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Wireless Sensor Network - Localization

Habitat Monitoring

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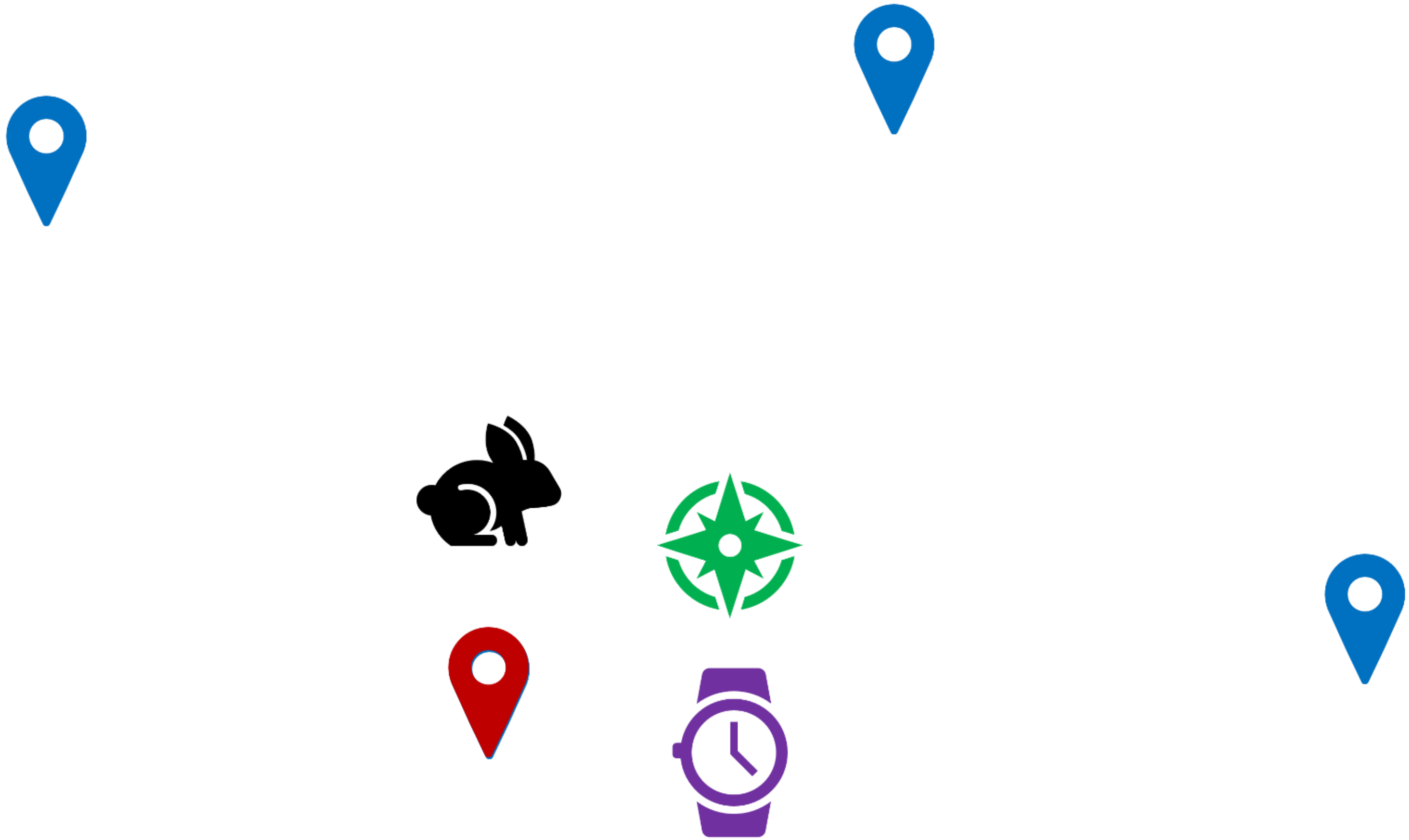

Localization??

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- All nodes in the network have an idea about their absolute/relative position

Localization

- Dynamic environment
- Hundreds of sensors are placed randomly – over a large area
- Initial location of the nodes may been unknown
- Estimation of a nodes position used
  - Measurement without position is useless
  - Allows energy efficient geographic routing
  - Self-organization and Self- healing is easier
  - Obstacles can be found and by-passed
  - Tracking – Measurement itself

Position Estimation

- Not possible to equip every node with GPS
- Anchors, beacons, landmark nodes
  - Triangulation
  - Tri-Lateration
  - Multi-Lateration

Method to estimate distances based on

Time Period
- ToA
- TDoA

Signal Attenuation
- RSS
- MTP

Neighborhood Information
- Connectivity
- Hop Count

Localization– Modes of Operation

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- Initialization
- Post – Deployment Operation - Mobile

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Wireless Sensor Network - Localization – Distance Estimation

Time of Arrival (ToA)

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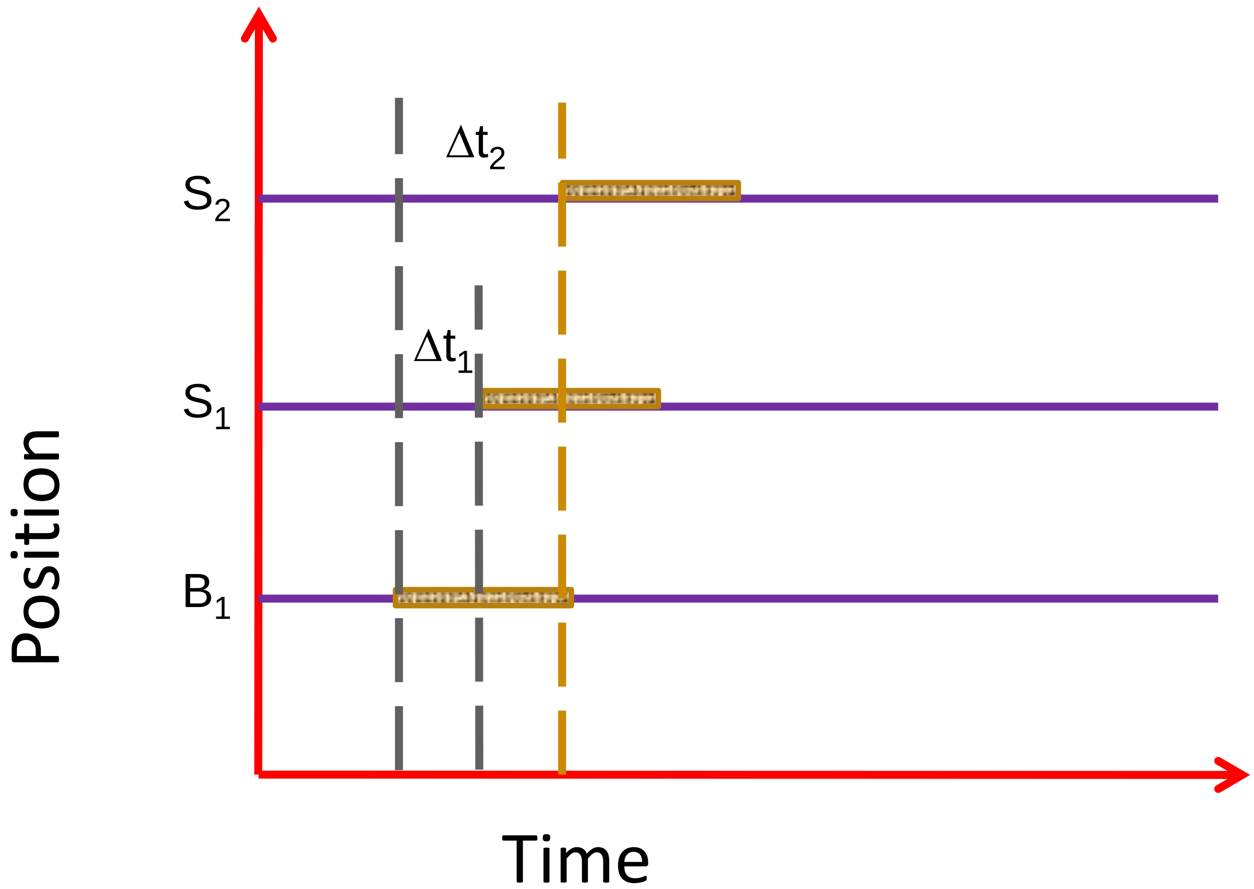

$$\mathbf{d} = \mathbf{c}_{\mathbf{AIR}}\,\boldsymbol{\Delta}\mathbf{t}$$

Issues with ToA??

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- C_{AIR} - 297,702 km/s $\approx 3x10^6$ m/s
- d = 30cm btwn B1 & S1
- Δt = 1ns

Time of Arrival (ToA)

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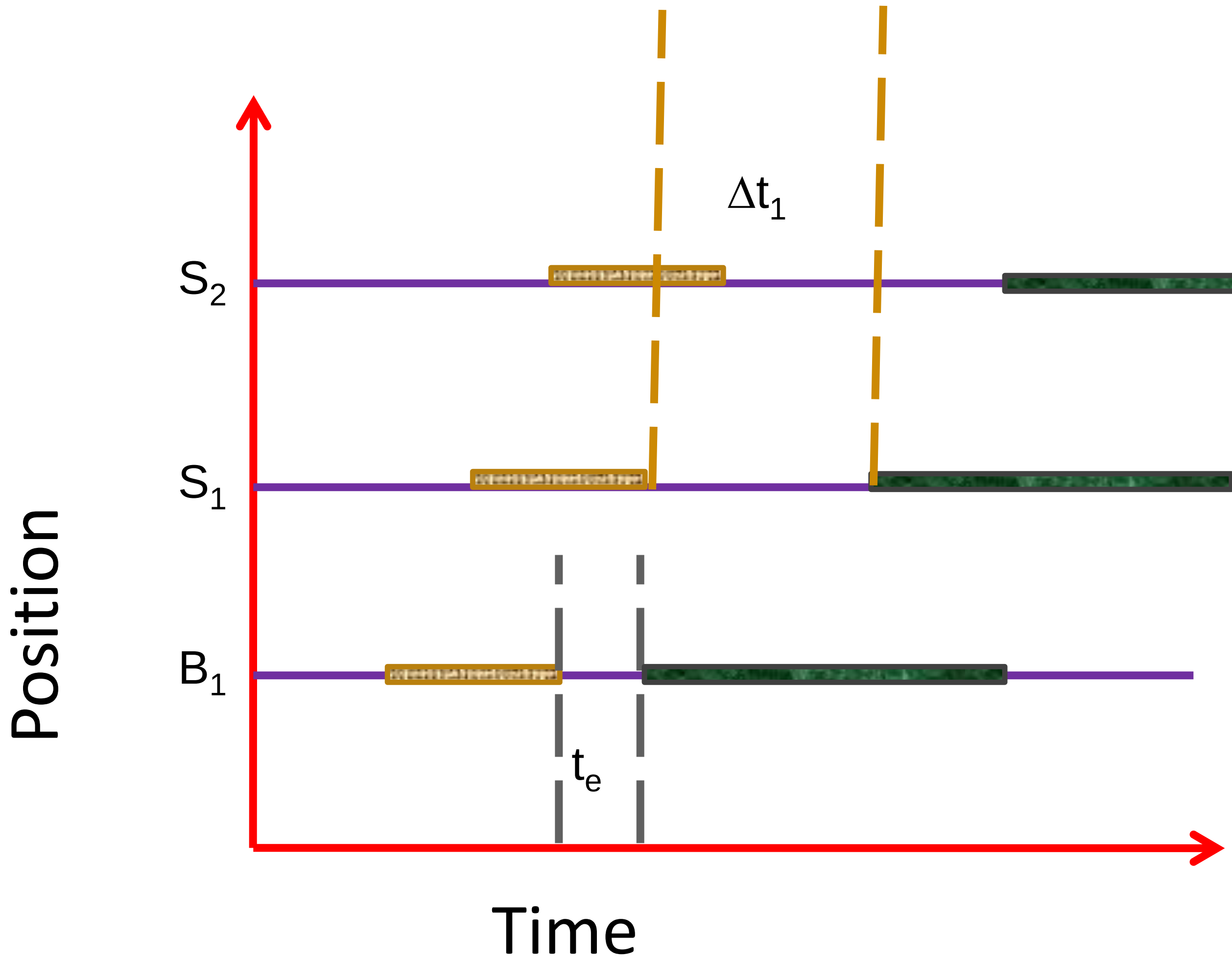

$$\mathbf{d = c_S * (\Delta t_1 - t_e)}$$

Improvement??

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- C_S - 340 m/s
- All time measurements will not be affected by lack of time sync
- Sound unpredictable medium
- Additional hardware

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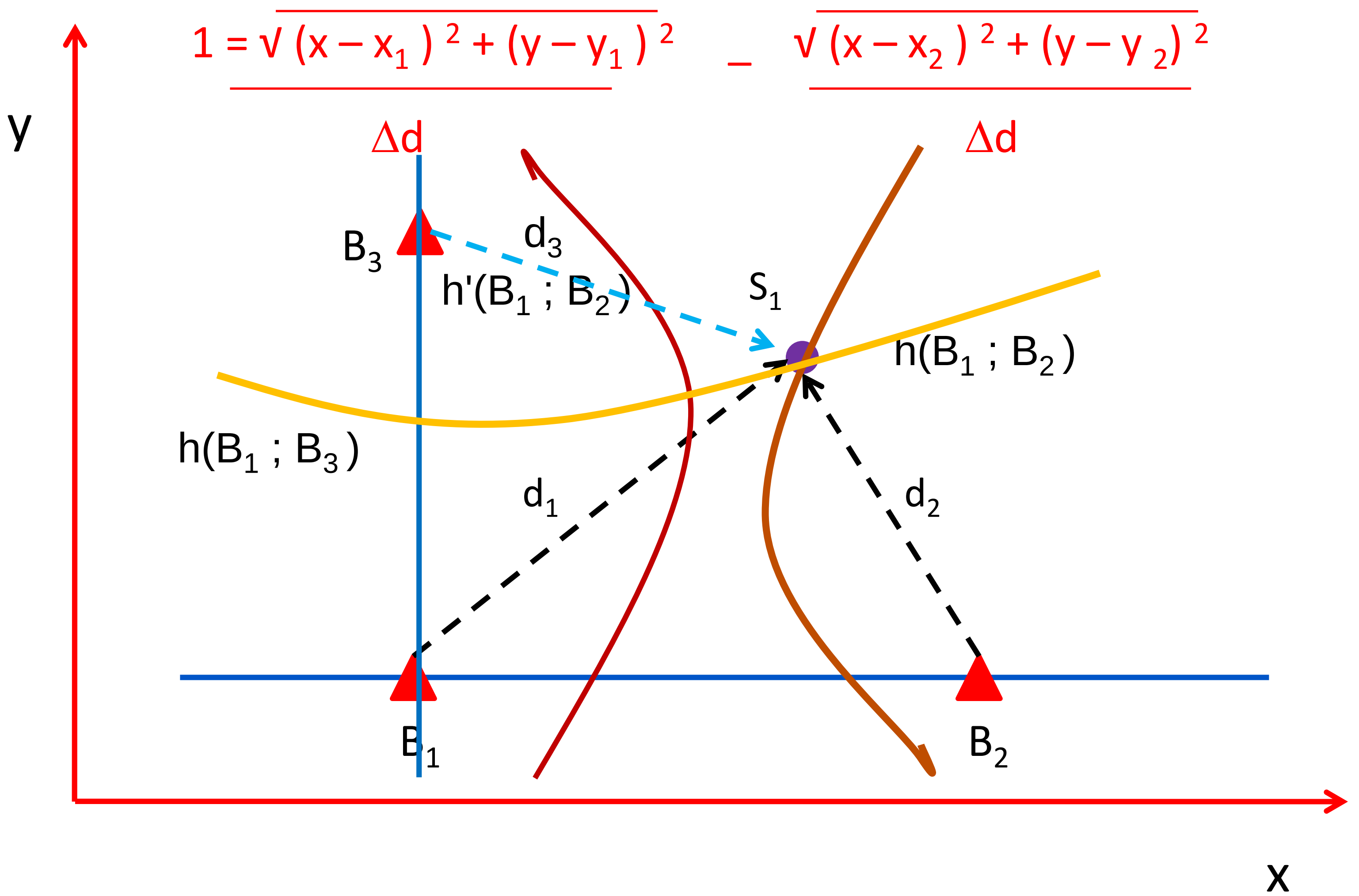
Wireless Sensor Network - Localization – Distance Estimation

Time Difference of Arrival (TDoA)



$d_1 - d_2 = \Delta t.c = \Delta d \qquad \Delta t = t_{end} - t_{start}$

Issues with TDoA??

- No. of Beacons required
- Localized nodes can act as beacons themselves

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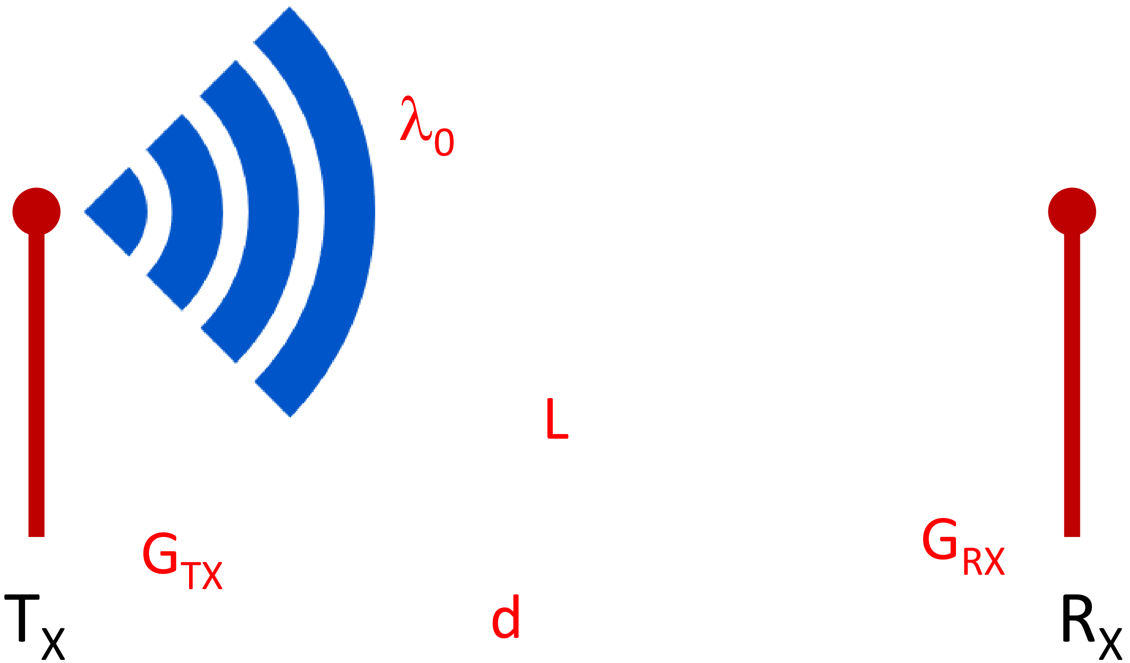
Wireless Sensor Network - Localization – Distance Estimation

Received Signal Strength (RSSI)

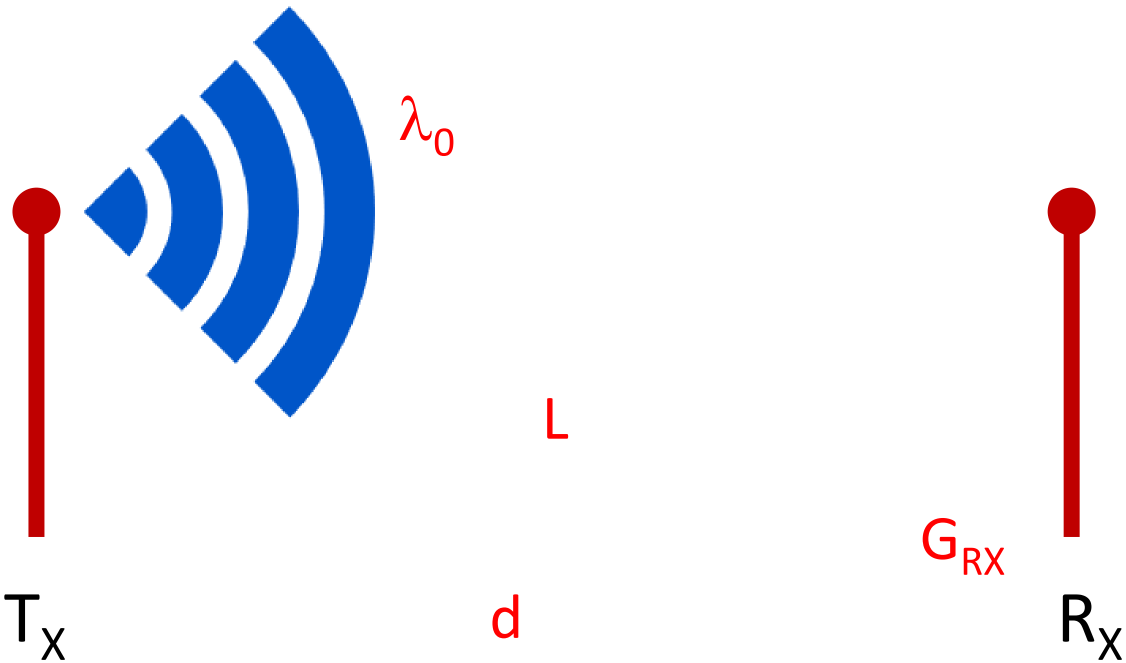
$$\frac{P_{RX}}{P_{TX}} =$$

Received Signal Strength (RSSI)



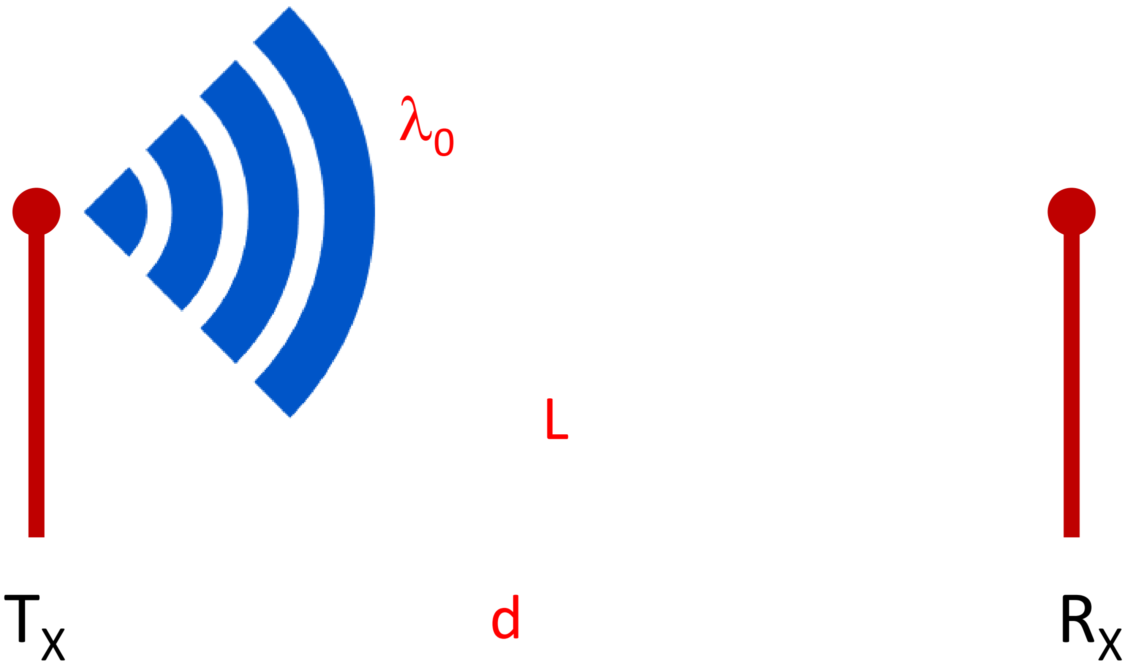
$$\frac{P_{RX}}{P_{TX}} =$$

Received Signal Strength (RSSI)



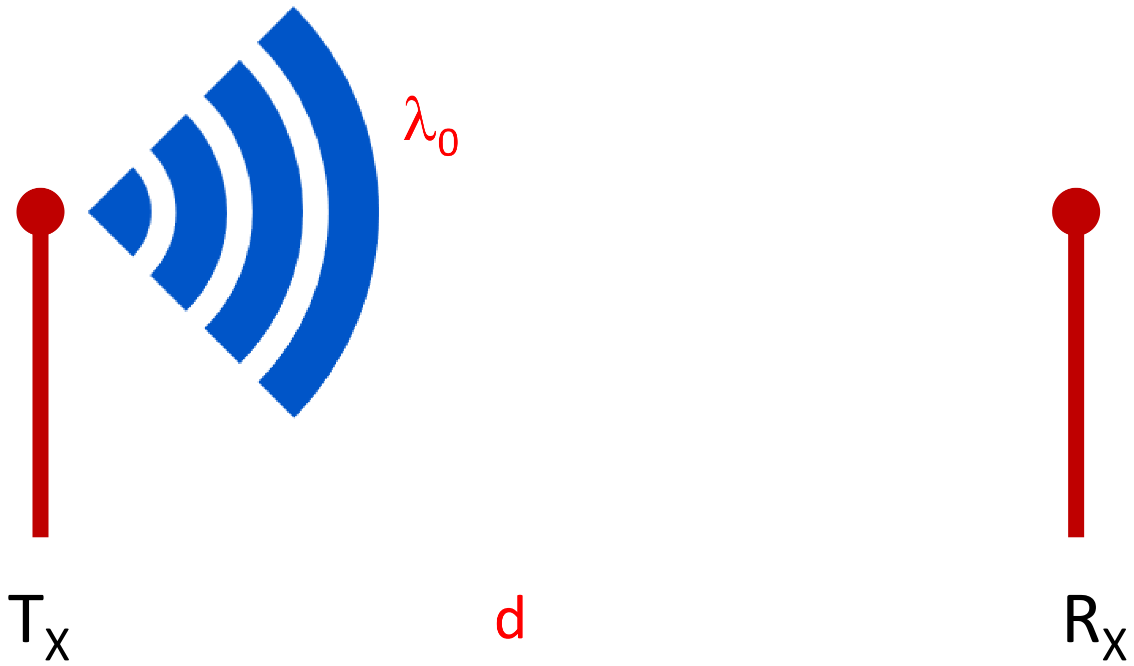
$$\frac{P_{RX}}{P_{TX}} = G_{TX}$$

Received Signal Strength (RSSI)



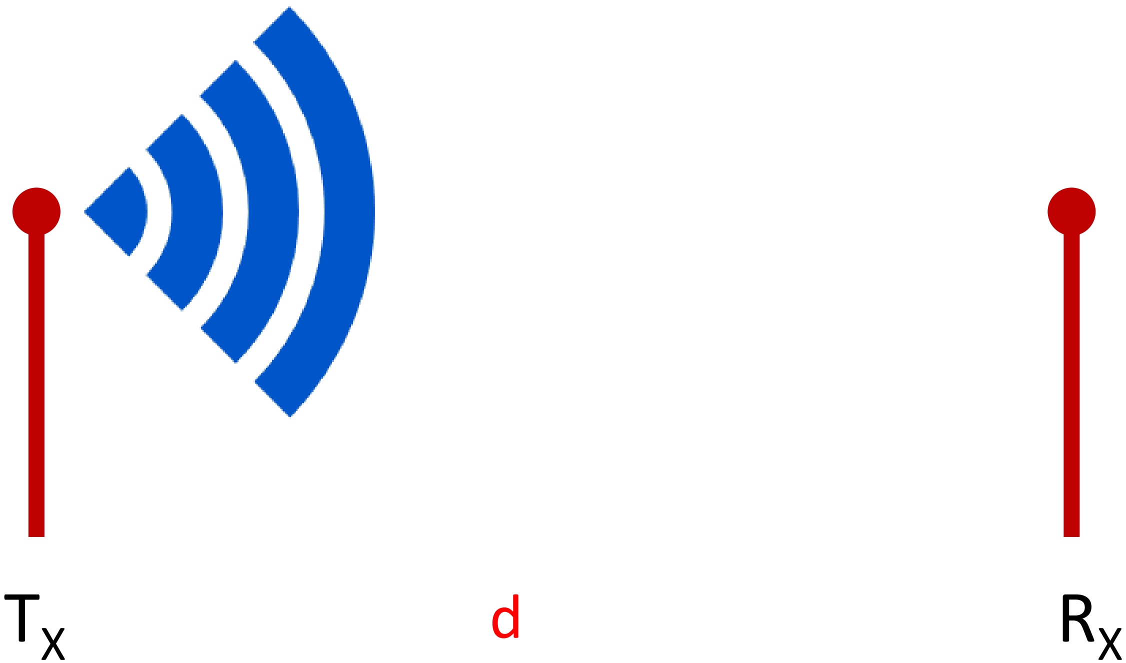
$$\frac{P_{RX}}{P_{TX}} = G_{TX} \; G_{RX}$$

Received Signal Strength (RSSI)



$$\frac{P_{RX}}{P_{TX}} = \frac{G_{TX}\ G_{RX}}{L}$$

Received Signal Strength (RSSI)



$$\frac{P_{RX}}{P_{TX}} = \frac{G_{TX}\ G_{RX}}{L} \qquad \lambda_0$$

Received Signal Strength (RSSI)

$$\frac{P_{RX}}{P_{TX}} = \frac{G_{TX}\ G_{RX}}{L}$$

λ_0

d

Received Signal Strength (RSSI)

$$\frac{P_{RX}}{P_{TX}} = \frac{G_{TX}\ G_{RX}}{L}\left\{\frac{\lambda_0}{4\pi d}\right\}^2$$

Received Signal Strength (RSSI)

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$$\frac{P_{RX}}{P_{TX}} = \frac{G_{TX}\ G_{RX}}{L}\left\{\frac{\lambda_0}{4\pi d}\right\}^2$$

FRIIS Equation

$$PL = 10\log\ \frac{G_{TX}\ G_{RX}}{L}\left\{\frac{\lambda_0}{4\pi d}\right\}^2$$

$$d_{max} = \frac{\lambda_0}{4\pi 10^{-PLmax/20}}$$

Issues with RSSI??

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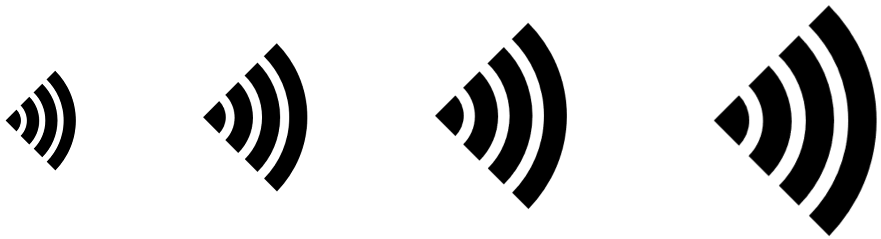
- Ideal Gain & No Loss Assumption
- Loss is unpredictable
- Need for measurement technique

Minimum Transmission Power (MTP)



- Motes allow multiple power levels

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Wireless Sensor Network - Localization – Algorithms

Issues ??

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- Resource Constraints
- Node Density
- Non-Convex Topology – Border Node Problems
- Environmental Obstacles & Terrain Irregularities

Requirements of LA

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- High Precision
- Minimal cost
- Fully distributed – robust & reliable
- Adaptive to environmental changes
- Mobility must be accommodated
- Resource- Efficient

Types

- Approximate Vs Precise
- Central Vs Distributed
- Range based Vs Range Free
- Relative Vs Absolute
- Indoor Vs Outdoor
- Beacon-Free Vs Beacon based

Wireless Sensor Network - Localization – Algorithms

Centroid Localization

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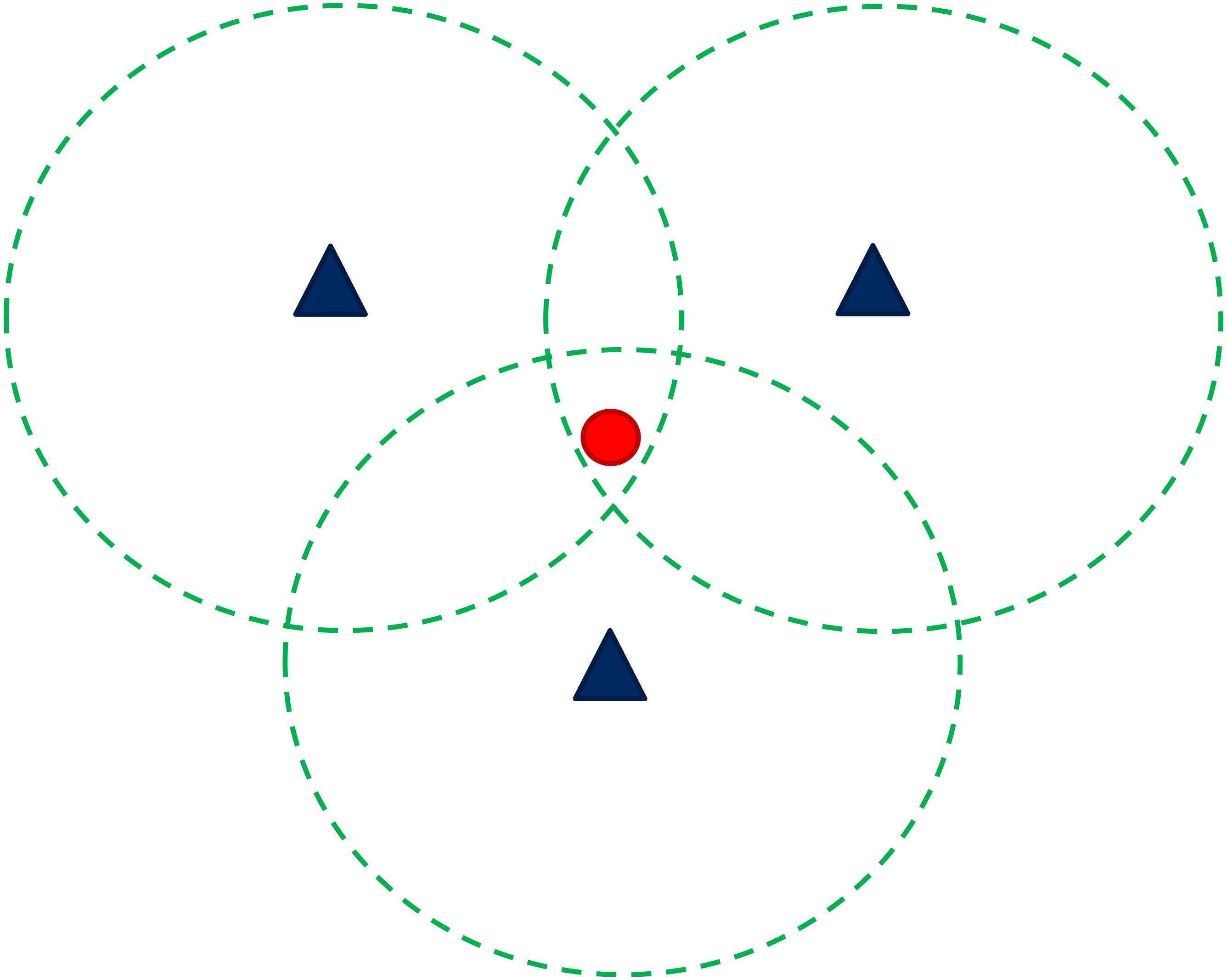
- Based on the concept of Trilateration
- Extended to Multilateration

Trilateration



$(B_iS)^2 = (B_i(x_i) - S(x))^2 + (B_i(y_i) - S(y))^2$

Assumptions

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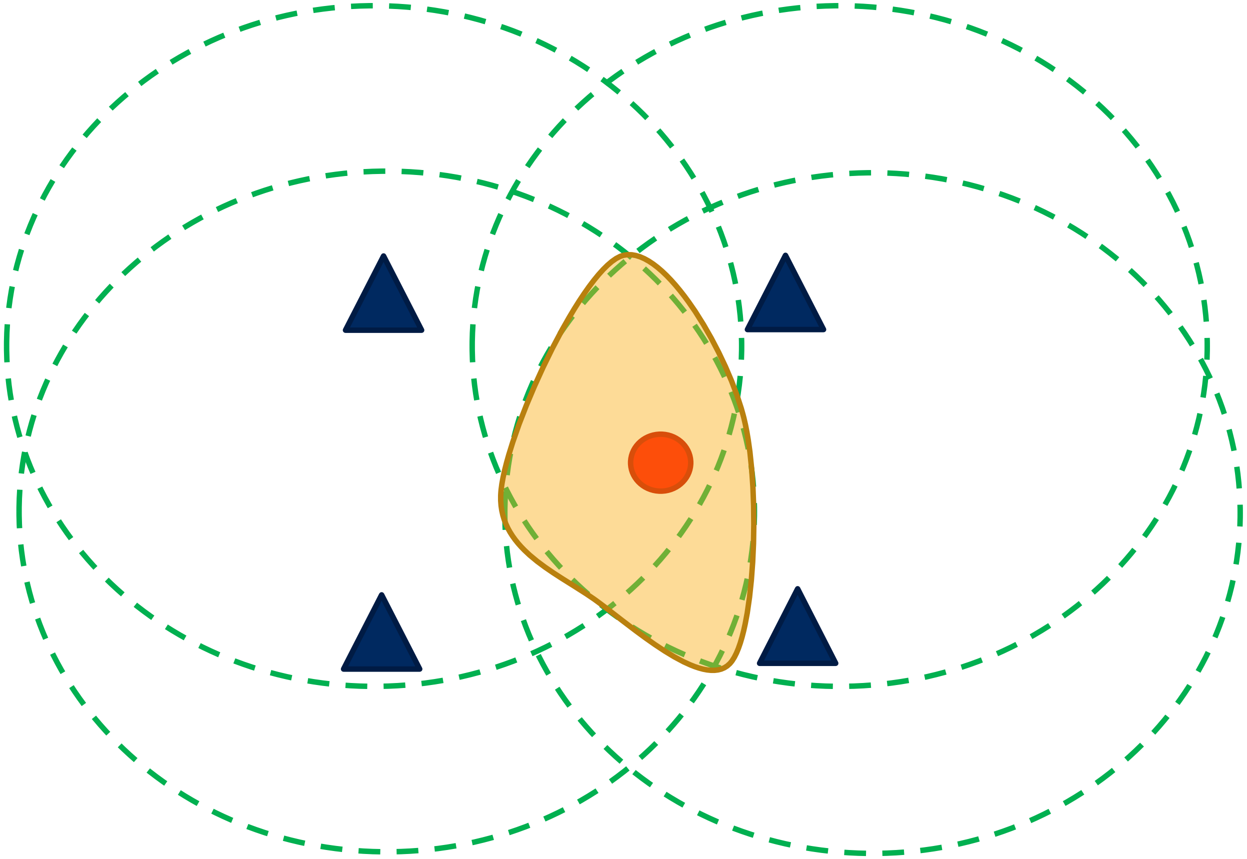
- Perfect Spherical Radio Propagation
- Identical Tx range for all radios
- The neighbouring signal points can be sync so that they do not overlap in time

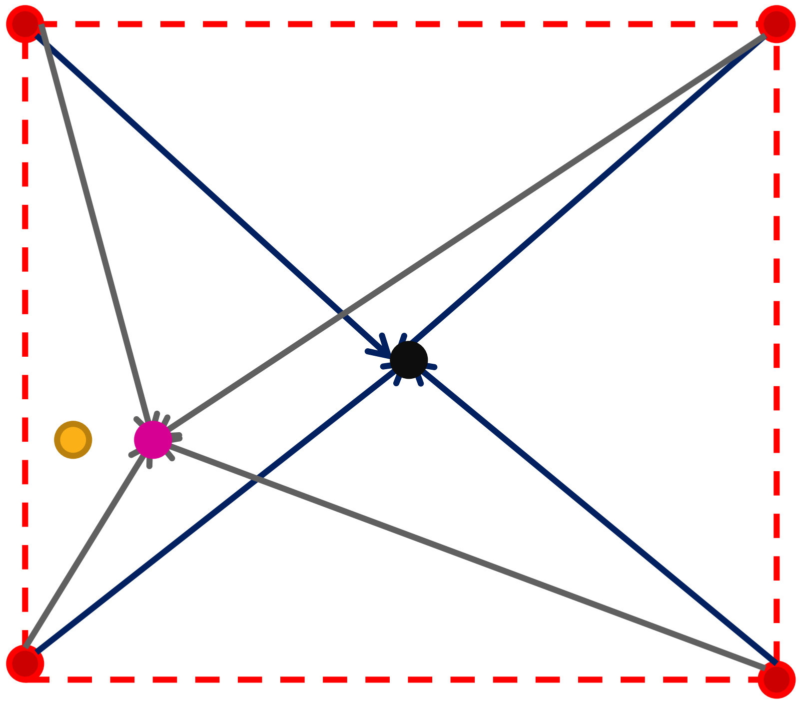
Multi-Lateration



Position Estimation

$$S(x,y) = 1/n \sum_n B(x_i, y_i)$$

Issues with Centroid



Assign Weights

Weighted Centroid

- Weights
- RSSI
- ToA