# Designing a High-Reliability Low-Power Status Monitoring Protocol

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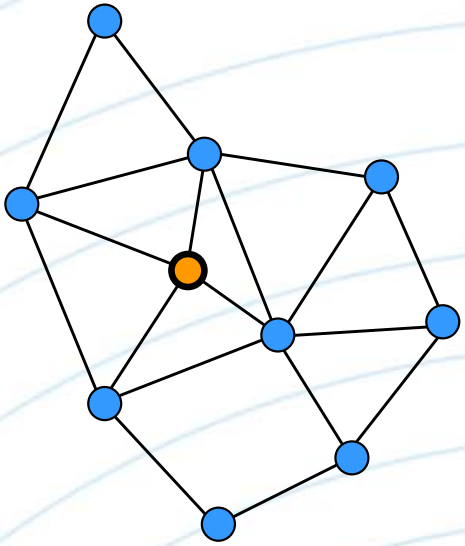
# Motivation

- Safety and security requires status monitoring
  - High reliability, robustness and low power
  - Multiple (wireless) hops to sink
  - Lifetime of a couple of years (2 AA batteries)
  - Fire-detector regulations require reporting in 5min

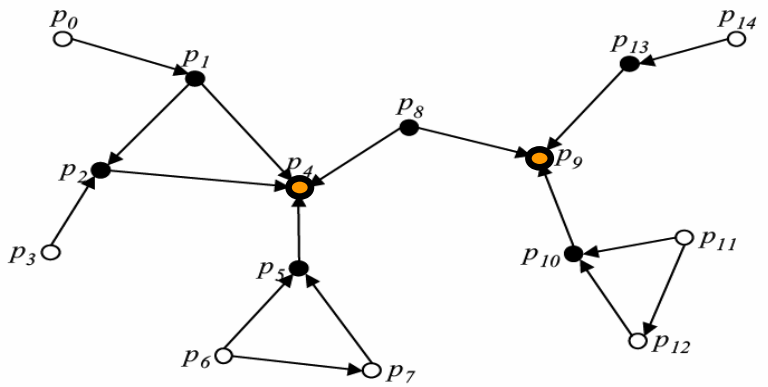


Sink node

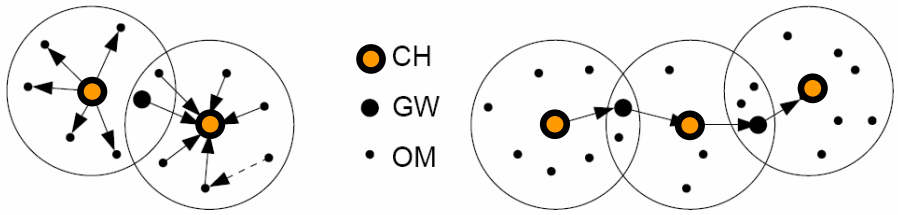
Sensor nodes

# Related Work – Status Observation in WSNs

- Wang et al. [DSN'03]
  - Heartbeat, Gossiping (Random, Coordinated)
  - No link layer (energy) considerations
  - No delay awareness




- Tai et al. [DSN'04]
  - Cluster based with heartbeat
  - No link layer (energy) considerations
  - No delay awareness




(a) Intra-cluster (b) Inter-cluster

- Rost et al. [SECON'06]
  - Combined with regular data traffic
  - Energy consumption considered but not
  - No delay awareness

Open questions: latency, energy and feasibility

# Wireless Characteristics

- Shared (broadcast) medium
- Unpredictable radio communication
- Reliability, robustness and timeliness
- Energy constraints (3 years, 2 AA batteries)

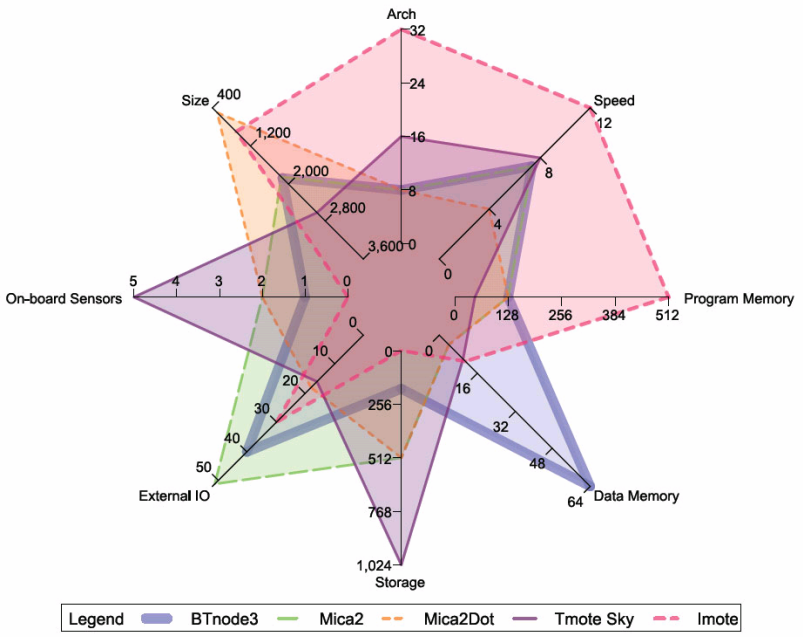
## Medium access control coordinates the channel access:

A. Random access protocols
  - e.g. B-MAC, WiseMAC, X-MAC, SCP-MAC...
  - Collisions possible, idle listening overhead
  - Not suited well to guarantee timeliness

B. Coordinated channel access (TDMA)
  - Especially suited for a known traffic pattern
  - Commonly considered to be optimal

# Initial Platform Evaluation

- Protocol must suit potential platform (and vice versa)
- Evaluate and select candidate platform
  - BTnode, Mica2, Mica2Dot, Tmote Sky, Imote...
  - Numbers from datasheets (radio characteristic, µC)
  - Knowledge base, support

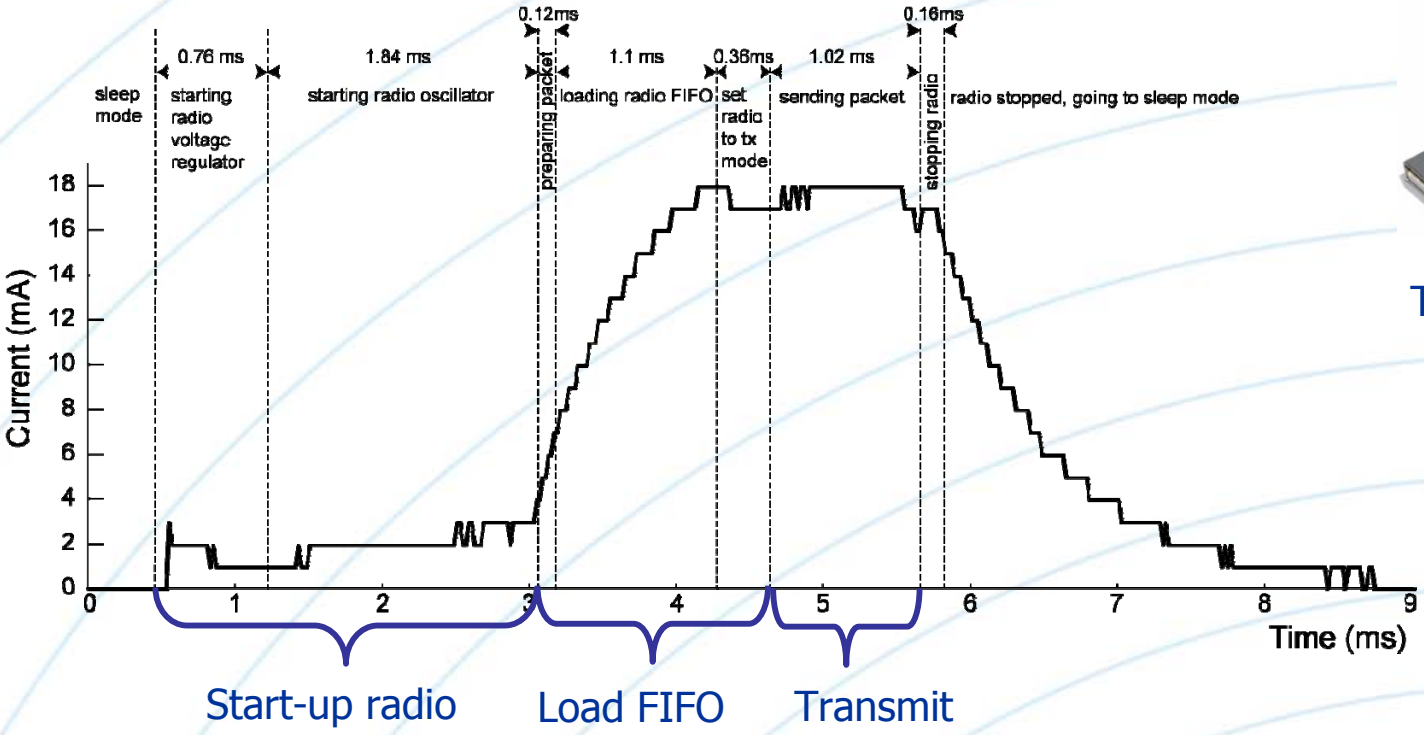



[J. Beutel RealWSN'06]

Tmote Sky (CC2420):
- Fast (switching) radio
- Low sleep power
- Widely used

# Detailed System Analysis

- Power consumption and timing of a TX sequence:
  - Similar characteristic for reception and idle listening

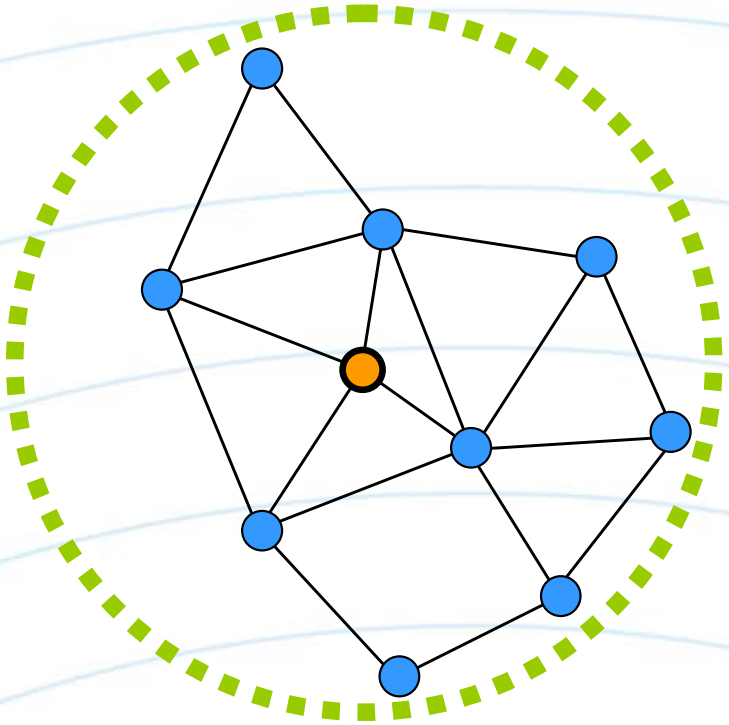



Tmote Sky (CC2420)

Powering up the radio and loading the FIFO requires substantial time

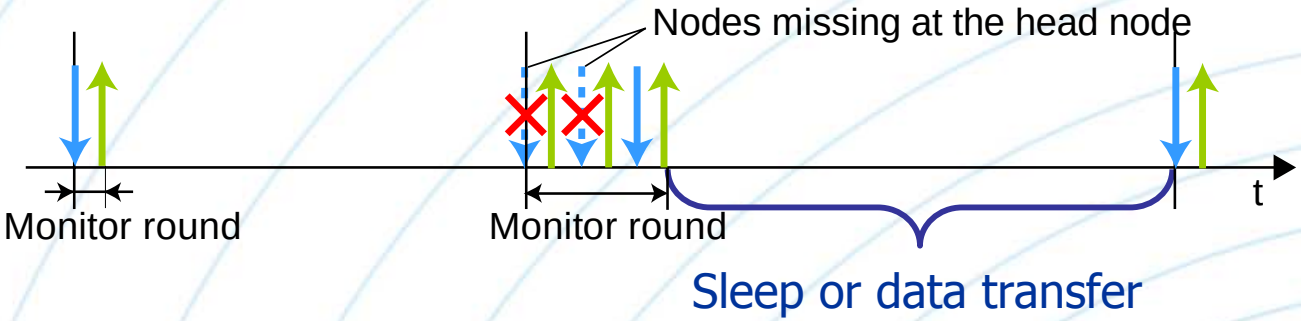
# Protocol Design I: Wave Scheme

- Periodic heart beats (waves)
  1. Report wave (aggregation)
  2. Sink node checks status
  3. Acknowledge wave
     - Includes synchronization



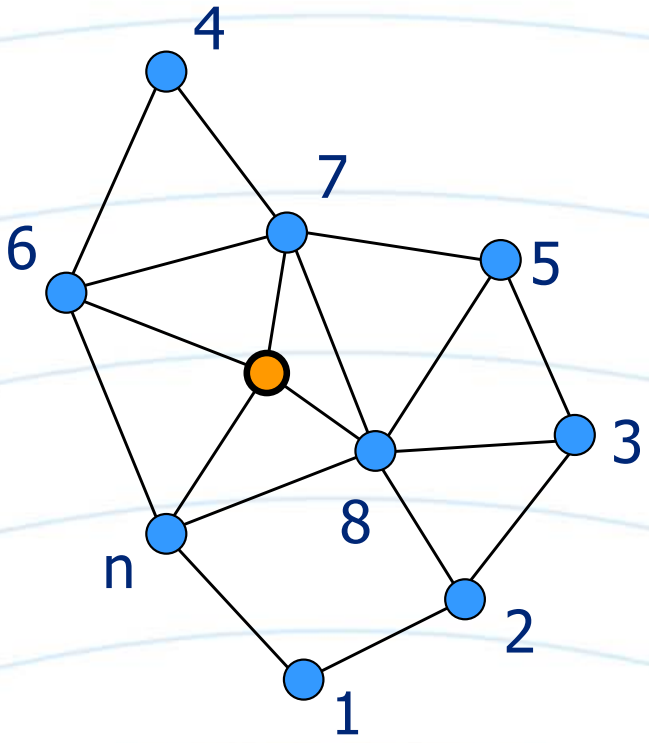
## Twofold robustness:

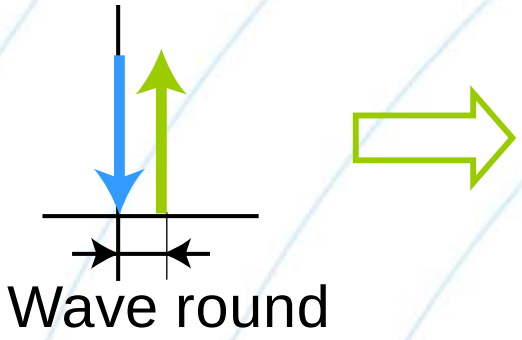
1. Redundant paths (within a wave)
2. Additional recovery wave(s) if node is missing

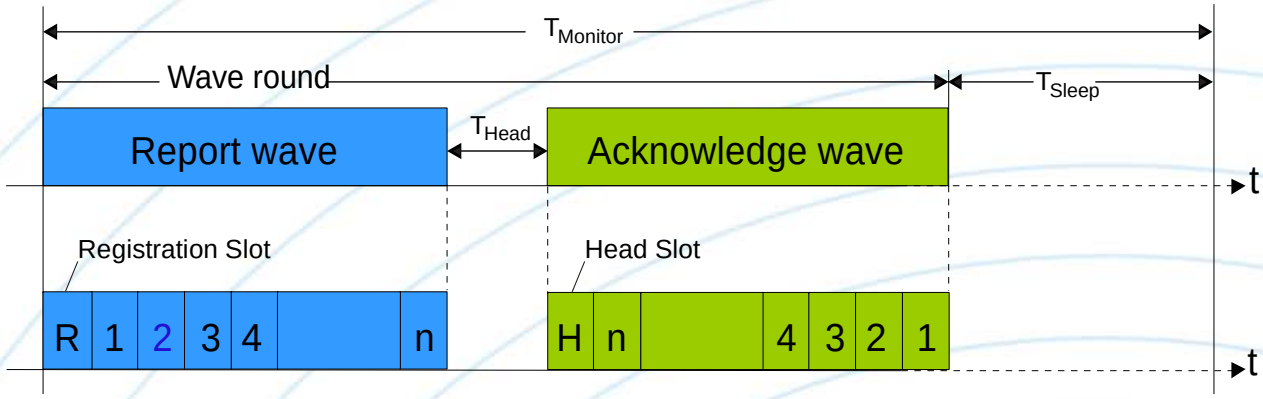


# Protocol Design II: TDMA Schedule

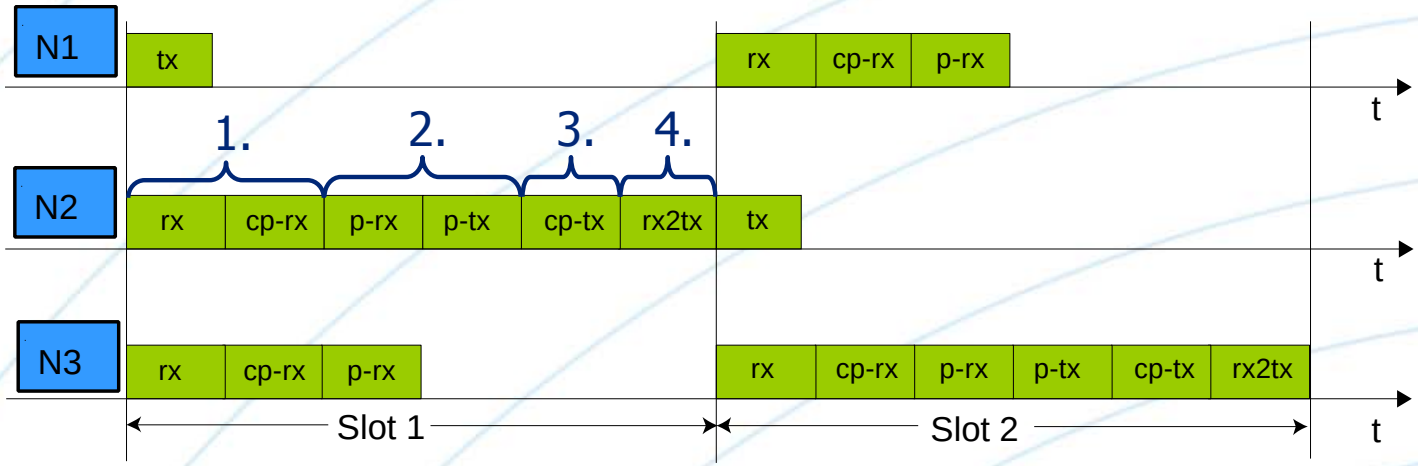
- One transmission per slot only
  - Remaining nodes are listening
  - Adds redundancy, increases robustness
- Slot assignment according to hop count
- Sink node initializes ack wave
  - Includes synchronization



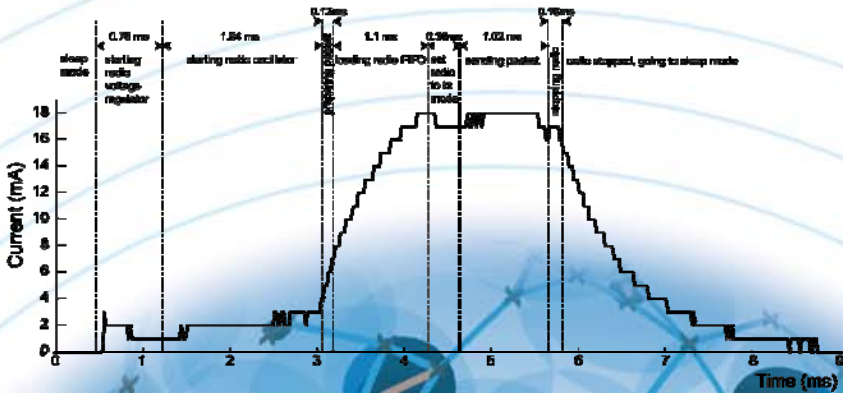



# Example: Timeline of a 3-node scenario



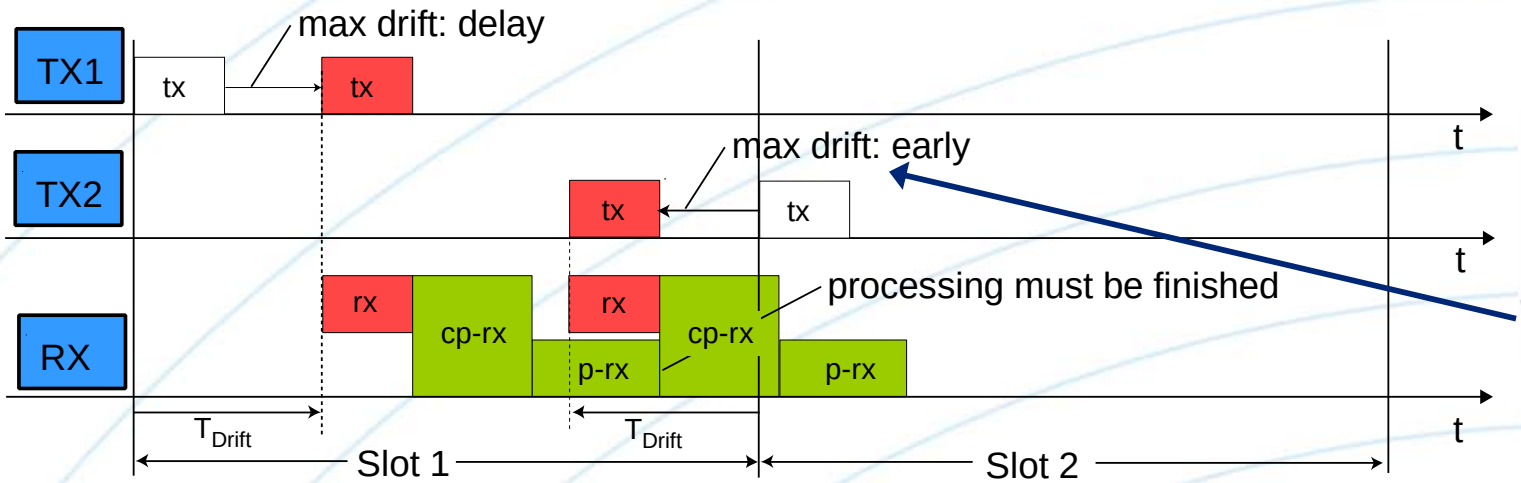

Implementation dependent

1. Receive packet and copy from radio to µC
2. Process rx packet and prepare tx packet
3. Copy packet from µC to radio
4. Switch radio from rx to tx



# Minimizing Slot Time – Constraint II: Clock Drift Compensation

- Worst case: TX1 late, TX2 early




Clock drift:
$\theta$ = 30ppm

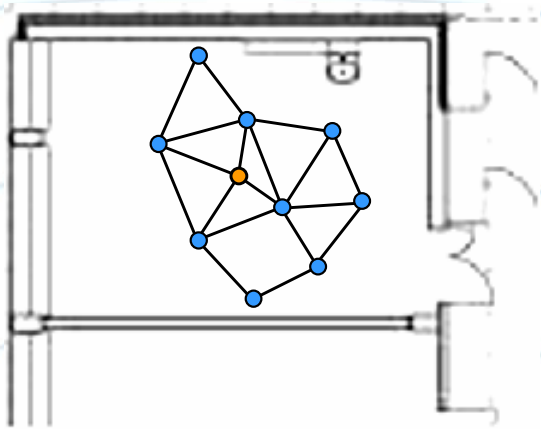
- Requires to guard the clock drift since last ack-wave ($T_\Delta$)

$$T_{slot}(T_\Delta) = 2\theta T_\Delta + T_{rx} + T_{cp-rx} + T_{p-rx}$$

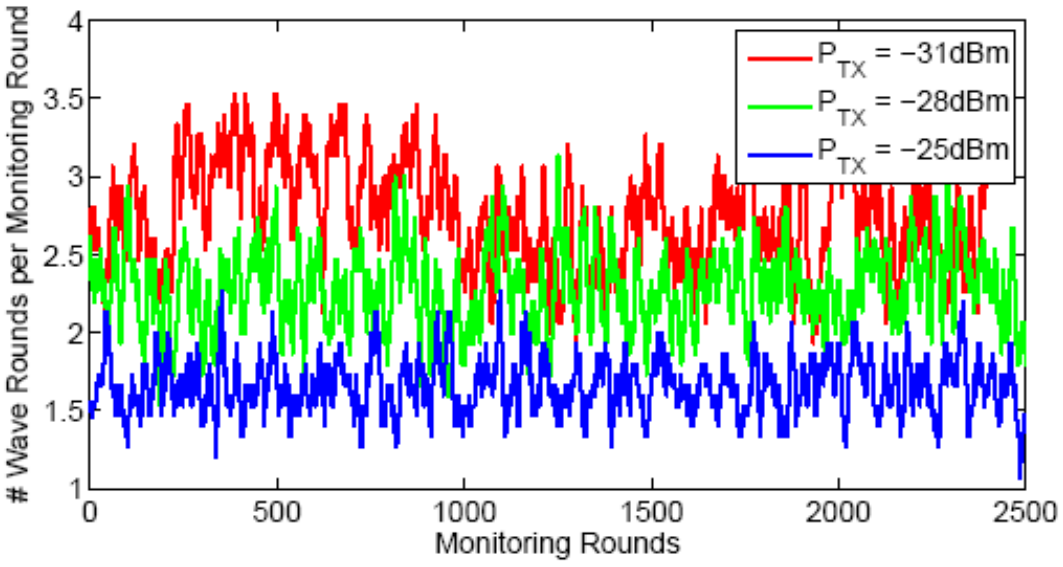
$$T_{wave} = (n+1) \cdot T_{slot} \cdot (1+2\theta)$$

# Performance Evaluation: Robustness Analysis

- Node deployment:
  - Office setting with a dozen of nodes
  - 2-hop neighborhood



- Test status monitoring with unreliable links
  - Set $P_{TX}$ to the limit of the reception sensitivity
  - Despite the low signal level, nodes are still reported
    - Recovery rounds necessary



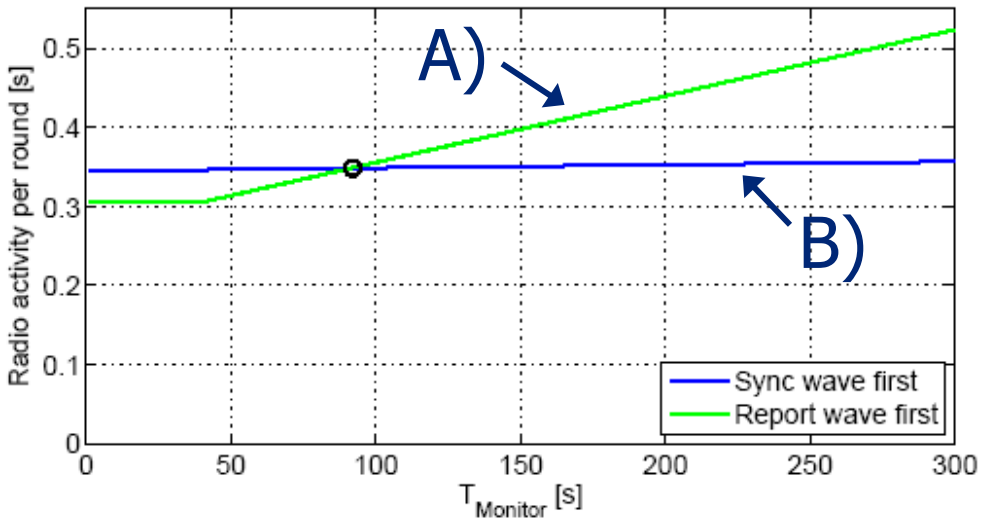
## 2 Alternatives:

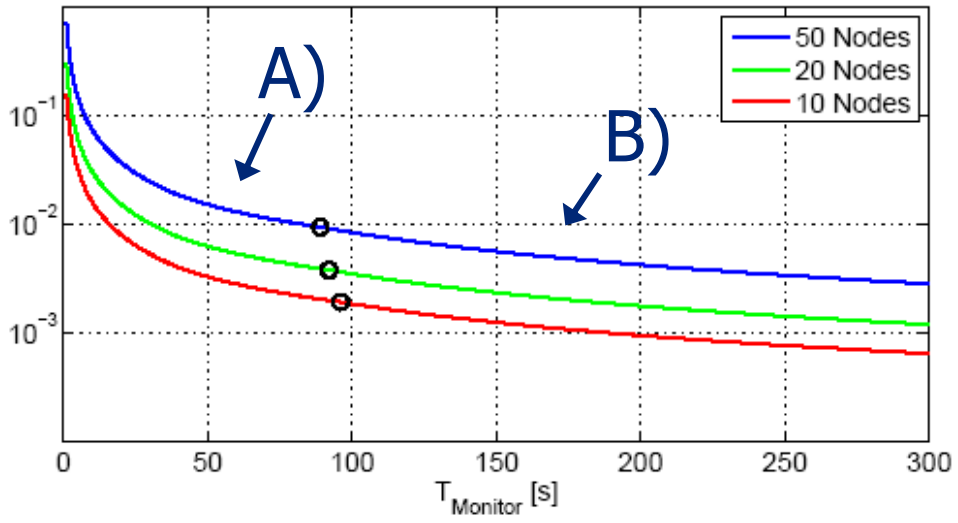
### A) Start with the report wave

- Long guard times in report wave
- At least two waves (report, ack)

### B) Start with a sync wave

- Short guard times in all waves
- At least three waves (sync, report, ack)



# Conclusion

- Safety and security WSN apps require status monitoring
  - Reliability, energy efficiency and timeliness
- Designing such a protocol requires:
  - In depth understanding of the hardware
  - Designing for this hardware
- TDMA based wave scheme with twofold robustness:
  - Multiple paths for link failure
  - Immediate recovery rounds if necessary

# Thank you for your attention

## Questions?

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