School of Electronic & Electrical Engineering
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Tracking Technology

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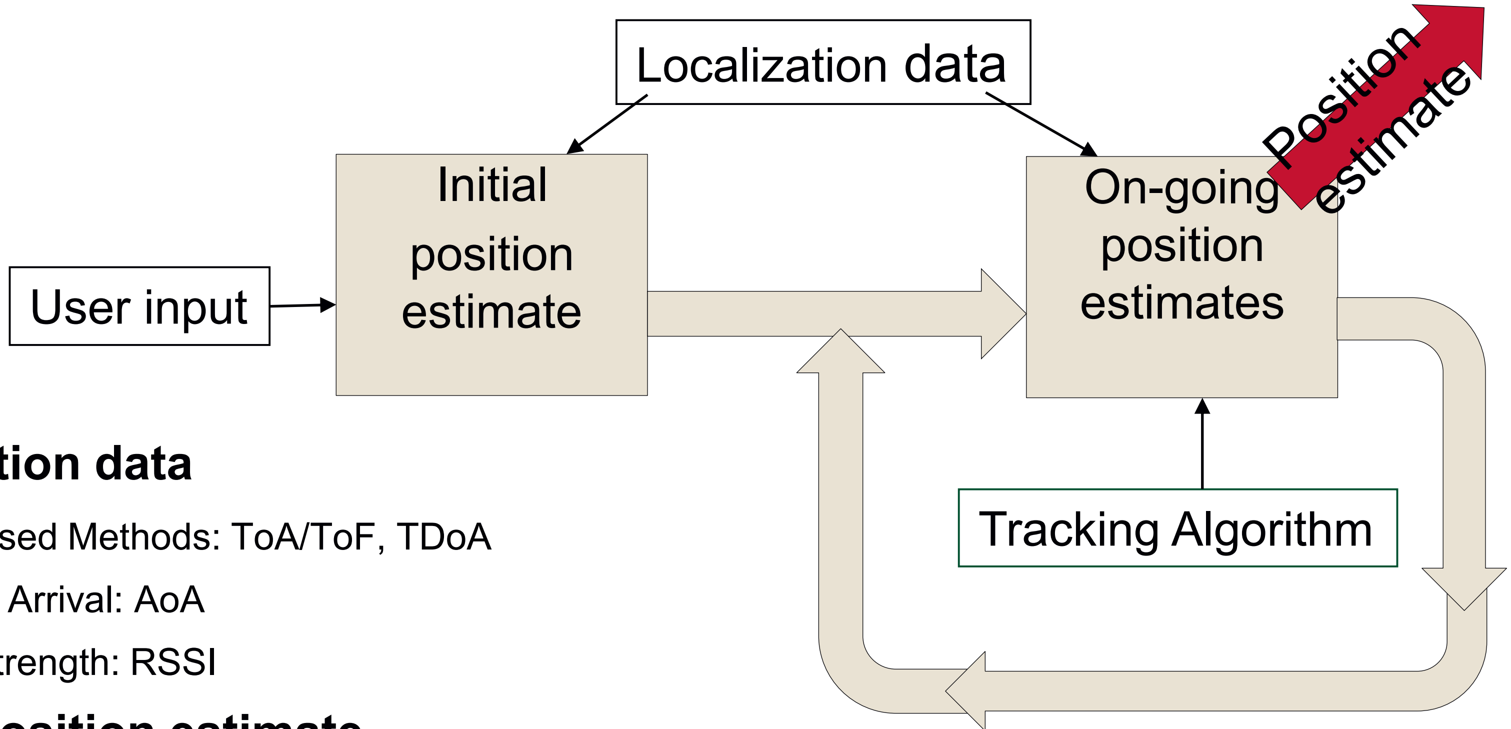
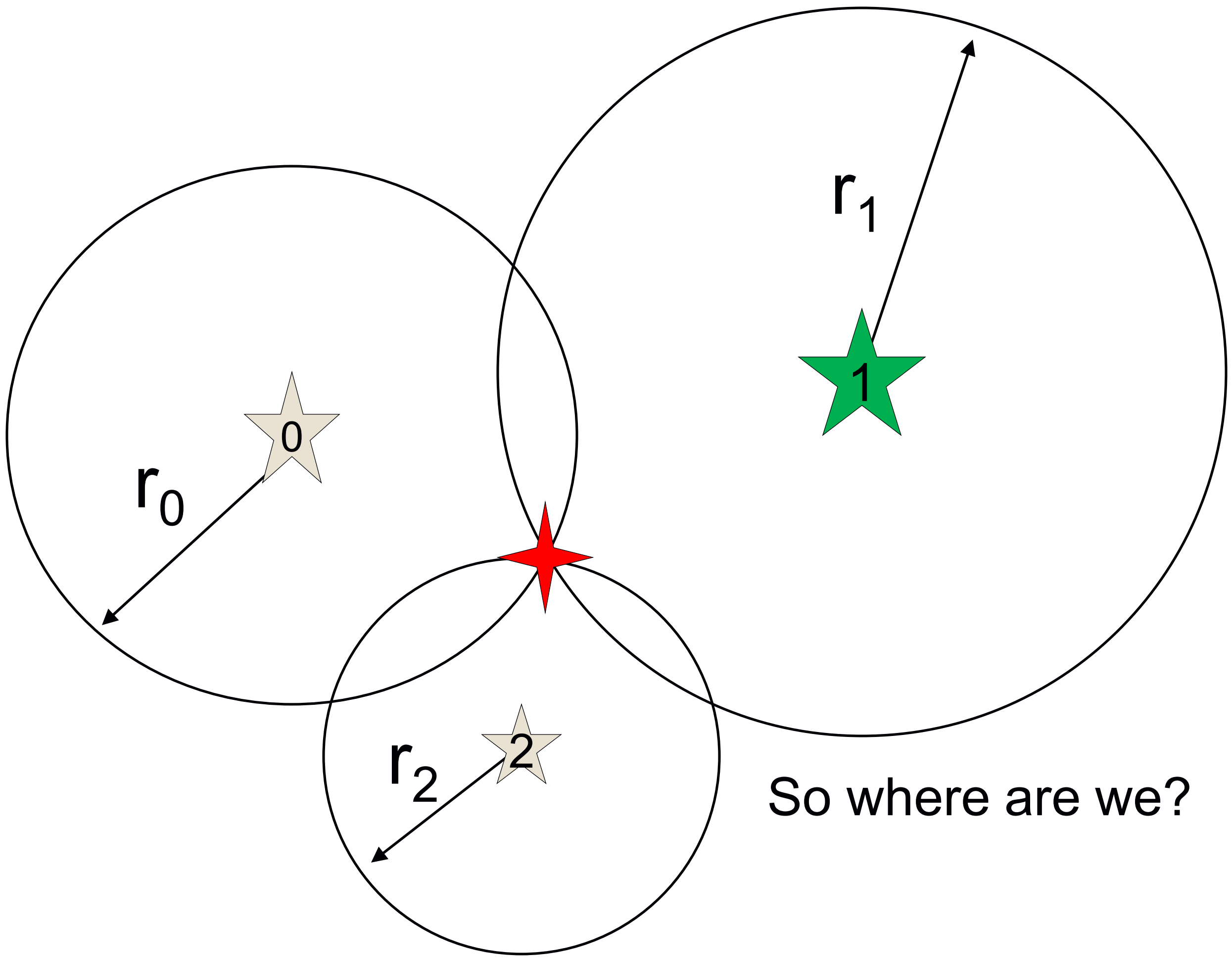


- **Localization data**
  - Time-based Methods: ToA/ToF, TDoA
  - Angle of Arrival: AoA
  - Signal strength: RSSI
- **Obtain position estimate**
  - Trilateration,
  - Triangulation,
  - Statistical Technique
  - Connectivity
- **Tracking algorithm**

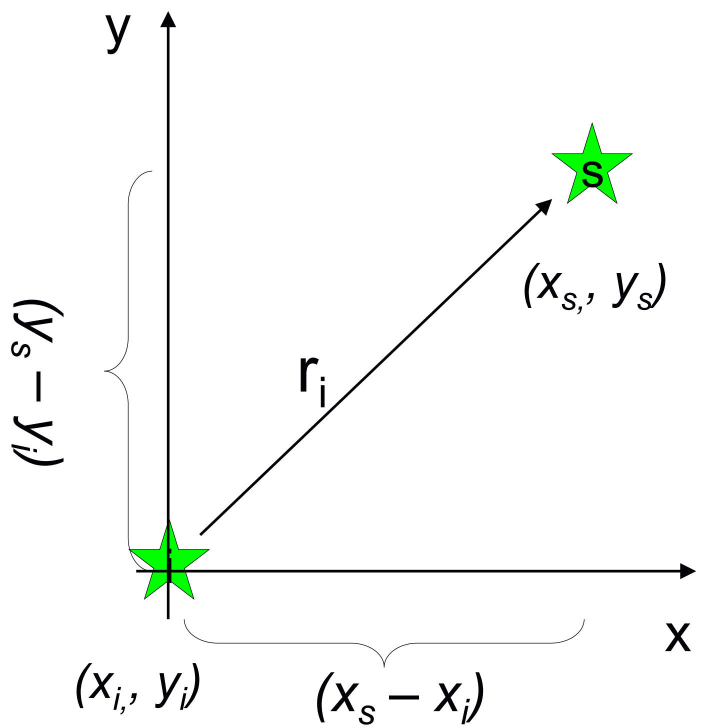
Basic localization methodology



So where are we?

Basic localization methodology

- So how do we actually do this?
- *Trilateration* (cf. triangulation).
- Assume:
  - 3 anchors A_i i.e. 3 devices at known positions $(x_i, y_i, i = 0..2)$.
  - We have some way of determining the distance/range, r_i, from the anchors to our unknown position (x_s, y_s).
  - From Pythagoras' theorem we can readily see that:
  - $(r_i)^2 = \{(x_s - x_i)^2 + (y_s - y_i)^2\}$



Analytical methodology

Solve system of equations (using Pythagoras!)

- (x_i, y_i) : coordinates of ***anchor point*** A_i, r_i distance to anchor A_i from ***s*** which is at (x_s, y_s).
    - $(r_i)^2 = \{(x_s - x_i)^2 + (y_s - y_i)^2\} \quad for \quad i = 0..2$
- We now construct 3 equations with 2 unknowns (x_s, y_s).
- By subtracting 3rd equation from 1st & 2nd we make the equations linear in our unknowns:

$$(r_0^2 - r_2^2) - (x_0^2 - x_2^2) - (y_0^2 - y_2^2) = 2x_s(x_2 - x_0) + 2y_s(y_2 - y_0)$$

$$(r_1^2 - r_2^2) - (x_1^2 - x_2^2) - (y_1^2 - y_2^2) = 2x_s(x_2 - x_1) + 2y_s(y_2 - y_1)$$

Analytical methodology

- This can be expressed in matrix form as:

$$\begin{pmatrix} (r_0^2 - r_2^2) - (x_0^2 - x_2^2) - (y_0^2 - y_2^2) \\ (r_1^2 - r_2^2) - (x_1^2 - x_2^2) - (y_1^2 - y_2^2) \end{pmatrix} = 2 \begin{pmatrix} x_2 - x_0 & y_2 - y_0 \\ x_2 - x_1 & y_2 - y_1 \end{pmatrix} \begin{pmatrix} x_s \\ y_s \end{pmatrix}$$

- In matrix form this is: **[b] = [A][s]**

- With [b] = $\frac{1}{2}\begin{pmatrix} (r_0^2 - r_2^2) - (x_0^2 - x_2^2) - (y_0^2 - y_2^2) \\ (r_1^2 - r_2^2) - (x_1^2 - x_2^2) - (y_1^2 - y_2^2) \end{pmatrix}$

[A] = $\begin{pmatrix} x_2 - x_0 & y_2 - y_0 \\ x_2 - x_1 & y_2 - y_1 \end{pmatrix}$ and [s] = $\begin{pmatrix} x_s \\ y_s \end{pmatrix}$

Practice

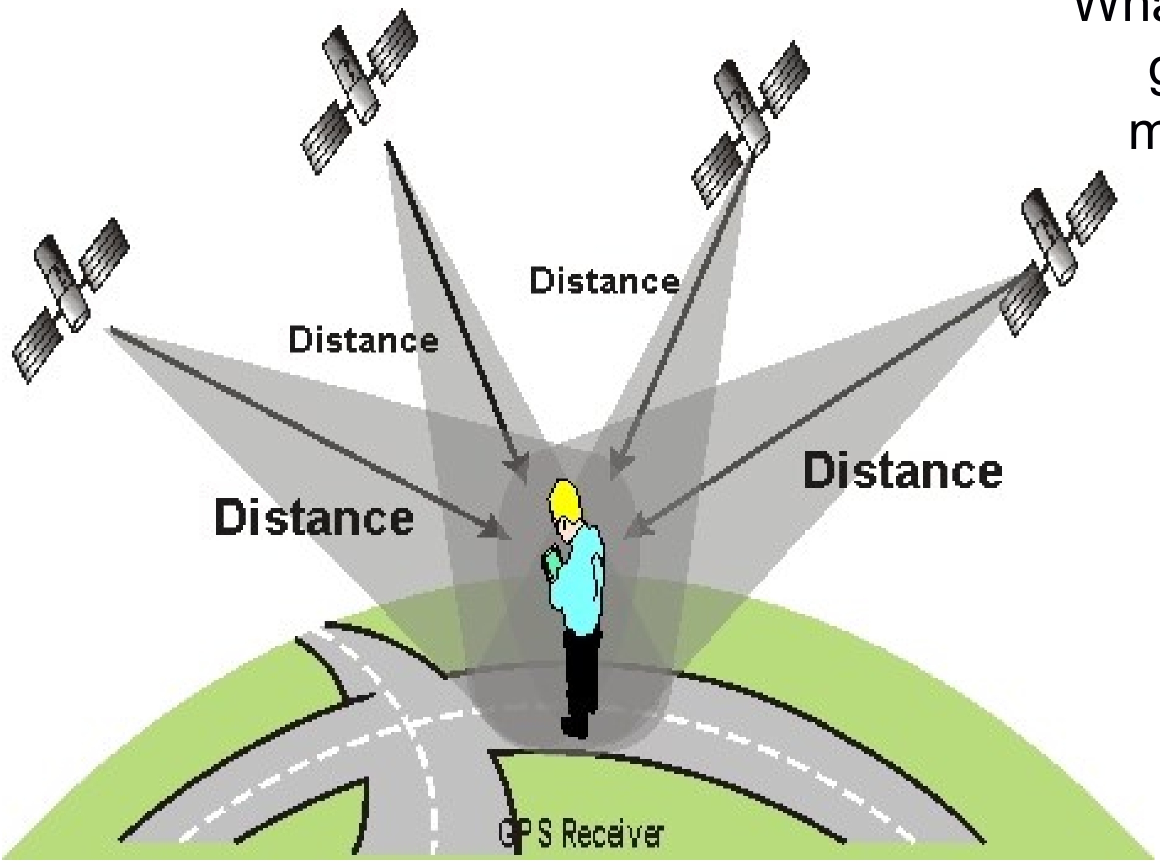
Time for an exercise:

We have 3 anchors $A_0..A_2$ on a flat x, y, grid measured out in metres, at: $A_0(10, 5)$, $A_1(2, 10)$ and $A_2(10, 15)$. The range from each anchor to the subject is $r_0 = 8m$, $r_1 = 5m$, and $r_2 = 12.8m$.

Where is the subject?

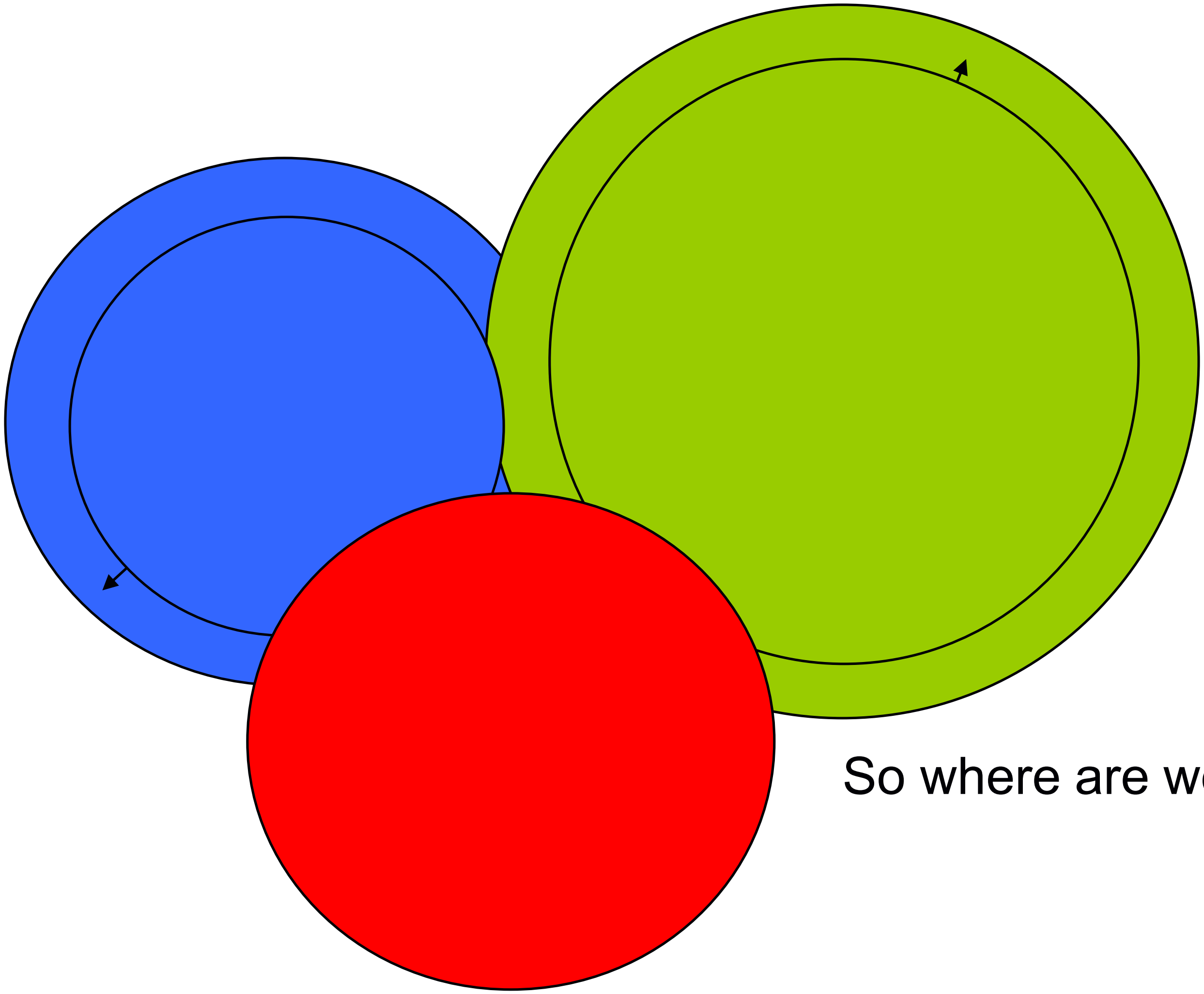
$$(x_s, y_s) = (2, 5)$$

Problem



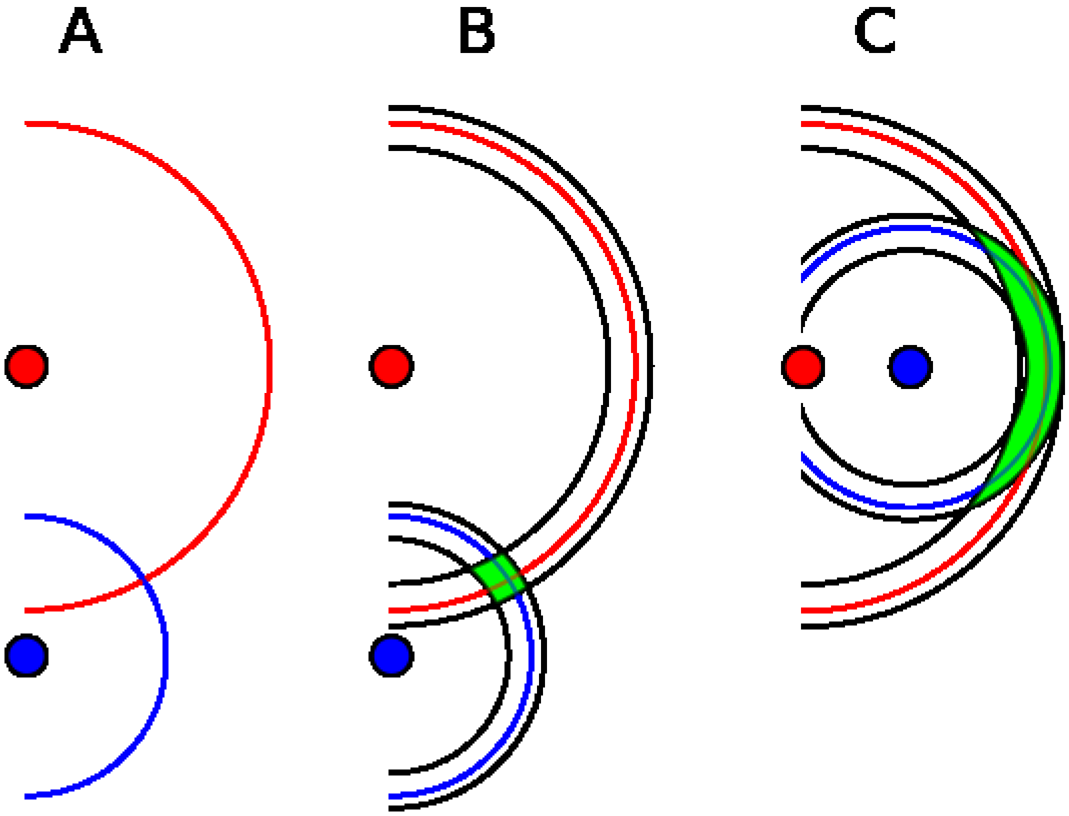
What happens if we can't get an accurate range measurement from our satellite?

Ambiguity



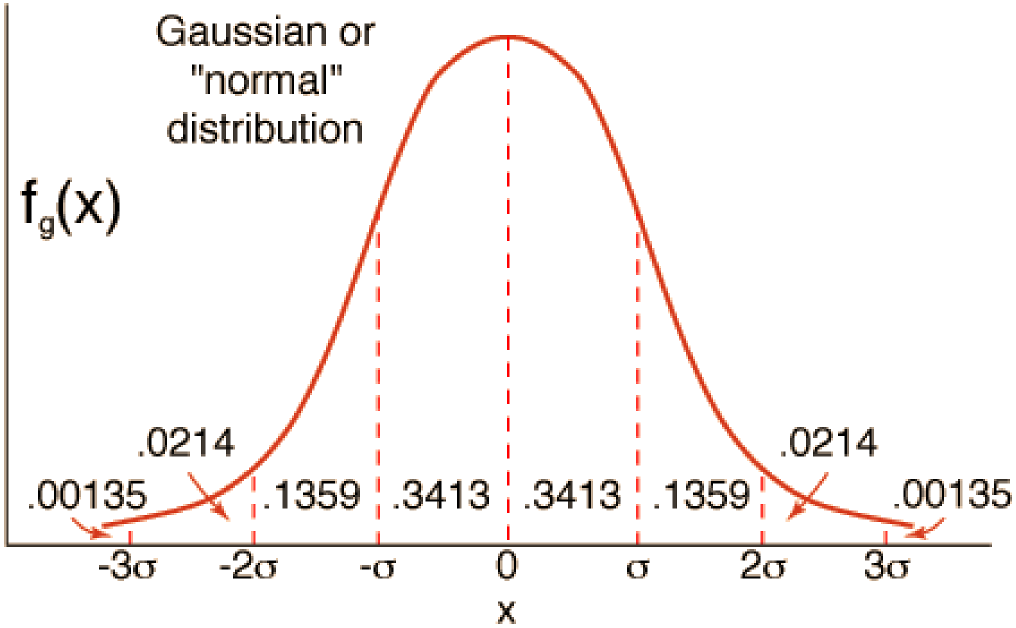
So where are we?

GDOP



Probabilistic ranges

- From our ranging mechanism we obtain a range *estimate*
- Provided this is **unbiased,** estimates will have a mean of the correct range
- Each estimate will have a random error



Resolution of some current technologies

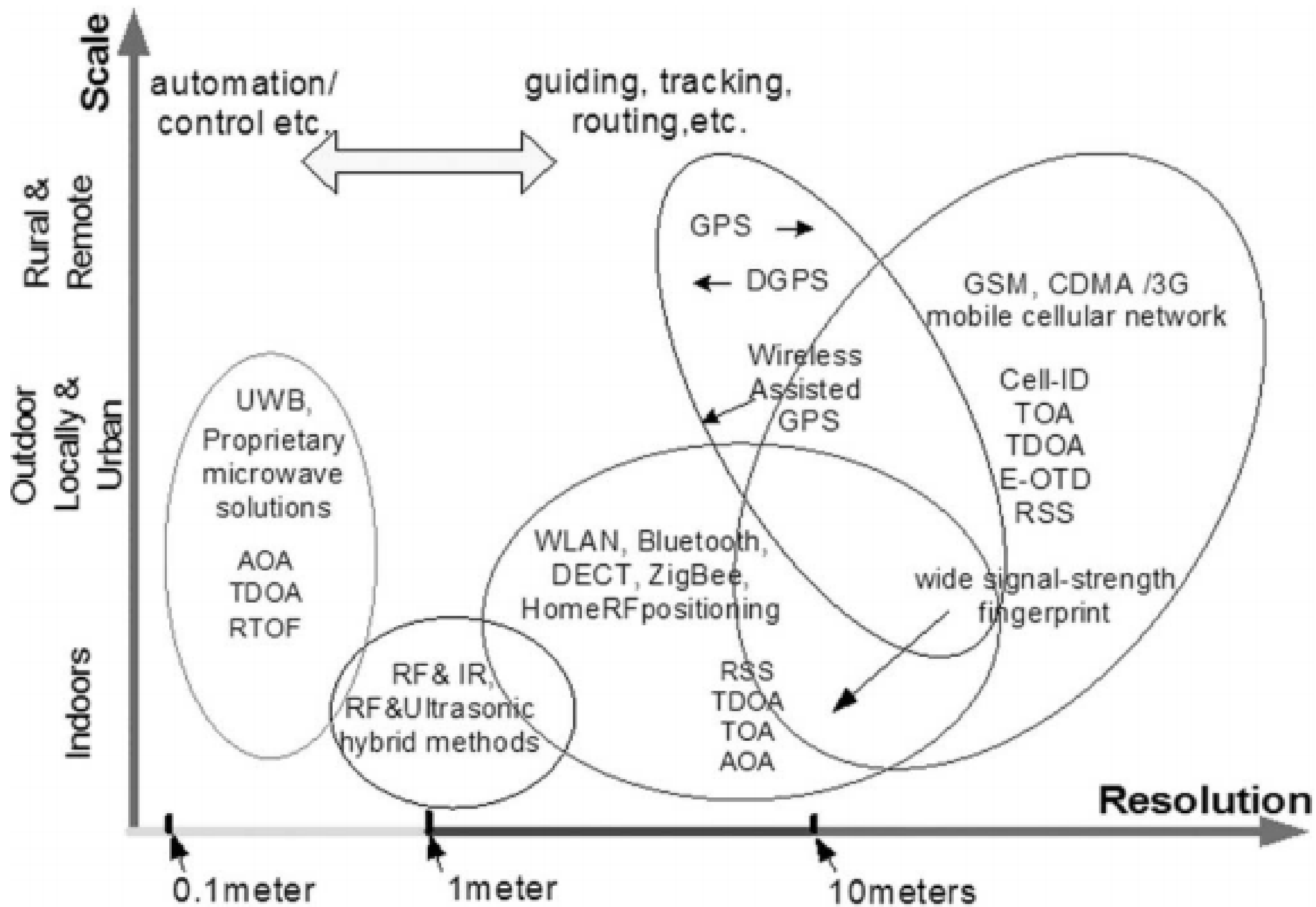


Fig. 6. Outline of current wireless-based positioning systems.

Conclusion

- The tracking methodology relies on some kind of positioning method
- The positioning method inherently displays probabilistic inaccuracy
- Averaging will enhance an unbiased system
- Tracking algorithms can enhance positioning performance

TABLE I. LOCALIZATION SYSTEMS

System	Network	Accuracy	Method	Overall Evaluation (A: Advantage; D: Disadvantage)
WhereNet [31]	RFID	2m to 3m	TDOA	A: Uniquely identify equipment and person. D: Need numerous infrastructure components
RADAR [32]	WLAN	2.26m out of $312m^2$	Triangulation	A: Reuse the existing WLAN infrastructure. D: Low level accuracy, no consideration of privacy
EKAHAU [33]	WLAN	1m	RSSI	A: Low cost and power level of the battery. D: Low level accuracy and only provide 2D location information.
COMPASS [34]	WLAN	1.65m out of $312m^2$	Fingerprint	A: Consider the orientation impact of the user. D: Only consider single user.
Ubisense [35]	UWB	Tens of centimeters	TDOA and AOA	A: No requirement of line-of-sight; large coverage area; 3D location; high accuracy D: The price of the system is high.
Active Badge [26]	Infrared	Room level	RSS	A: Address privacy D: Low accuracy; long transmission period; influenced by fluorescent light and sunlight
Firefly [27]	Infrared	3.0mm	Not available	A: High level accuracy; small measurement delay of 3 ms D: Use wire to connect tags and the coverage area is limited to 7m.
OPTOTRAK [28]	Infrared	0.1mm to 0.5mm	Not available	A: High accuracy; able to measure relative motions on the different parts of one object. D: Limited by line-of-sight requirement.
Sonitor [36]	Ultrasound	Room level	Not available	A: Energy efficient D: Low level accuracy
IRIS_LPS [37]	Infrared	16cm out of $100m^2$	Triangulation	A: Larger covered area D: Subject to interference from florescent light and sunlight
Active Bat [29]	Ultrasound	3cm out of $1000m^2$	Multilateration	A: Cover large area; provide 3-D position. D: Subject to reflections of obstacles; use a large number of transmitters on the ceiling.
Cricket [30]	Ultrasound, RF	10cm	TOA and triangulation	A: Address privacy; low cost, decentralized administration. D: More energy consumption