Implementation and Evaluation of a Synchronization-based Data Gathering Scheme for Sensor Networks

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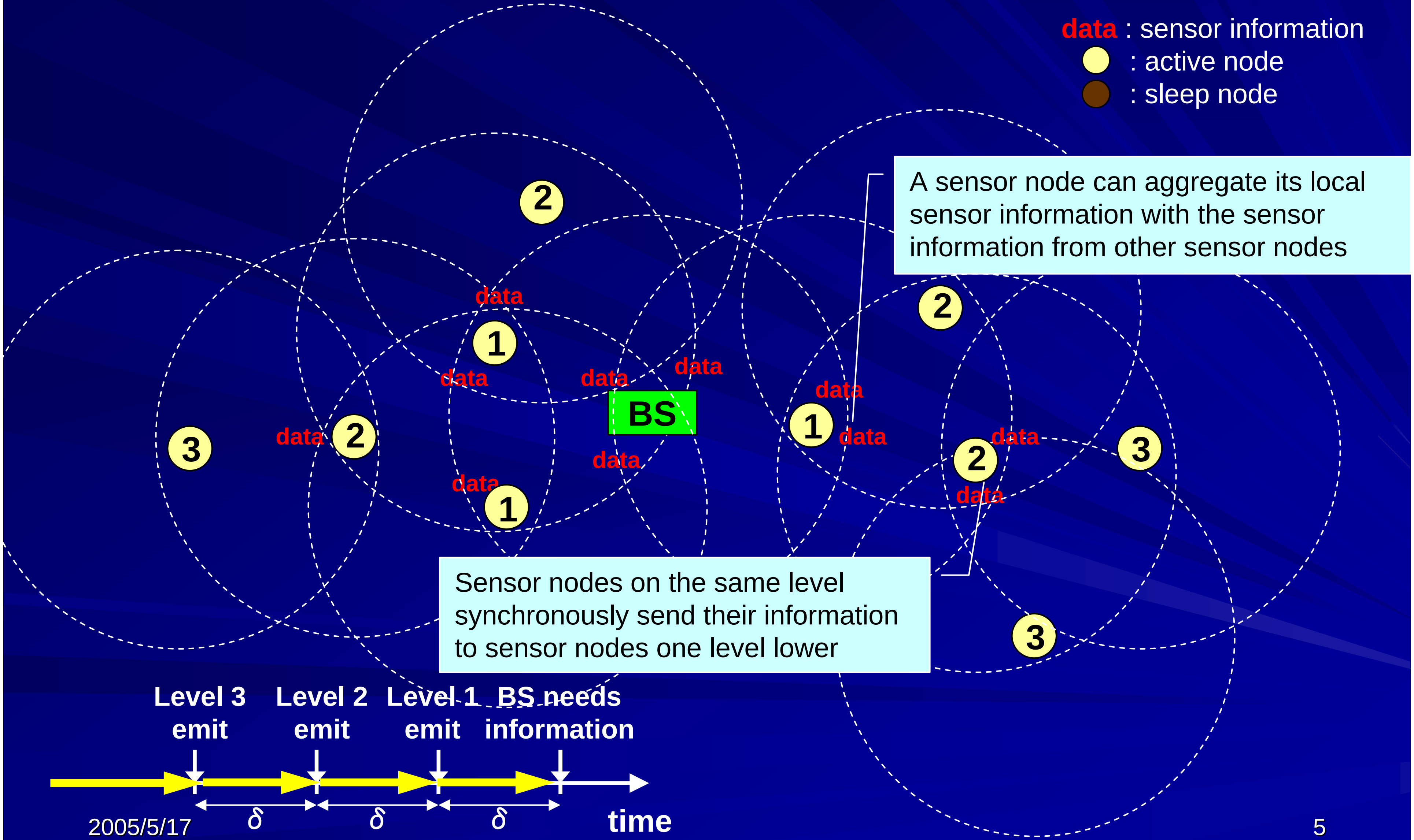
Background

- Sensor network must use a data gathering scheme that is energy-efficient
  - A sensor node is typically powered by a battery that cannot be replaced often
- The scheme must also adapt to the addition, removal, and movement of sensor nodes without any centralized control
  - Sensor nodes are often deployed and distributed in an uncontrolled way

Synchronization-based Data Gathering Scheme (1)

- A scalable, robust, and energy-efficient scheme for periodic data gathering in sensor networks
- Sensor information periodically propagates from the edge of a sensor network to a base station
  - Each sensor node has a timer
  - Each sensor node emit their sensor information based on their own timers, but in synchrony with others of the same number of hops **(called level)**
- Energy-efficiency
  - Each sensor node needs to turn on its transceiver component only at regular intervals
  - The amount of data that needs to be transferred can be effectively reduced

Data Gathering Scheme

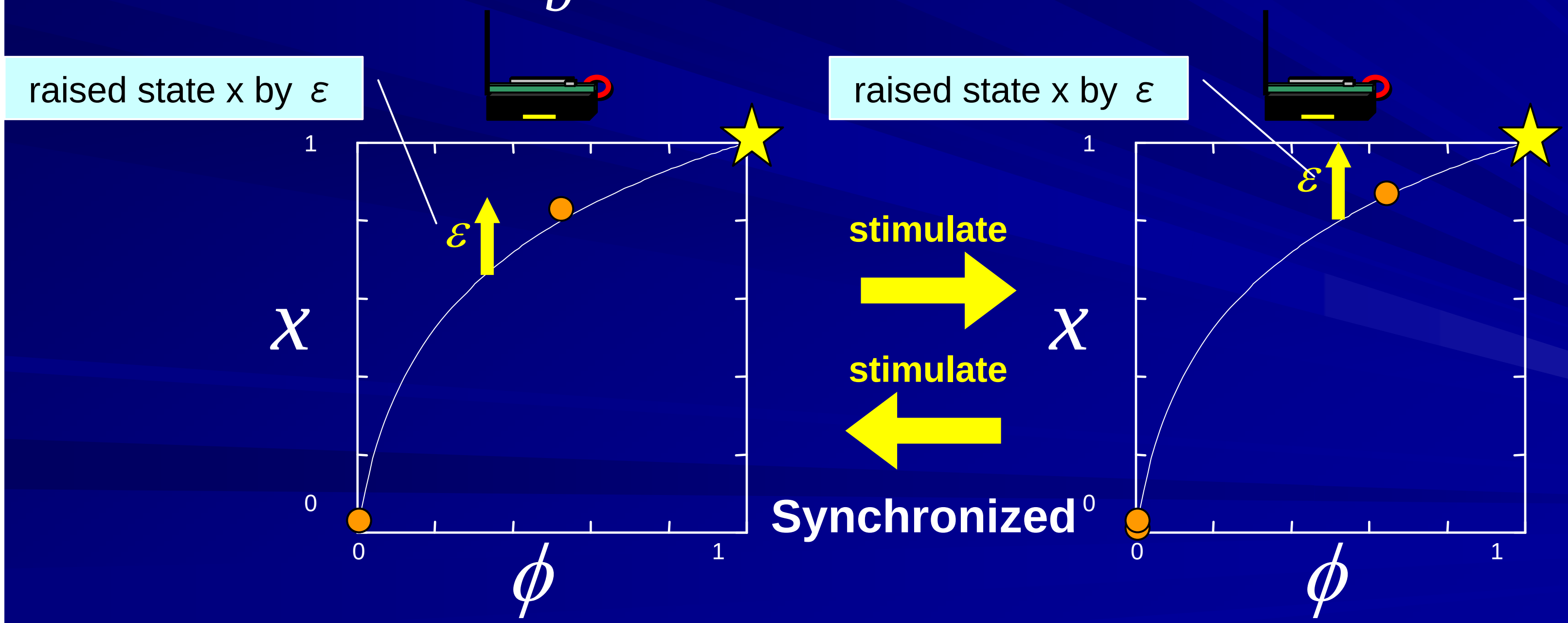


Synchronization-based Data Gathering Scheme (2)

- Synchronization is accomplished without any centralized control by adopting pulse-coupled oscillator model
  - Scalable because of no centralized control
  - Adaptive to the addition, removal, and movement of sensor nodes without any manual operations

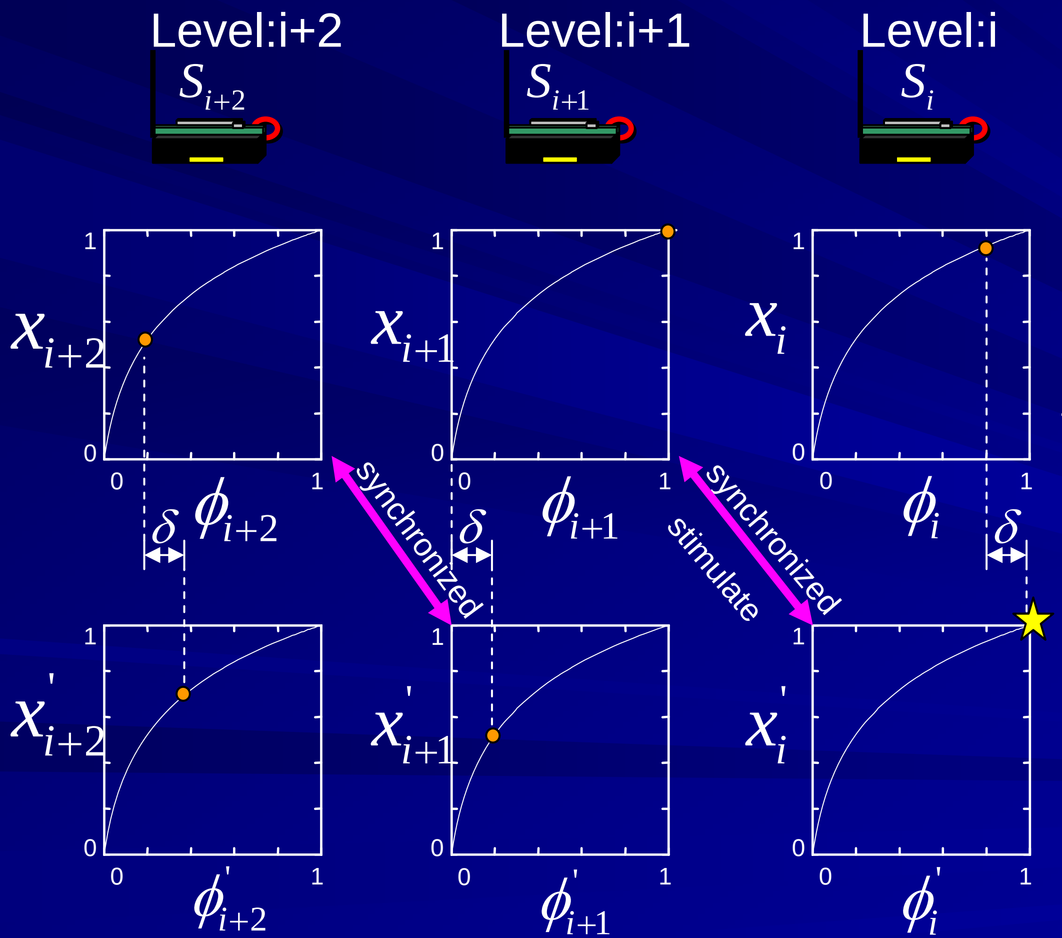
Pulse-coupled Oscillator Model

- Based on biological mutual synchronization
  - Flashing fireflies, chirping crickets, and pacemaker cells
- Each nodes have phase ϕ and state x of timer
  - $x = f_i(\phi_i) = \frac{1}{b}\ln\left[1 + \left(e^b - 1\right)\phi_i\right]$



Apply Pulse-coupled Oscillator Model

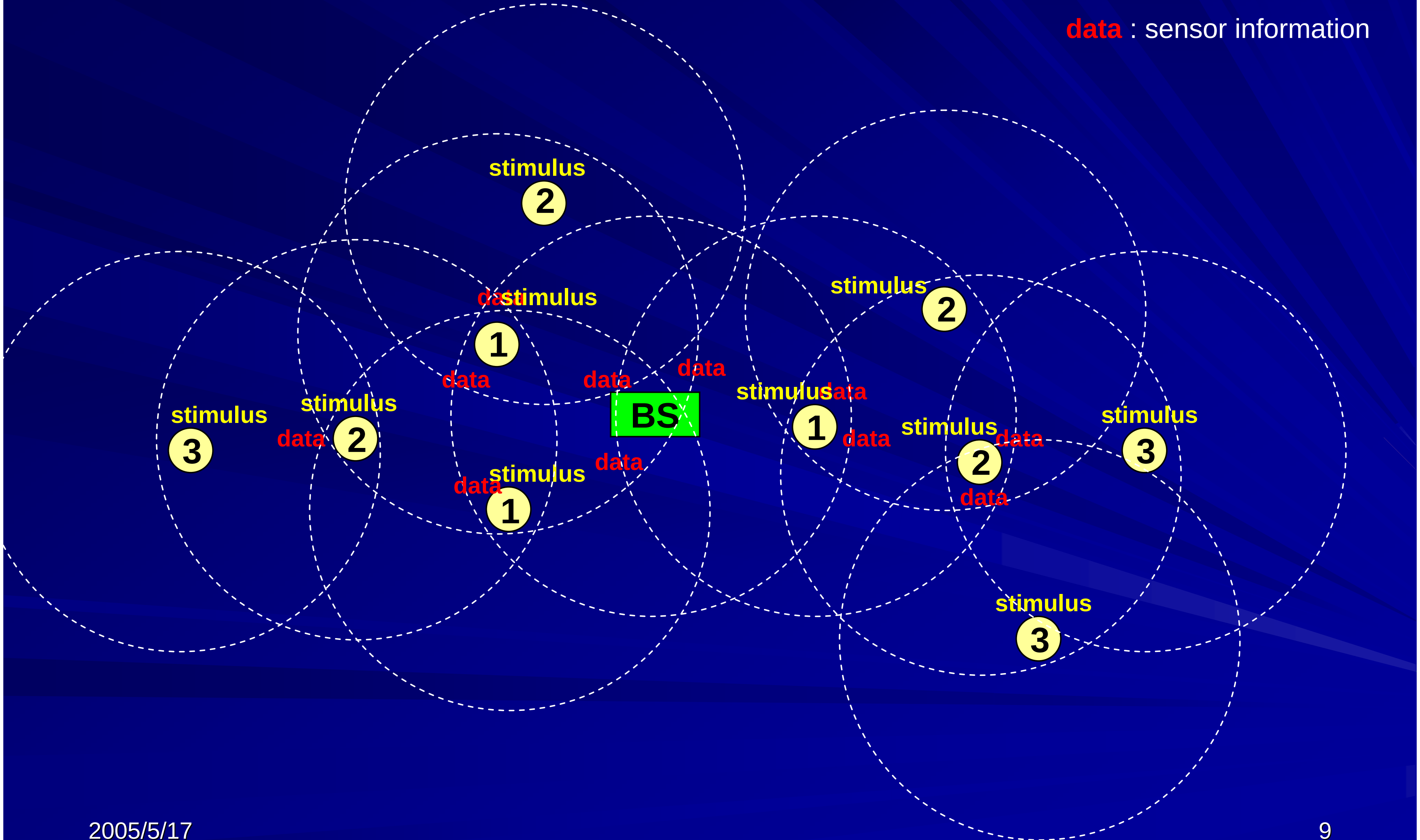
- Each sensor also have regulated phase ϕ' and regulated state x'



$$
\begin{cases}
\phi_i' = p(\phi_i,\delta_i) = \begin{cases} \phi_i+\delta_i, & \text{if } \phi_i+\delta_i \le 1 \\ \phi_i+\delta_i-1, & \text{otherwise} \end{cases} \\
x_i' = f(\phi_i') = \dfrac{1}{b}\ln\left[1+\left(e^b-1\right)\phi_i'\right]
\end{cases}
$$

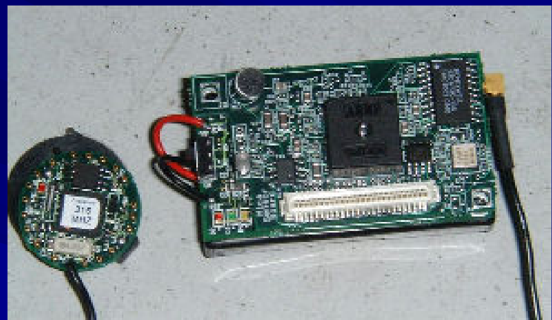
Level Adaptation

data : sensor information



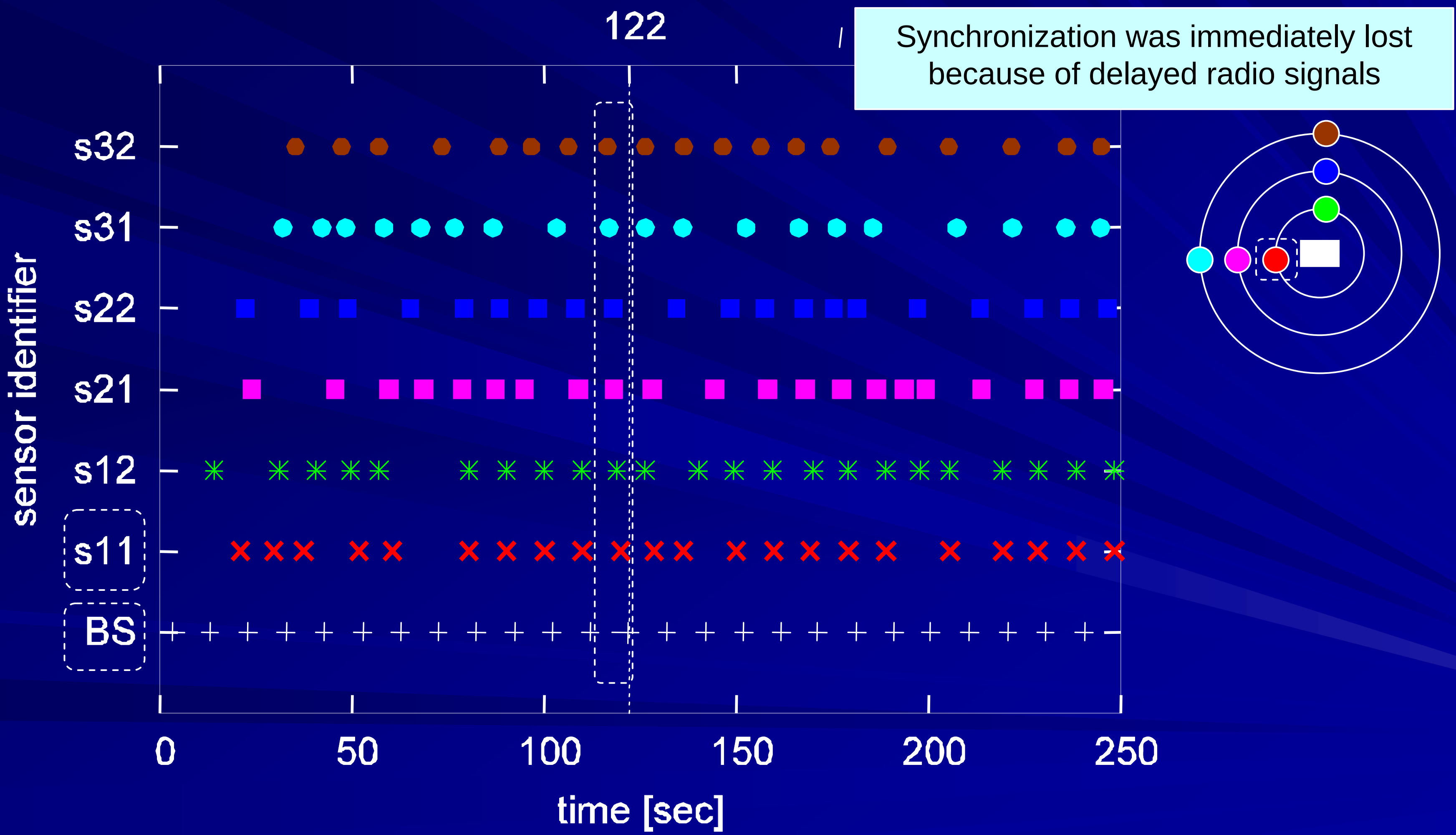
Implementation

- We implemented our scheme in sensor networks composed of wireless sensor units :MOTE

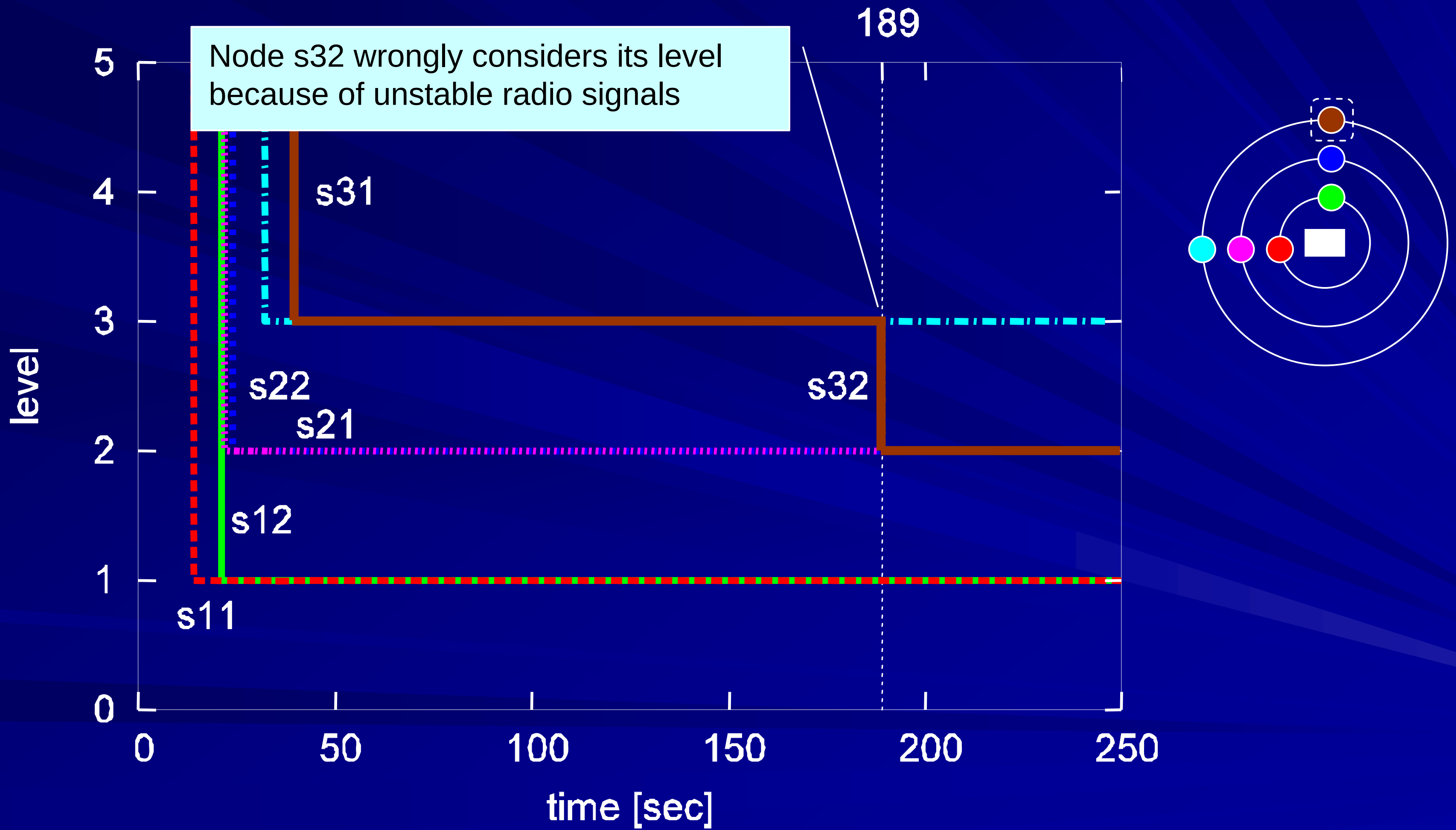


- The experiments were conducted on a roof with few obstructions

Experimental Result (Proposed Scheme) -Synchronization-



Experimental Result (Proposed Scheme) -Level Identification-



Problems

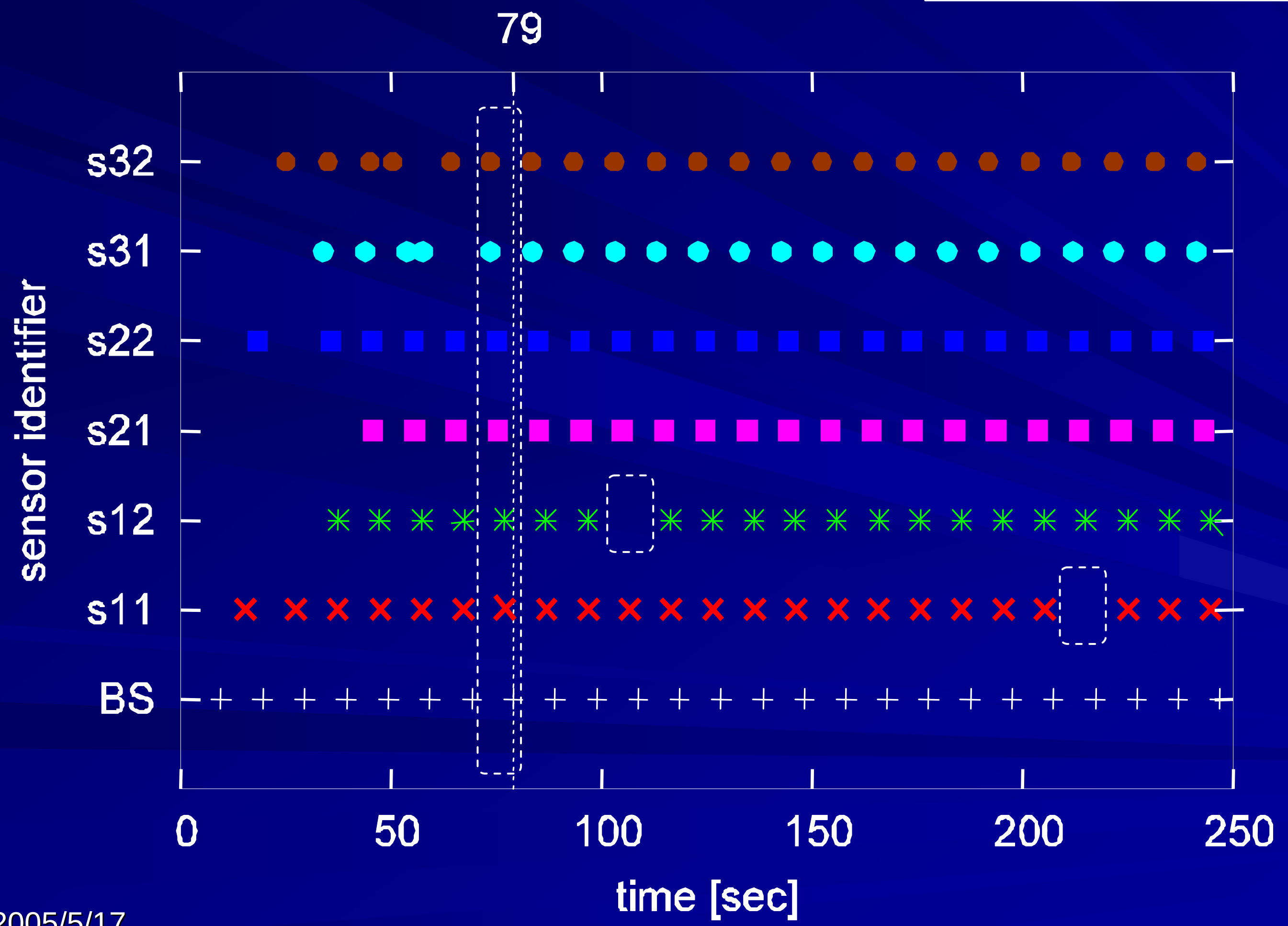
- In real wireless communications, radio signals are often delayed and unstable
  - Delayed radio signals
    - Synchronization is lost when state of the sensor nodes is raised by delayed signals
  - Unstable radio signals
    - When radio signals of further sensor nodes accidentally reach to a sensor node, level is wrongly identified
    - Sensor nodes can’t attain synchronization and become isolated

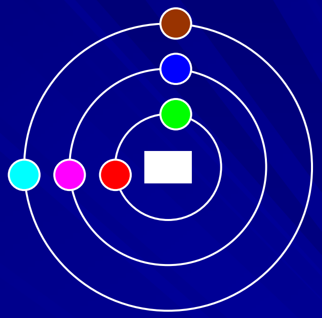
Improved Scheme

- Three filtering mechanisms to solve problems
  - For delayed radio signals
    1. Ignore radio signals discriminated to be delayed
  - For unstable (too weak or infrequent) radio signals
    2. Ignore radio signals whose reception strength are too weak
    3. Ignore radio signals which infrequently arrive (less than twice in three timer cycles)

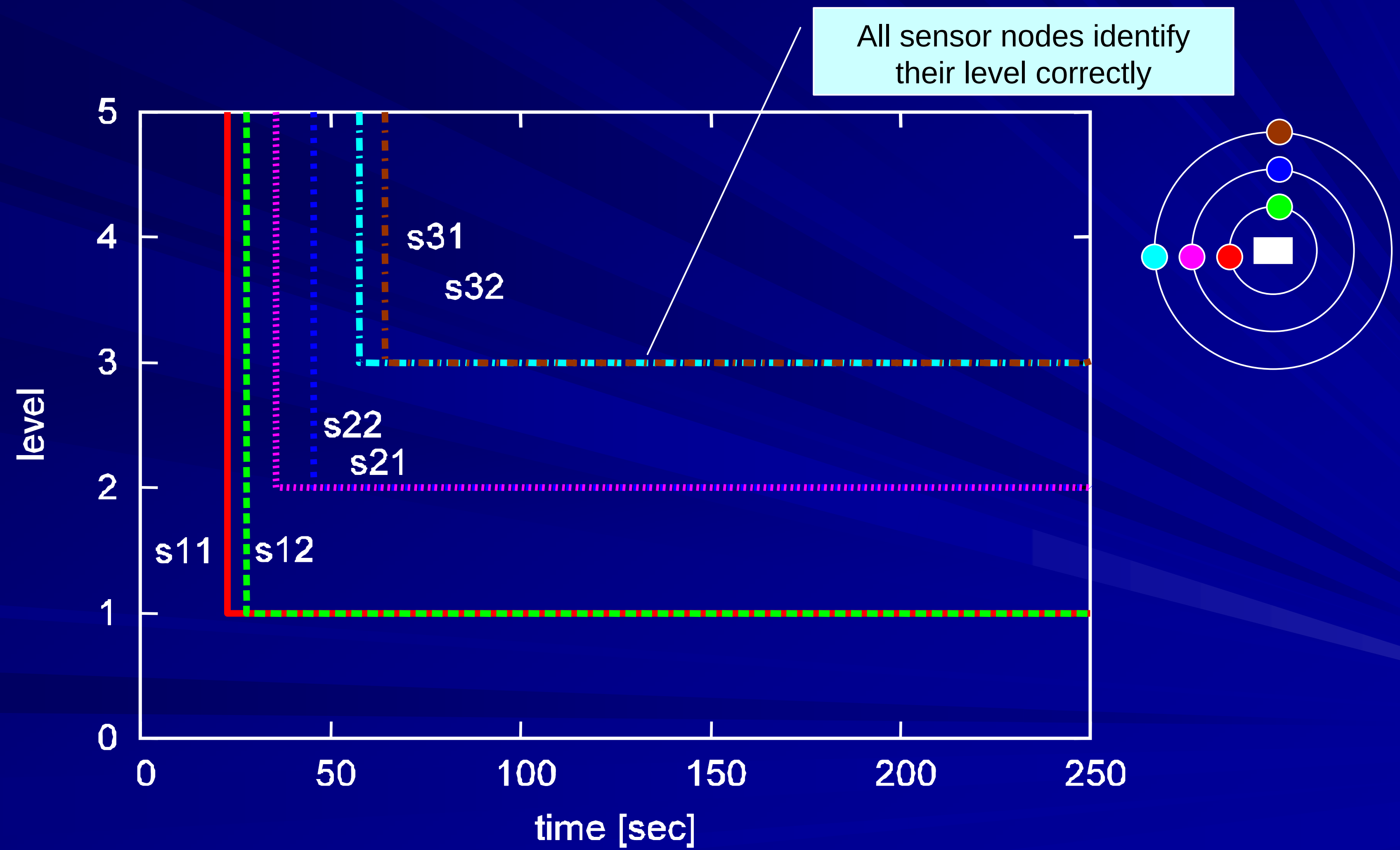
Experimental Result (Improved Scheme) -Synchronization-

Synchronization was maintained





Experimental Result (Improved Scheme) -Level Identification-

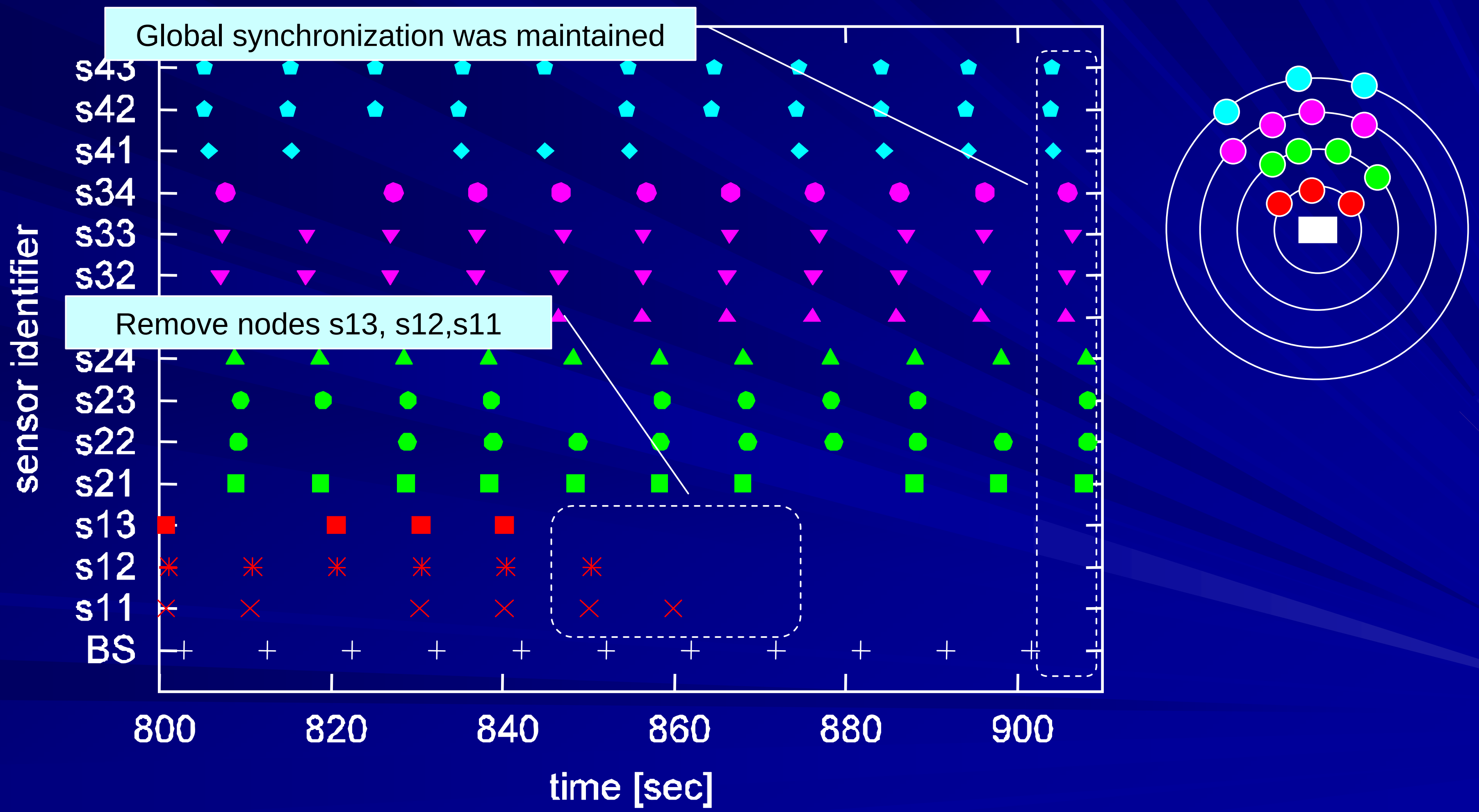


Conclusion & Future Works

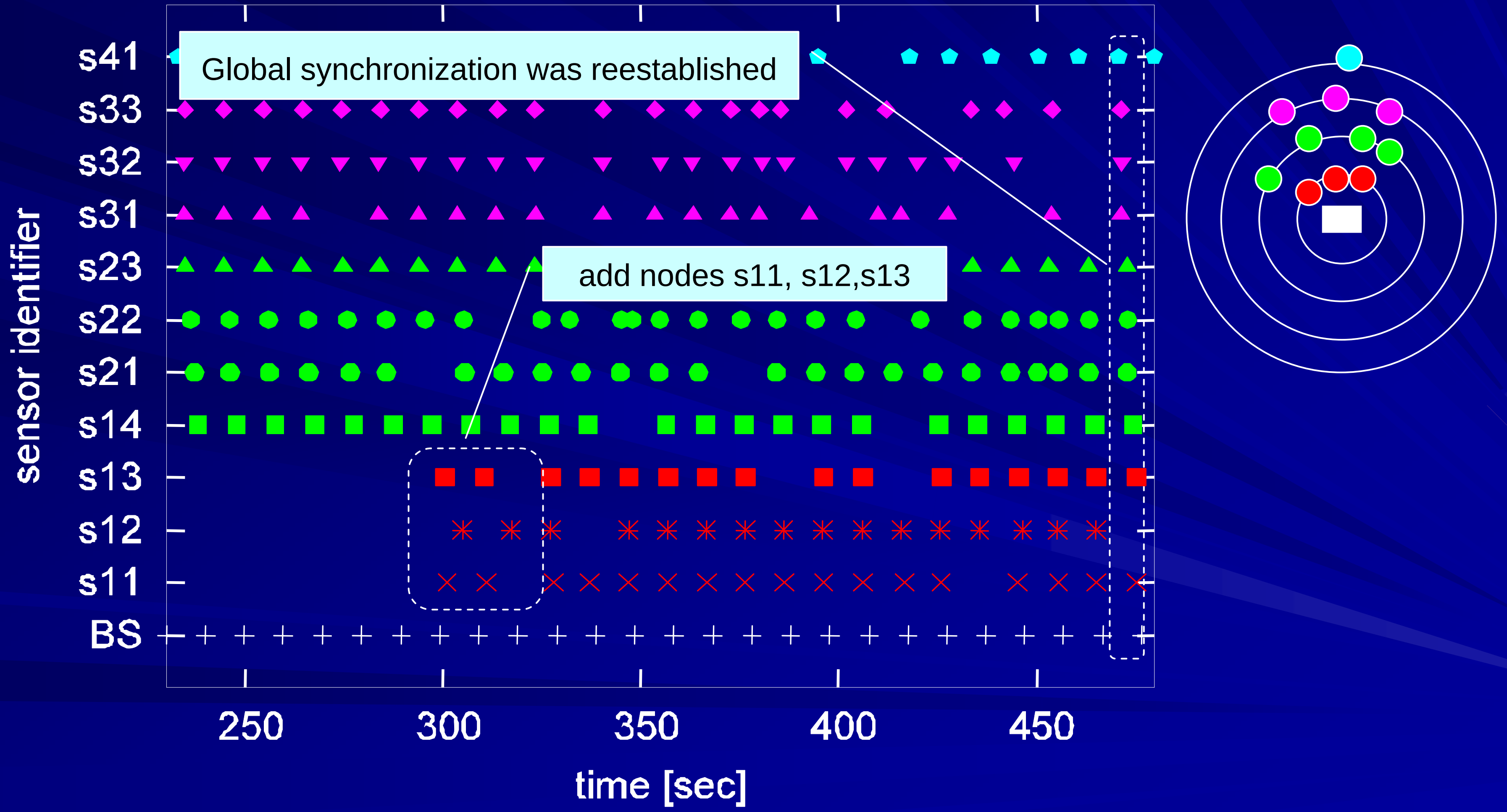
- Conclusion
  - The proposed scheme could not establish the synchronization in real environment
    - because of unstable wireless communications
  - several improvements to solve problems
    - filtering mechanisms
  - Improved scheme could periodically gather sensor information from sensor nodes
- Future Works
  - Experiments with more obstructions, interference, collisions
  - Confirm scalability, robustness, and energy-efficiency

- Thank you

Experimental Result (Improved Scheme) -Removal of Nodes-



Experimental Result (Improved Scheme) -Addition of Nodes-



Experimental Result (Improved Scheme) -Change in Frequency of Data Gathering-