Clocks, Time Stamping and Time Synchronization

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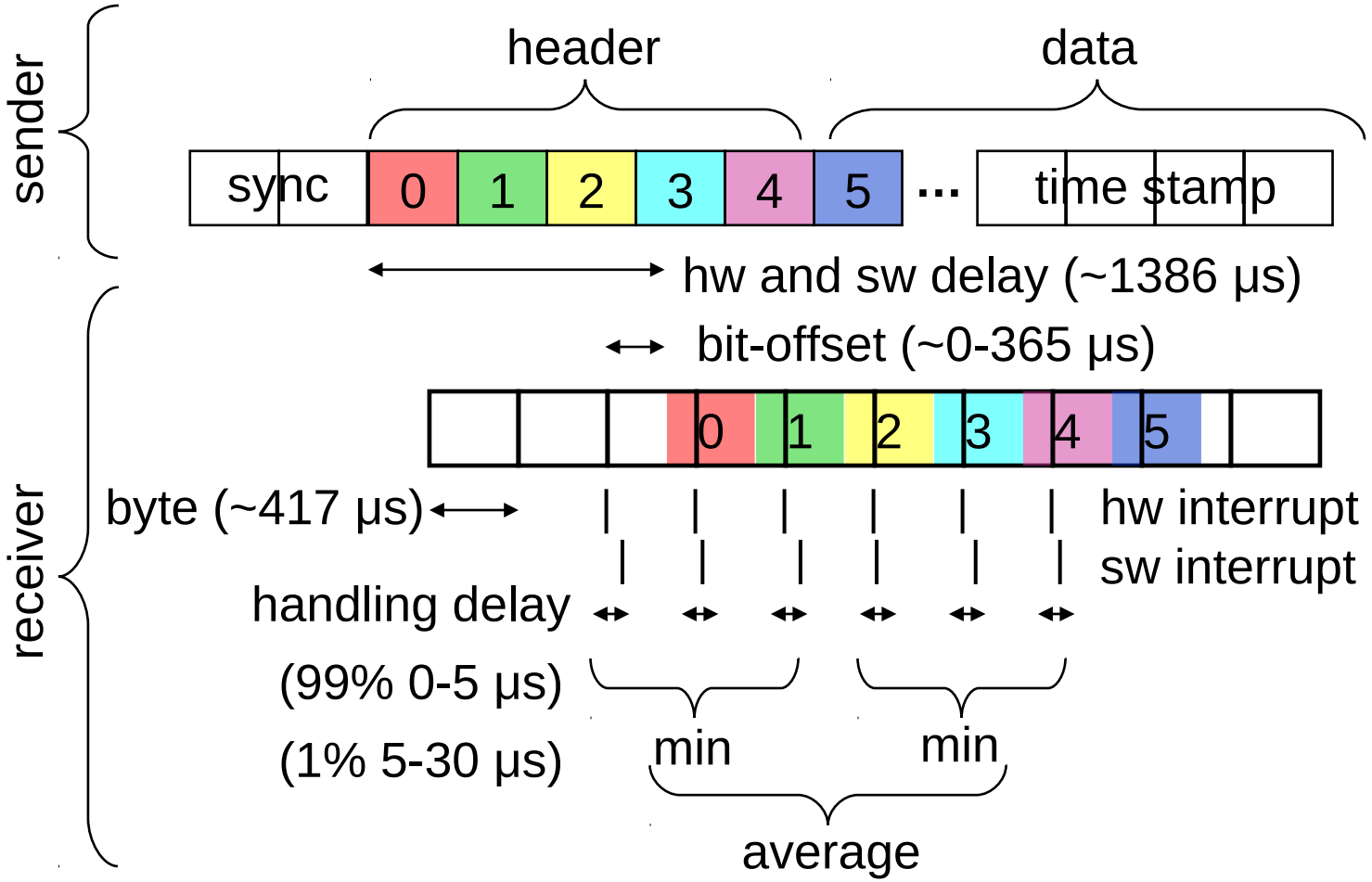
Clocks and Time Stamping

- Local time source
  - CPU clock: high resolution, not stable, stops in power-down mode (*SysTimeC*)
  - External clock: low resolution, stable, keeps running in power-down mode, hard to implement on the Micas
- Time stamping is a **time synchronization primitive**: establishing time reference points between a sender and receiver(s) using a single radio message
  - Sender obtains timestamp when the message was actually sent in its own local time
  - The message can contain the local time of the sender at the time of transmission (or the elapsed time since an event)
  - Receiver obtains timestamp when the message was received in its own local time
- Available for Mica2 and Mica2dot (*SysTimeStampingC*)
- Calibration is necessary because of receiver side bit-offset (non-uniform error)
- Uses
  - time synchronization
    - RBS: receiver side time stamping
    - TPSN: sender and receiver side time stamping
    - FTSP: embedded and receiver side time stamping
  - time synch debugging
  - acoustic ranging
  - implicit time synch while routing

Time Stamping on MICA2



Mica2: 1.2 µs average error,
4.5 µs maximum error

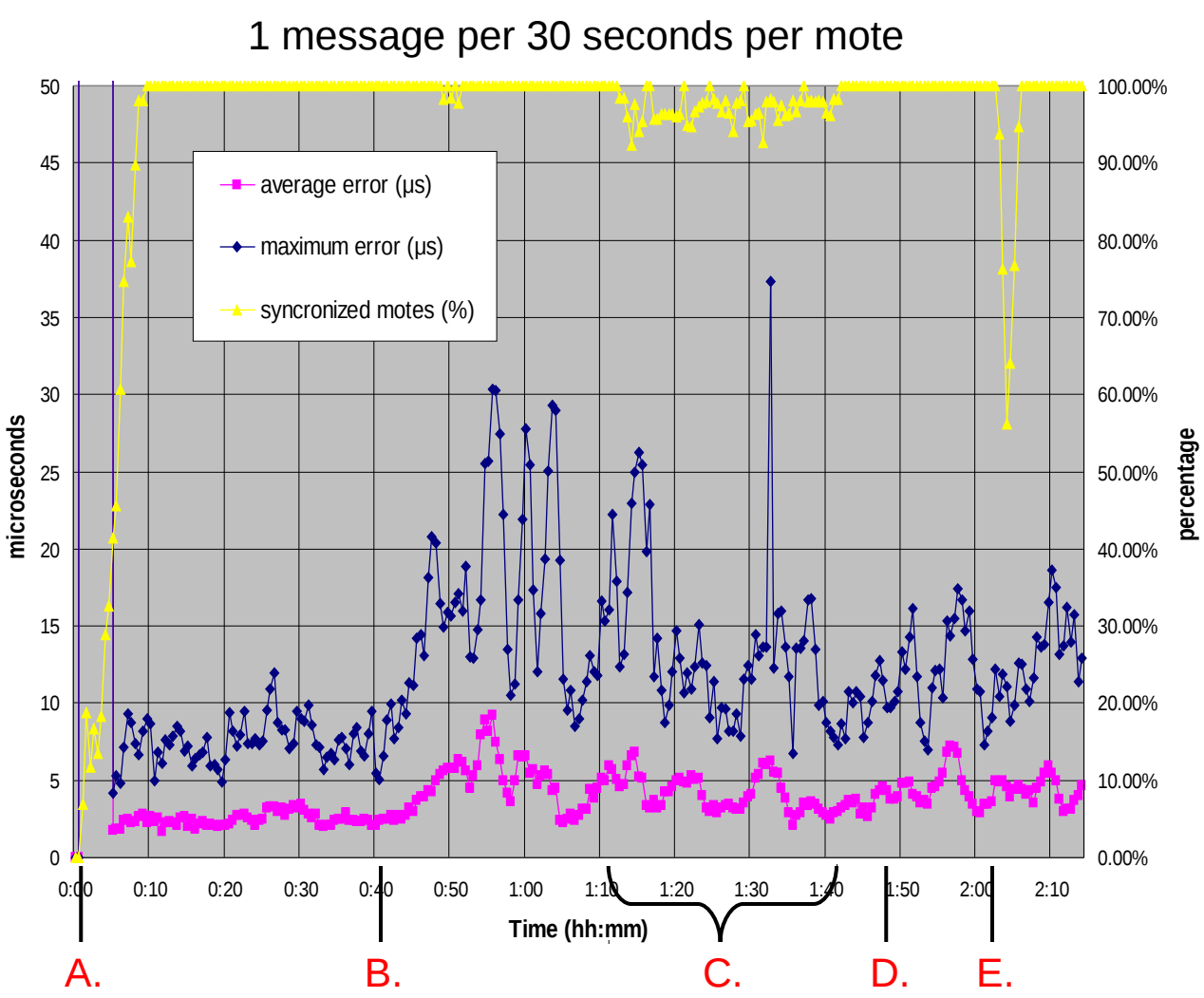
Mica2dot: 4 µs average,
12 µs maximum error

Limiting factor: the stability of the CPU clock

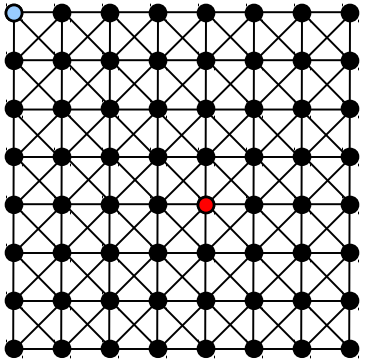
Time Synchronization

- Time Synchronization metrics
  - It should NOT be end-to-end accuracy only
  - Network load (in msgs per second per mote)
  - Start-up time (as a function of the network diameter)
  - Fault tolerance
    - nodes leaving and entering the network
    - nodes with incorrect or unstable local times
    - network topology changes
- Flooding Time Synchronization Protocol (FTSP)
  - Sender-receiver multi-hop time synchronization
  - Integrated leader election, global time is synchronized to the local time of the leader
  - End-to-end accuracy: average 1.4 μs per hop, maximum 6 μs per hop
  - Constant network load: 1 msg per 30 second per mote
  - Start up time: network diameter times 90 seconds
  - Uses the Time Stamping module
  - Topology change tolerant: motes can move with speed less than 1 hop per 30 seconds.
  - Available from the *contrib/vu/tos/lib/TimeSync* directory of the TinyOS CVS.
- Challenges:
  - scalability
  - rootless time synch
  - minimal startup time
  - power management (sleep + synchronize)
  - actuation (*SysClock* beta project)

Time Synch Experimental Evaluation



layout and links:



first leader
second leader

A. All motes are turned on
B. The first leader is turned off
C. Randomly selected motes were reset every 30 seconds
D. Half of the motes were switched off
E. All motes were switched back on