Clock Synchronization for Wireless Sensors at the Physical Layer

Omid Abari, Hariharan Rahul and Dina Katabi

Synchronized Wireless Sensors

Frequency synchronization opens many new opportunities:
- Data aggregation over the air
- Distributed Modulation
- Distributed Compressive Sensing over the air

Why are today’s wireless sensors not synchronized?
Wireless nodes have different clocks with slightly different frequencies.

AirClock transmits a reference clock over the air.

Challenge

Wireless nodes typically use a sine wave of 10-40 MHz for their reference clock.
FCC forbids transmitting such a low-frequency signal for unlicensed use.

AirClock

Transmits two sine waves separated by the desired clock frequency.
Eg., for a clock of 10 MHz, send tones at 175 MHz and 185 MHz.
Each wireless node multiplies the received reference signal by itself and applies a band pass filter to extract the desired clock frequency.

\[(\cos(2\pi f_1 t) + \cos(2\pi f_2 t)) \cdot (\cos(2\pi f_1 t) + \cos(2\pi f_2 t)) = \cos(2\pi (f_2 - f_1) t) + \cos(2\pi (f_2 + f_1) t) + \frac{1}{2} \cos(2\pi 2f_1 t) + \frac{1}{2} \cos(2\pi 2f_2 t) + 1\]

Microbenchmark

Coherent Transmission

TX and RX nodes use the same reference clock that they receive over the wireless medium.

AirClock reduces the CFO by 300-400 ×

Application 1

Distributed Rate Adaptation

Sensors transmit simultaneously and create distributed codes over the air.

Throughput gains of 1.6–3 × over ZigBee for 6 sensors

Application 2

Over-the-air Function Computation

Sensors transmit coherently so that sink directly receives the desired function value.

Many different functions: sum, mean, variance, max, min, median, etc.

Quadratic throughput gains