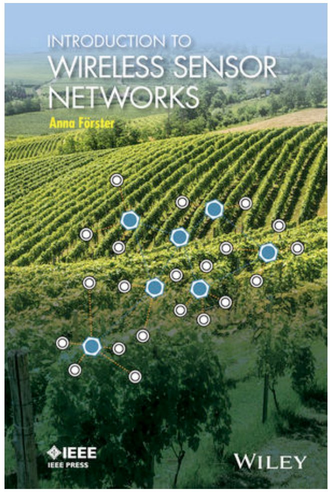

INTRODUCTION TO WIRELESS SENSOR NETWORKS

CHAPTER 7: TIME SYNCHRONIZATION

Anna Förster

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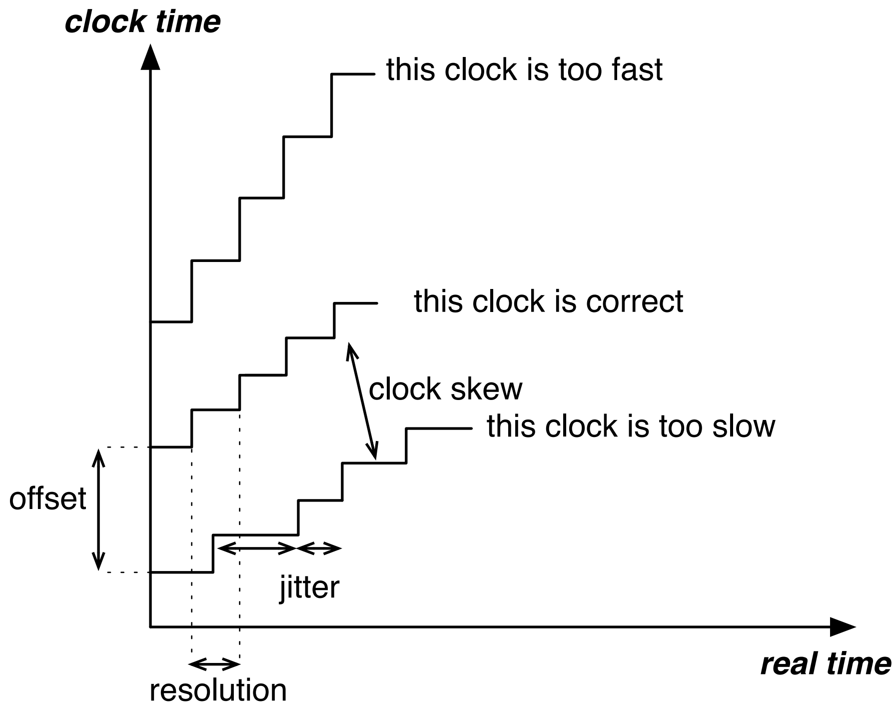
OVERVIEW

1. Clocks and Delay Sources
2. Requirements and Challenges
3. Time Synchronization Protocols
    1. Lightweight Tree Synchronization
    2. Reference Broadcast Synchronization
    3. NoTime

Clocks and Delay Sources

- ***Clock resolution or rate*** *is the step at which the clock progresses and can be read*
- ***Clock skew or drift*** *is the difference between the progressing speeds of two clocks*
- ***Clock offset*** *is the difference between the time shown by two different clocks*
- ***Clock jitter*** *is when the individual ticks of a clock are not perfectly the same*



Requirements and Challenges (1)

- **Two clocks drift apart even after synchronization**
- **The maximum drift rate of a clock dictates the synchronization period**

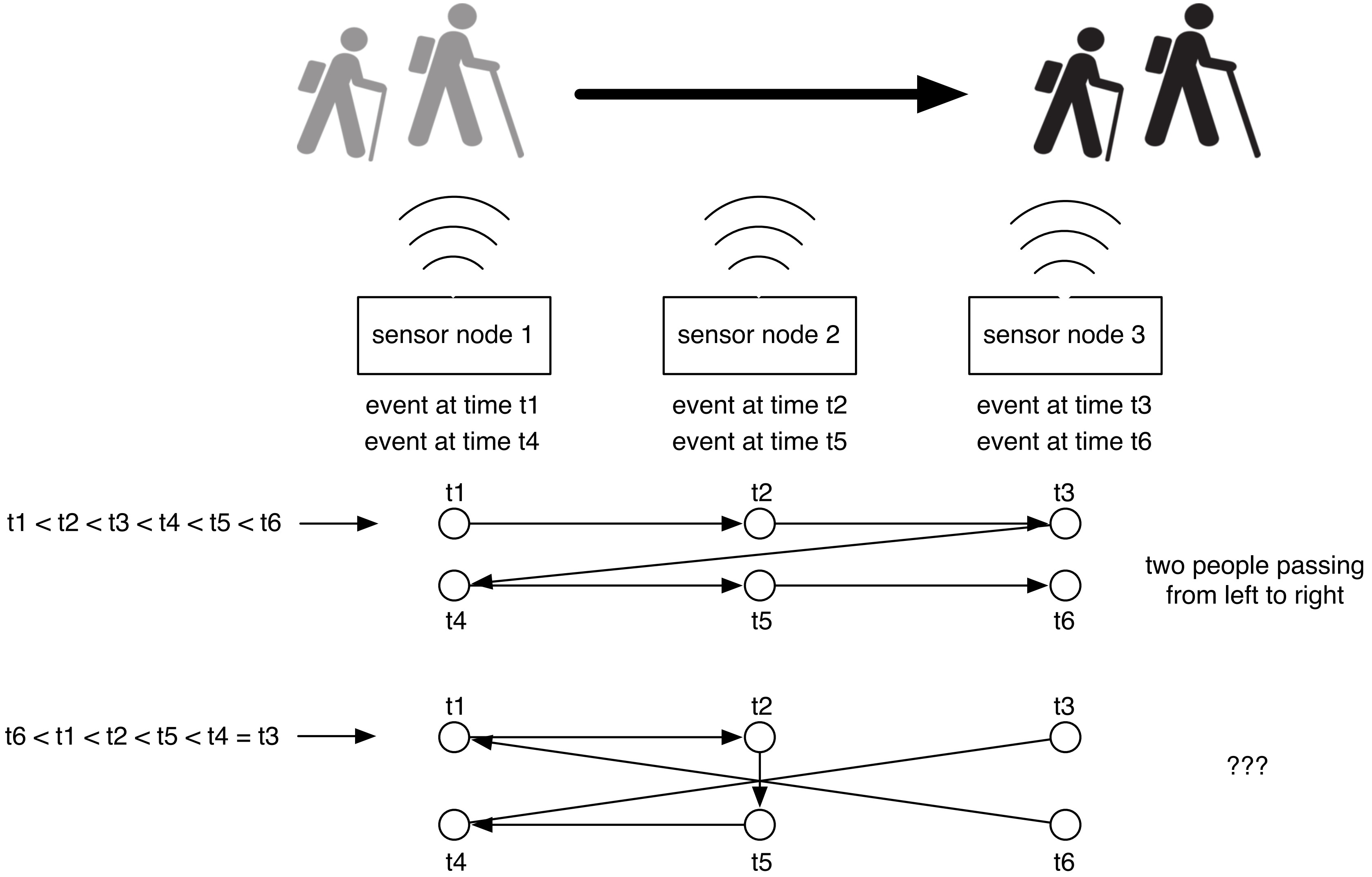
$$\tau_{sync} = \frac{\delta}{2\rho}$$

where ρ is the maximum drift rate in ppm (parts per million), δ is the maximum allowed drift in seconds and τsync is your needed synchronization period.

Requirements and Challenges (2)

- **The time synchronization protocol cannot jump back and forth in time.**
- ***Time synchronization accuracy*** *is the maximum offset between the synchronized clock and a reference clock (for example global time).*
- ***Time synchronization precision*** *is the maximum offset between any two synchronized clocks.*
- **Time synchronization precision is important to understand the sensor data.**

Understanding Sensor Data

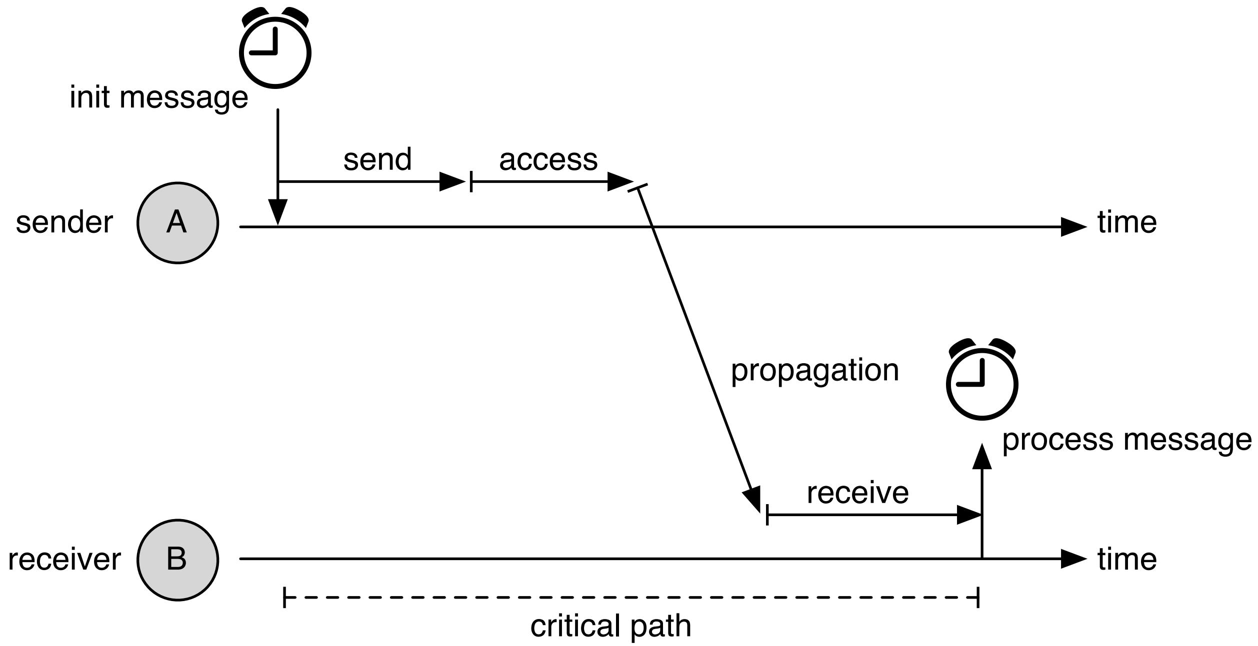


Anna Förster, Introduction to Wireless Sensor Networks, 2016

Time Synchronization Protocols

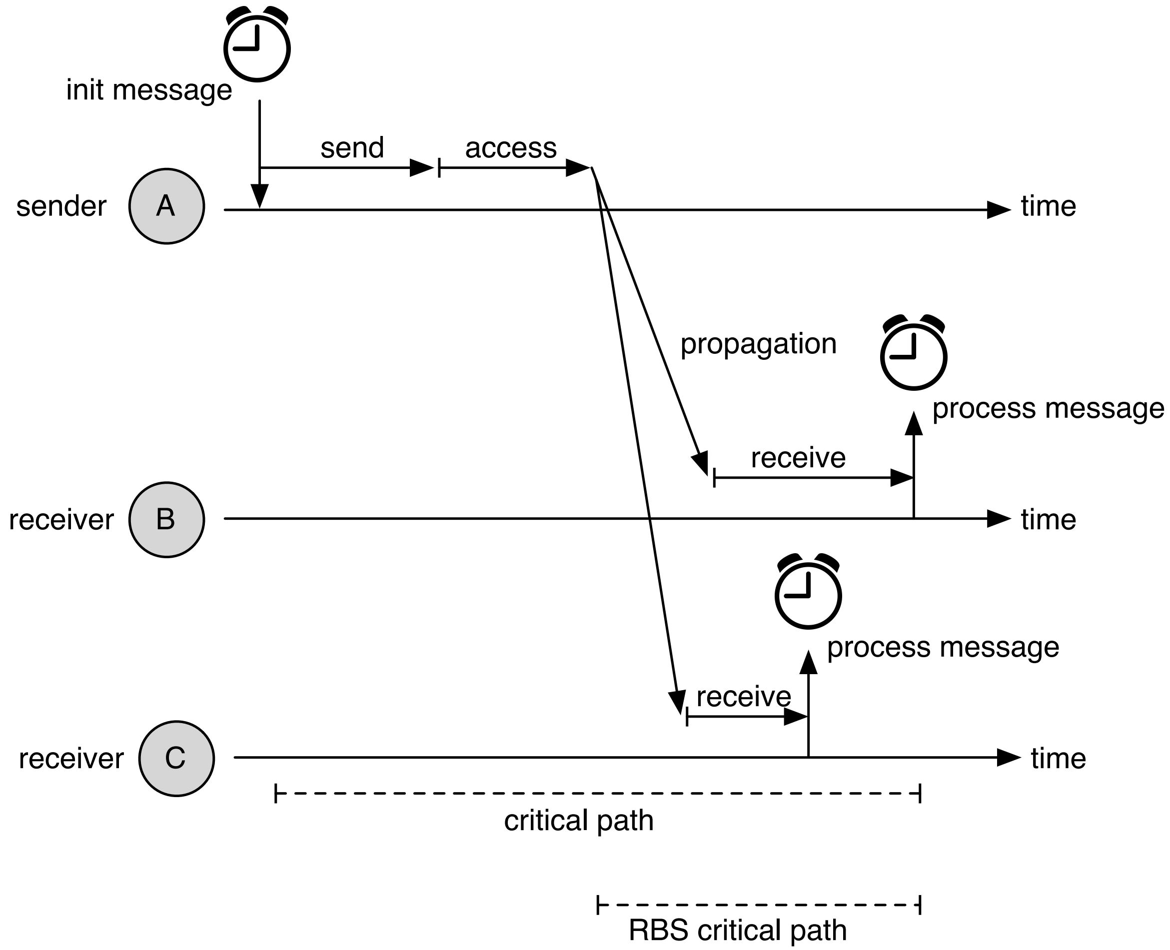
- **Externally** Synchronized: there is an external source of correct time data.
- **Internally** Synchronized: consistent view from all nodes, but not globally correct time.

Sender-Receiver Synchronization



- Long critical path

Receiver-Receiver Synchronization



- Shorter critical path

Lightweight Tree Synchronization (LTS)

- Build a spanning tree from root (sink) to all nodes
- Sink has globally correct time
- Sink sends a message to its children to sync them, then traverse the tree
- Use sender-receiver synchronization

- Precision depends on depth of tree and does not scale

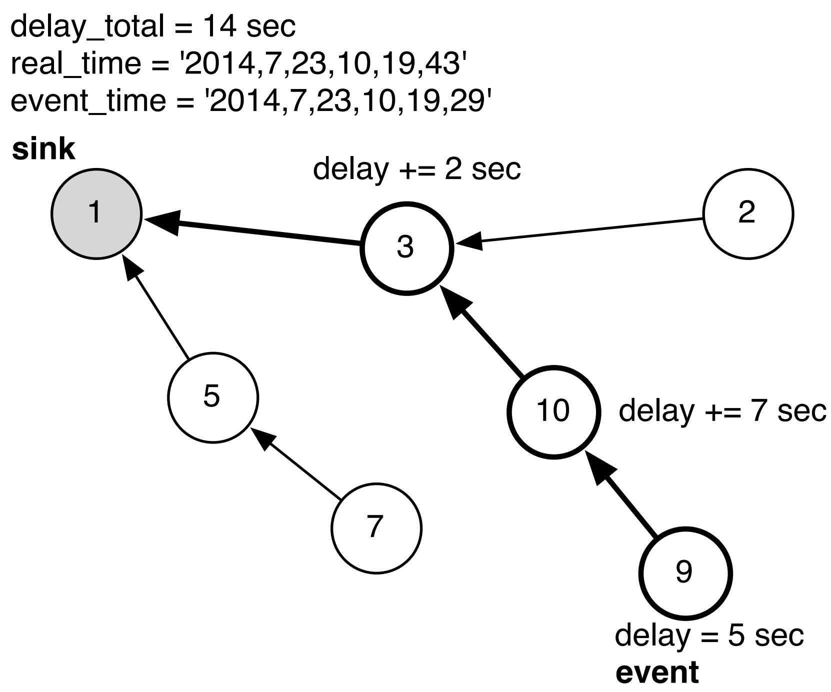
Reference Broadcast Synchronization (RBS)

- Uses receiver-receiver synchronization
- Broadcast correct time to all neighbors

- Total precision increases with number of broadcasts
- Scales well
- Not very efficient in terms of communication overhead

NoTime Protocol

- Do not try to time sync the nodes directly
- Provide enough information so that the sink can reconstruct the real time
- Save delays on the way



- Precision depends on:
  - Propagation Delay
  - Hardware Delay
  - Local time resolution

SUMMARY

- **Clock skew** causes two clocks to progress at different rates, while **clock jitter** causes a clock to tick irregularly.
- Provide efficiency and simplicity:
  - Regular synchronization is needed.
  - Available time cannot jump back and forth in.
- **Lightweight tree synchronization protocol (LTS)** uses the sender-receiver synchronization message exchange and is not scalable.
- **Broadcast reference protocol (RBS)** uses the receiver-receiver synchronization message exchange, has greater precision than LTS and is scalable.
- **NoTime** does not synchronize the nodes, but computes the in-network delay for each data packet, which enables the sink to compute the original event's real time.

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