MobiQuitous 2013

Focus and Shoot: Efficient Identification over RFID Tags in the Specified Area

Yafeng Yin[1], Lei Xie[1], Jie Wu[2], Athanasios V. Vasilakos[3], Sanglu Lu[1]

[1]State Key Laboratory for Novel Software Technology, Nanjing University, China
[2]Department of Computer and Information Sciences, Temple University, USA
[3]University of Western Macedonia, Greece

Outline

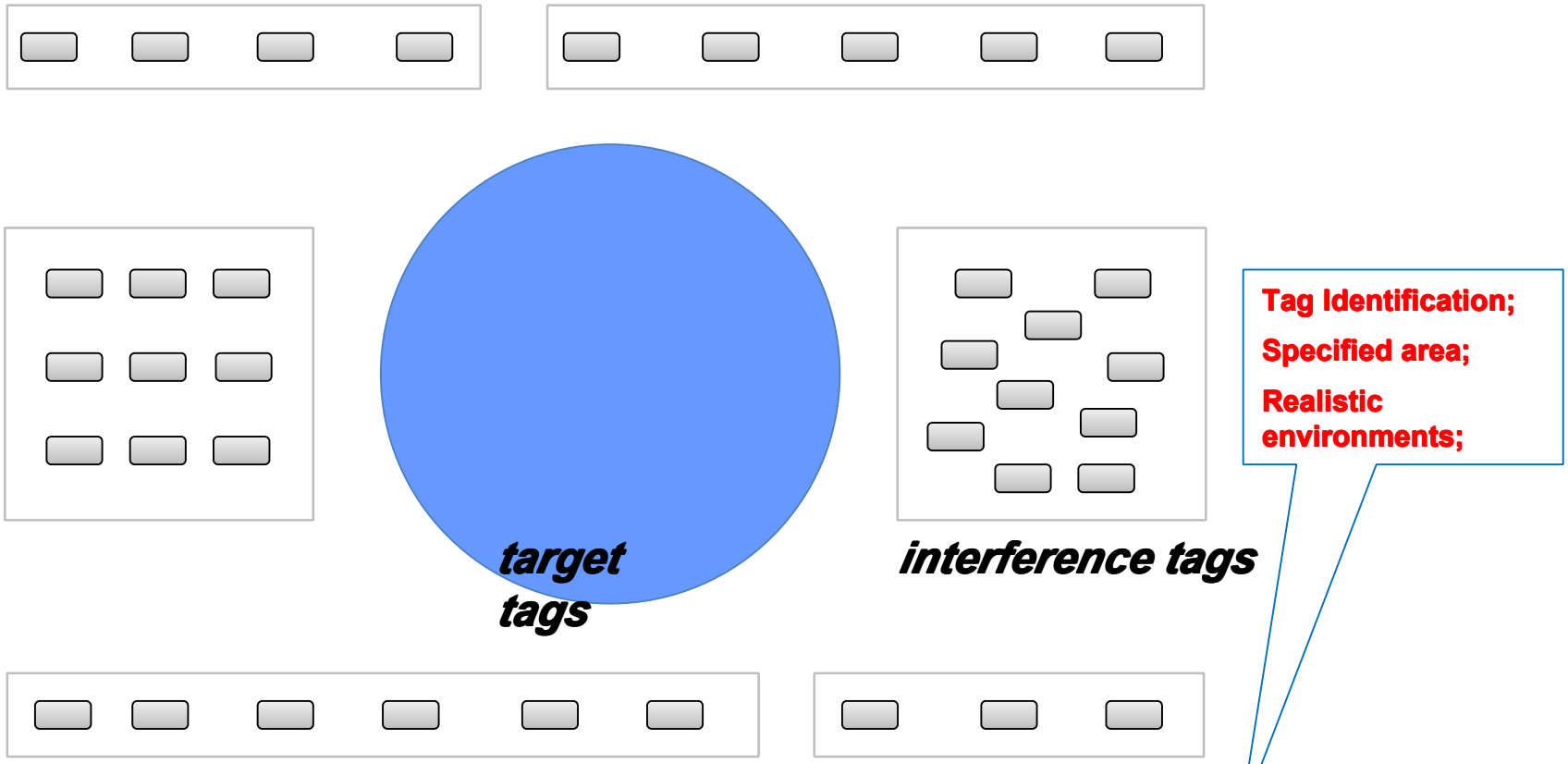
1. Motivation and Problem
2. Observations
3. Baseline Solutions
4. Our Solutions
5. Evaluation and Conclusion

Scenario

In these kinds of applications, in order to have a good knowledge of the tags in the specified area, we need to identify as many tags as possible in the area efficiently.

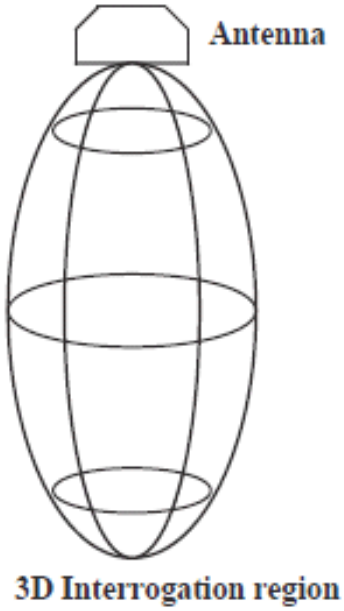
→ **How to efficiently identify the tags in the specified area ?**

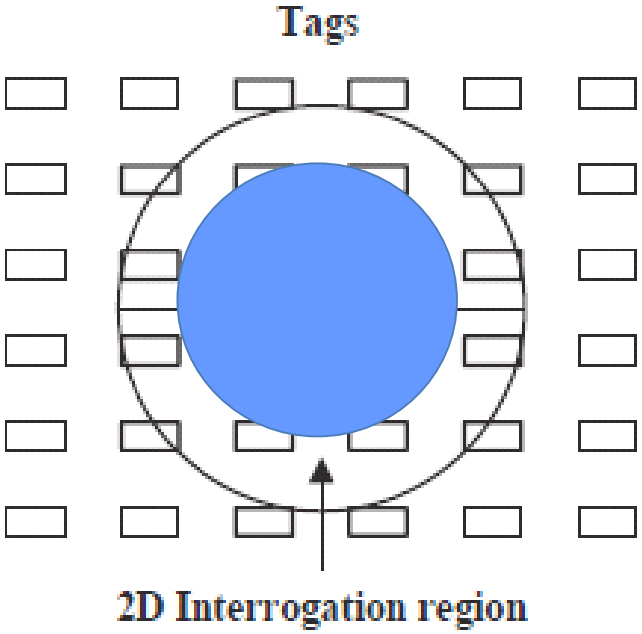
System Model



→ Efficient tag identification in the specified area in the realistic environments.

System Model

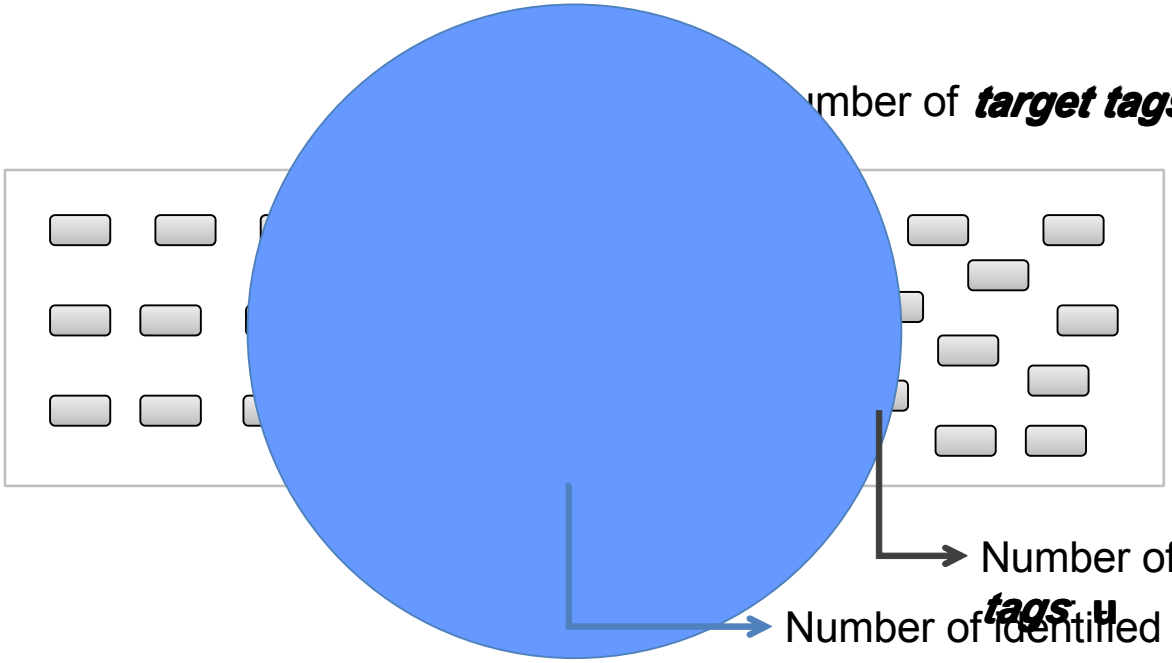




Antenna is rotatable.

Power is adjustable.

Problem Description



Efficient tag Identification in the specified area:

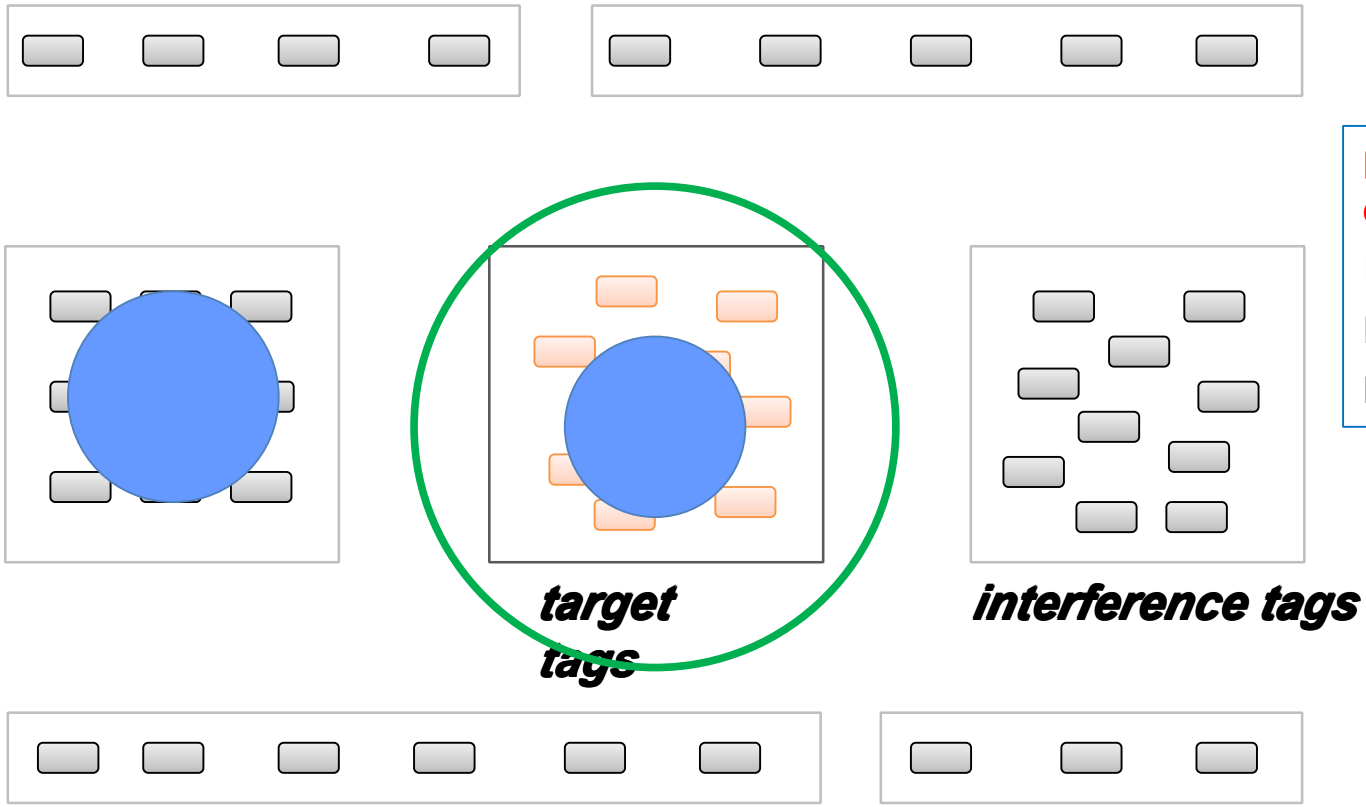
→ 1) **Constraint**: Coverage ratio $\beta = \frac{s}{m}$ **≥ α**

2) **Objective**: Minimize execution time ***T***

Misreading ratio: $\lambda = \frac{u}{u+m}$, which is related to ***T***.

Identify as many target tags as possible while minimize the execution time.

Challenge



Realistic environments:

Interference;

Energy absorption;

Multipath effect…

(1) Make the antenna face towards the specified area;

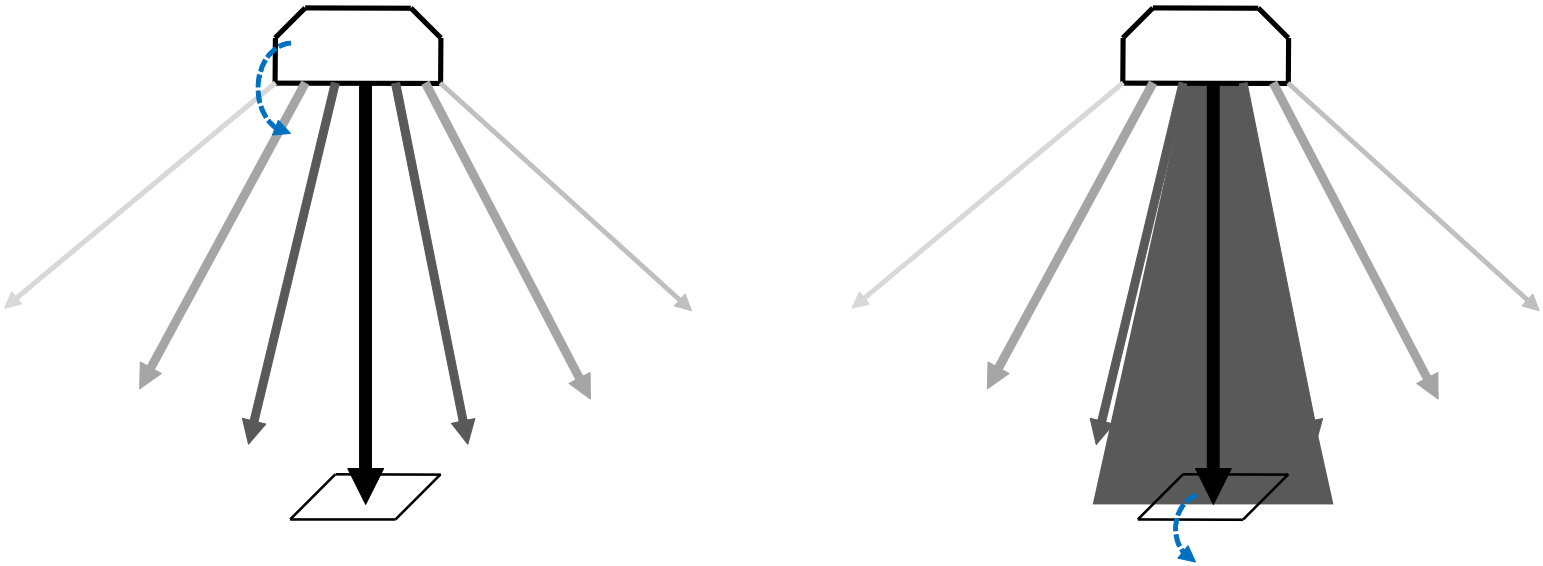
(2) How to find the boundary of the area?

(3) How to select the optimal power ?

How to efficiently focus on the specified area ?

Observations from the realistic environments

- Angle between the antenna and the tag

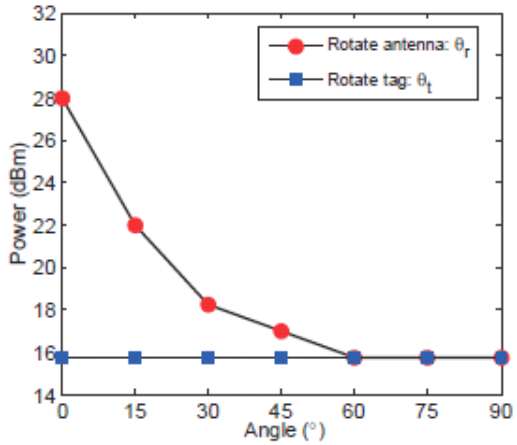


→1) As the **angle** between the radiation direction and the surface of the antenna **decrease**,
the reading **performance decreases**.

2) When a tag is located in the **center of the interrogation region**, the reader often has a **good reading performance**, no matter how the tag is placed.

Observations from the realistic environments

- Angle between the antenna and the tag



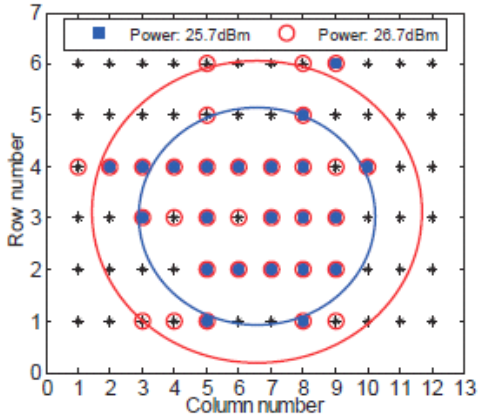
(a) Minimum power needed to activate the tag

→1) As the **angle** between the radiation direction and the surface of the antenna **decrease**, the reading **performance decreases**.

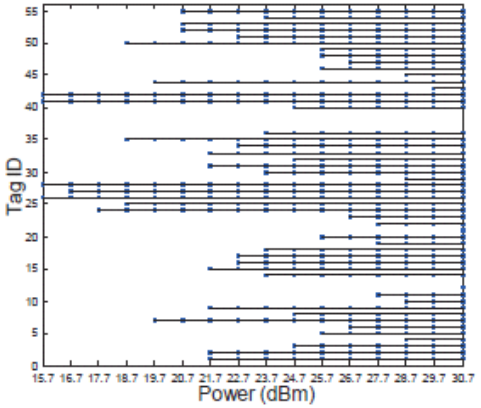
2) When a tag is located in the **center of the interrogation region**, the reader often has a **good reading performance**, no matter how the tag is placed.

Observations from the realistic environments

- Reader's Power



(d) Distribution of identified tags under different powers



(e) Identified tag IDs under different powers

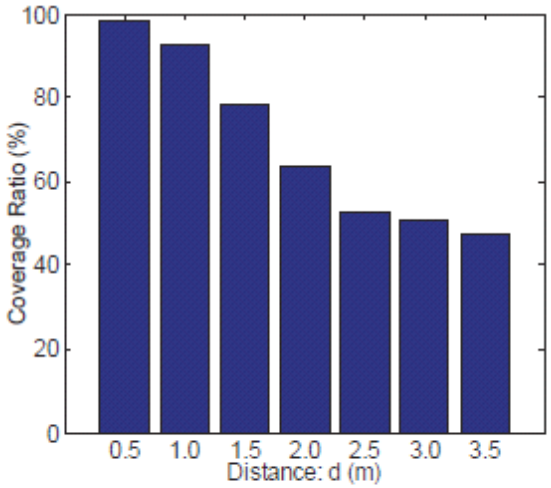
→1) The larger the reader's power, the larger the **interrogation region**.

2) As the power increases, the **new identified tags** may not be located in the boundary.

3) If a tag can be **identified** with a low power, it must be identified **with a larger power**.

Observations from the realistic environments

- Distance between the tags and the antenna



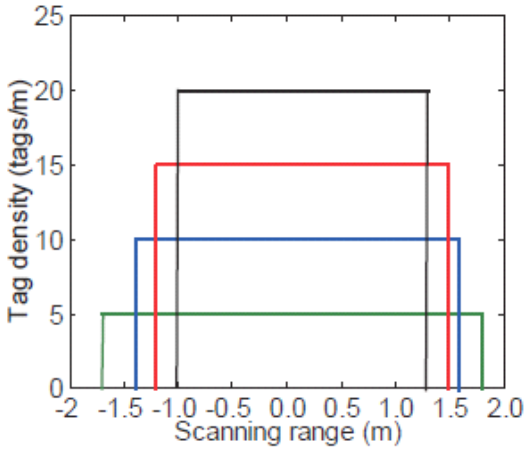
(f) Coverage ratio at different distances

→1) As the **distance** of the tags and the antenna **increases**, the reading **performance decreases**.

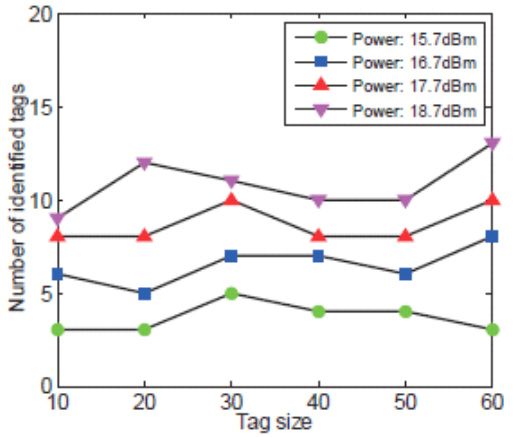
2) When the distance and the tags are fixed, the maximum **converge ratio has an upper bound**.

Observations from the realistic environments

- Effect of Tag Size



(e) Scanning range vs. tag densities



(h) Number of identified tags with different tag sizes

→1) The tag size can **affect** the effective **interrogation region**.

2) The tag size has **little effect** on the **number of identified tags**.

Indication from the realistic environments

When the distance between the tags and the antenna is fixed, the distribution of tags is fixed, the **converge ratio** has an upper bound (Depend on the realistic Environments).

If we want to improve the reading performance, we should make the objects be located **in the center of the interrogation region**.

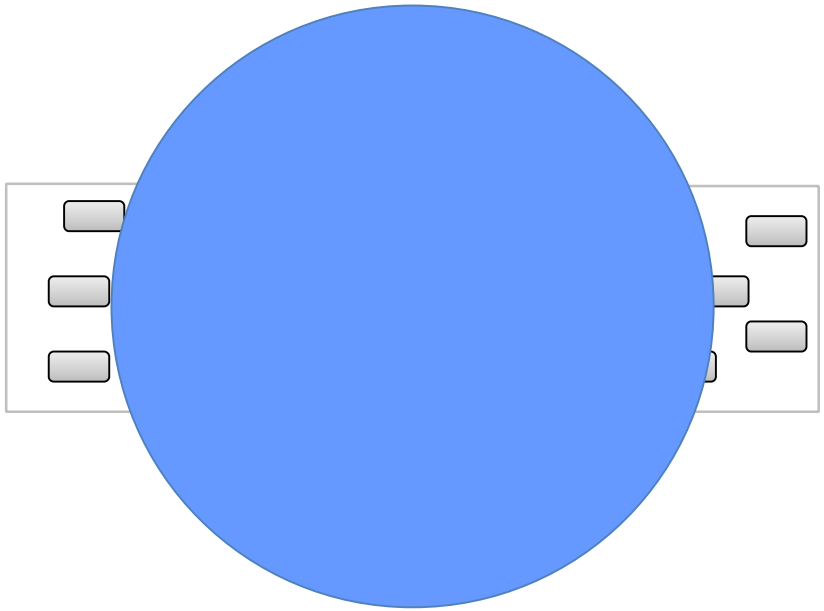
Since the tag size has little effect on the number of identified tag, we can **find the boundary** of the specified area by identifying some tags around the area.

When we need to focus on a specified area, we need to select an **optimal power**.

Baseline Solutions

- Identification with Maximum Power

In order to identify as many target tags as possible:
The solution uses the maximum power to identify the tags.



Identification with the maximum power.

Weakness:

1) More misreading ratio;

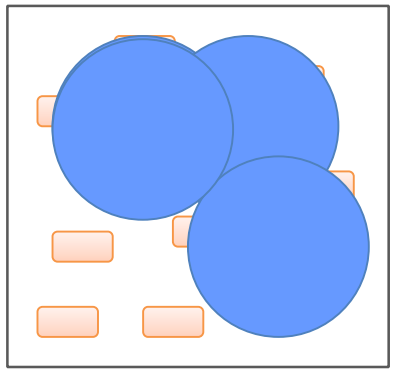
2) More execution time.

The effective **interrogation region is too large**.

Baseline Solutions

- Identification with Minimum Power

In order to only focus on the specified area (not identify the interference tags):
The solution uses the minimum power to identify the tags.



Identification with the minimum power.

→ It needs to rotate the antenna to scan all the target tags.

Weakness:

1) Multiple scans;
2) Low converge ratio;
3) More execution time

The effective **interrogation region is too small**.

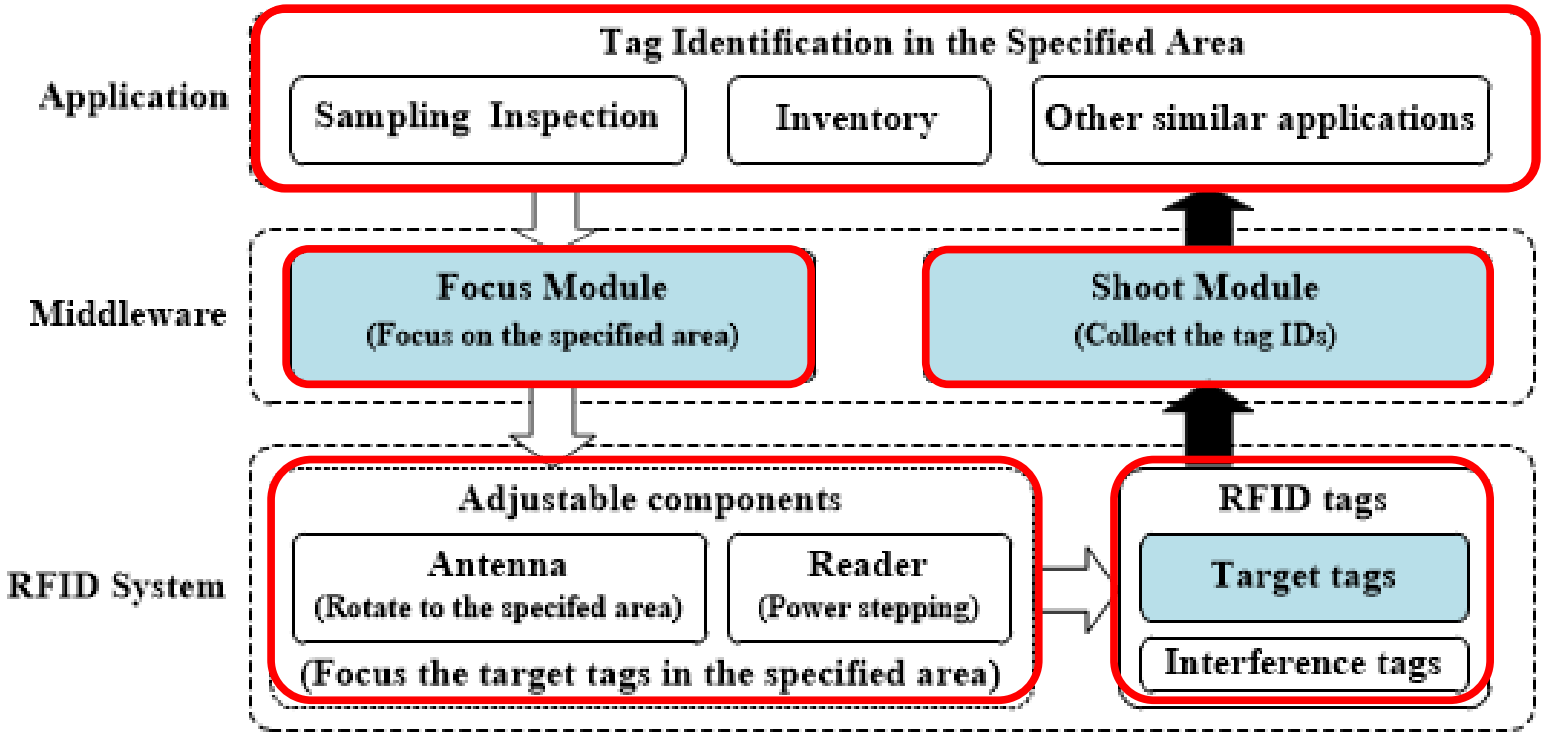
How to make the interrogation region just enough to cover the area ?

Photography based tag Identification with Distance measurement (PID)

The process of PID can be compared to the **picture-taking process** in a camera.

—— 1) **Focusing Process**: focus on the specified area (**area A**) with a 3D camera;

—— 2) **Shooting Process**: collect the tag IDs in the interrogation region.



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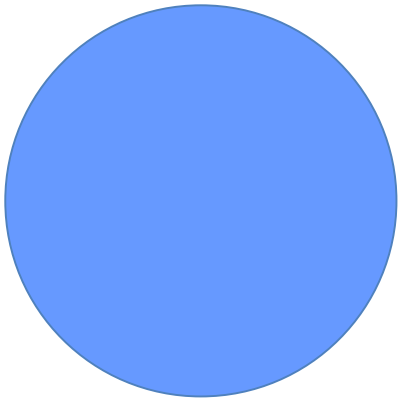
Focusing Process

The distance between the tags and the antenna is fixed.

The distribution of tags is unknown.

→ We can only adjust the antenna's **angle** and the reader's **power**.



1) The antenna rotates **towards** the center of the specified **area *A*** with a 3D camera;

2) The reader adjusts the power to make its scanning range just enough to **cover the area *A***:

—— Establishing the boundary;

—— Power Stepping;

Photography based tag Identification with Distance measurement (PID)

Focusing Process

1) **Establishing the boundary**:

Although the specified area A is appointed by a 3D camera, the reader can hardly find the boundary of the area.

→ Outline the specified area.

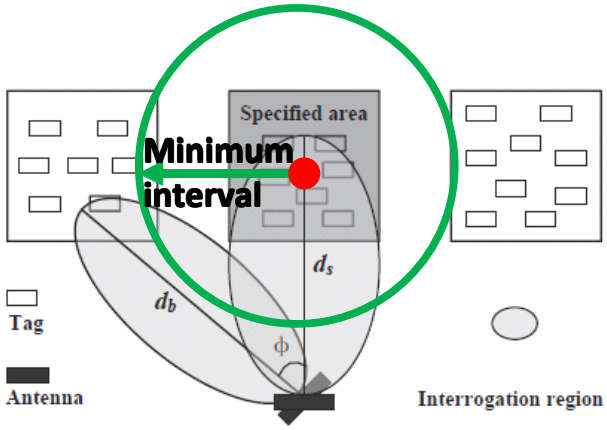


Fig. 4. Identify the tags in the specified area with a 3D camera

1) Identify a part of interference tags in the boundary:

$$N_b = \{ID_1, ID_2, \ldots, ID_{n_b}\}$$

2) Use these tags as reference tags of the boundary.

$n_b \geq n_\varepsilon$, n_ε represents the number of tags that should be steadily identified, in order to describe the boundary.

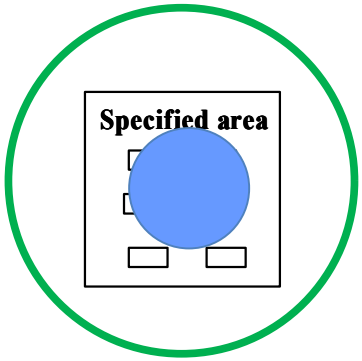
Photography based tag Identification with Distance measurement (PID)

Focusing Process

2) **Power Stepping**:

Adjust the reader's power to make its scanning range be just enough to cover the area A.

→ Find optimal power to just enough cover the area A.



1) Choose the minimum active power P_{wb};

2) Update reader's power: $P_w = P_{wb} + k_b \times \Delta P_w, k_b \in \mathbb{Z}^+$

3) Identify n_c tags in the boundary:

—— When $\frac{n_c}{n_b} = \delta = \alpha$, optimal power $P_w^* = P_w$

$n_b \geq n_\varepsilon$, n_ε is related to the realistic environments, while δ can be derived from the value coverage ratio.

Photography based tag Identification with Distance measurement (PID)

Shooting Process

We do not modify any parameter of the commercial reader (Alien-9900+), which conforms
to EPC C1G2 Standard.

Objective: Collecting the tag IDs in the interrogation region.

Approach: —— Identifying one tag ID in each slot.
—— Only no tags respond to reader, the process terminates, which means
each tag has transmitted its tag ID to the reader.

Photography based tag Identification with Angle rotation (PIA)

Identify the target tags without any auxiliary equipment.

Focusing Process

1) **Exploring the boundary**:
Rotate the antenna to explore the boundary of the specified area.
→ Outline the specified area.

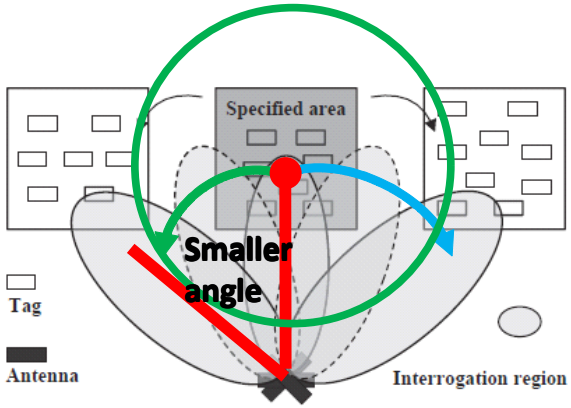


Fig. 5. Identify the tags in the specified area without any auxiliary equipment

1) Identify a part of target tags:
$N_s = \{ID_1, ID_2, \ldots, ID_{n_s}\}$

2) Identify some interference tags N_l (N_r) of the boundary by rotating $\Delta\theta_{r_l}$ ($\Delta\theta_{r_r}$) to left (right);

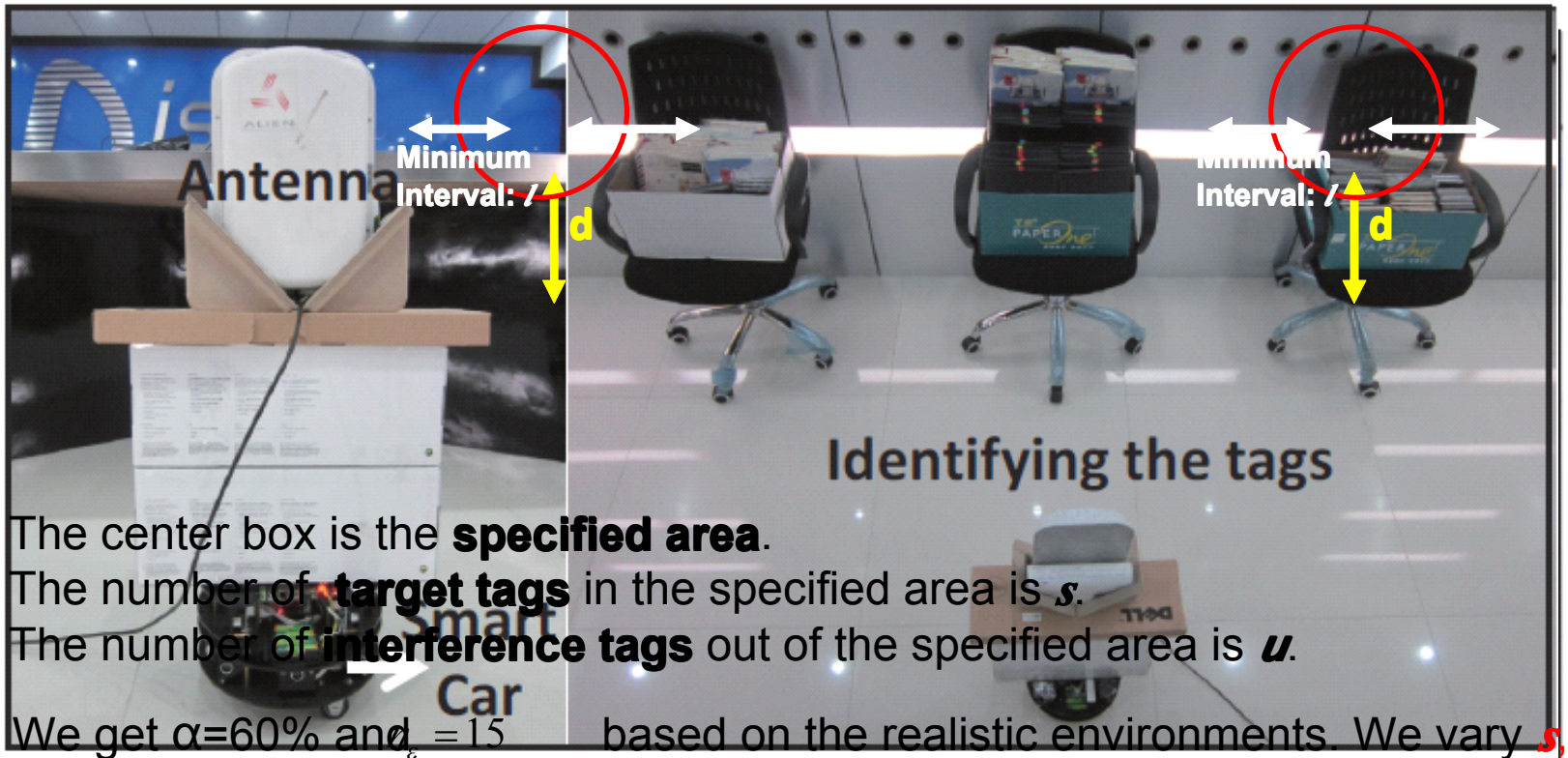
3) Use the tags identified with smaller angle as the **reference tags** N_b of the boundary.

$$n_s \geq n_\varepsilon \quad \text{and} \quad n_b \geq n_\varepsilon \ .$$

The remaining process is the same as that in PID.

Performance Evaluation

- System Prototypes



The center box is the **specified area**.
The number of **target tags** in the specified area is ***s***.
The number of **interference tags** out of the specified area is ***u***.

We get α=60% and $\theta_\varepsilon = 15$ based on the realistic environments. We vary ***s***, ***u***, ***d***, ***l*** to evaluate the performance of each solution.

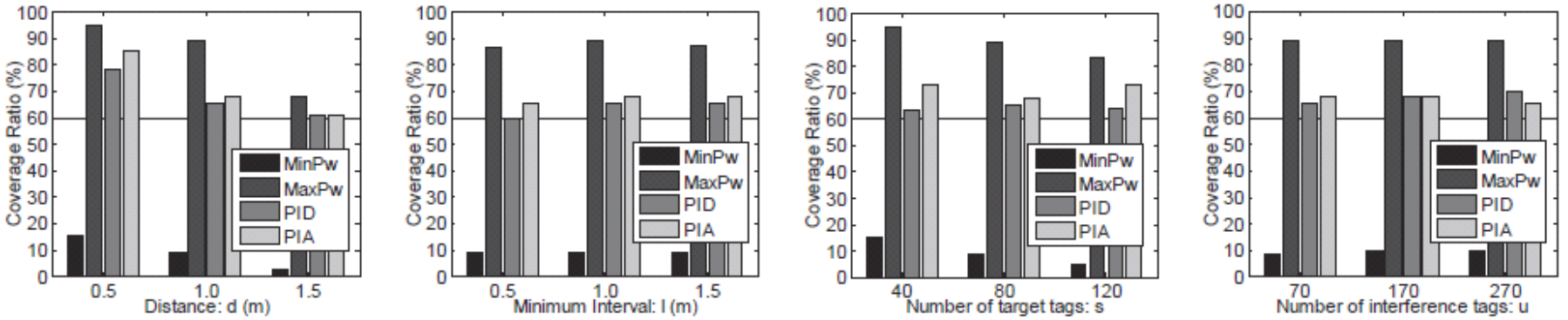
(b) PIA

Performance Metrics: **Execution time, coverage ratio**, **misreading ratio**.

Performance Evaluation

We set d=1m, l=1m, s=80, u=70 by default.

Coverage Ratio ρ



(a) ρ vs. d (b) ρ vs. l (c) ρ vs. s (d) ρ vs. u

Fig. 7. $\alpha = 60\%$, Coverage ratio

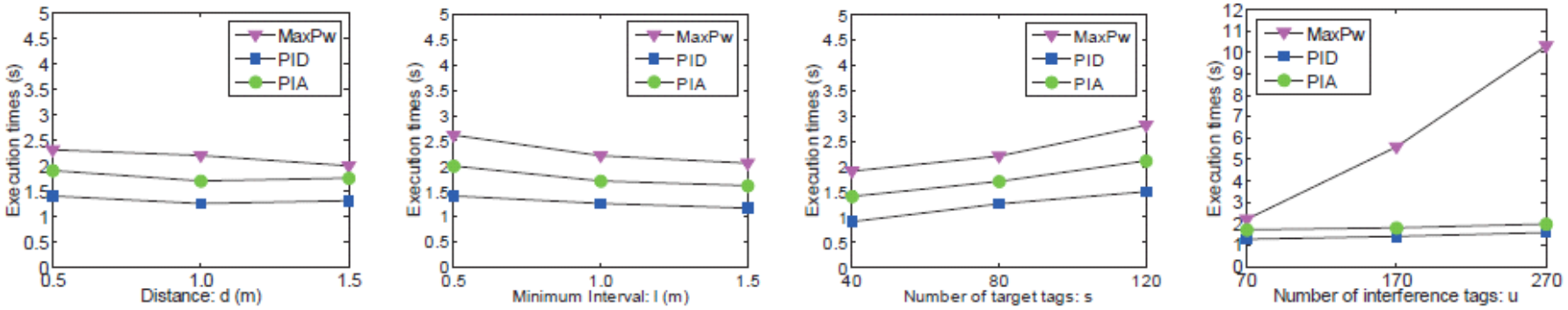
PID, PIA, and MaxPw can satisfy the requirement of coverage ratio.
MinPw can not satisfy the requirement because of its power is too small.

→ We ignore MinPw in the following comparisons.

Performance Evaluation

We set d=1m, l=1m, s=80, u=70 by default.

Execution Time T



(a) T vs. d (b) T vs. l (c) T vs. s (d) T vs. u

Fig. 8. $\alpha = 60\%$, Execution time

PID and PIA have better performances than MaxPw.

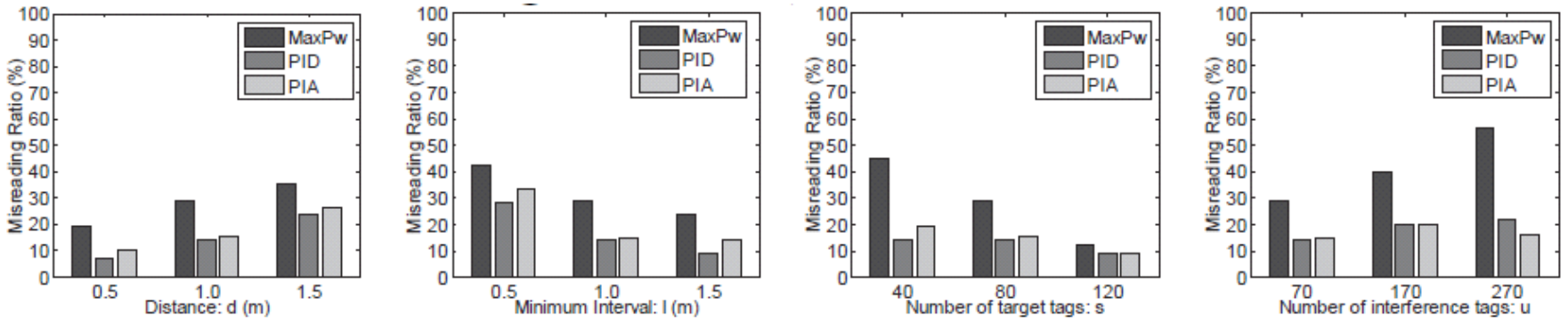
When s=120, PID can reduce T by 46% compared to MaxPw.

When u=270, PID can reduce T by 84.5% compared to MaxPw.

Performance Evaluation

We set d=1m, l=1m, s=80, u=70 by default.

Misreading Ratio λ



(a) λ vs. d (b) λ vs. l (c) λ vs. s (d) λ vs. u

Fig. 9. $\alpha = 60\%$, Misreading ratio

PID and PIA have lower misreading ratios that MaxPw, because PID and PIA only focus
on the specified area and use the optimal power.

Conclusion

—— We investigate the problem of tag identification in the specified area.

—— We conduct extensive experiments on the commodity RFID systems.

—— We propose the photography based identification method, which works in a similar way of picture-taking in a camera.

Based on the picture-taking scheme, we propose two solutions PID and PIA.

1) PID works with a 3D camera;

2) PIA works without any auxiliary equipment.

—— Realistic environments show that our solutions outperform the baseline solutions.

Questions ?

Thank you !