# A Traveling Wave-based Self-Organizing Communication Mechanism for WSNs

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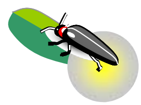
## Overview of our communication mechanism [1]

- Organize periodical communication patterns depending on application requirements
  - Information gathering from all sensor nodes (e.g. temperature data)
  - Information diffusion to all sensor nodes (e.g. control signals)
- Based on traveling wave phenomena of pulse-coupled oscillator model
  - Adaptive, robust, fully-distributed, and self-organizing
  - Synchronized message emission

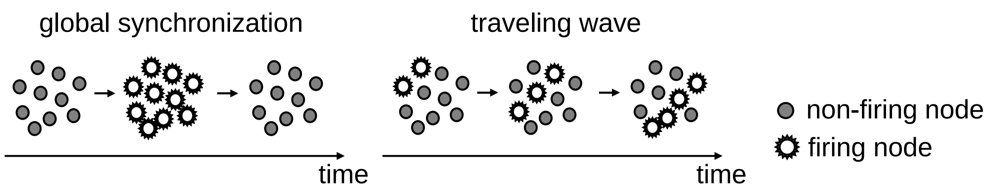
    →Efficient sleep scheduling (energy-efficiency)
  - But several iterations are necessary to form a traveling wave

## Pulse-coupled oscillator model

- Explains synchronous behavior of biological oscillators, e.g., flashing fireflies
- Basic Behavior



  - Oscillator *i* has a timer with phase $\phi_i \in [0,1]$
  - When the phase reaches 1, 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 $\Delta(\phi_i)$
- Through mutual interactions, global synchronization or traveling wave appears
  - Global synchronization: all oscillators fire synchronously
  - Traveling wave: oscillators behave synchronously keeping fixed phase difference




  - The condition of PRC (Phase Response Curve) function $\Delta(\phi)$ to generate a traveling wave from random initial condition is discussed in [1]

[1] Y. Taniguchi, N. Wakamiya, M. Murata, “A Traveling Wave based Communication Mechanism for Wireless Sensor Networks”, Journal of Networks, Vol.2, No.5, pp.24-32, September 2007

## How does the mechanism work?

- Any of sensor nodes can become a fusion/diffusion point, called core node, from which messages are disseminated or to which messages are gathered
- Sensor node $i$ has a timer $\phi_i \in [0,1]$, PRC function $\Delta(\phi_i)$ , level value $l_i$ , session identifier $s_i$ , direction $\delta_i$ , offset $\tau_i$
  - Core node: $l_i \leftarrow 0$, $s_i \leftarrow s_i + 1$ for new session
- Sensor node broadcasts a message when timer reaches 1
  - A message contains level value $l_i$ , session identifier $s_i$ , direction $\delta_i$ , sensor data
- When sensor node receives a message, it adjusts control parameters and is stimulated
- Once traveling wave is organized, sensor node can sleep during $\tau_{max} < \phi_i < 1-\tau_{max}$

Level value $l_i$ : number of hops from core node
Direction $\delta_i$ : 1 for diffusion and -1 for gathering
Offset $\tau_i$ : the interval of message emission between a node of level $l$ -1 and that of level $l$

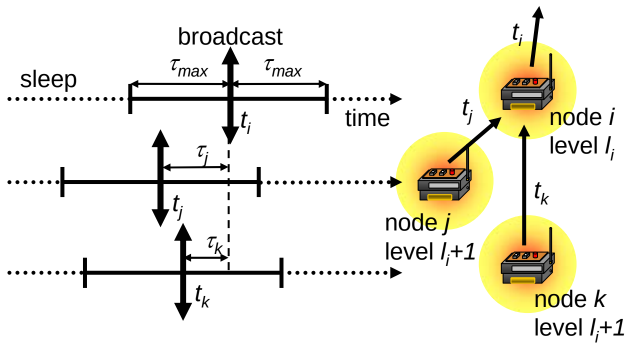



Fig. 1: Timing of Message Emission

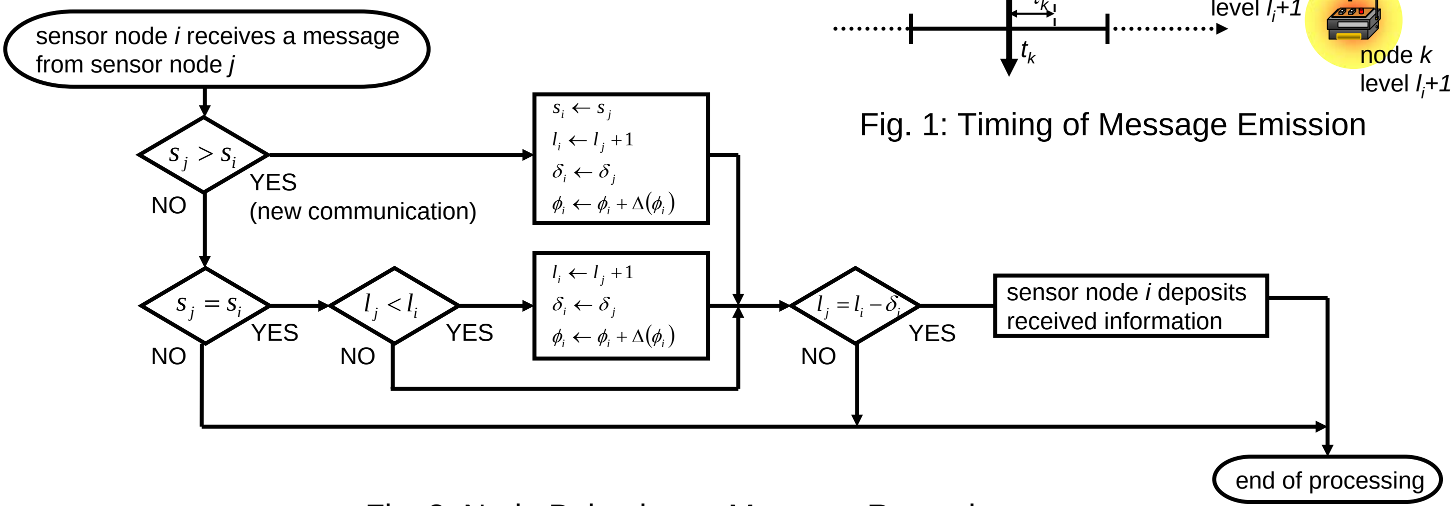



Fig. 2: Node Behavior on Message Reception

## Demonstration

- We can choose any sensor node as a core node for information diffusion or gathering
- Flashes of LEDs propagate from/to a core node
- We can add and remove sensor nodes

Dashed lines indicate neighbor relations

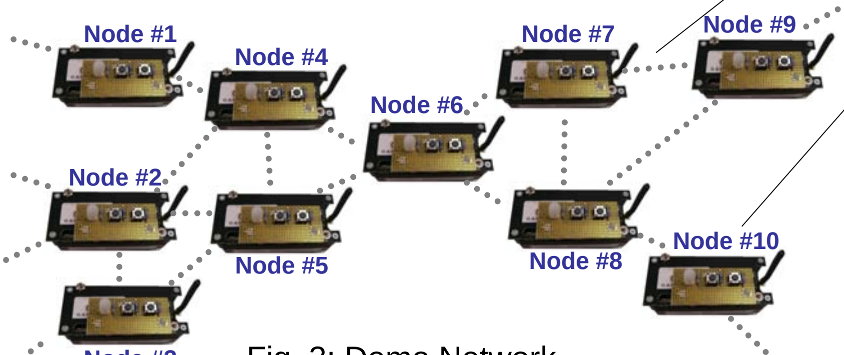



Fig. 3: Demo Network

***PUSH SW (LEFT) :***
Set a core node for information gathering

***PUSH SW (RIGHT) :***
Set a core node for information diffusion

***LED (RED) :***
Flashes when the sensor node broadcasts a message