Power Optimization in Tracking Device and Technology for Logistics Applications

Senior Design Project Presentation

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Outline

- Project Overview
- System Model
  - Hybrid and Collaborative Mechanism
  - Tag Classification
  - Control Center
- Optimization Formulation
- Numerical Results
- Conclusion

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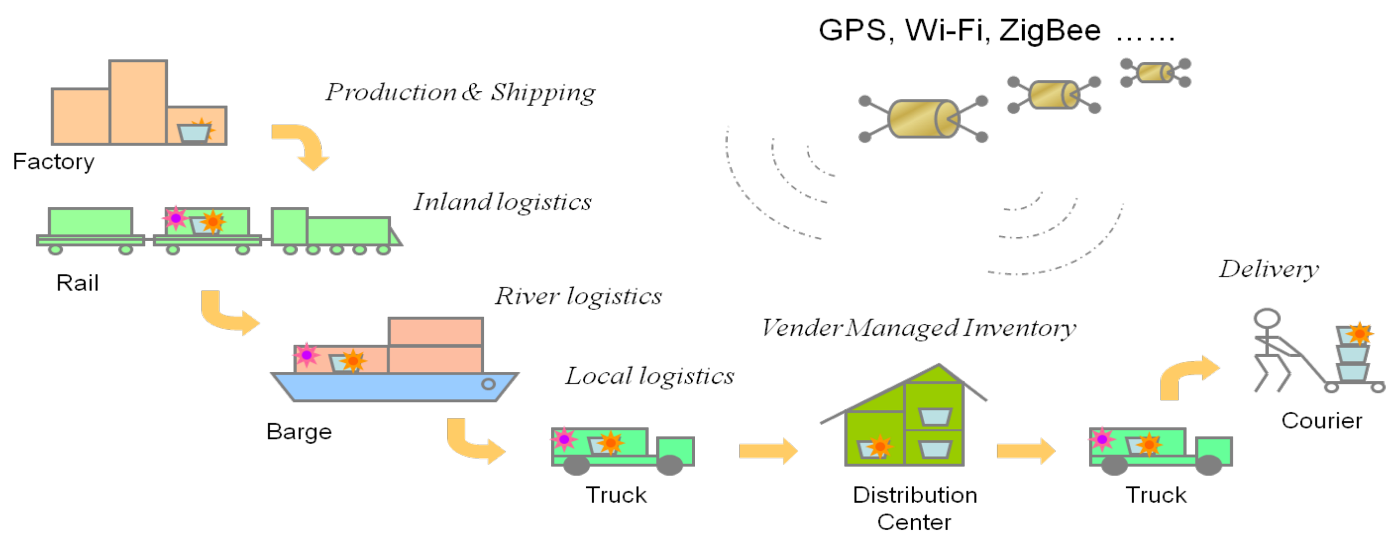
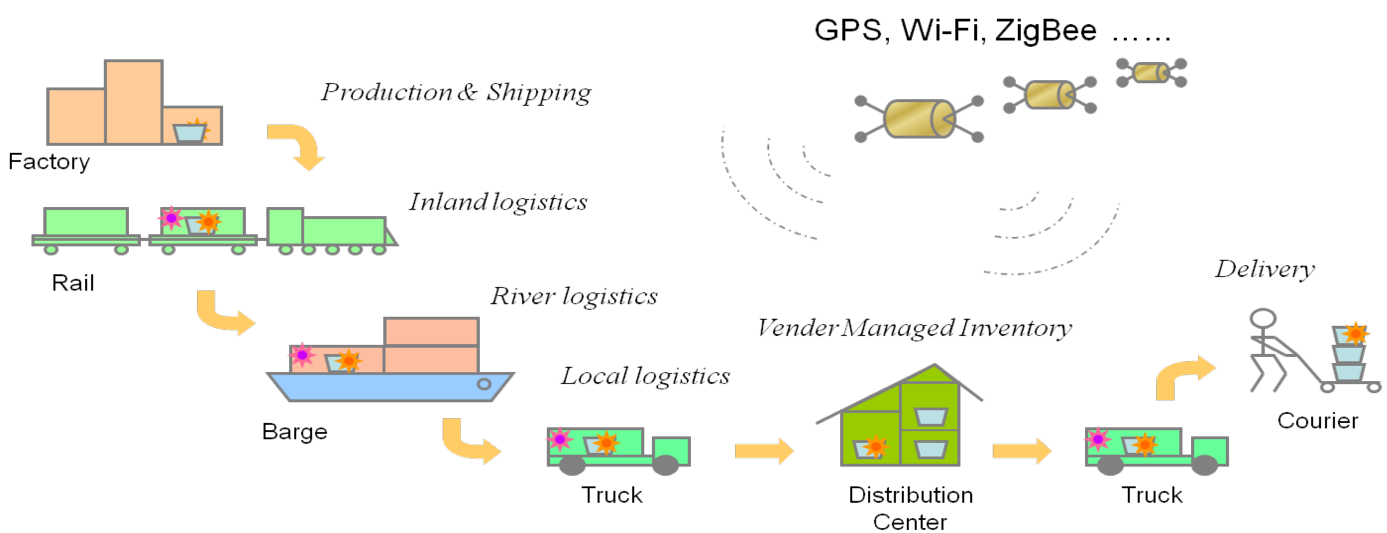
Project Overview

- Objectives: to develop low-cost tracking devices and ubiquitous tracking technologies for logistics applications.



Project Overview

- Challenges:
  - How to realize ubiquitous positioning?
  - How to minimize power consumption in the location-based services?



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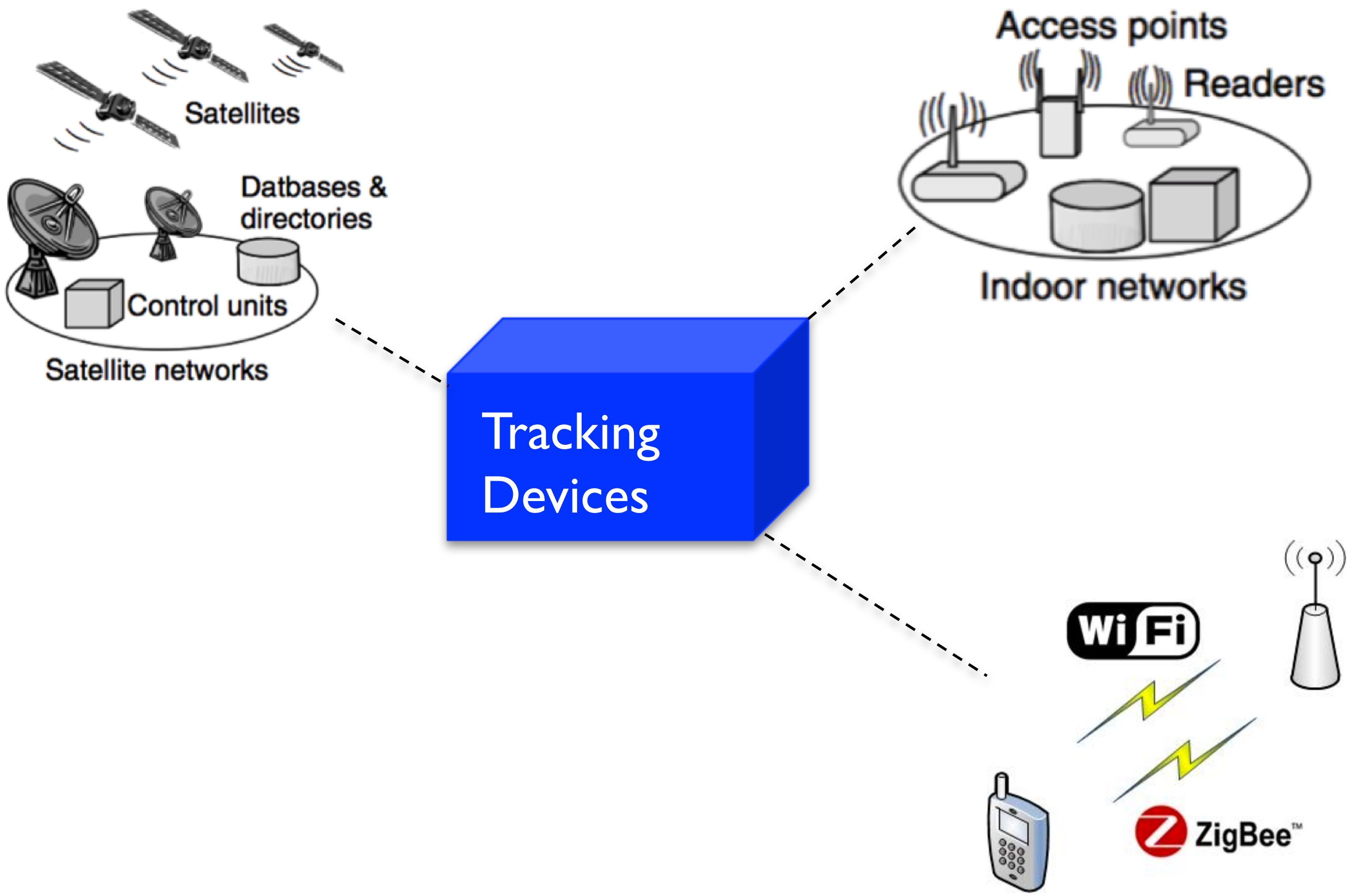
System Model

- Hybrid Mechanism



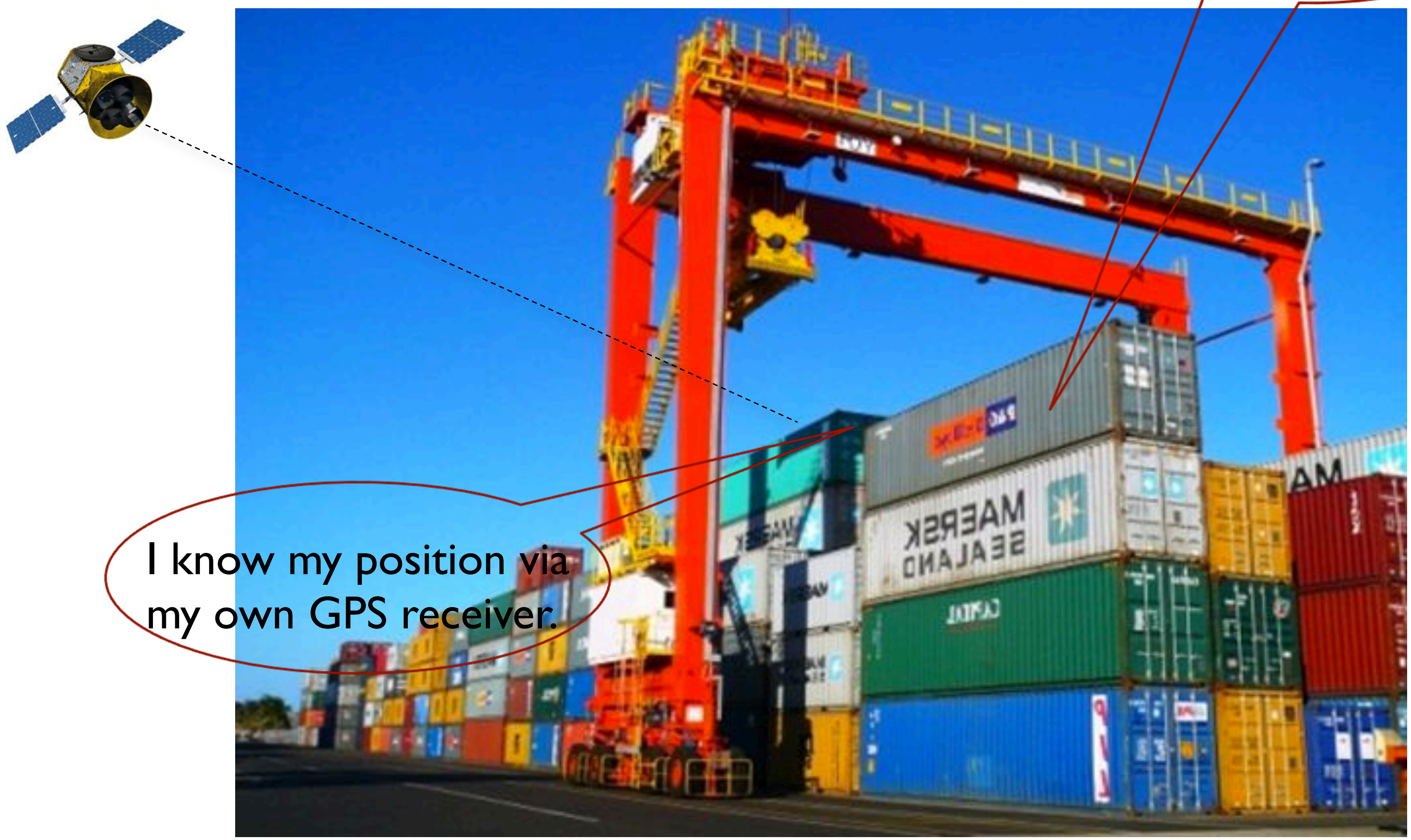
System Model

- Hybrid Mechanism

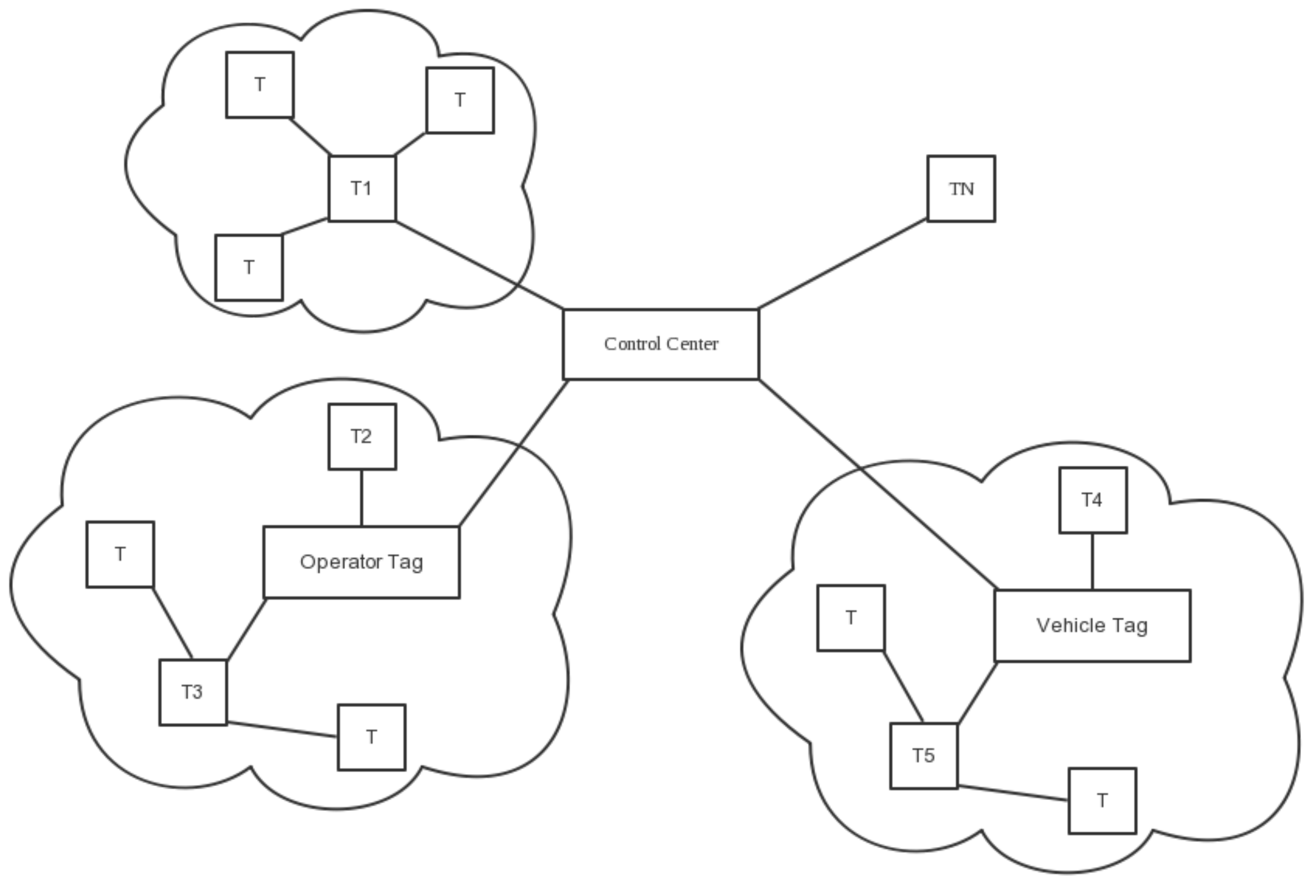
Positioning Technology	Indoor or Outdoor	Accuracy	Range & Coverage	Deployment Cost	Mobile Unit Cost	Operation & Maintenance Costs
GPS	***Outdoor***	Medium	Long Global	N/A	Low	Low
GPRS	Indoor & Outdoor	***Low***	Long	N/A	Medium	High
Wi-Fi	Indoor & Outdoor	***Medium***	Long	Medium	Low	Low
ZigBee	Indoor & ***Confined Outdoor***	High	Medium	Medium	Low	Low
Hybrid	***Indoor & Outdoor***	***High Adaptive***	***Long & Global***	***Low to Medium***	***High***	***High***

System Model

- Collaborative Mechanism

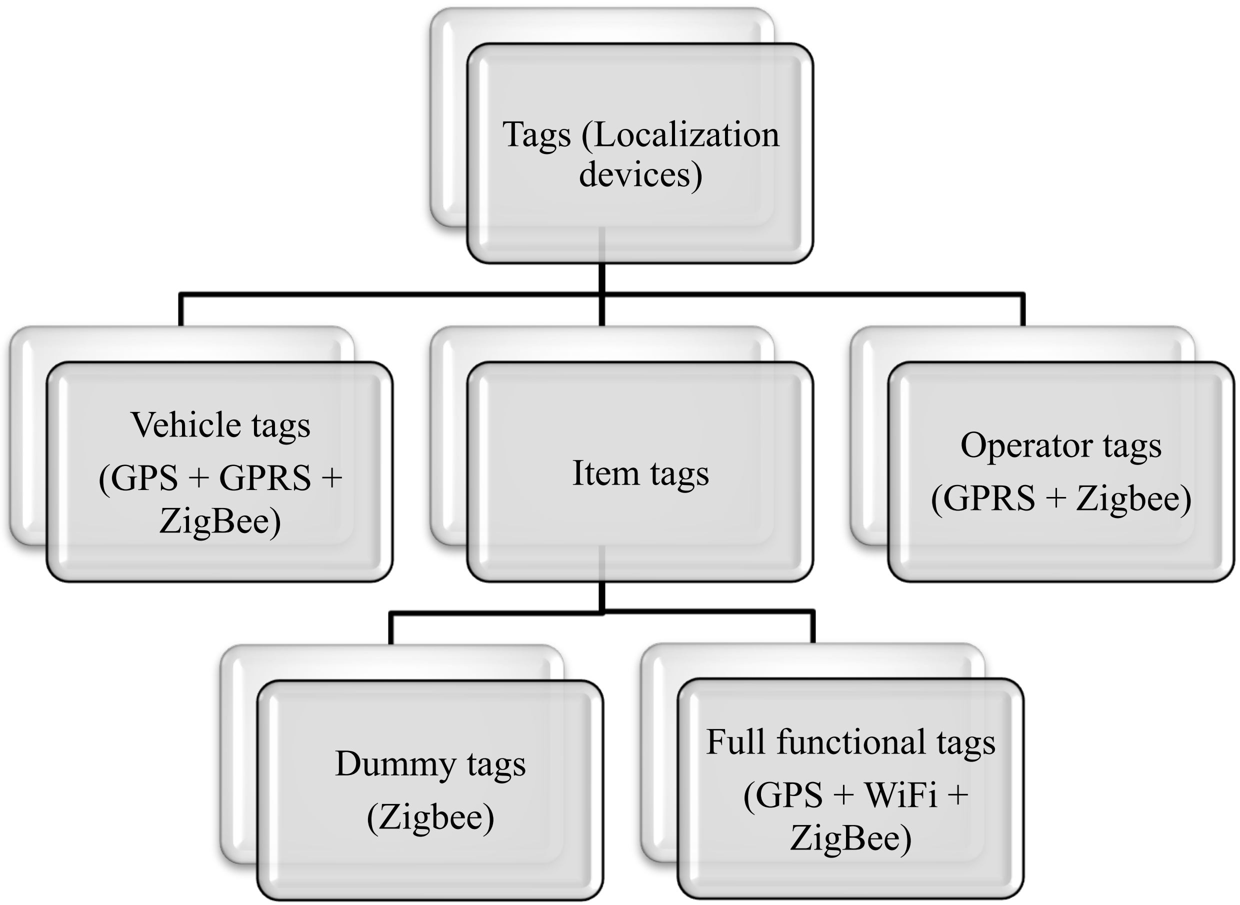


System Model



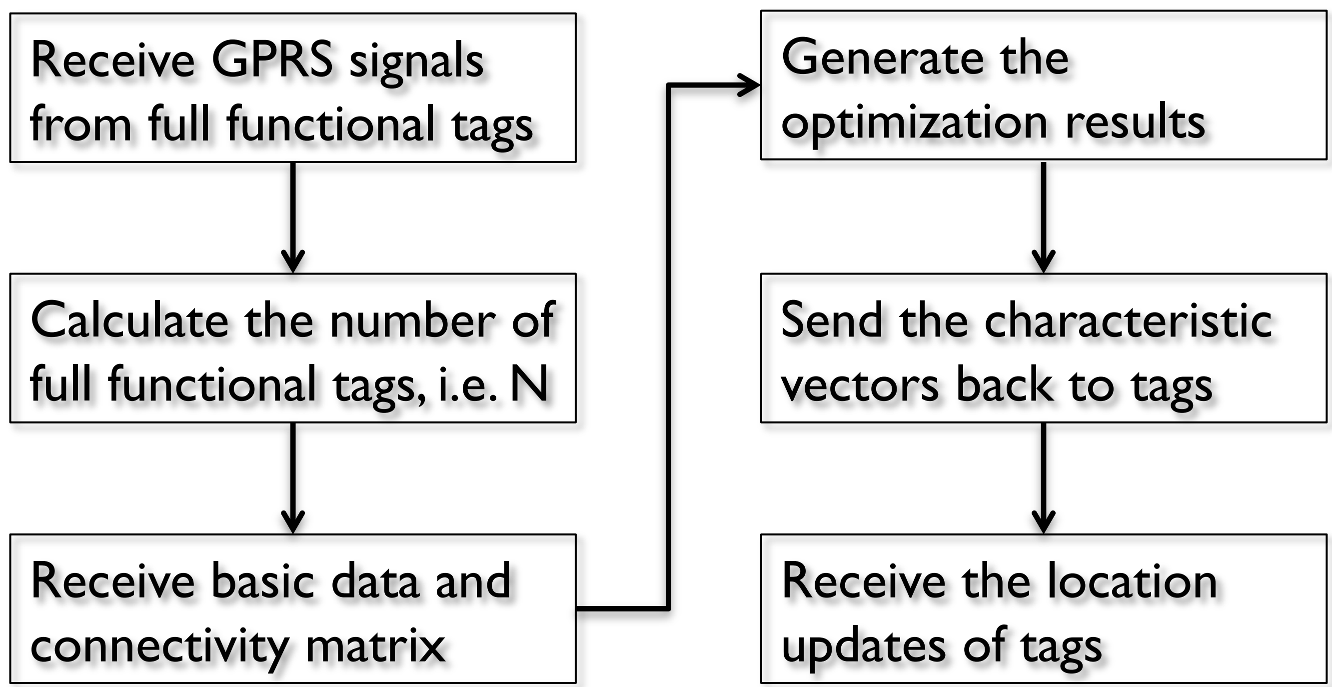
System Model

- Tag Classification



System Model

- Algorithm of Control Center



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Optimization Formulation

- Control center: unlimited in energy and power
- Dummy tags: fixed amount of energy
- Operator or vehicle tags: unlimited in energy
- Major concern: power consumption of full functional tags

- Full functional tags: $\mathbf{T} = \{T_1, T_2, \ldots, T_N\}$
- Zigbee neighbor discovery

$$Z = \{Z(i,j),\ i,j = 1,\ldots,N\}$$

$$Z(i,j) = \begin{cases} 1, & \text{if i and j are connected} \\ 0, & \text{otherwise} \end{cases}$$

Optimization Formulation

- Power Consumption of Tag T_i

$$E_i = f(\overrightarrow{X_i}) = (X_{i,1}, X_{i,2}, X_{i,3}) \begin{pmatrix} AE_1 \\ AE_2 \\ AE_3 \end{pmatrix}$$

where

$$X_{i,1} = \begin{cases} 1 & \text{if GPS module of } T_i \text{ is enabled} \\ 0 & \text{otherwise} \end{cases}$$

$$X_{i,2} = \begin{cases} 1 & \text{if WiFi module of } T_i \text{ is enabled} \\ 0 & \text{otherwise} \end{cases}$$

$$X_{i,3} = \begin{cases} 1 & \text{if Zigbee module of } T_i \text{ is enabled} \\ 0 & \text{otherwise} \end{cases}$$

$$AE_k = \begin{cases} T_1 + C & k = 1 \\ T_2 & k = 2 \\ T_3 & k = 3 \end{cases}$$

is the average consumption of GPS, WiFi, and Zigbee module respectively.

T_k: energy consumption for transmission

C: energy consumption for GPRS communication

Optimization Formulation

- Positioning Uncertainty of Tag $\mathrm{T_i}$

$$g(\overrightarrow{X_i}) = \begin{cases} \Delta_j & \text{if } X_{i,j} = 1, j \in \{1,2\} \\ R_{\text{Zigbee}} + \min g(\overrightarrow{X_i}) & \text{if } X_{i,j} = 0, j \in \{1,2\}, X_{i,3} = 1, Z(i,k) = 1 \end{cases}$$

$\Delta j,\ j \in \{1,2\}$ is the positioning uncertainty of GPS and WiFi module.

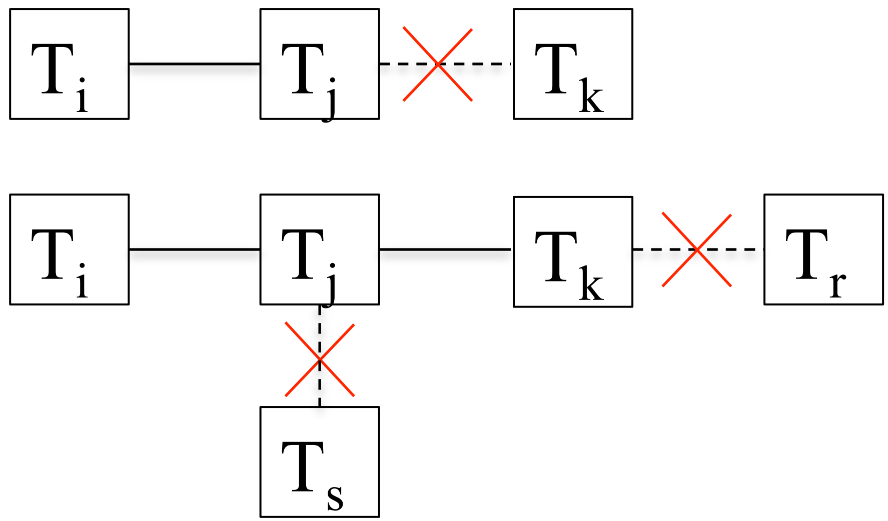
R_{ZigBee} is the transmission range of Zigbee module.

- Positioning Uncertainty of the System

$$\overline{PU} = \frac{1}{N}\sum_{i=1}^{N} PU_i$$

Optimization Formulation

- Constraints on Number of Tags Connected



$$g(\overrightarrow{X_i}) = \begin{cases} \Delta_j & \text{if } X_{i,j} = 1, j \in \{1,2\} \\ R_{\text{Zigbee}} + \min g(\overrightarrow{X_i}) & \text{if } X_{i,j} = 0, j \in \{1,2\}, \\ & X_{i,3} = 1, Z(i,k) = 1, X_{k,3} = 0 \end{cases}$$

Optimization Formulation

- Optimization Function
  - Objective: To minimize the total power consumed by all full functional devices

$$\min \sum_{i=1}^{N} E_i$$

  - The above optimization objective is subject to

$$\overline{PU} \leq \Delta$$

where Δ is the threshold of the required system positioning accuracy.

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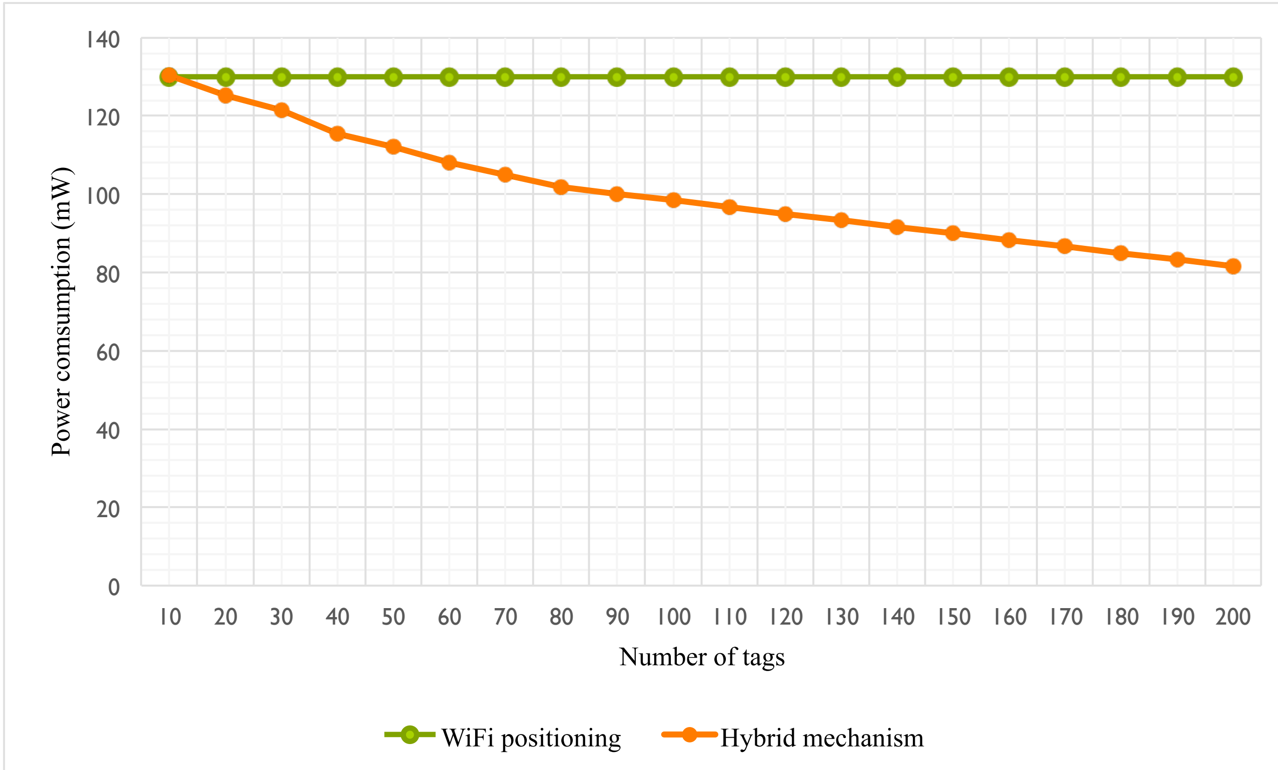
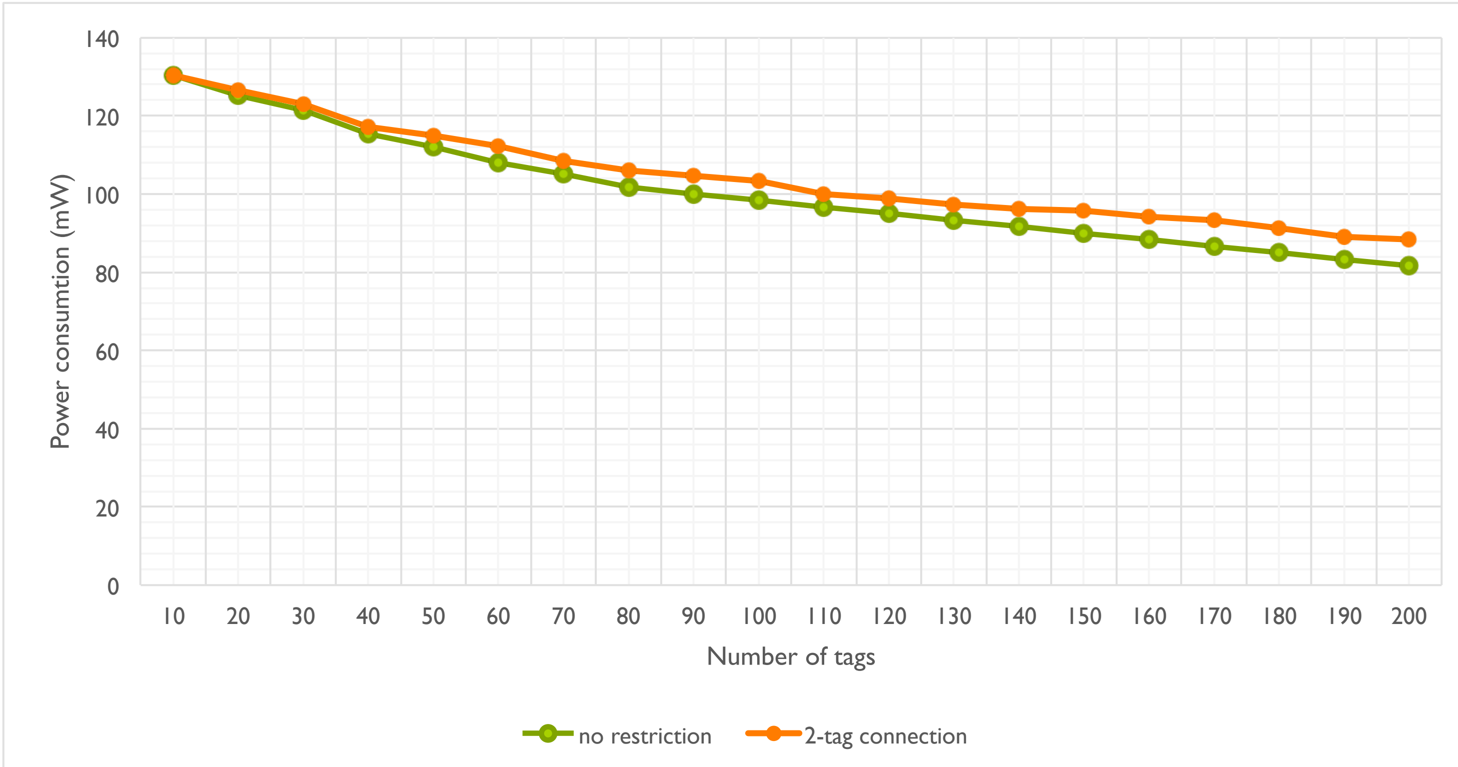
Numerical Results



Normalized power consumption with accuracy requirement of 30m

Numerical Results



Normalized power consumption with constraints on the number of tags connected

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Conclusion

- Results of computation have shown that the normalized power consumption has decreased when the number of tags is increasing.
- The hybrid and collaborative mechanism we have proposed outperforms any single positioning mechanism, i.e. GPS, WiFi, etc.
- Further improvements may lie on more realistic power consumption and accuracy assumptions.

Thank you!

Q&A

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