Technische Universität Braunschweig

Institute of Operating Systems and Computer Networks

InPhase: No-Cost Phase-Based Ranging and Localization

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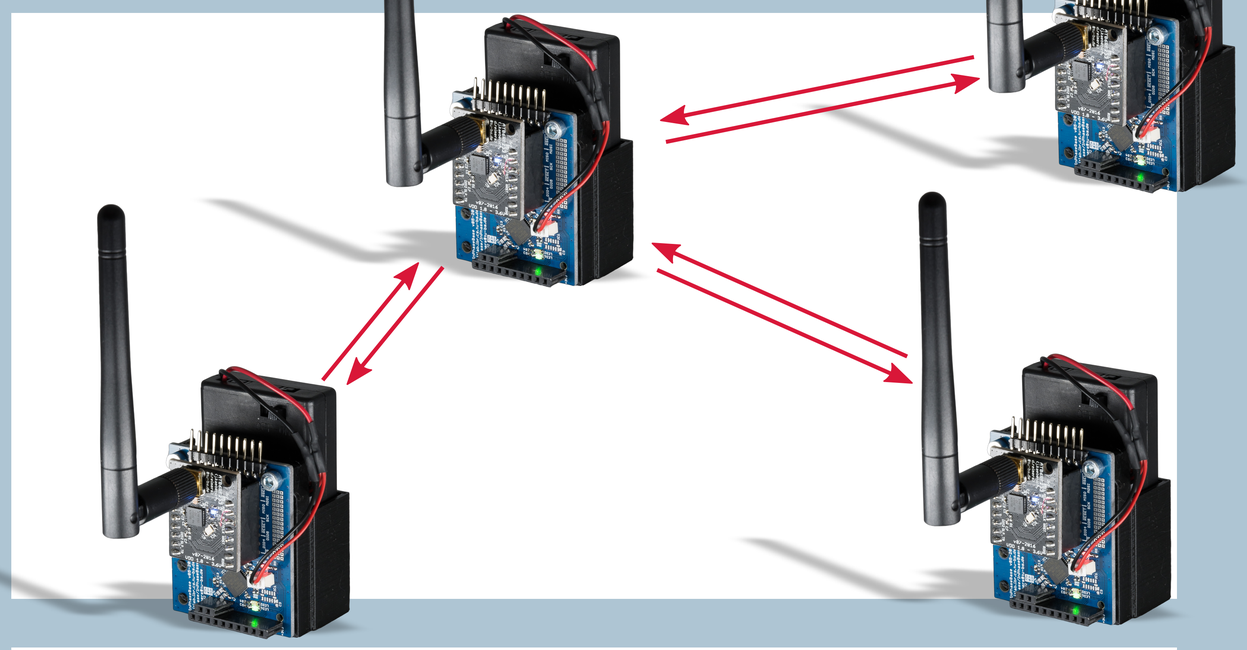
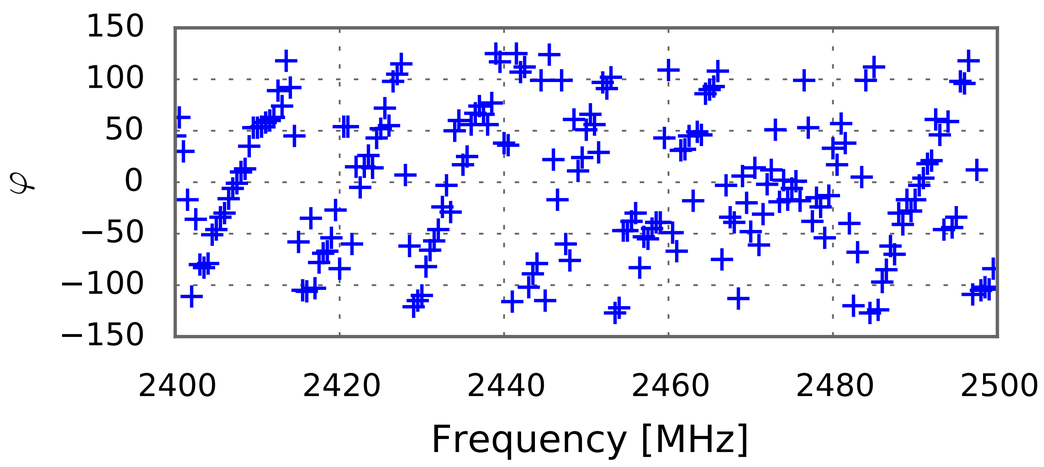
Active-Reflector-Ranging

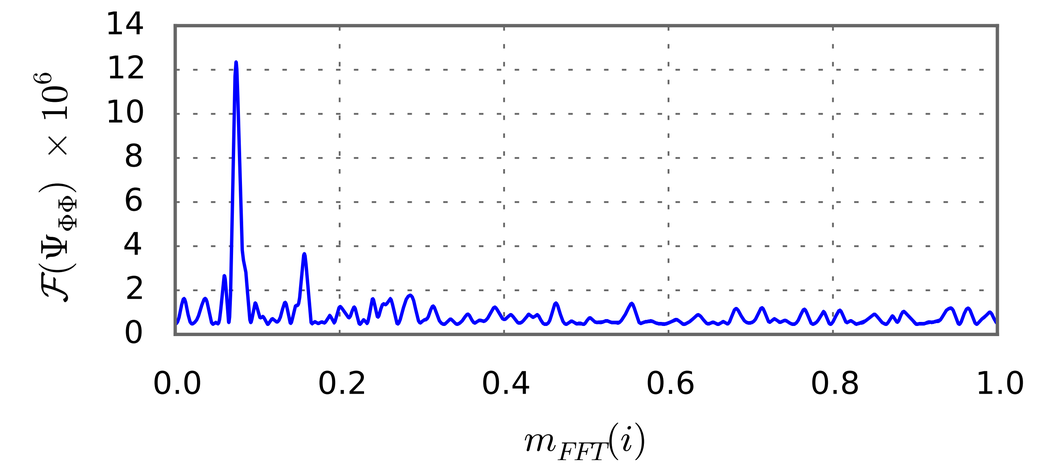
- Off-the-shelf **IEEE 802.15.4 radios with Phase Measurement Unit**
- Software can be **retrofitted to existing WSN hardware**
- One pair of sensor nodes executes the AR-Ranging at a time:
  1. Node A: Sends **Continuous-Wave signal**
  2. Node B: **Measures phase angle** φ
  3. **Swap roles** and execute 1. and 2. again
  4. Switch to next frequency and start at 1.
  5. Transmit results





Phase Information

- **Phase response** Φ of the 2.4 GHz band is gathered
- Spectrum is sampled from 2 400 to 2 500 MHz in 500 kHz steps
- Maximum distance at 500 kHz step size: **150 m**
- Radios report phase angle φ as signed 8-Bit value in range $[-\pi, \pi[$
- Measurements from both nodes are subtracted (AR-Principle)
- Phase response Φ resembles a **sawtooth signal**
- Measurement is **disturbed by other signals and noise**
- Steepness of **slope is proportional to distance**



Distance Estimation

- Dominant frequency of Φ contains distance information
- Noise in Φ is suppressed via **auto correlation**:

$$\Psi_{\Phi\Phi}(j) = \sum_n \Phi_n \cdot \Phi_{n-j}$$

- Frequency is recovered via **Fast-Fourier-Transform:** $FFT(\Psi_{\Phi\Phi})$
- Distance is proportional to FFT bin index of **maximum peak**
- Peak height is used as Distance Quality Indicator (DQI)
- **Low DQI indicates Non-Line-of-Sight/Multipath propagation**

Localization

- Distances to **anchor nodes with known positions** are measured
- Anchor nodes are chosen in **round-robin** fashion
- **Measurement rate: ~10 Hz**
- **Particle filter** solves the localization problem
- DQI is used as additional weighting factor
- **Non-Line-of-Sight measurements are weighted less** due to DQI
- Real-time operation and visualization as web application