Power Optimization in Tracking Device and Technology for Logistics Applications

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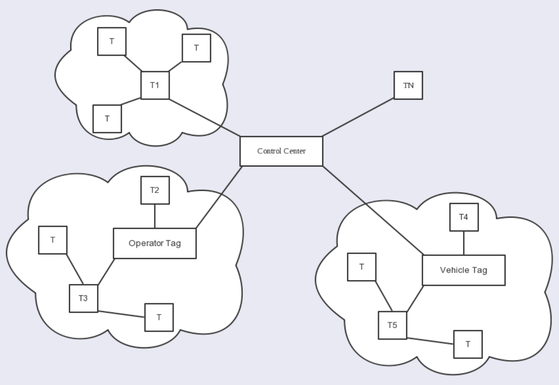
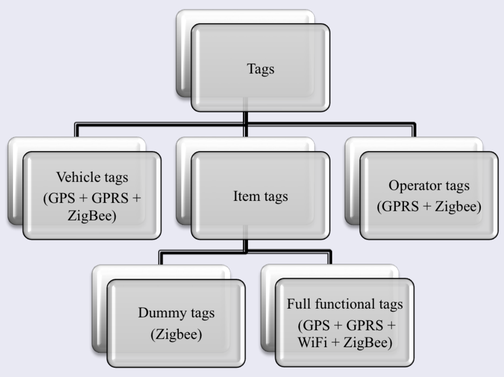
Abstract

- None of the localization methods, by itself, such as GPS, WiFi positioning, works well under all conditions.
- A hybrid and collaborative localization mechanism is proposed to provide location-based service for logistics applications.
- An optimization problem is formulated to minimize the power consumption of tracking devices in the hybrid mechanism.
- Result shows that the proposed hybrid mechanism outperforms any single localization.

System Model

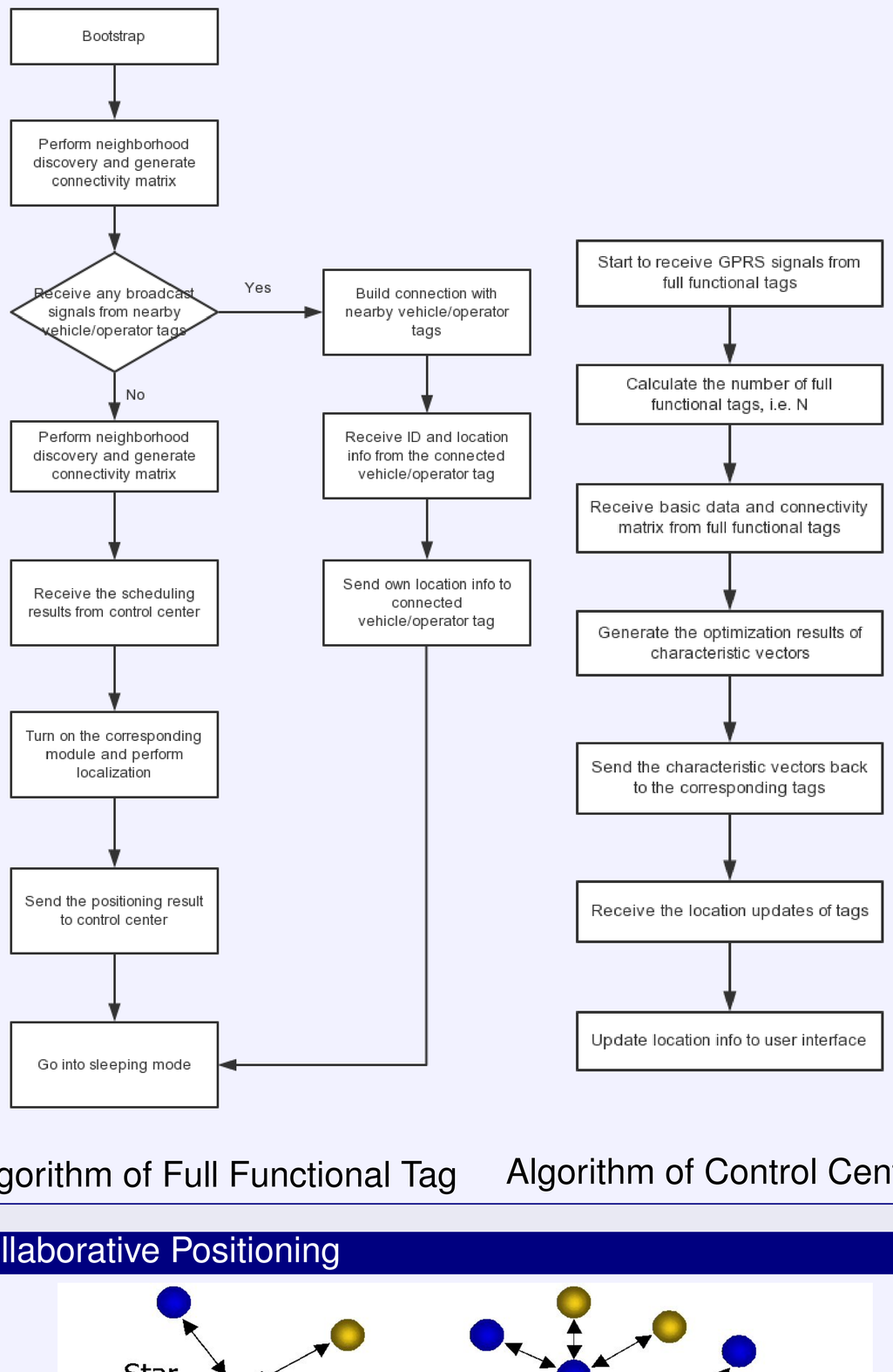


System Structure



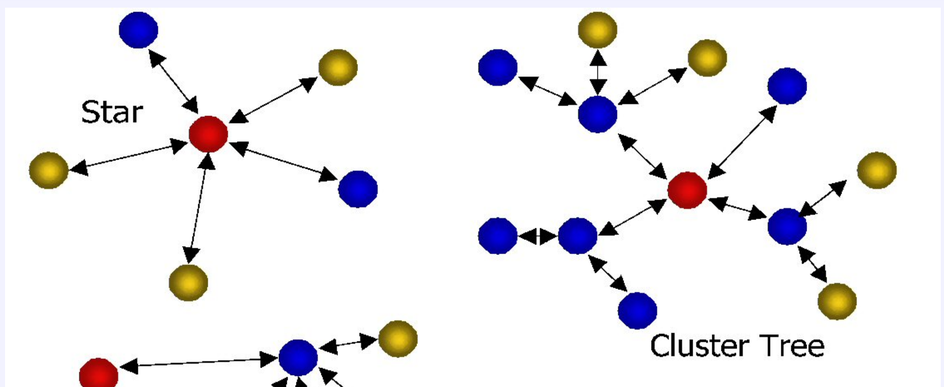
Tag Classification

Algorithms



Algorithm of Full Functional Tag Algorithm of Control Center

Collaborative Positioning



- If a full functional device can find a neighboring tag with an active GPS receiver, it can turn its own GPS receiver off and connect with its neighbor via Zigbee module.
- Certain tags are called reduced function devices.
- The structure can be roughly categorized into star structure, mesh structure, and coster tree structure.

Optimization Formulation

Zigbee Neighborhood Discovery

The number of tags to which a single tag T_i is connected is called the degree of the tag T_i.

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

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

Energy Calculation

Assume that the same module in different tags have the same working principle and power consumption.

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

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

T_k: energy consumption for transmission

C: energy consumption for GPRS communication

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 $X_{i,1}$, $X_{i,2}$ or $X_{i,3}$ is 1 when GPS, WiFi or Zigbee module of T_i is enabled, respectively. Otherwise it is zero. And the vector $\overrightarrow{X_i} = (X_{i,1}, X_{i,2}, X_{i,3})$ is called the characteristic vector of tag T_i. Since we assume that one tag only has one module on at a time, then $\left\| \overrightarrow{X_i} \right\| = 1$.

Positioning Uncertainty

Positioning Uncertainty of Tag T_i:

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

where Δ_1 and Δ_2 is the positioning uncertainty of GPS and WiFi module respectively. And the transmission range of Zigbee module is R_{Zigbee}.

Positioning Uncertainty of the System

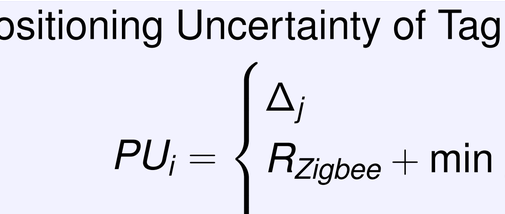
$$\overline{PU} = \frac{1}{N} \sum_{i=1}^{N} \left(PU_i + T_3 \sum_{i=1}^{N} \sum_{\substack{k=1 \\ i \neq k}}^{N} Z(i,k) \right)$$

Objective Function

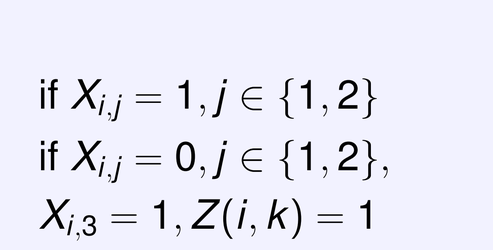
$$\min \sum_1^N E_i \; \textit{subjective to} \; \overline{PU} \leqslant \Delta$$

where Δ is a given requirement of positioning accuracy.

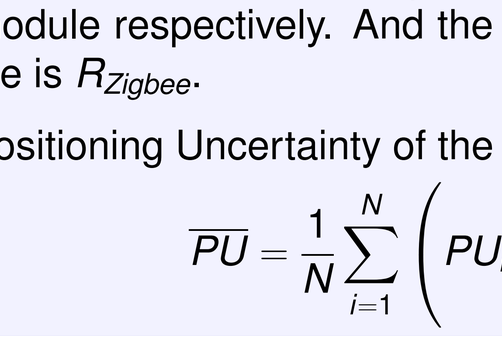
Numerical Results



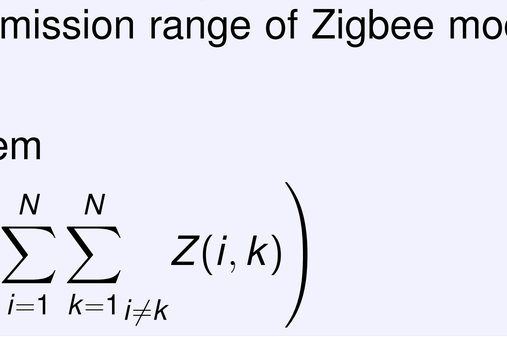
Total power consumption with accuracy requirement of 30m



Normalized power consumption with 30m accuracy requirement



Total power consumption with different number of tags



Normalized power consumption with different number of tags

Conclusion

- The hybrid and collaborative localization mechanism proposed outperforms any single positioning method when the number of tags are sufficiently large.