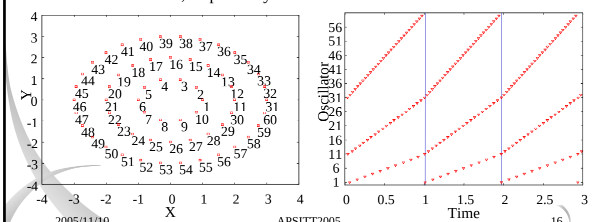
- Radar-like traveling wave
  – Oscillators fire in the order of their level
  – Oscillators fire simultaneously along the front of the "radar beam"



- Assumptions
  – An oscillator receives stimuli only from neighboring oscillators on the same circumference and those in the same radius
  – The center node does not fire, or oscillators on the innermost circle ignore firing of the center node
- We can apply the same condition in the case of the ring for each circumference

Generation of traveling waves Radar (2)

- Simulation results
  – 60 oscillators
  – τ was set at 0.0964, 0.0482, 0.0323 for the inner, middle, and outer circle, respectively



A distributed and self-organizing data gathering scheme

- Assumptions
  – Static and stable sensor network (no addition, removal, or movement of sensor nodes)
  – Communication delay is negligible
- A sensor node has a timer
- Core node: sensor node or a base station that gathers or disseminates information

Initial Settings: Core node

1. Core node determines
   – PRC function $\Delta(\phi)$
   – phase-difference τ
2. Core node broadcasts a message within its range of radio signals
   – $\Delta(\phi)$
   – τ
   – type of traveling wave
   – direction of information propagation
   – level value: 0 (diffusion) or N (fusion)

Sensor nodes: Message reception

- Uninitialized node
  - Adjusts its level and phase in accordance with the type of traveling wave
- Initialized node
  - Examines the message to decide whether it has to be stimulated or not
  - shifts the timer and periodically emits messages
    - sensor information
    - level value

Conclusion and future work

- Conclusion
  - Investigation of initial conditions that lead to desired phase-lock conditions in the pulse-coupled oscillator model
  - Presentation of a brief sketch of a scenario to apply the pulse-coupled oscillator model to data gathering
- Future work
  - More details taking into account changes in network topology and radio conditions
  - Application scenarios to show the benefit of our scheme

Thank you