PnPLoc: UWB Based Plug & Play Indoor Localization

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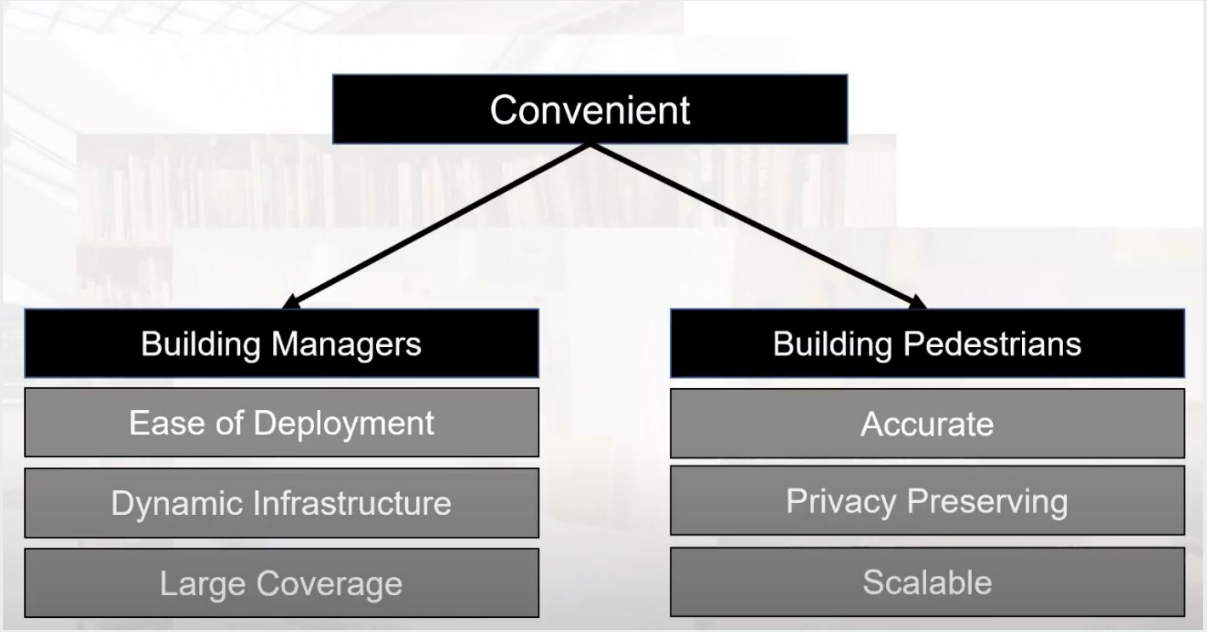
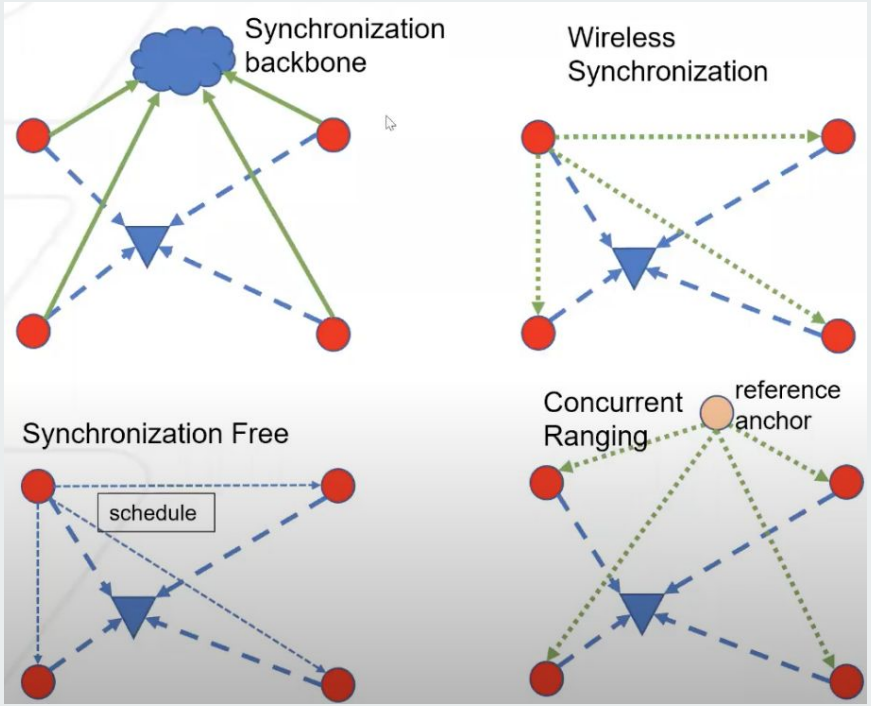
Indoor Localization Use Cases

- Navigation
- Recommendation
- Tracking assets
- and many more

Localization System Properties



Problems with passive TDoA Schemes

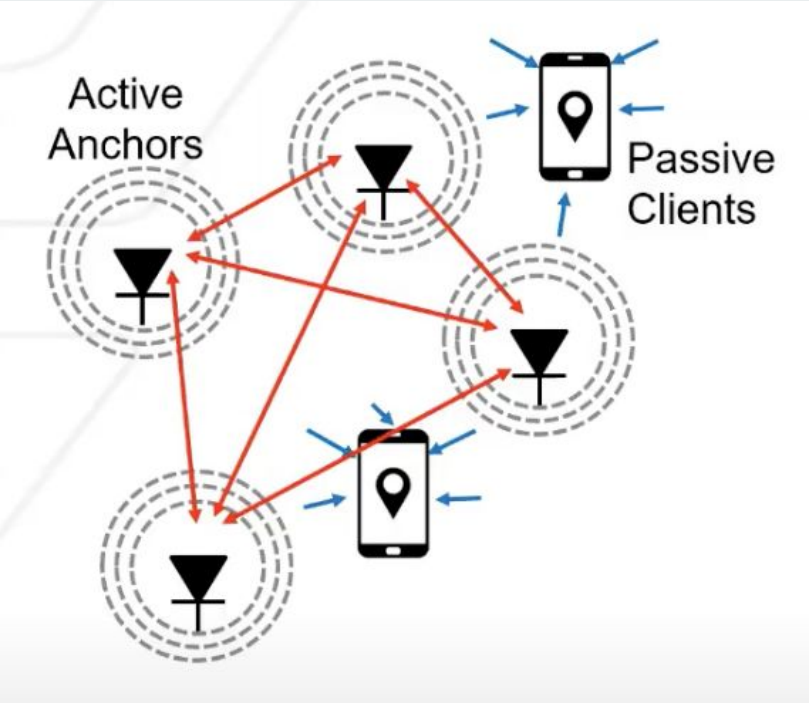


- **Sensitive to clock drift error**
- **Cost and communication overhead**
- **Scalability**
- **Speciality nodes make large scale deployment hard**

Key contributions in PnPLoc:

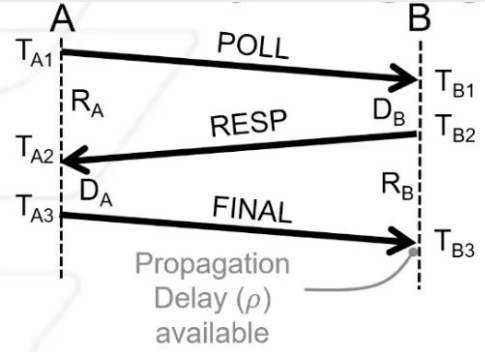
- **Time-difference of arrival (TDoA) algorithm that removes strict timing requirements on anchor transmissions.**
- **An anchor deployment algorithm that guides technicians when deploying anchors**
- **A real-time anchor selection algorithm to improve localization accuracy for mobile user devices.**

Passive TDoA Protocol (2-WAY) PnPLoc



- Anchor nodes perform 2-way ranging among themselves
- Client devices can compute the TDoA to anchor devices by hearing the 2-way messages

Two Way ranging (TWR) refresher



Clock Drift

$\widehat{R}_A = (1+\delta_A)R_A,\ \widehat{D}_A = (1+\delta_A)D_A,$
$\widehat{R}_B = (1+\delta_B)R_B,\ \widehat{D}_B = (1+\delta_B)D_B$

Clock drift error:

$$\rho = \frac{1}{4}[(R_A - D_B) + (R_B - D_A)]$$

$$\frac{1}{2}(\delta_A + \delta_B)\rho + \frac{1}{4}(\delta_A - \delta_B)(D_B - D_A)$$

10^{-5} 10^{-9} 10^{-5} 10^{-3}

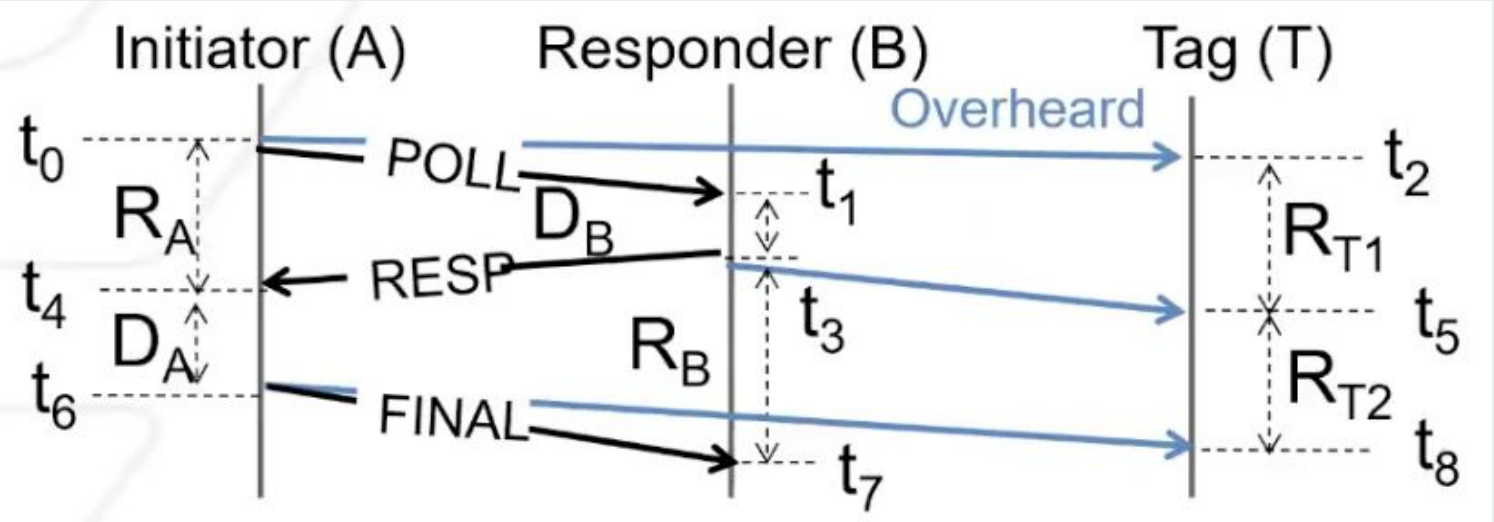
$$\rho = \frac{(R_A R_B) - (D_A D_B)}{2(R_A + D_A)}$$

$\delta_B \rho$

10^{-5} 10^{-9}

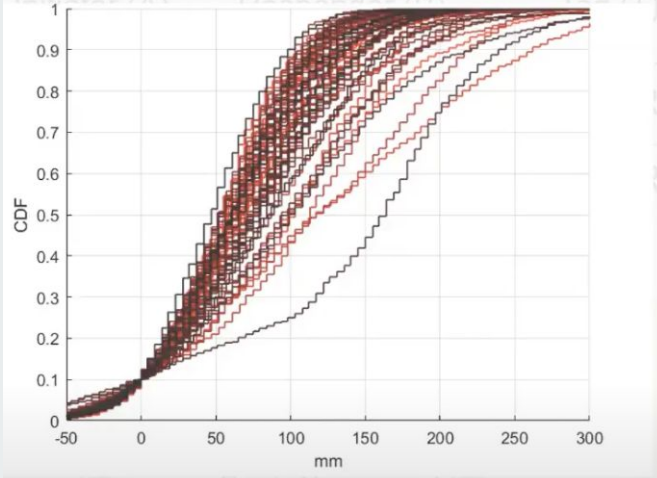
A better ranging protocol should null the clock drift error regardless of system configuration.

PnPLoc-TDoA


Initiator (A)
Responder (B)
Tag (T)
Overheard
POLL
RESP
FINAL
t_0
t_1
t_2
t_3
t_4
t_5
t_6
t_7
t_8
R_A
D_B
R_B
D_A
R_{T1}
R_{T2}

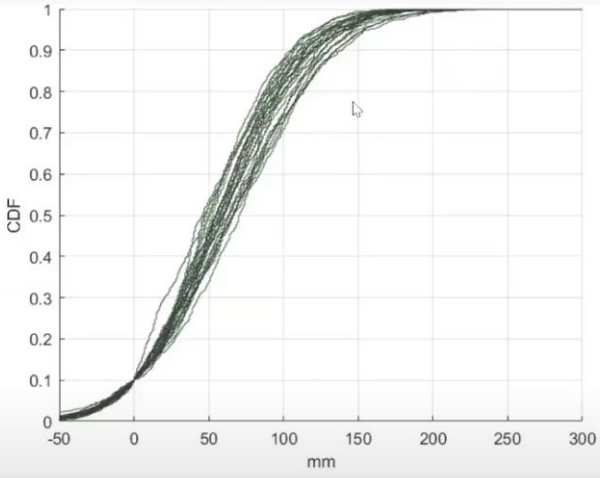
PnPLoc-TDoA Clock Drift Comparison

High variability
in individual TDoAs



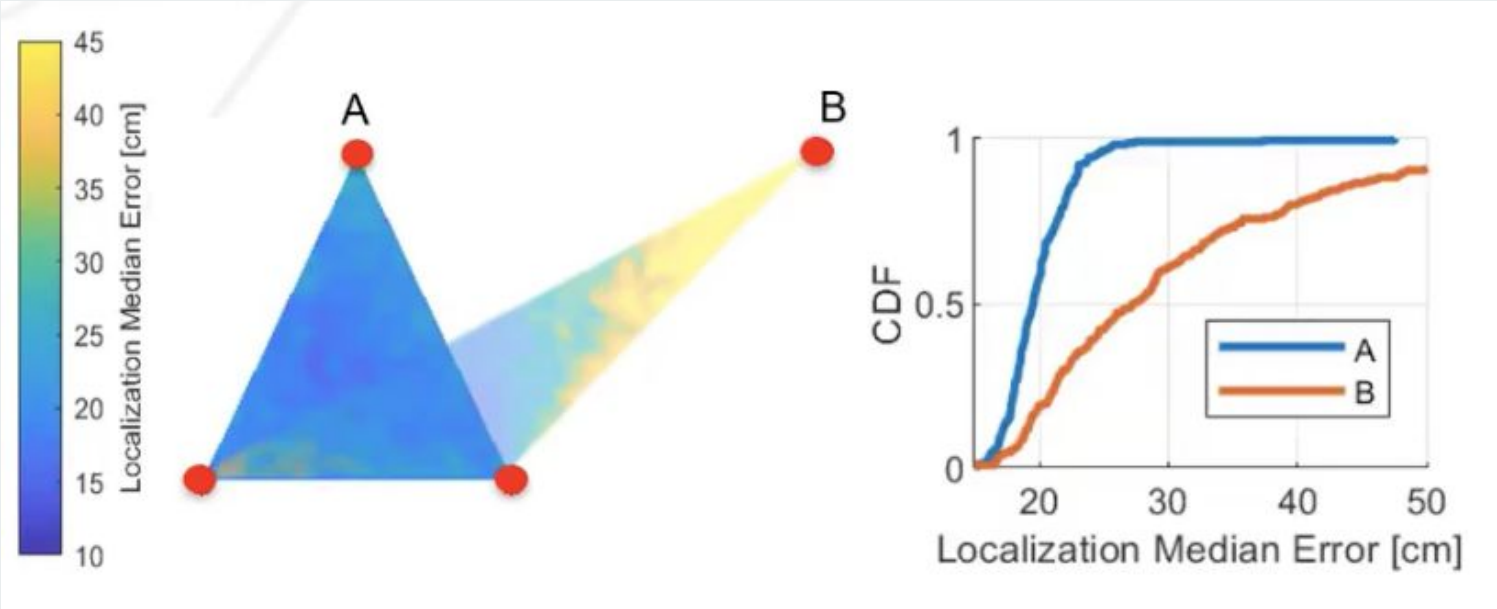
TDoA* with Clock Drift
Compensation

All individual TDoAs have
almost the same behavior



Our Formulation with no Clock Drift
Compensation required

Anchor Deployment



Heuristic: anchors in equilateral triangles have lower tag localization error

Signal Strength

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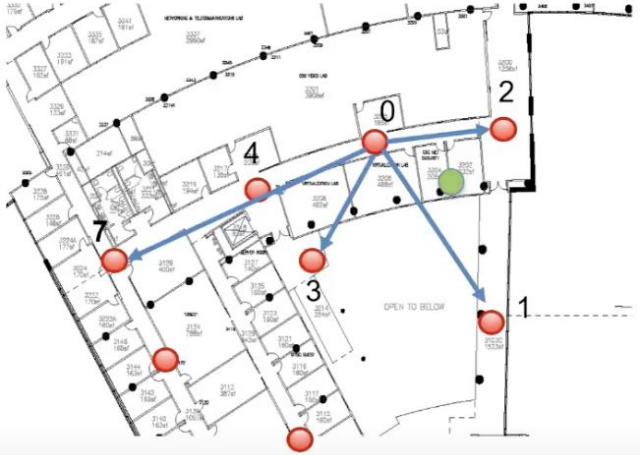
Signal Strength (Filtering)

Anchor ID	DDoA	RX Power
2	2134 mm	-91 dBm
1	8740 mm	-78 dBm
3	10967 mm	-100 dBm
4	12893 mm	-85 dBm
7	21738 mm	-105 dBm

Filter out anchor 7

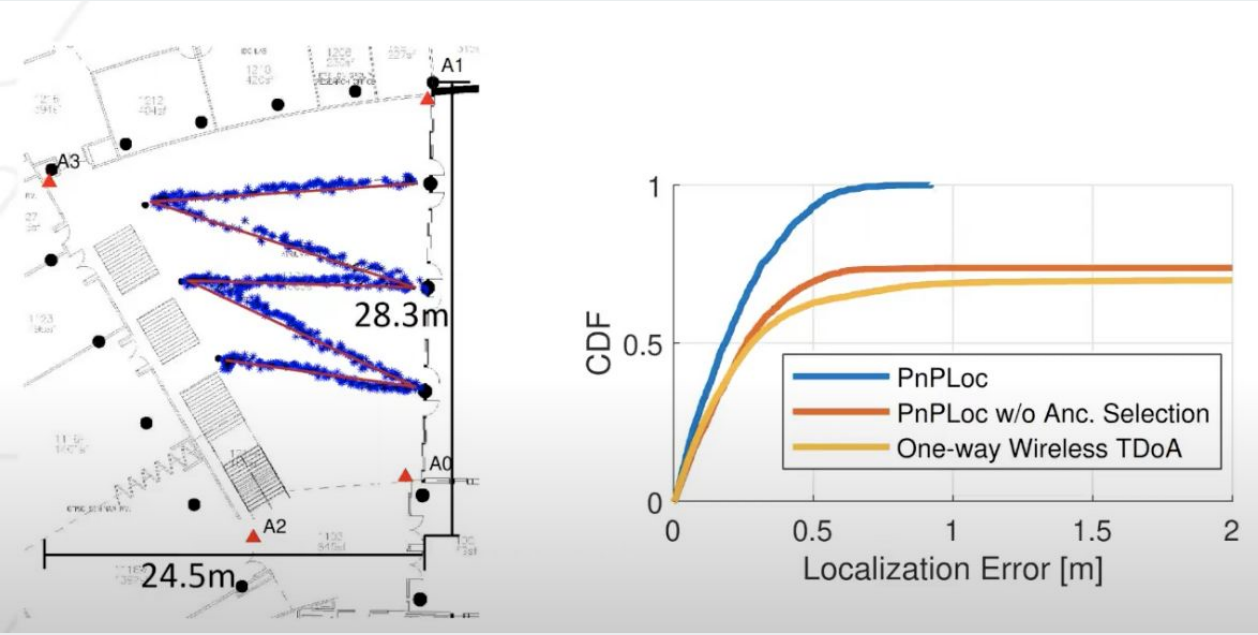


Drop the TDoA with low RX Power
Choose the anchor with best geometry

Evaluation

- DW1000
- 3 Test environment (open atrium, library, research building)

Evaluation (open atrium)



Evaluation (Library and research hall)

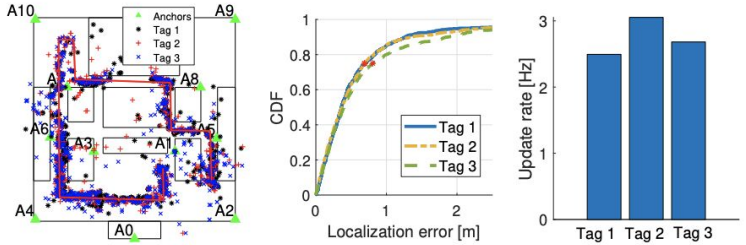


Fig. 11: Building L with 3 co-located mobile tags: (1) solution scatter plot; (2) localization error CDF; (3) update rate.

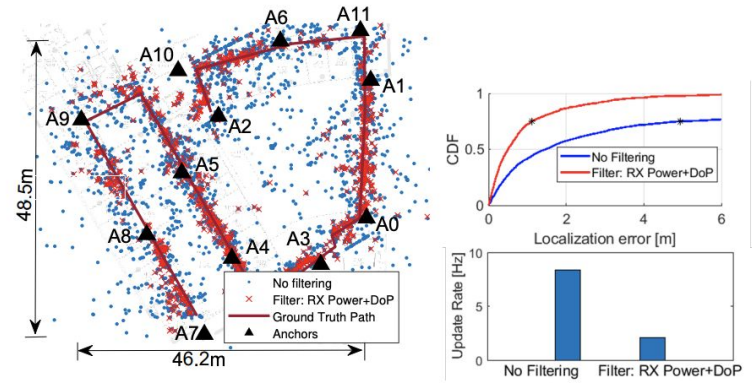


Fig. 12: Localization result of mobile tag in Building K: (a) scatter plot, (b) update rate and accuracy.

Comparison

System	75% error	90% error	Test area
PnPLoc	28.9 cm	44.0 cm	A 695 m^2 (1304 samples)
	69cm	125cm	L 1208m^2 (2329 samples)
	110cm	251cm	K 2241m^2 (1139 samples)
SnapLoc [19]	55.8-74 cm	NA	31.36-60.5 m^2
CHORUS [20]	~80 cm	~100 cm	42.0-83.2m^2
TALLA [33]	69 cm	89 cm	1875 m^2