TerraSwarm

# PolyPoint UWB Localization

http://terraswarm.org/

Wait, What? Demo

September 9-11, 2015

## The Importance of Indoor Localization

**High-fidelity indoor localization enables a bevy of applications, powering today's *Robot Café* demo and empowering tomorrow's swarms of autonomous flying robots. The TerraSwarm project is exploring localization on multiple thrusts including PolyPoint with symmetric ultra-wideband RF, Harmonia with asymmetric ultra-wideband RF, ALPS with ultrasonic, and Luxapose with visible light.**

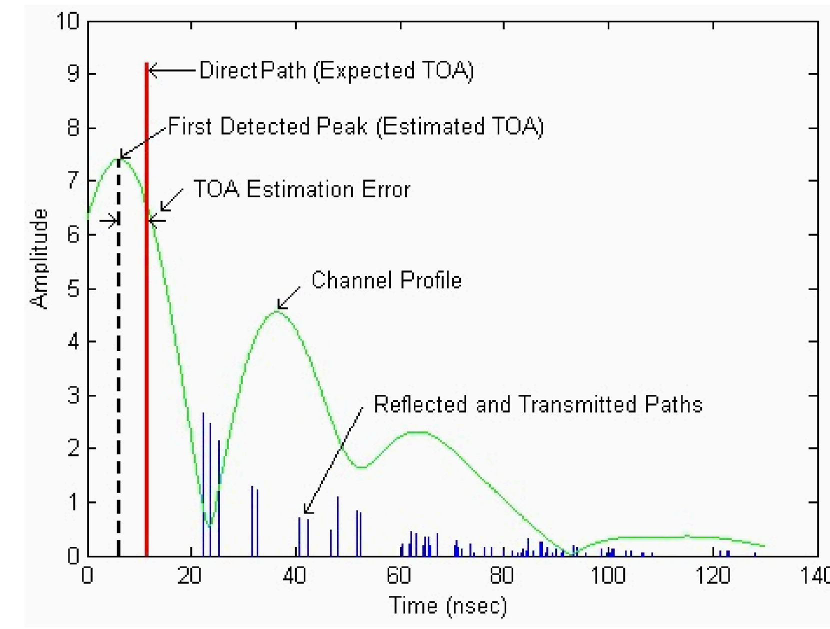
Scan to learn more about Luxapose
http://lab11.eecs.umich.edu/projects/vlc_localization/

Scan to learn more about Harmonia
http://lab11.eecs.umich.edu/projects/harmonia/

Scan to learn more about ALPS
http://wise.ece.cmu.edu/redmine/projects/alps/wiki

## Challenges of RF Indoor Localization

Many localization systems aim to measure the time of flight between nodes. This presents two issues. First, there must be a line-of-sight path between the two nodes. This is often attainable with careful node placement, such as on ceilings or near lights. Second, however, reflections from walls or obstacles in the room can "blur" the line-of-sight path, making it difficult to estimate the exact time of arrival. At the speed of light, 1 nanosecond of timing error can lead to 30 centimeters of ranging error.



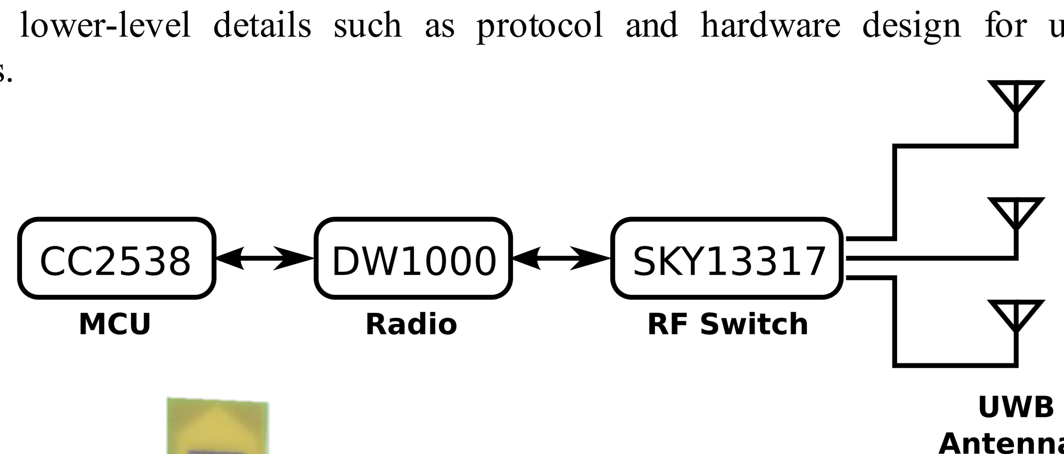

*Graphic from "Distance Measurement Error Modeling for Time-of-Arrival Based Indoor Geolocation", Ph.D. Thesis by Bardia Alavi*

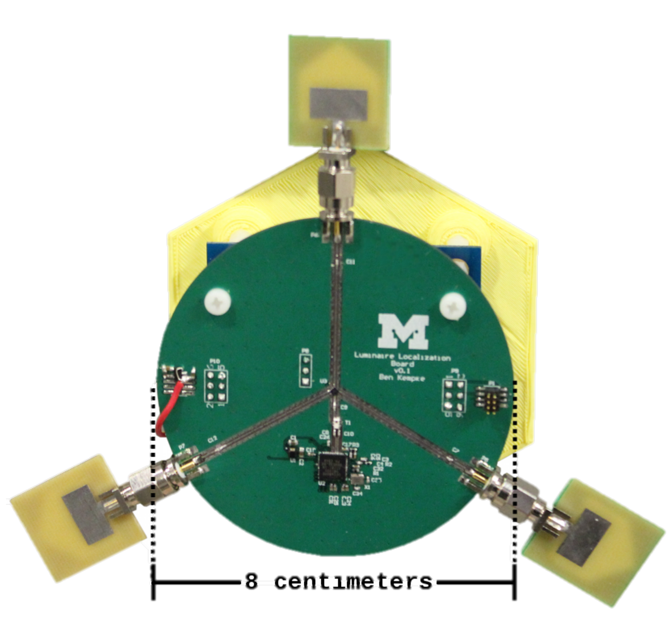
By increasing the utilized bandwidth, the multipath resolution improves, leading to the use of ultra-wideband signals in systems that require high accuracy in indoor environments. PolyPoint leverages the new DecaWave ScenSor UWB transceiver coupled with antenna and frequency diversity to achieve best-in-class RF-only indoor localization.

## The PolyPoint Ultra-wideband Localization System

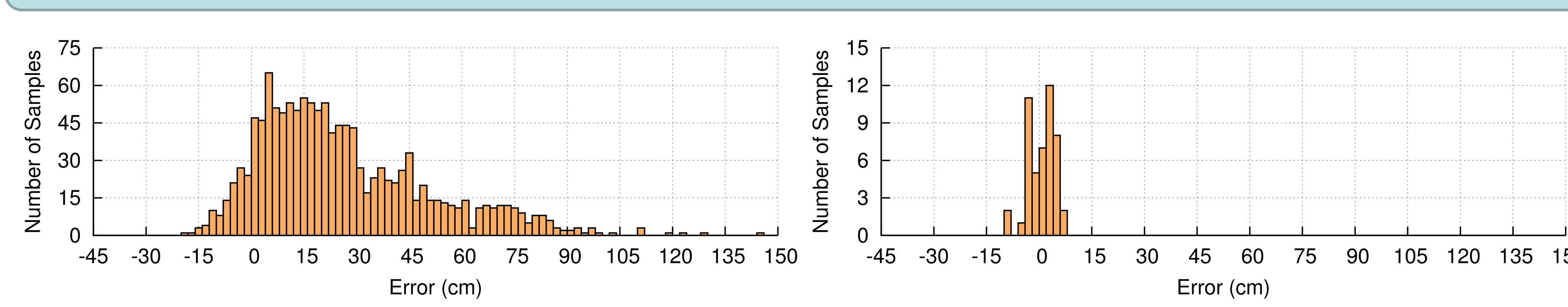
### Tag Architecture and Hardware

PolyPoint nodes consist of a DecaWave DW1000 ScenSor transceiver for data transmission and timestamping, a SKY13317 RF switch and three UWB antennas for diversity, and a CC2538 system-on-chip for protocol orchestration and data offload. PolyPoint uses the same hardware for both the tag and anchors, leading to a simple and symmetric design intended to aid further research in lower-level details such as protocol and hardware design for use in tailored applications.




### Antenna and Channel Diversity Improve Accuracy




### Novel Ranging Protocol Efficiently Exploits Diversity

Deriving a high-precision time-of-flight range estimate between two unsynchronized nodes requires *three* packets per range pair. Basic unsynchronized time-of-flight only sends a POLL from a tag to an anchor and a RESPONSE from an anchor to a tag:

$$①\ \text{Tag} \xrightarrow{Poll} \text{Anc} \quad ②\ \text{Anc} \xrightarrow{Resp} \text{Tag}$$

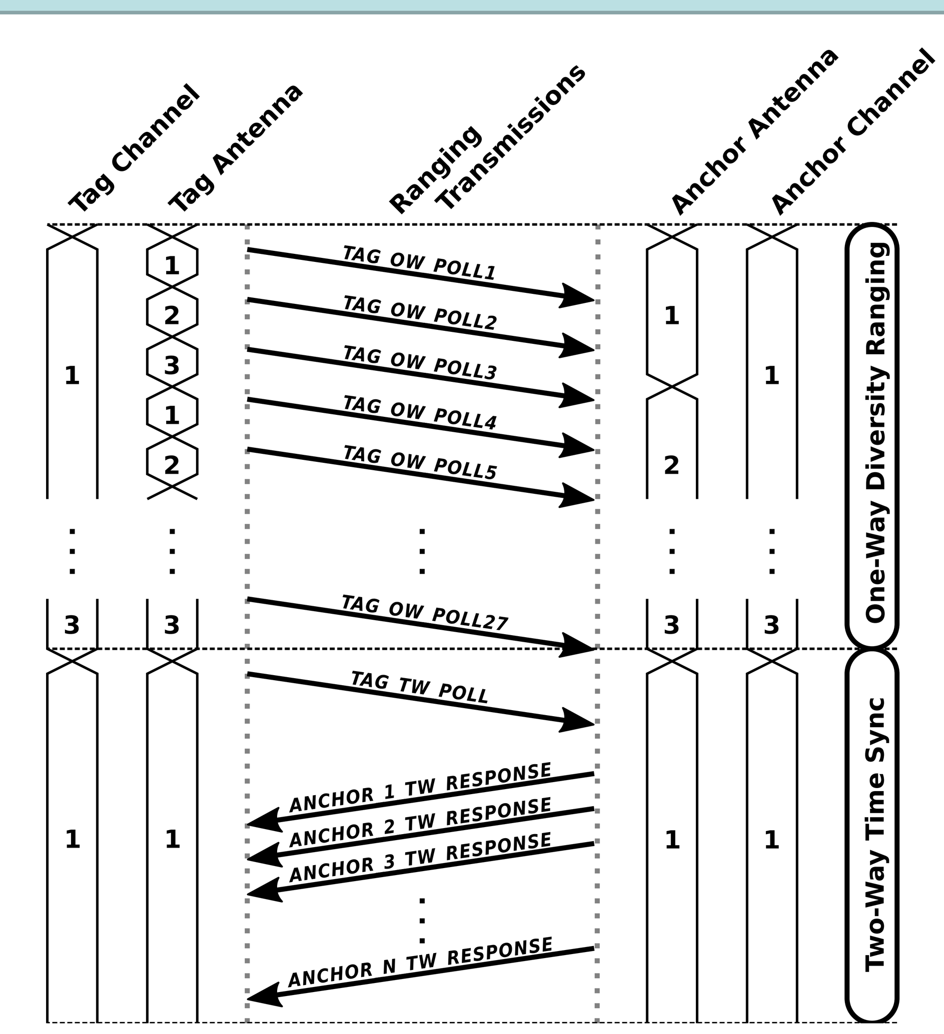
$$ToF = [(\text{Tag}_{RX\_Resp} - \text{Tag}_{TX\_Poll}) - (\text{Anc}_{TX\_Resp} - \text{Anc}_{RX\_Poll})]/2$$

Critically, however, this assumes that the clocks on the tag and anchor are running at exactly the same frequency. To compensate for crystal variances, one must send an additional packet, REF, usually before sending POLL. Adding in crystal correction, unsynchronized time-of-flight is now

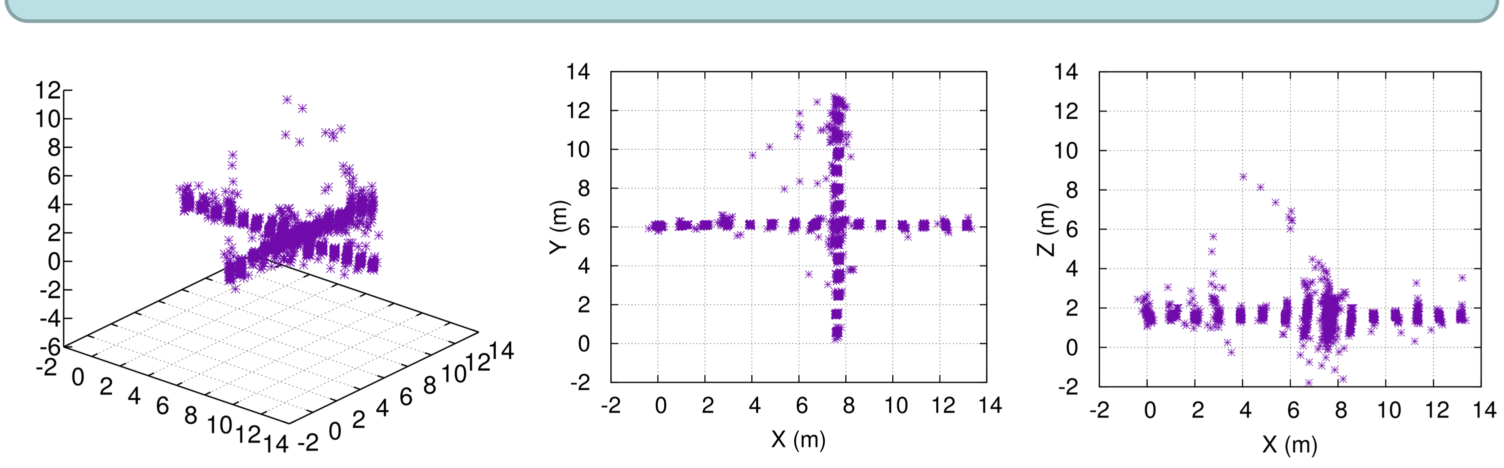
$$①\ \text{Tag} \xrightarrow{Ref} \text{Anc} \quad ②\ \text{Tag} \xrightarrow{Poll} \text{Anc} \quad ③\ \text{Anc} \xrightarrow{Resp} \text{Tag}$$

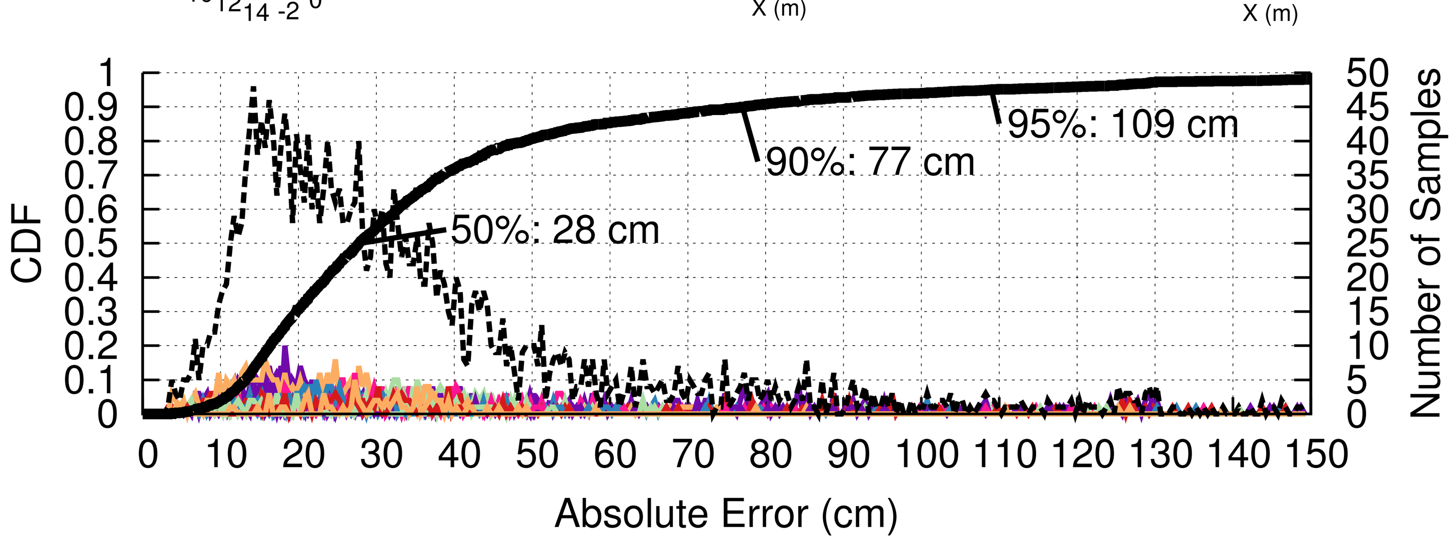
$$K = \frac{\text{Tag}_{TX\_Poll} - \text{Tag}_{TX\_Ref}}{\text{Anc}_{RX\_Poll} - \text{Anc}_{RX\_Ref}}$$

$$ToF = [(\text{Tag}_{RX\_Resp} - \text{Tag}_{TX\_Poll}) - K * (\text{Anc}_{TX\_Resp} - \text{Anc}_{RX\_Poll})]/2$$

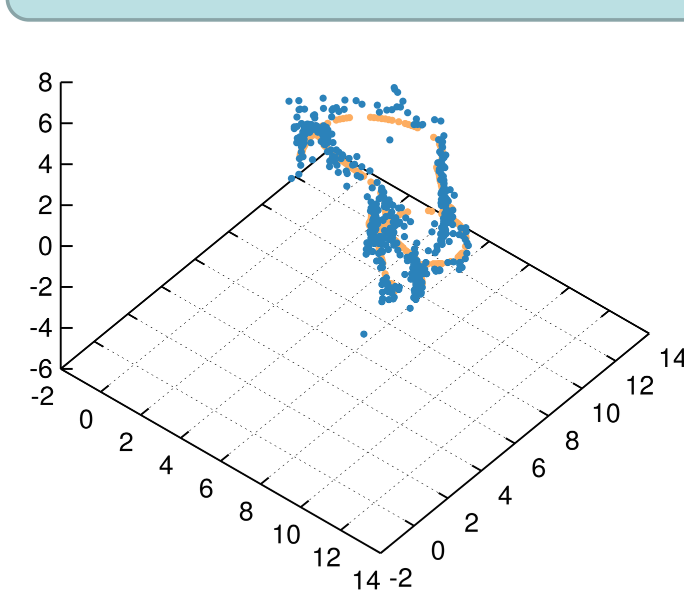


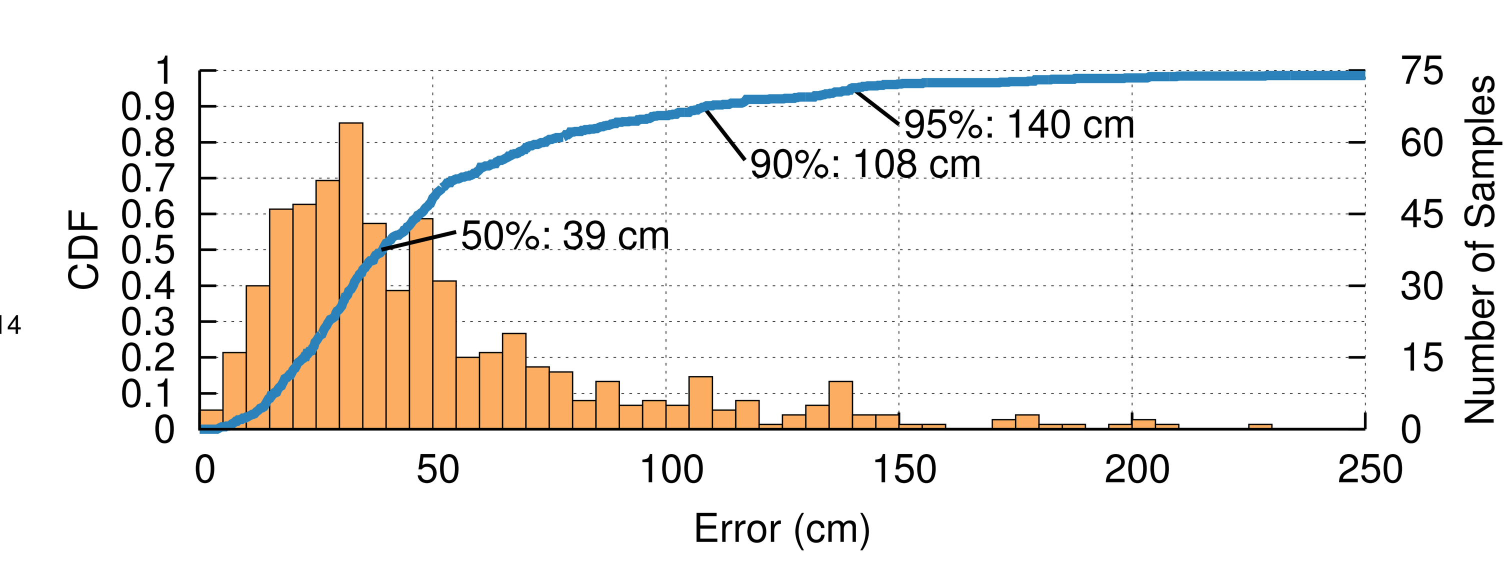

### Stationary Position Results




### Tracking a Fast-Moving Quadcopter in Free Space







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