Tickless Contiki

Efficient timekeeping for low-power sensor nodes

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The problem

- Low-power, scarce energy
    - Must sleep most of the time
- Distributed system
    - Time is not a local internal reference
    - Need for precise synchronization with neighbors
        - DSME beacons, GTS/ TSCH slots
- High resolution timers
    - Software MAC implementation

Traditional approach

- Periodic interrupt, software clock counting ticks : Hz (polling !)
  - Every 1/Hz seconds, increment absolute clock value ⇒ waste of energy
- Local clock in every node
  - Neighbors drift appart
- Resolution for timers
  - Hz = 100 means a resolution of 0.01 seconds (Linux jiffies)
    - Cannot sleep less and be more precise than 10 ms
  - Waking up more often ⇒ waste even more energy

Rounding issues

- Problem with timer resolution
- Periods that are not integer numbers of clock tick
  - 32 kHz, 31.25 µs resolution clock
  - How to wait for 40 symbols (2.4 GHz radio) ?
    - 640 µs = 20.48 ticks !
- Need for high resolution timers

Timers in Contiki

- `clock` : system time
- `timer`, `stimer` : needs polling
- `ctimer`, `etimer` : callbacks and events
  - for protocols and applications
- `rtimer` : real-time, architecture specific timers
  - preempt any running process
- Naive and inefficient implementation
  - Polling, O(n) list search, …

Precision

- TMoteSky
  - 16 bit counter with Hz = 128
  - 65536 / 128 = 512 wrap around every ~8’30”
- Longest Beacon Interval
  - 960 x 2^{14} x 16.10^{-6} ~ 251 s ~ 4 min 11 s
  - 251 x 128 - 1 = 32127 useless interrupts between two beacons !

What do we need ?

- Efficient implementation, less running code ⇒ energy savings
- Long sleep periods, tickless timekeeping ⇒ energy savings
- High resolution timers
  - Software MAC implementation: order of symbol ~ 16 µs
- Precise synchronization with neighbors
  - Clock calibration / drift compensation
  - Smaller wake-up margins ⇒ energy savings

Modern timekeeping

- Tickless or dynamic ticks for a long time in GPOSes (Linux, BSD, …)
  - Prevent waking up idle CPUs and/or cores
  - Reduce load in virtualized environments
- HiRes timers : timeouts vs. timers
  - High performance NICs, multimedia
- Deferrable timers / Timer coalescing
  - Group non critical work in batches

Tickless for sensor nodes

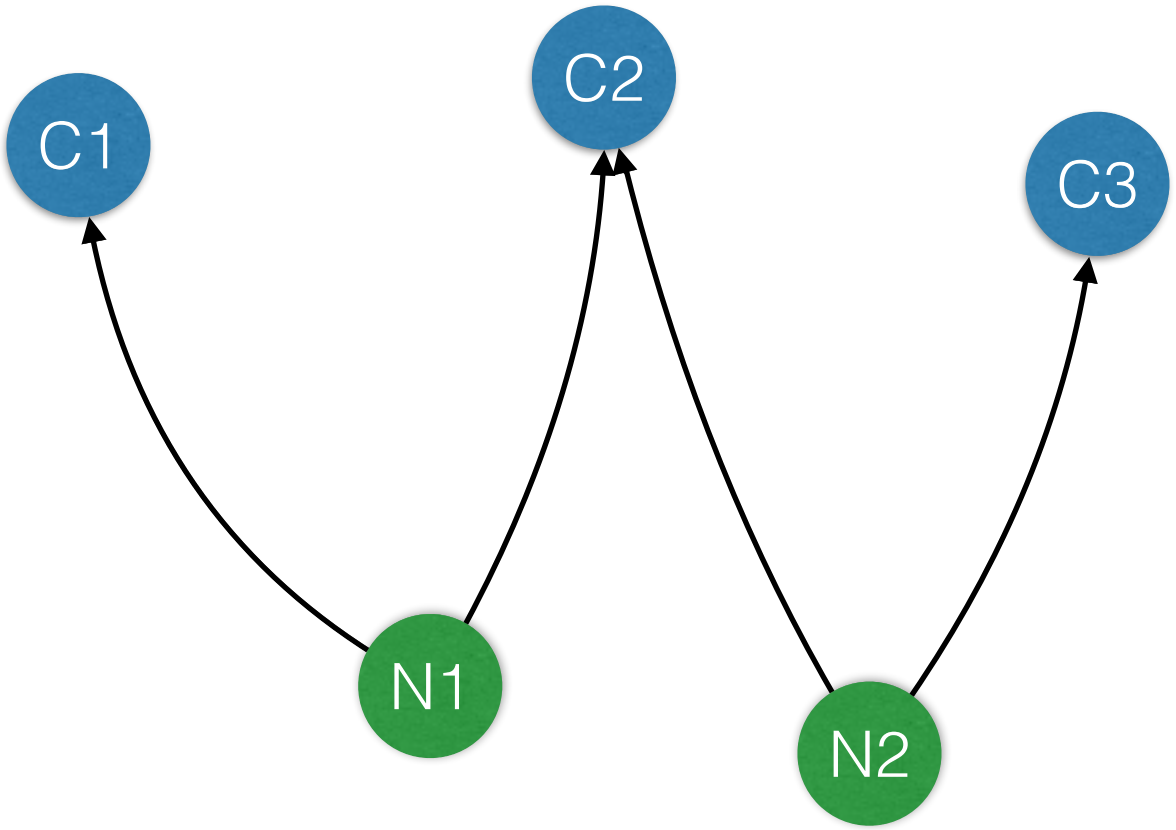
- Some RTOSes for embedded systems support tickless
  - FreeRTOS, RIOT OS, FireKernel, …
- In Contiki
  - Implemented for one target (not found yet)
  - Close enough in the current ST GreenNet implementation
  - Should be architecture dependent code
    - Factor out this code in the core Contiki

Requirements (i)

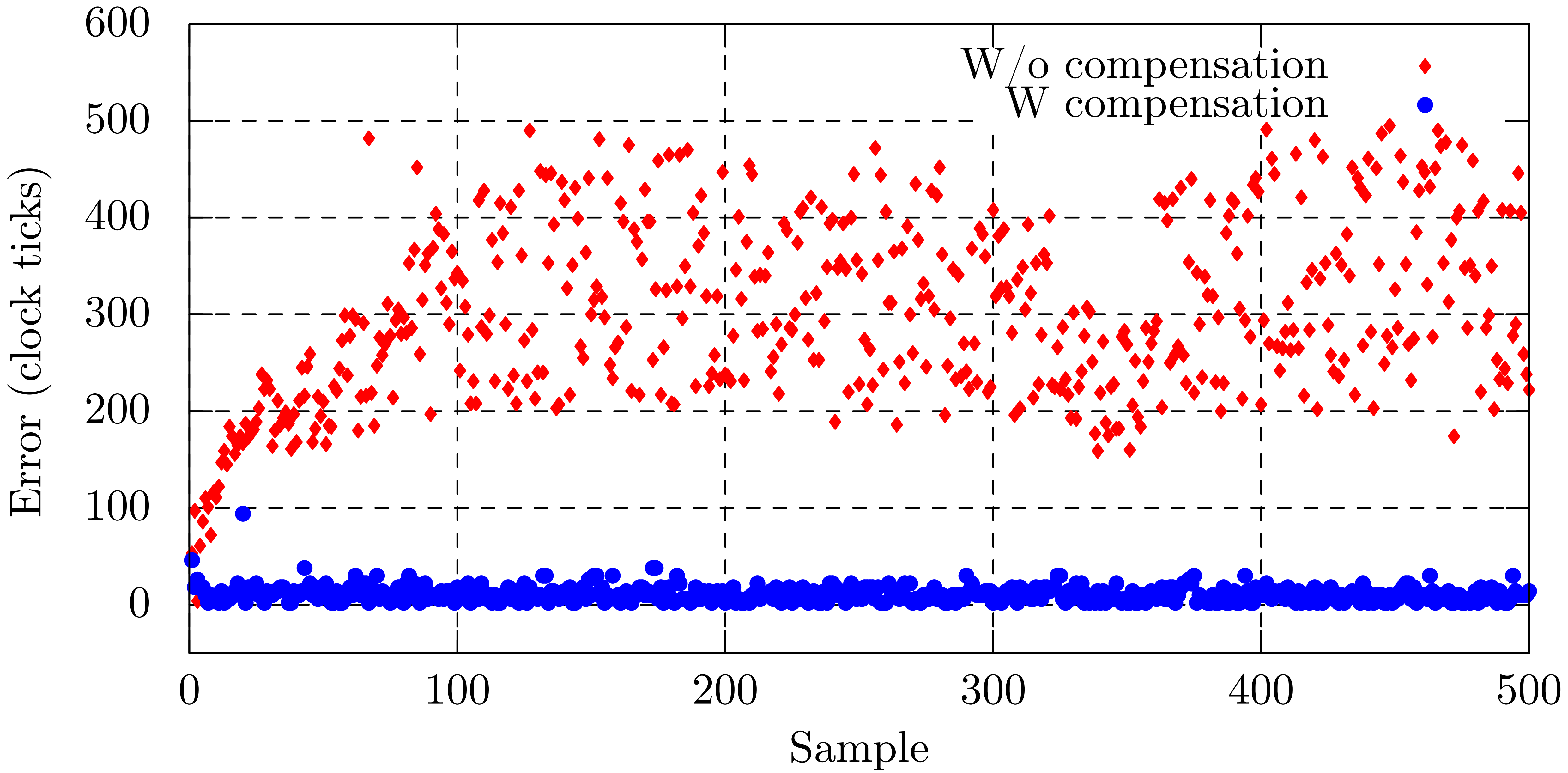
- Support for multiple clock sources
    - Several HW sources
        - HiRes and LowRes
- Handle wrap around transparently
    - 16 bit architectures

Requirements (ii)

- Multiple virtual clocks
- Clock calibration
- Tracking several neighbors
  - DSME
  - TSCH
  - Wake on Idle

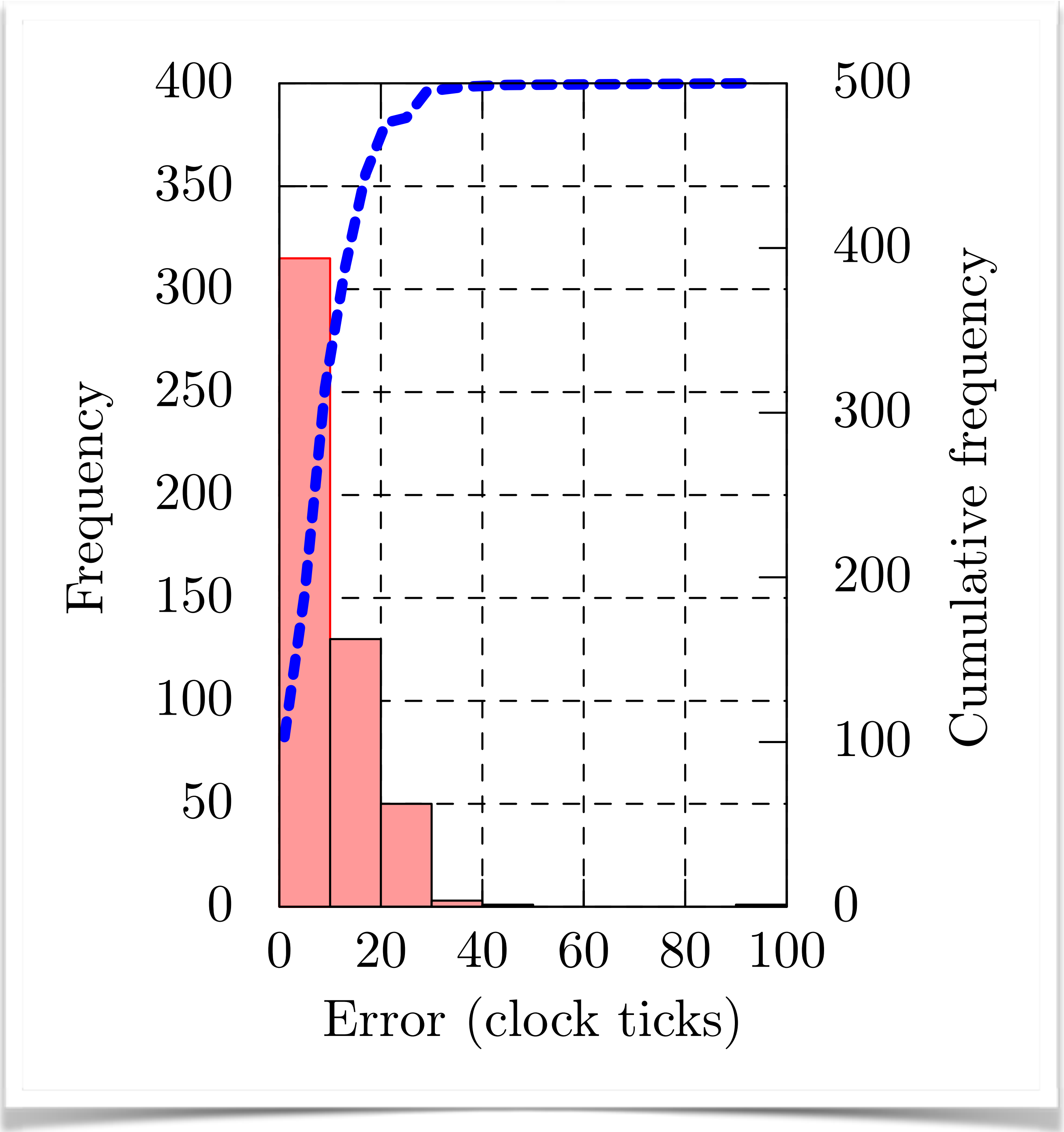


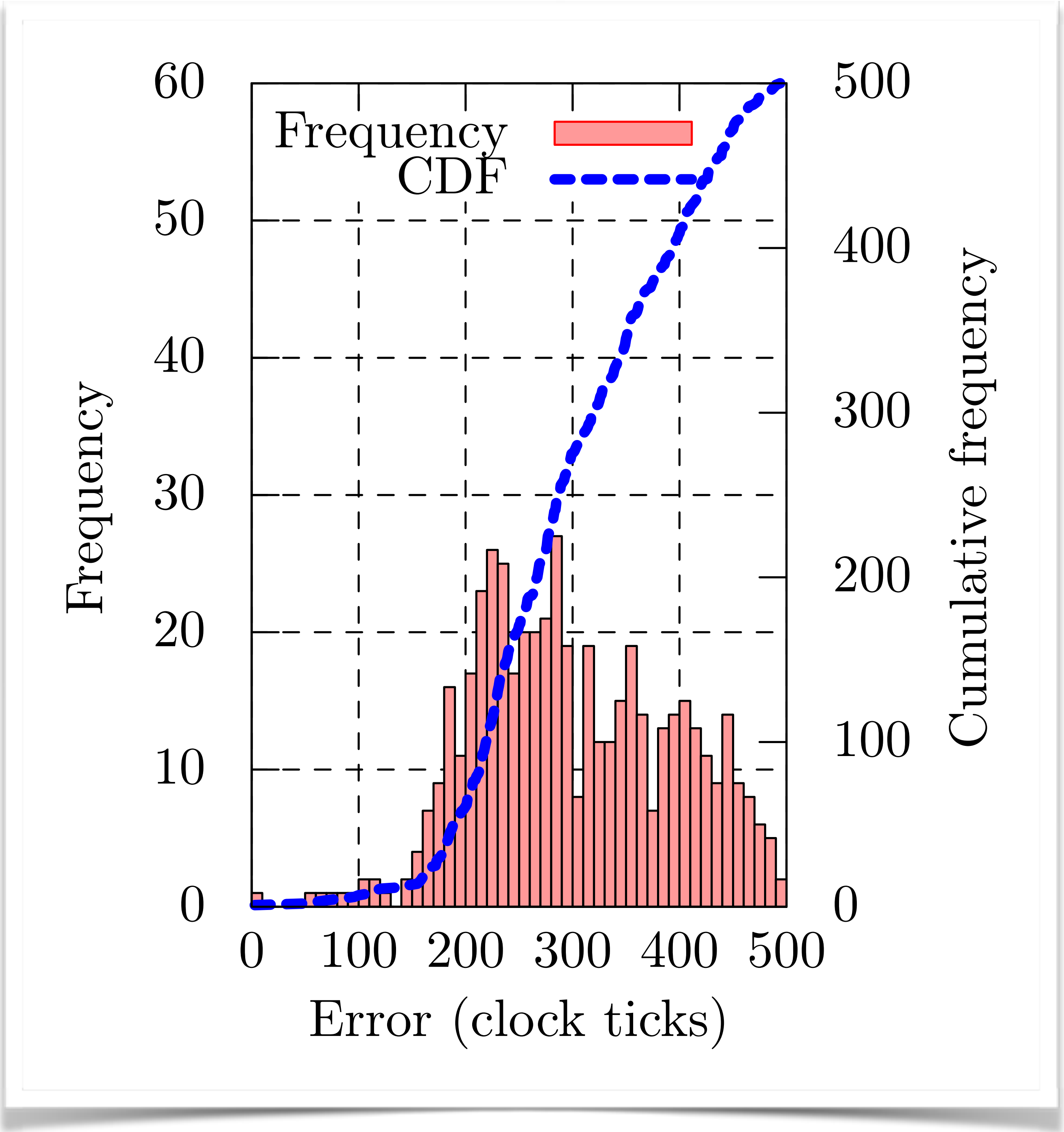
Clock drift



eZ430, 12 kHz VLO

Efficiency of drift compensation





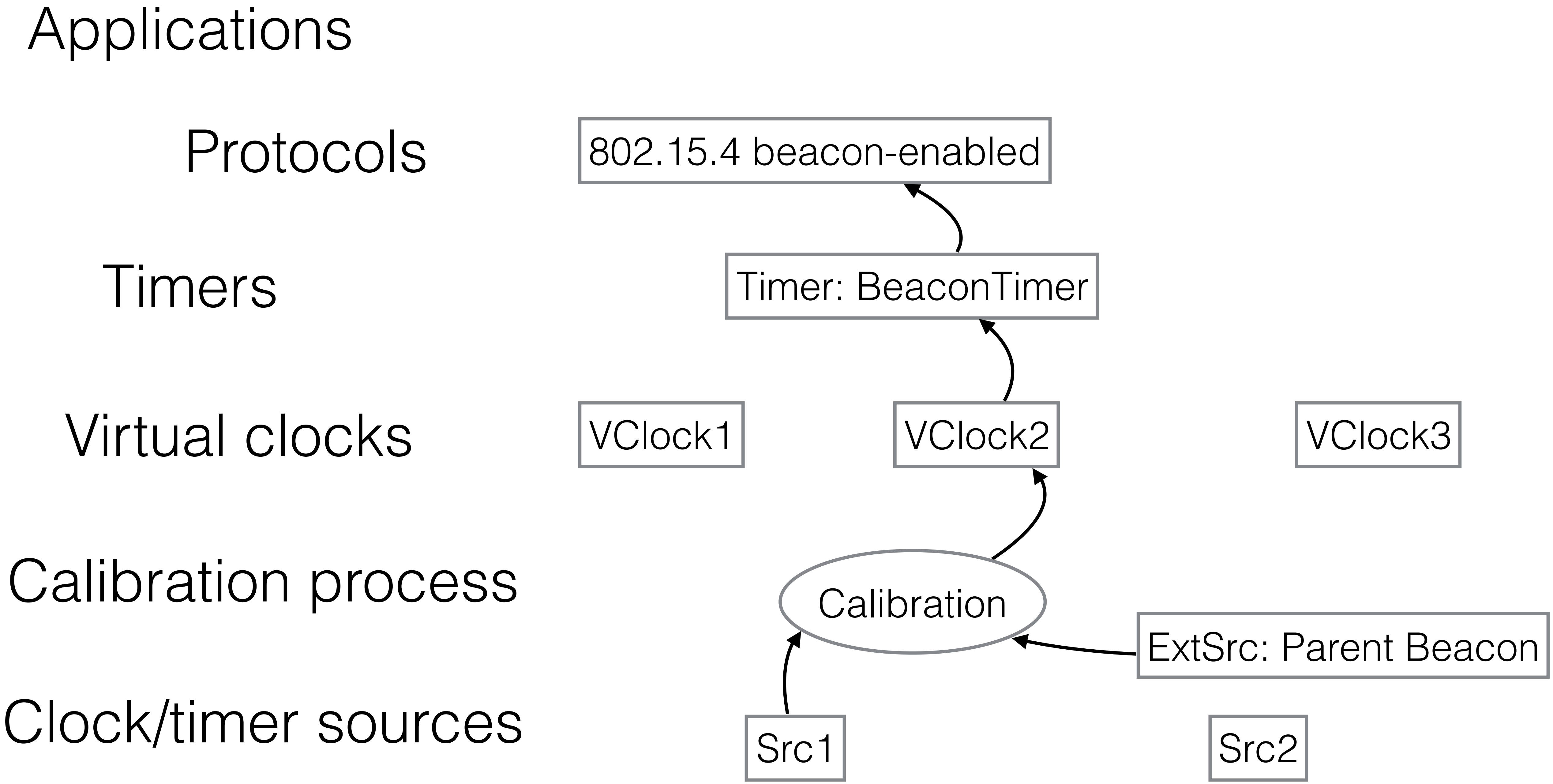
Requirements (iii)

- Timer correction
  - Rounding issues
- Keep compatibility with existing API
  - Wake up tasks just before polling

Pending issues

- Efficient data structures and algorithms
- Generic transparent calibration possible ?
    - No need to worry in user code

Tentative architecture



Applications

Protocols

802.15.4 beacon-enabled

Timers

Timer: BeaconTimer

Virtual clocks

VClock1

VClock2

VClock3

Calibration process

Calibration

ExtSrc: Parent Beacon

Clock/timer sources

Src1

Src2