Autonomous Localization Method in Wireless Sensor Networks

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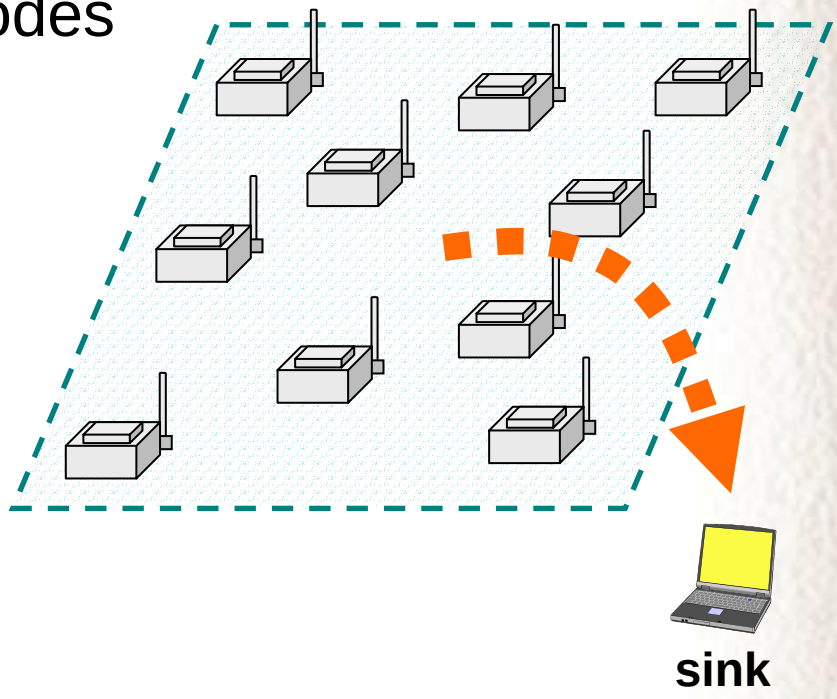
Wireless Sensor Networks

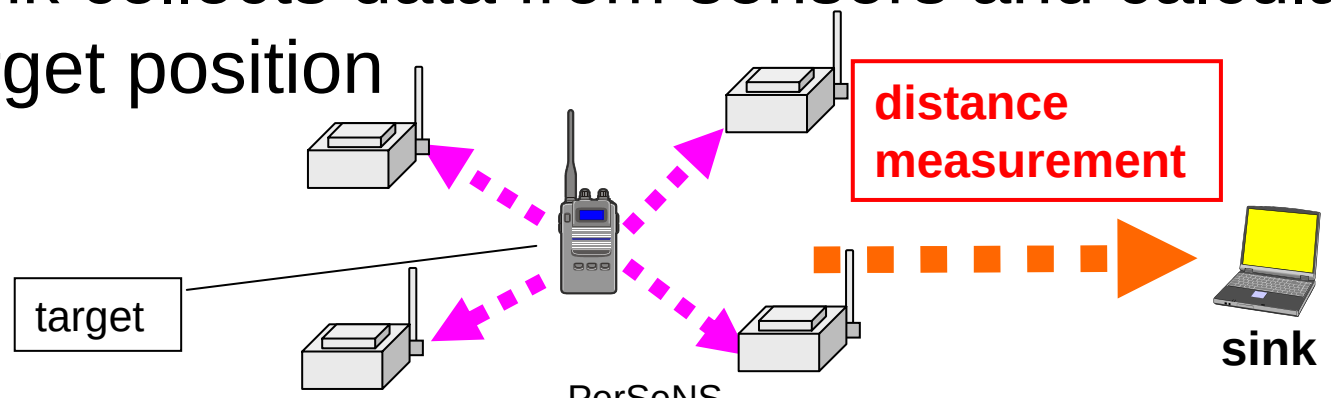
- Consist of micro-sensor nodes
- Objective
  - Monitor environment
    - temperature, motion
- Features
  - Pros
    - easy deployment
    - low cost
  - Cons
    - limited battery
    - low communication speed
    - low computation power



Sensor nodes cannot send much data

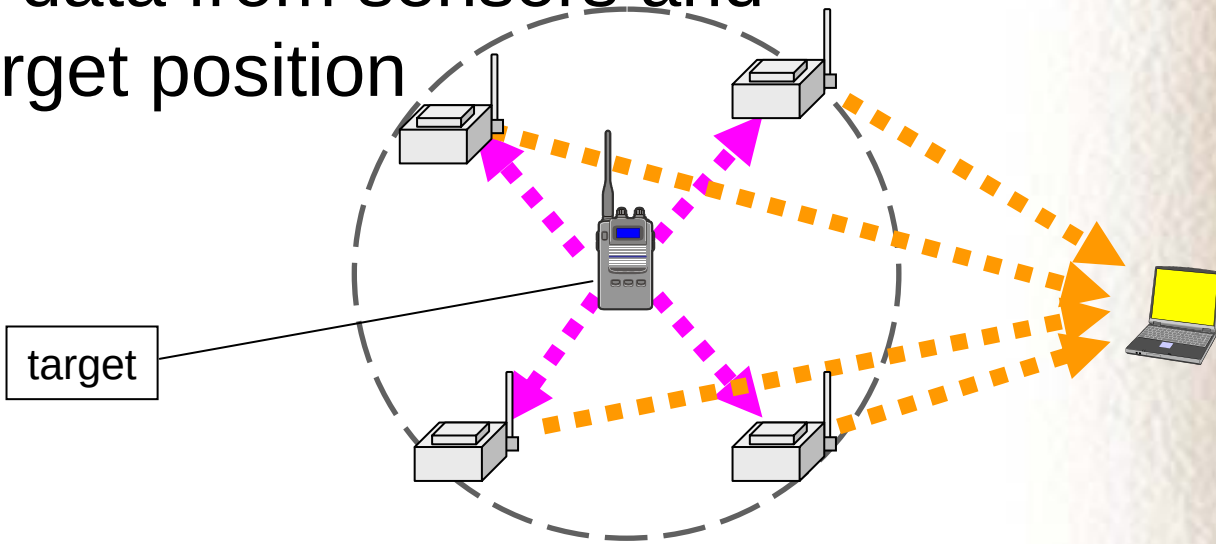
Localization System in Sensor Networks

- Sensor networks are needed for indoor localization, because GPS cannot work indoors, e.g.
  - Localization of sensor position
  - Consumer position in supermarket
  - Visitor position in exhibition, fair, etc.
- Sink collects data from sensors and calculates target position



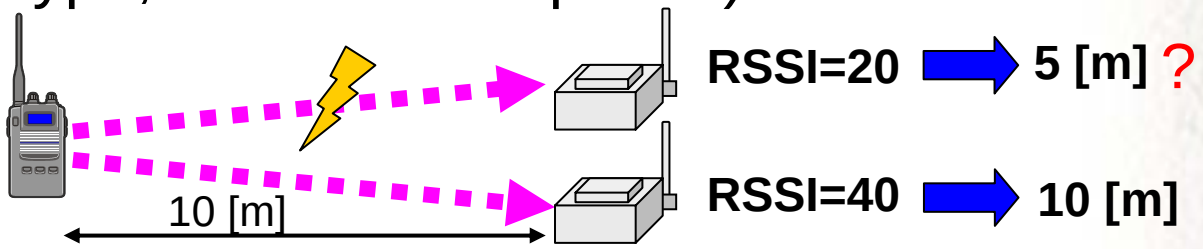
Details about Localization System

- Sensors measure the distance from target
  - Target has device which can send signal
  - Sensors receive signal from target and measure RSSI (Received Signal Strength Indicator)
- Sink collects data from sensors and calculates target position



Characteristics of RSSI Measurement

- Lower configuration cost than other methods (e.g. laser and ultrasonic wave)
- Larger error because RSSI is subject to negative effects of the fading channel
  - Radio interference
  - Obstacles (persons, walls)
  - Individual differences of transmitters and receivers (antenna type, transmission power)



Position Estimation Algorithm

- Overview
  - Sink estimates target position *(X, Y)* by using sensor position and measured distance
- Minimum Mean Squared Error (MMSE)
  - Calculate *(X, Y)* to minimize $\sum_{i=1}^{N} f_i(X,Y)^2$

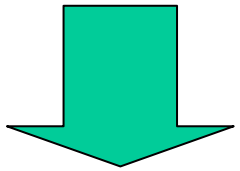
$$f_i(X,Y) = \sqrt{(X-x_i)^2 + (Y-y_i)^2} - d_i$$

(x_i, y_i) : position of sensor i d_i : distance measured by sensor i
N : amount of collected data

  - Measurements from at least three nodes required
  - Estimate position accurately in case of target being evenly surrounded by sensors
  - Cannot estimate if sensors are placed on a line

Problem

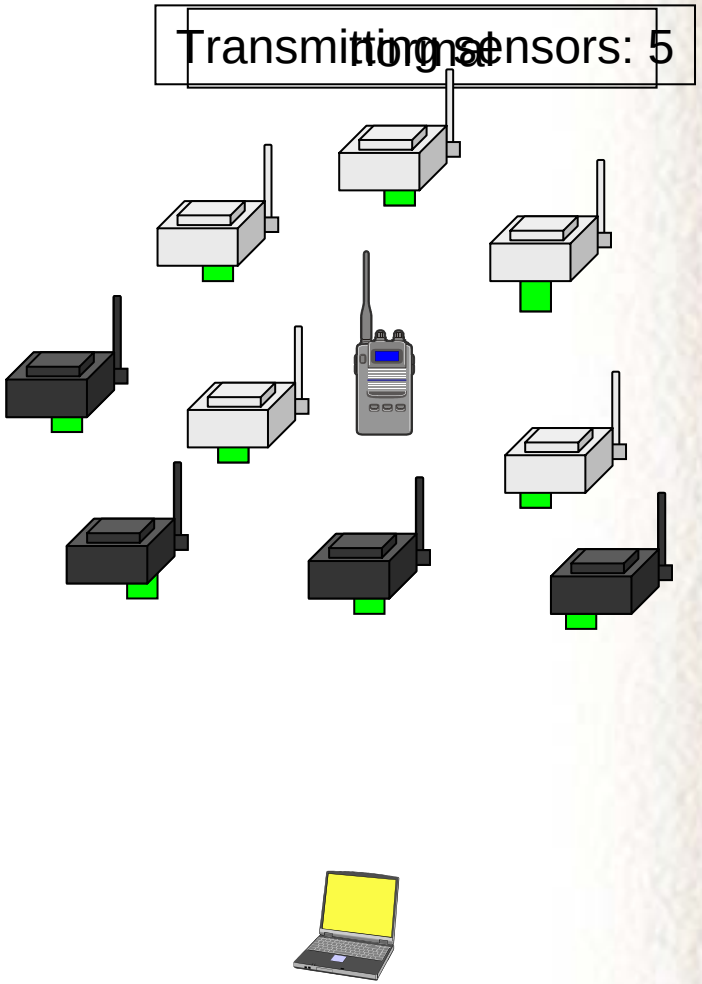
- It is difficult to collect a large amount of data in wireless sensor networks
  - Long delay
  - High energy consumption



The amount of data collected by the sensors must be controlled.

Data Collecting Technique

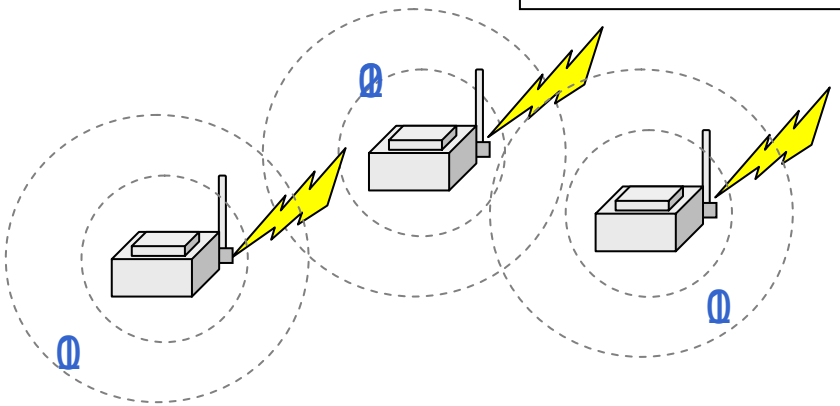
- Control the number of transmitting sensors
  - Use density of sensors and measured distance
- Our mechanism
  - Measure density of sensors
  - Control the number of transmitting sensors



Measure Density of Sensors

- Sensors count the number of surrounding sensors by receiving discovery packets from other sensors
- Density ρ_i around sensor i
  - $\rho_i = M_i / (\pi R^2)$

M_i ： number of sensors around sensor i
R ： radio range



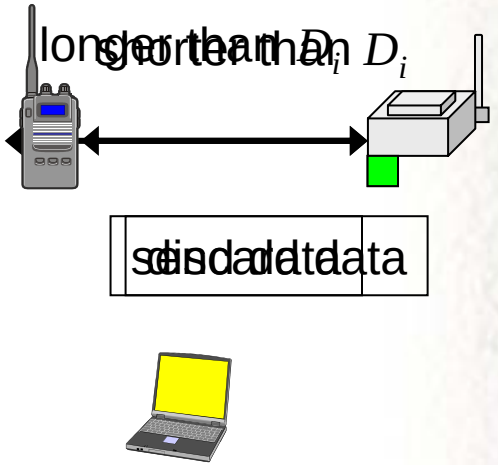
Transmission Control Method

- To control data transmission of Z sensors
  - Sensors decide to send data depending on the measured distance
    - sensors send data if distance is within D_i [m]
- Calculation of D_i
  - Use proportional relationship between D_i [m] and density ρ_i

$$\rho_i = \frac{Z}{\pi D_i^2}$$

$$D_i = \sqrt{\frac{Z}{\pi \rho_i}}$$

Z: amount of required data

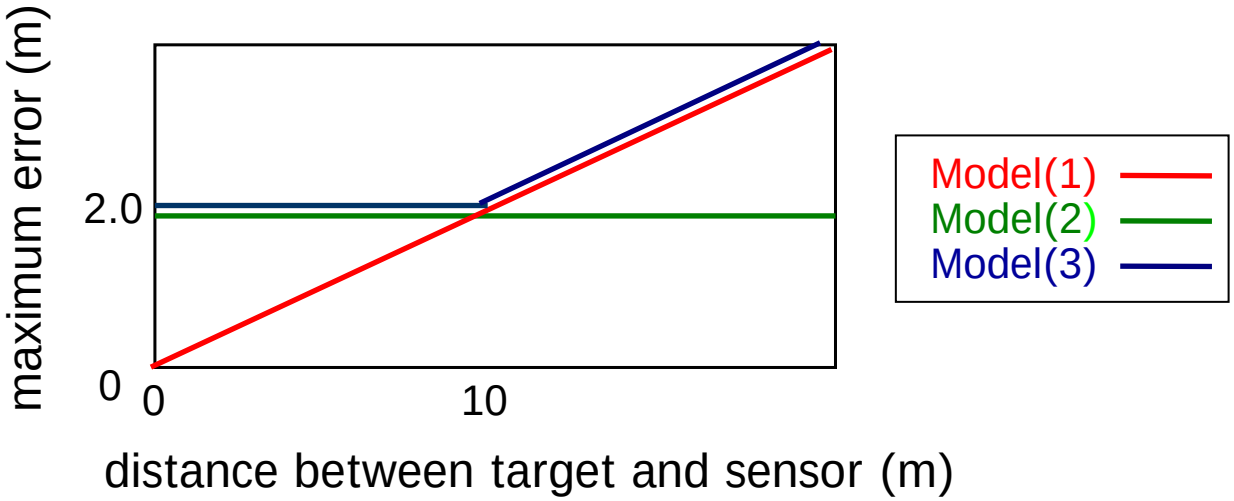


Simulation Settings

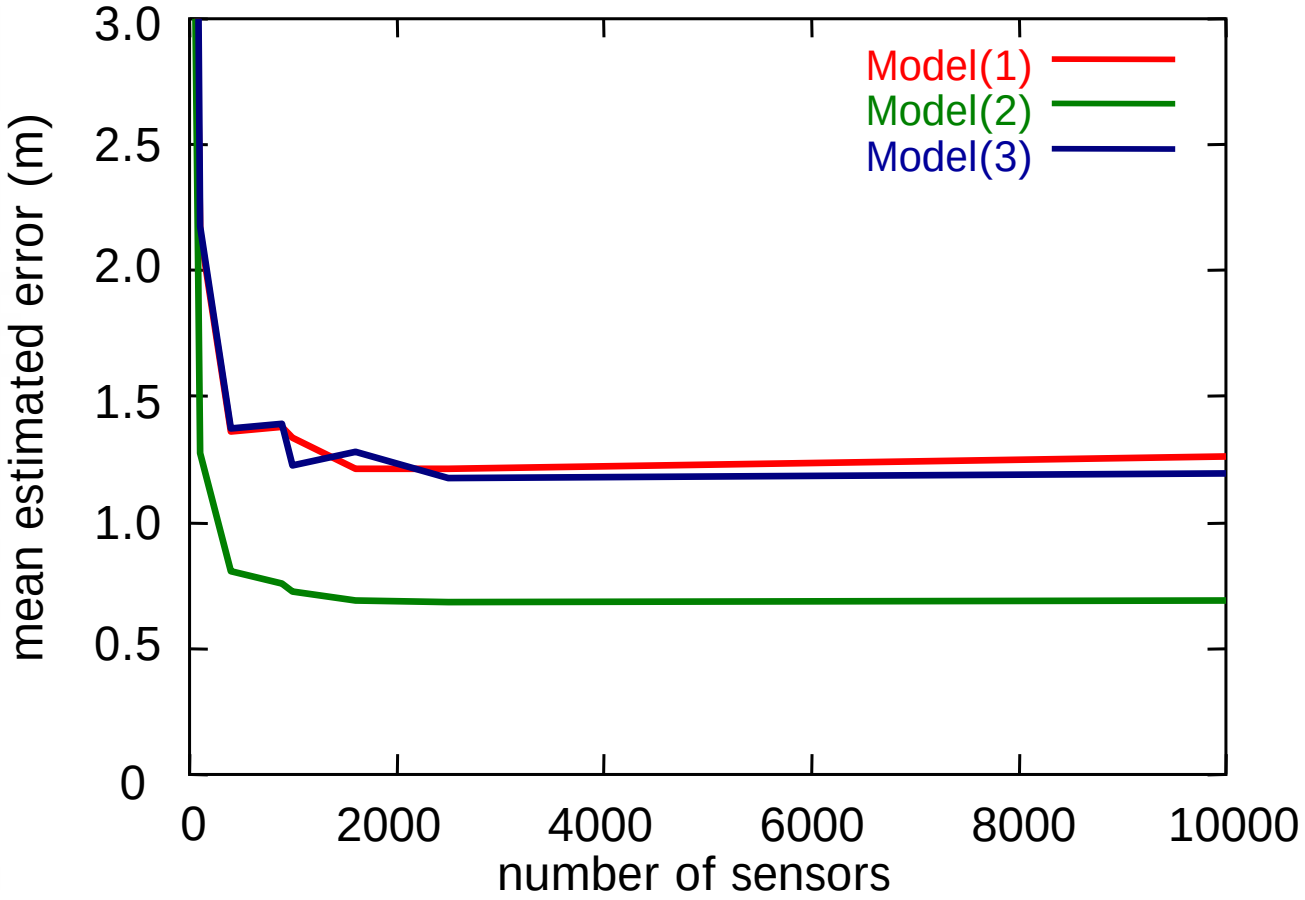
- Simulation area: 100×100 [m^2]
  - 25, 100, 400, 900, 1000, 1600, 2500, 10000 sensors deployed
  - Randomly generate target position
  - Topology is grid or random
- Radio range of target is 20 [m]
  - Sensors within 20 [m] from target can measure RSSI
- Estimate target position by using all collected data
- Measurement error of sensors

Measurement Error of Sensors

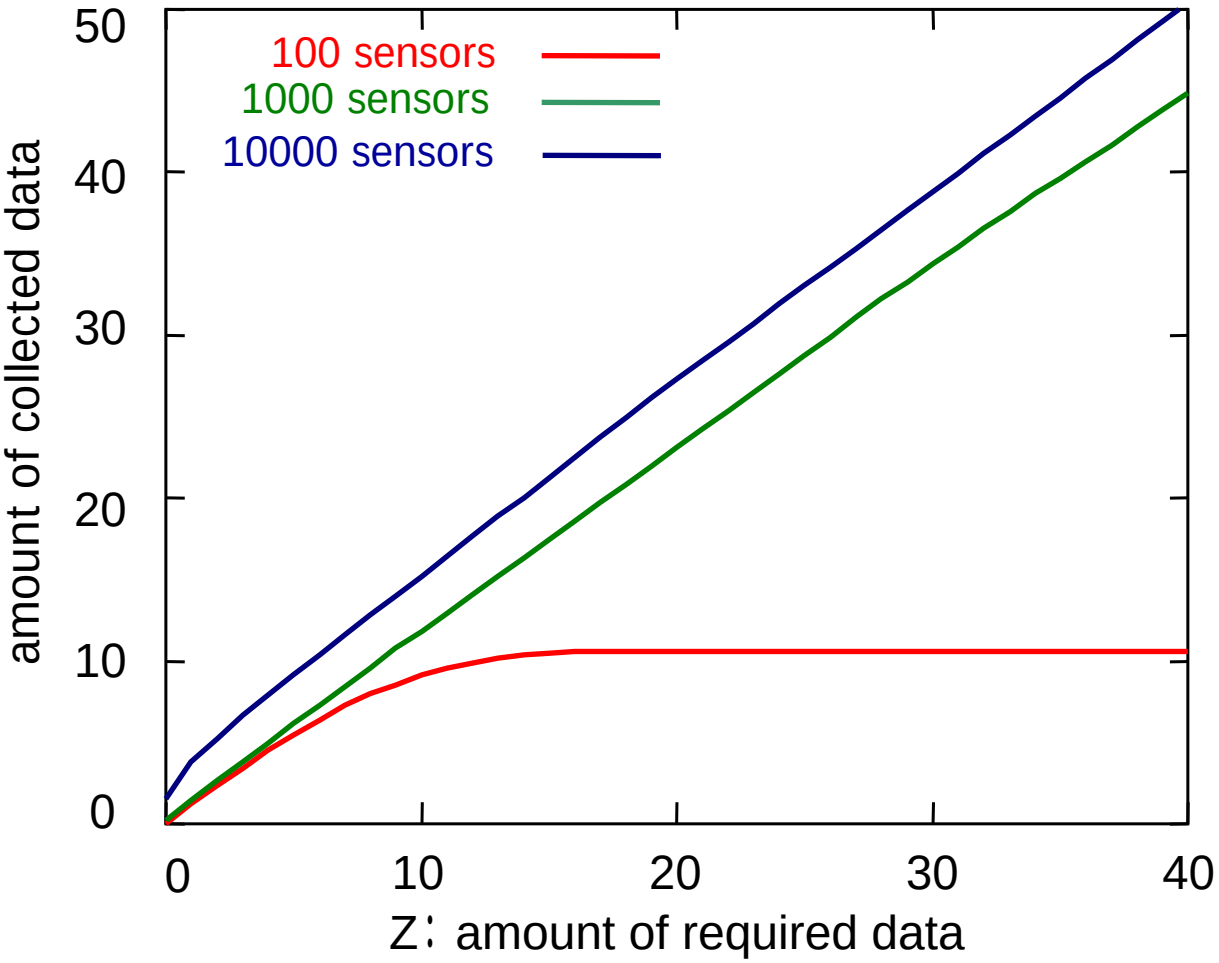
- 3 models with random measurement errors
  - Model(1)・・・ ± 20% of distance
  - Model(2)・・・ ± 2m
  - Model(3)・・・ ± 2m (distance under 10m)
    ± 20% of distance (distance over 10m)



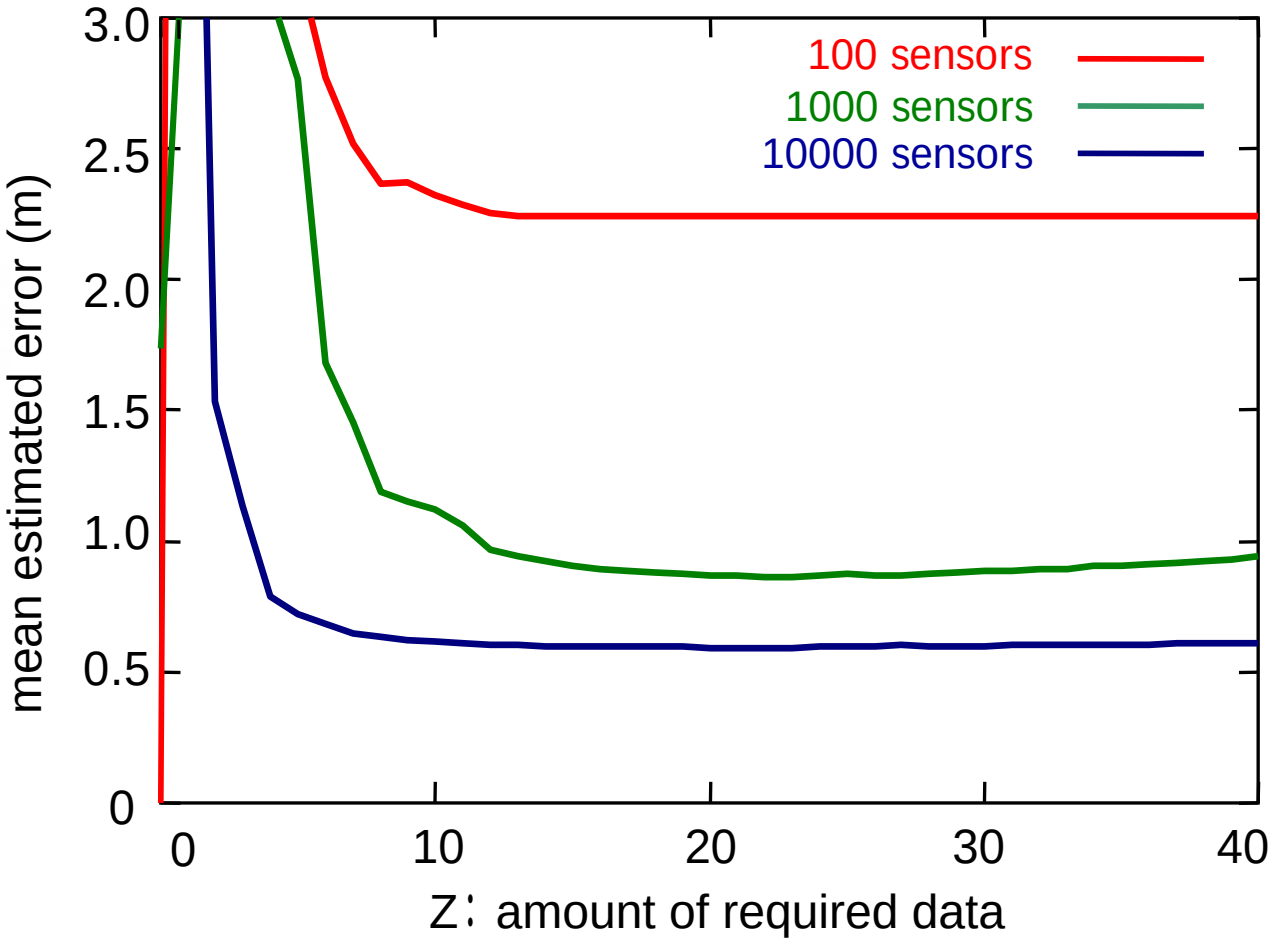
Localization Error vs. Number of Sensors



Performance of Data Collecting Technique (Number of Collected Data)



Performance of Data Collecting Technique (Localization Error)



Conclusion and Future Work

- Conclusion
  - We proposed a method for localization in sensor networks
    - Measurement of node density
    - Transmission is controlled depending on distance from target
  - Our proposal can control the amount of collected data and achieve high accuracy for localization

- Future Work
  - Evaluation of energy consumption and delay
  - Mechanism for operation in sparse networks