Automatic Calibration for Log-normal Path Loss Model Based on Bluetooth Low Energy Beacons

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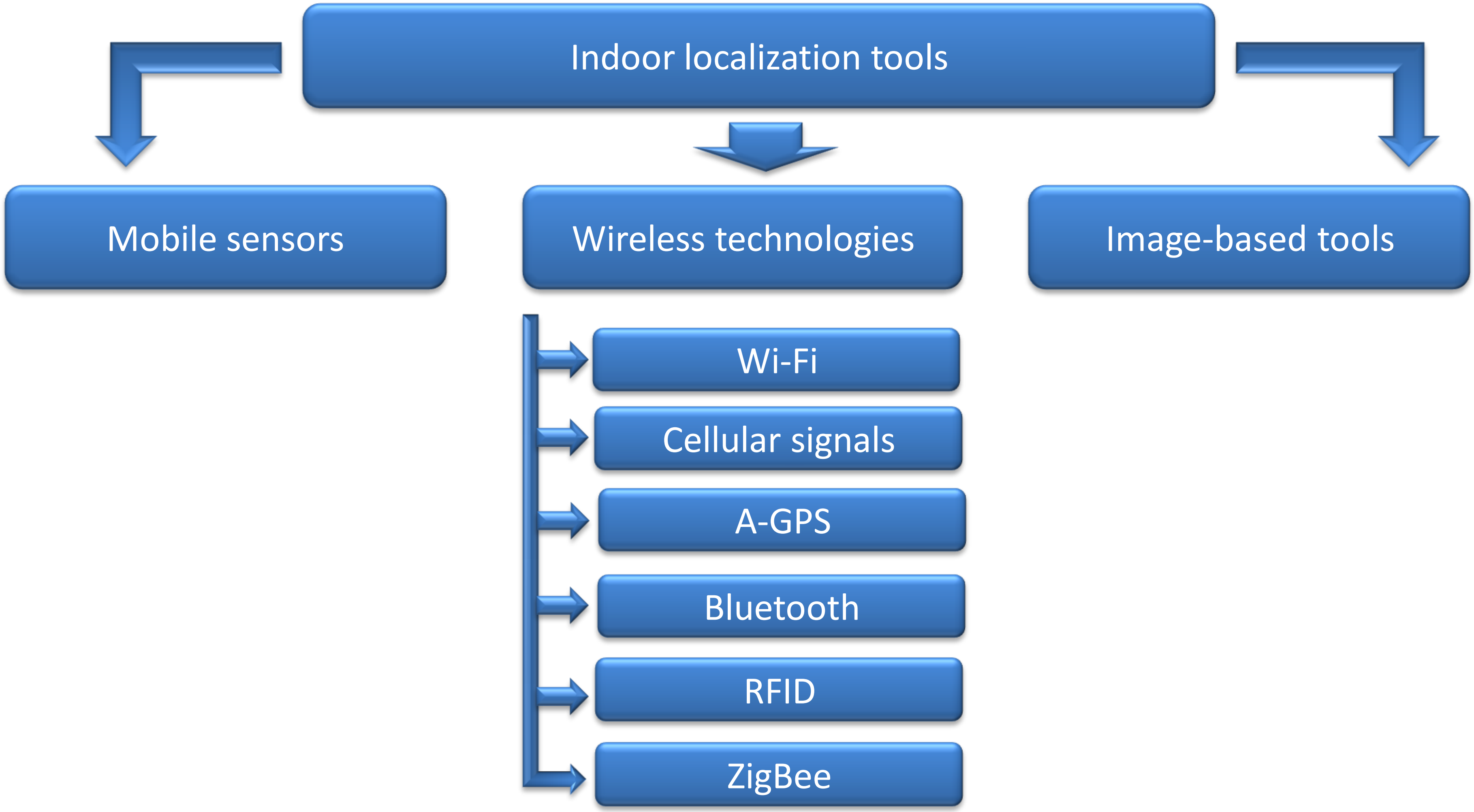
Motivation

- Indoor localization and navigation
- Contextual information provision
- Recommended information provision
- Tracking
- Statistical data aggregation and analysis

Indoor localization tools



Indoor localization system

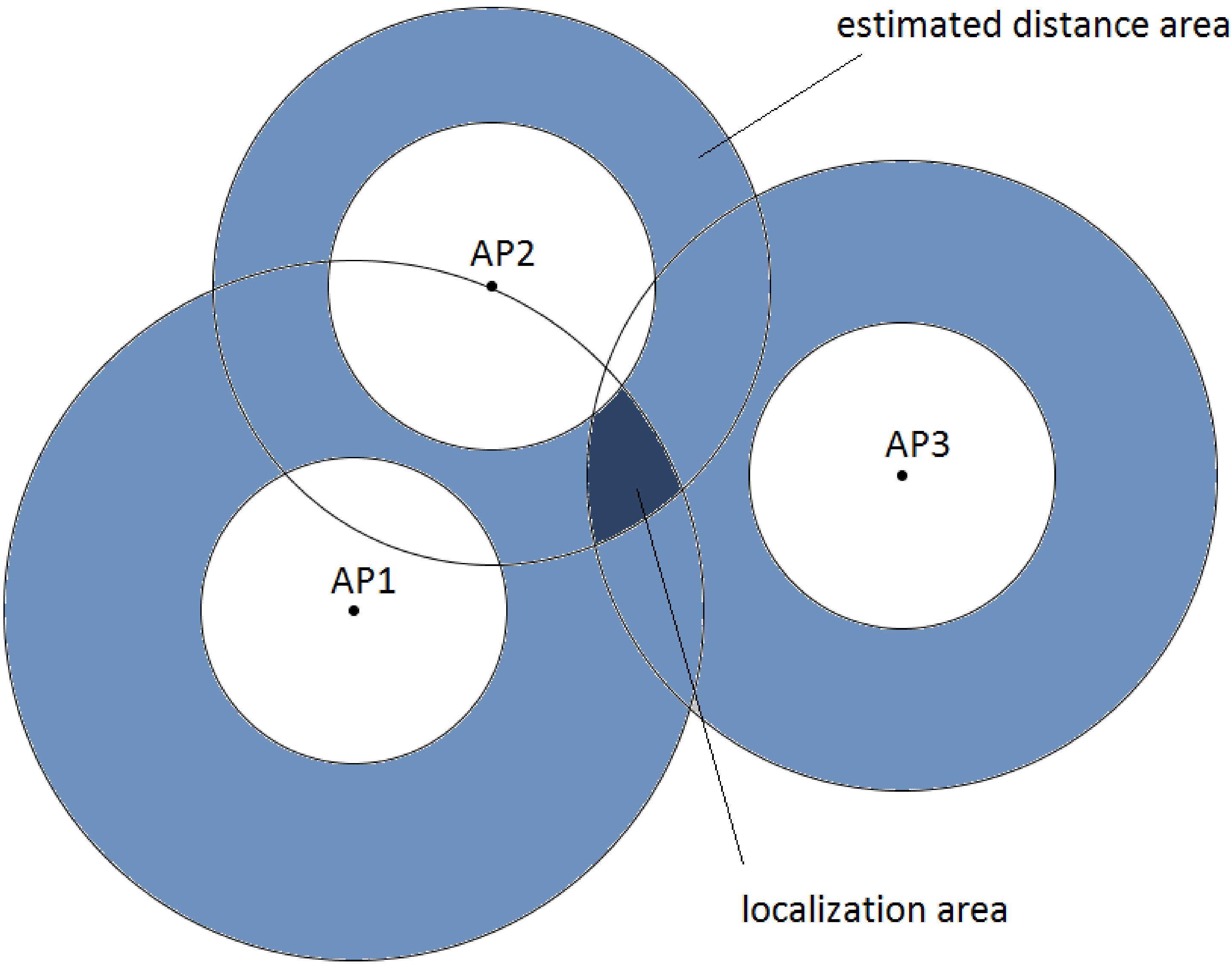
Indoor navigation

Context information

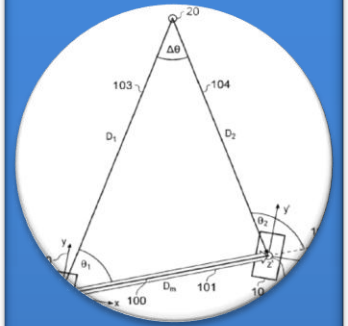
Bluetooth low energy beacons

- Low power consumption
- Low cost
- Compatibility with a number of mobile phones, tablets and computers
- Portability

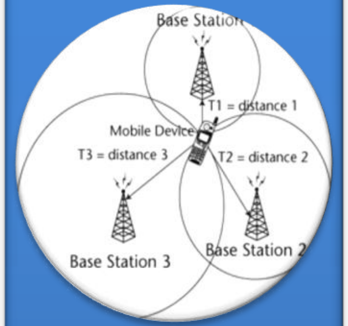
Intersection of proximity zones



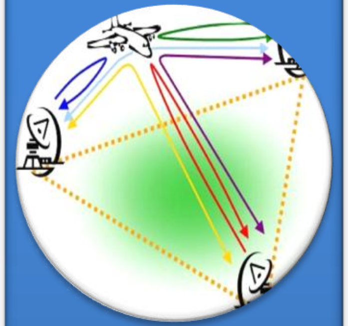
Indoor localization approaches



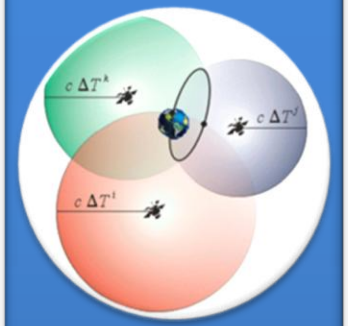
Triangulation



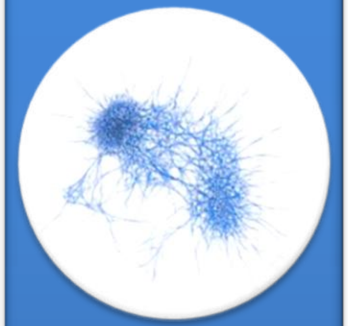
Time of arrival lateration



Time difference of arrival lateration

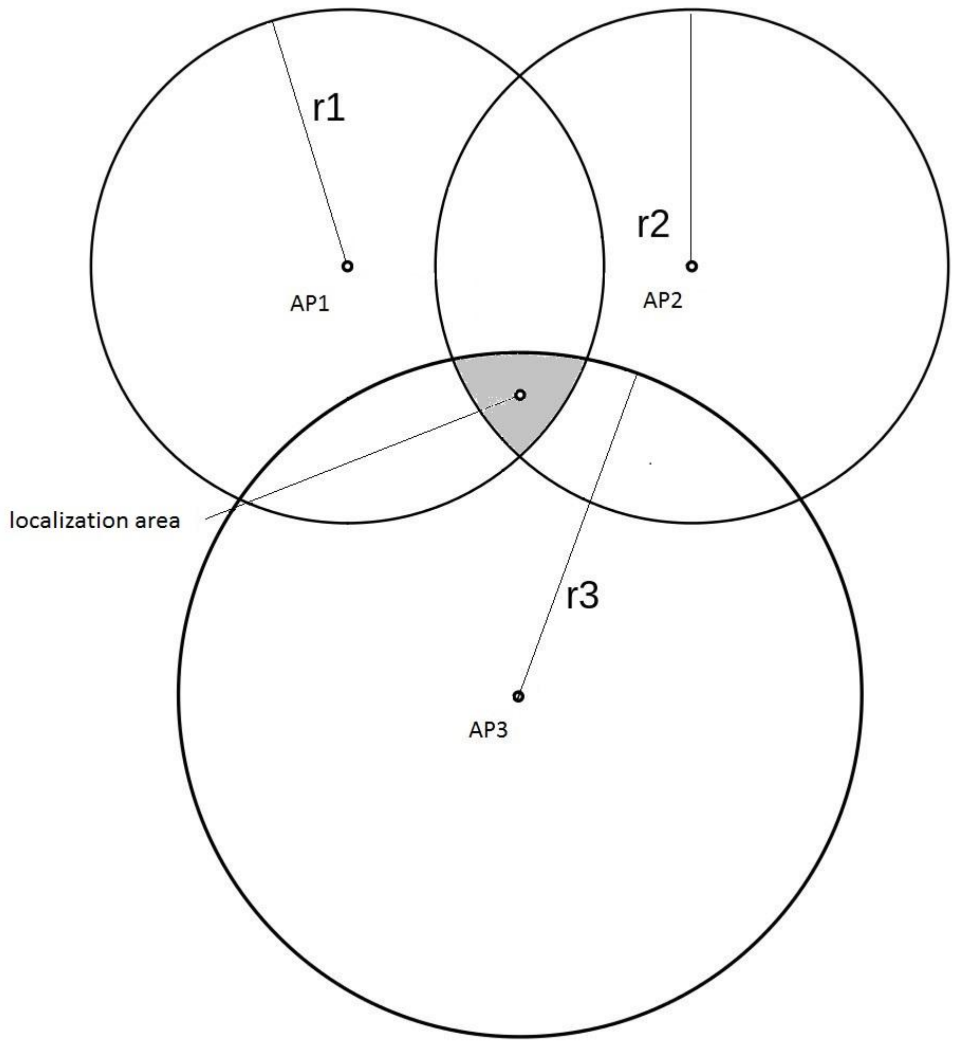


Receive signal strength lateration



Fingerprinting

RSS trilateration



$$r_1^2 = (x - x_1)^2 + (y - y_1)^2$$

$$r_2^2 = (x - x_2)^2 + (y - y_2)^2$$

$$r_3^2 = (x - x_3)^2 + (y - y_3)^2$$

Log-normal path loss model

$$RSS = P_t - PL(d_0) - 10\alpha \lg \frac{d}{d_0} + X_{\sigma_{RSS}}$$

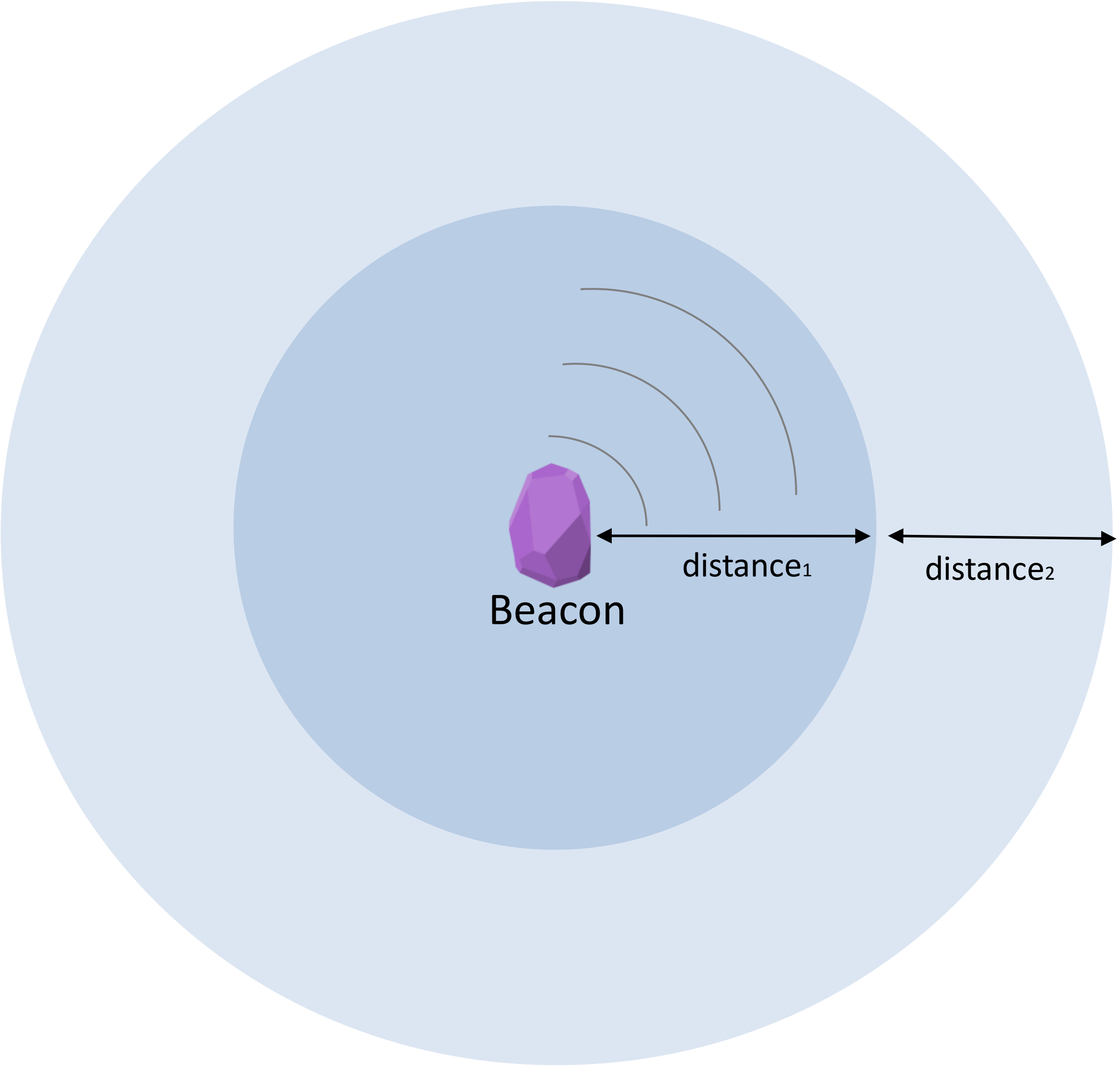
- *RSS* - the received signal strength dBm;
- *d* - is the true distance from the sender to the receiver;
- α is the path-loss exponent;
- P_t - the transmit power of the sender in dBm;
- $PL(d_0)$ - the power loss in dBm at a reference distance d_0;
- $X\sigma_{RSS}$ - a random variable in dBm representing the noise in the measured RSS.

Log-normal path loss model calibration

$$d = k10^{\frac{Pt - RSS}{10\alpha}}$$

where k is a constant incorporating both $PL(d_0)$ and $\lg(d_0)$.

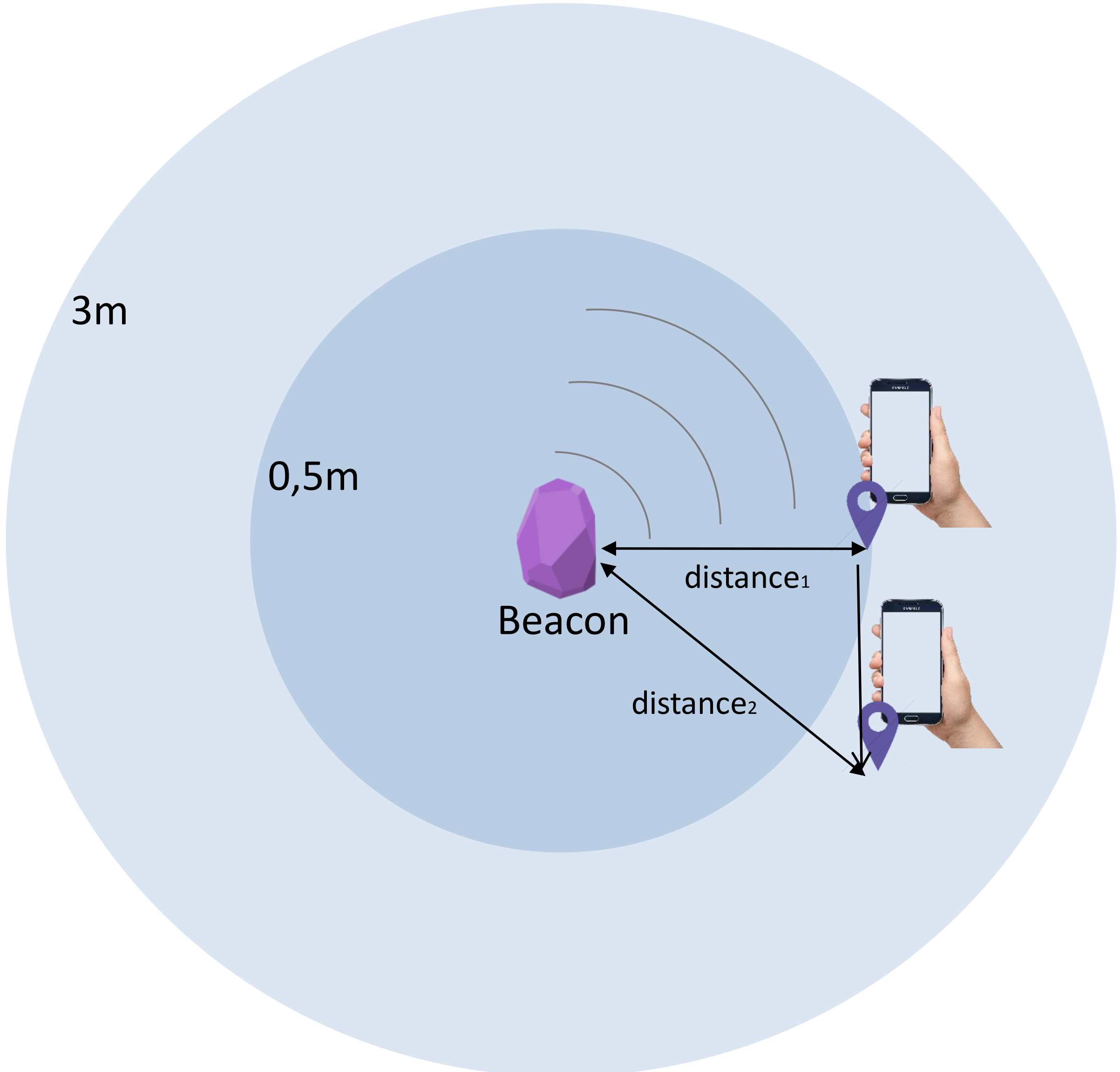
Two-dimensional Log-normal path loss



$$\hat{d}_1 = k_1 \cdot 10^{\frac{P_t - RSS_1}{10 \cdot \alpha_1}}$$

$$\hat{d}_2 = k_2 \cdot 10^{\frac{P_t - RSS_2}{10 \cdot \alpha_2}}$$

Automatic calibration procedure

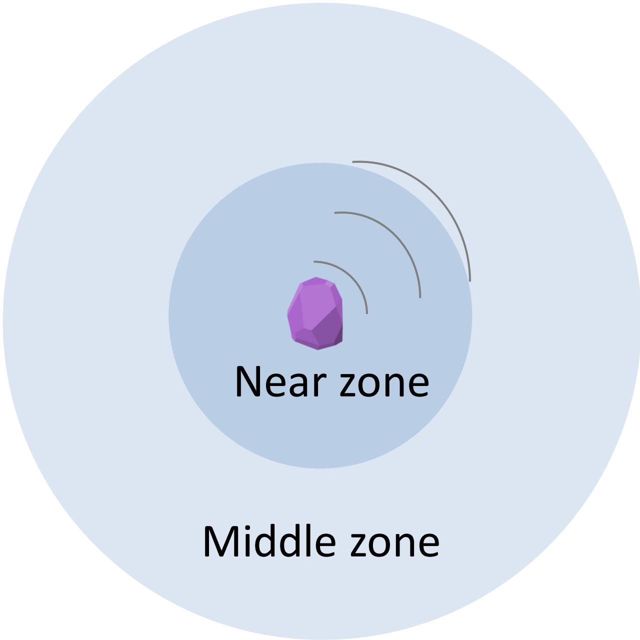


Automatic calibration procedure steps (1)

- *Step 1:* Parameter initialization. The initialization of parameters d_1 and RSS_1 for near proximity zone determination.

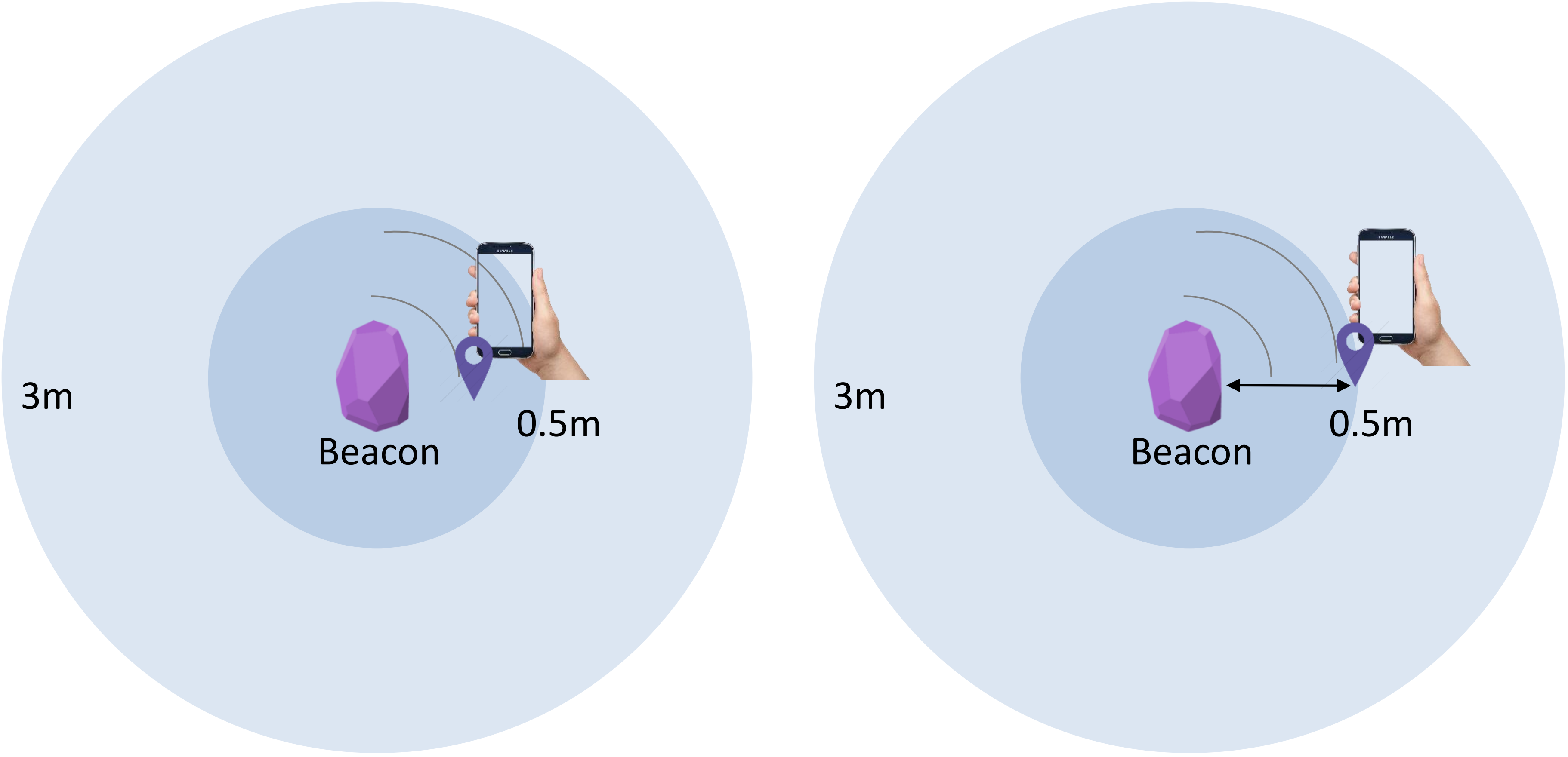
$$\hat{d}_1 = k_1 \cdot 10^{\frac{P_t - RSS_1}{10 \cdot \alpha_1}}$$

$$\hat{d}_2 = k_2 \cdot 10^{\frac{P_t - RSS_2}{10 \cdot \alpha_2}}$$



Automatic calibration procedure steps (2)

- Step 2: BLE beacon near proximity zone allocation detection.

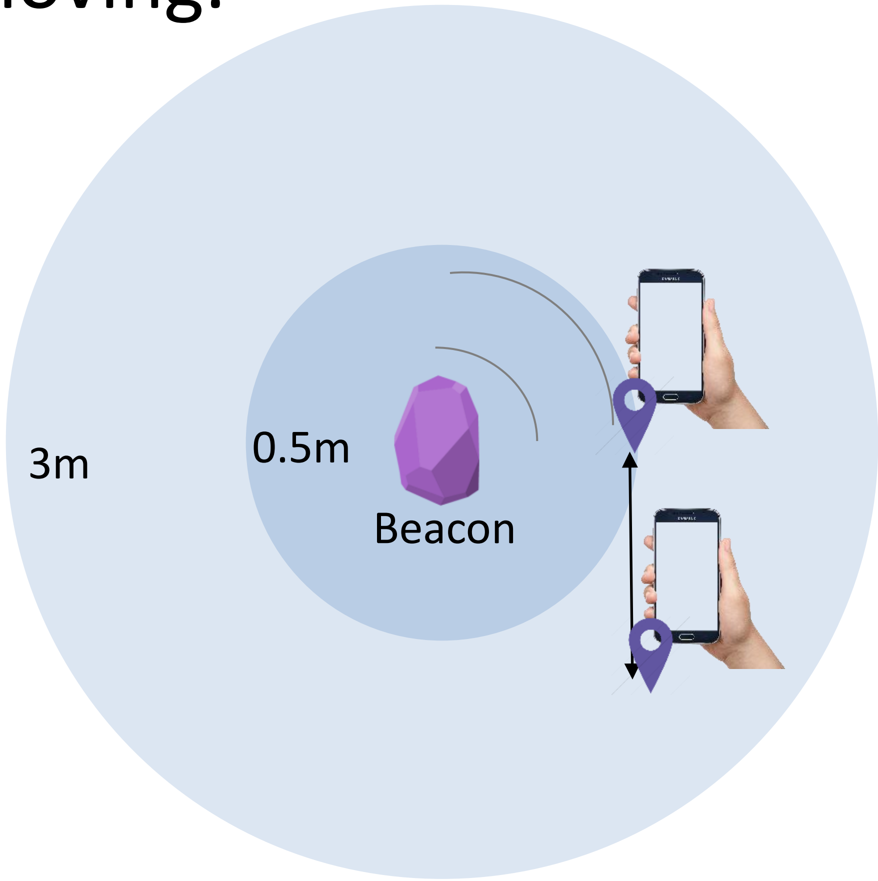


Automatic calibration procedure steps (3)

- Step 3: Calculate the distance via smartphone sensors by direct moving.

The beginning

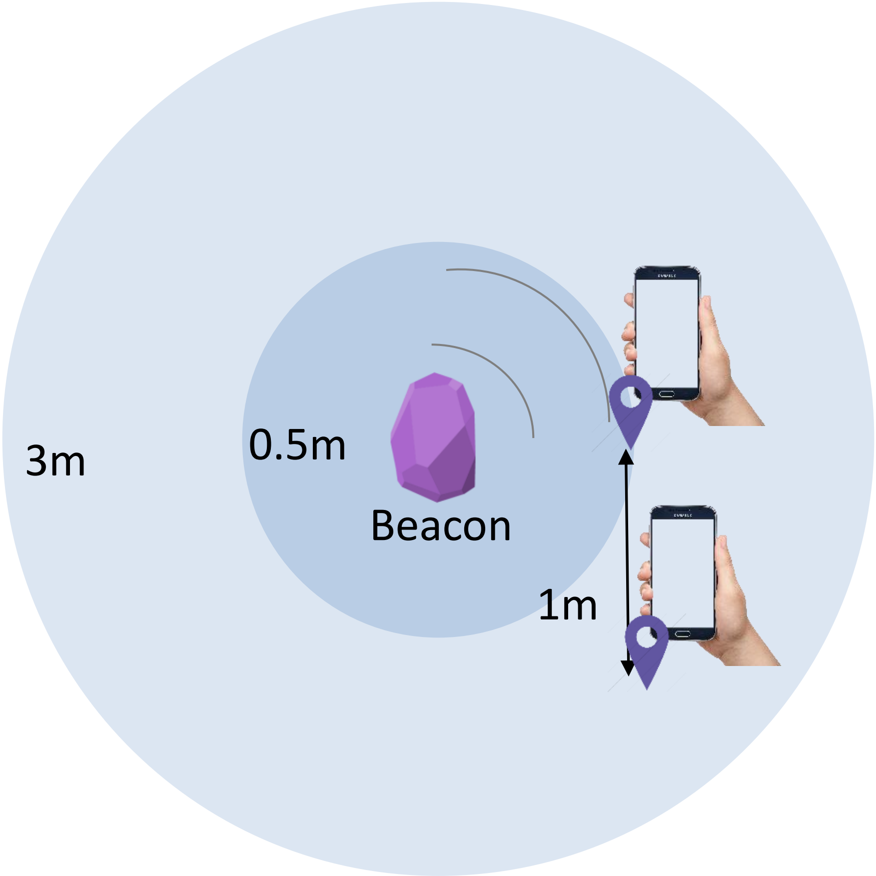
of steps counting.



Automatic calibration procedure steps (4)

- Step 4: If the distance is 1 meter measure RSS level.

$$\hat{d}_2 = k_2 \cdot 10^{\frac{P_t - RSS_2}{10 \cdot \alpha_2}}$$



Automatic calibration procedure steps (5)

- Step 5: Using the given equations calibrate the path loss model.

$$\alpha = \frac{RSS_1 - RSS_2}{10\lg \frac{d_1}{d_2}}$$

$$\lg k = \lg d_1 - 10^{\frac{(Pt - RSS)\lg \frac{d_1}{d_2}}{RSS_2 - RSS_1}}$$

Conclusion

- The presented automatic calibration procedure can be used for several wireless technology based indoor localization methods.
- The calibration procedure is sensitive to built-in smartphone sensor errors. Due to this drawback user should move only at direct line.
- The user can be an obstacle that produces estimation errors.
- The accuracy depends beacon allocation density.