Butterfly: Environment-Independent Physical-Layer Authentication for Passive RFID

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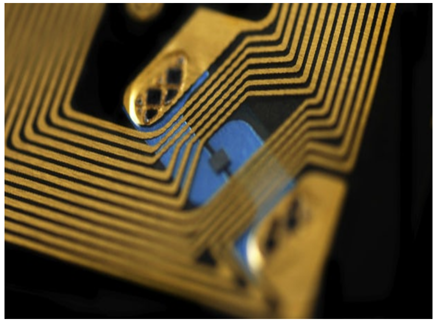
- Tag Seal
- Entrance check
- Logistic and warehousing

RFID Authentication is a crucial task for many applications!

Prior authentication methods



Tag counterfeiting?	Don't need Modification?	Tag mobility?
✗ E1G2 Protocol	✓ E1G2 Protocol	✓ E1G2 Protocol
✓ Cryptology method	✗ Cryptology method	✓ Cryptology method
✓ Physical-layer	✓ Physical-layer	✗ Physical-layer
✓ Butterfly	✓ Butterfly	✓ Butterfly

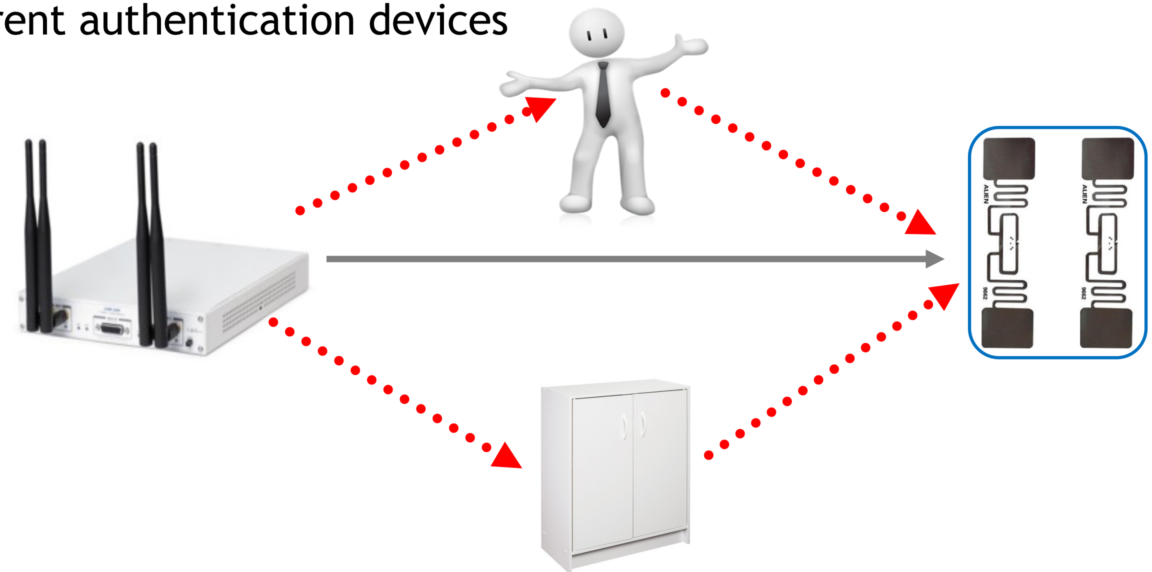
Outline

- Basic Idea
- System Design
- Experiments and Evaluation
- Conclusion

Problem Statement

Some practical factors introduce unpredictable errors in physical-layer signals:

- Position of the tag
- Surrounding environments
- Different authentication devices



Basic Idea

Our solution: employ two adjacent tags as an unit.

Constant vector

Feature

Received signal: $P = C^T + F^T + N_G + N_E + N_D$

Gaussian Noise

Environment Noise

Device Noise

Tag 1 $\quad P^{T_1} = C^{T_1} + F^{T_1} + N_G^{T_1} + N_E^{T_1} + N_D^{T_1}$

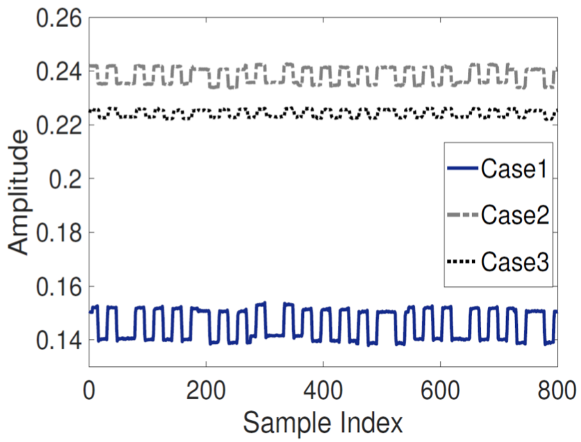
Tag 2 $\quad P^{T_2} = C^{T_2} + F^{T_2} + N_G^{T_2} + N_E^{T_2} + N_D^{T_2}$

$P^{T_1} - P^{T_2} \approx (C^{T_1} - C^{T_2}) + (F^{T_1} - F^{T_2})$

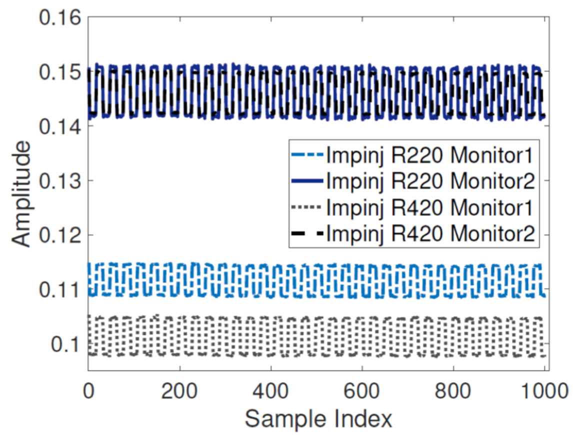
Basic Idea

Performance of noise elimination:

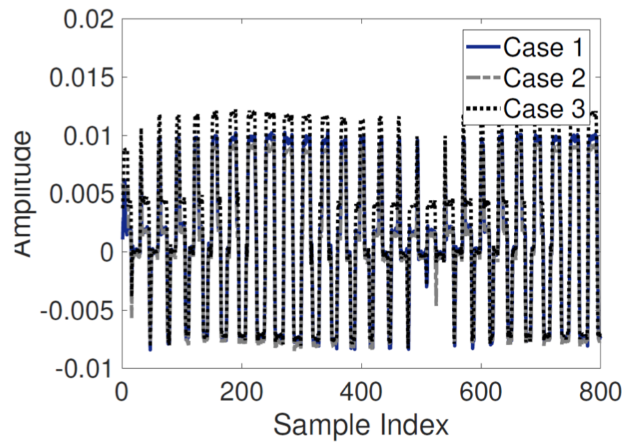
- Our method can effectively eliminate the environment and device noises!



- Signals in different environments



- Signals of different devices



- Signals after elimination

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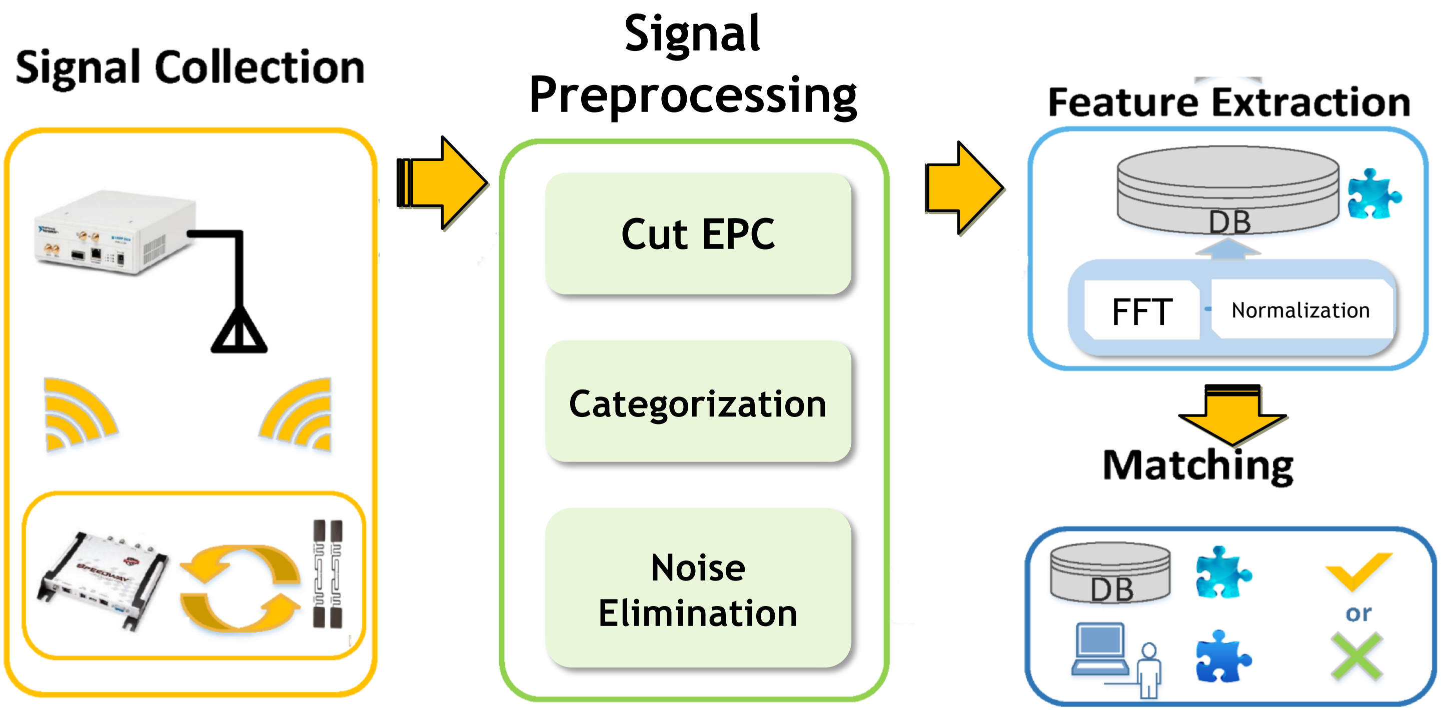
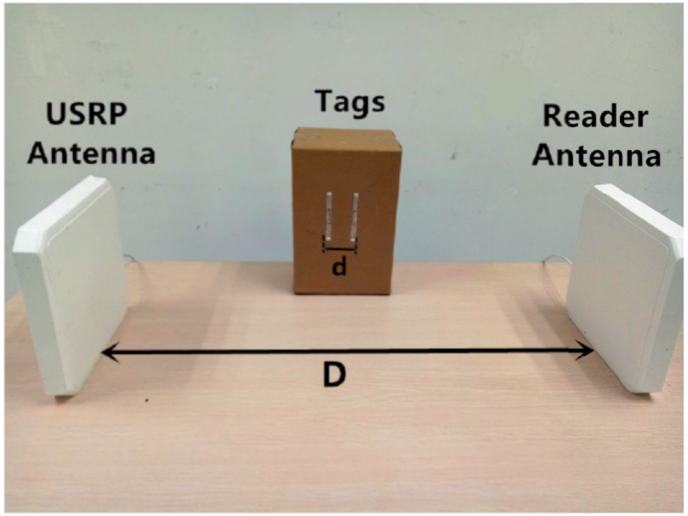
System Design



System Design: Signal collection

System deployment:

- USRP N210-based Monitor
- ImpinJ R220 Reader
- Two tags

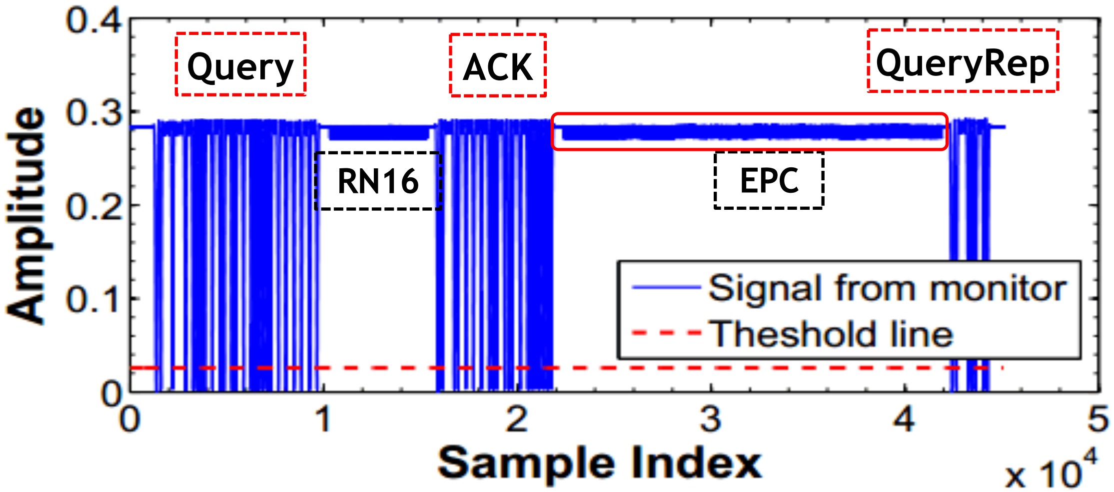


System deployment

System Design: Signal preprocessing

Signal preprocessing:

- Cut EPC segment
- Tag categorization
- Noise elimination

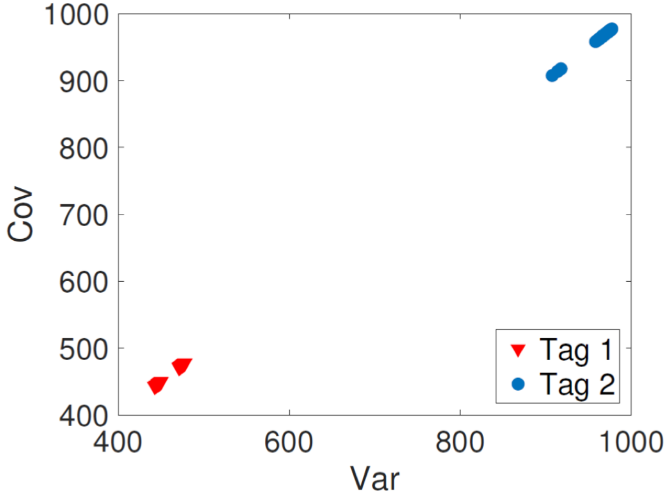


Signals received by the Monitor

System Design: Signal preprocessing

Signal preprocessing:

- Cut EPC segment
- Tag categorization
- Noise elimination

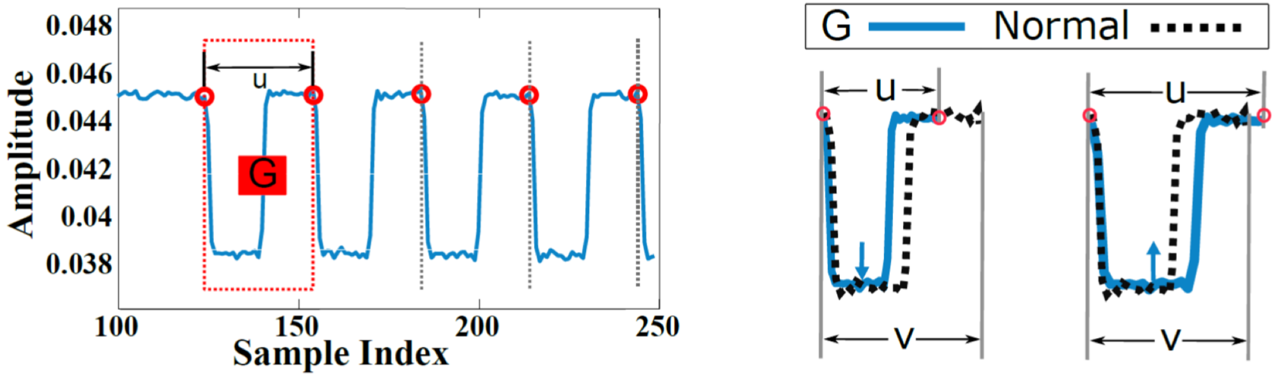


Tag categorization by K-Medoids

System Design: Signal preprocessing

Signal preprocessing:

- Cut EPC segment
- Tag categorization
- Noise elimination **ASP: Align Sample Point algorithm.**



(a) segment

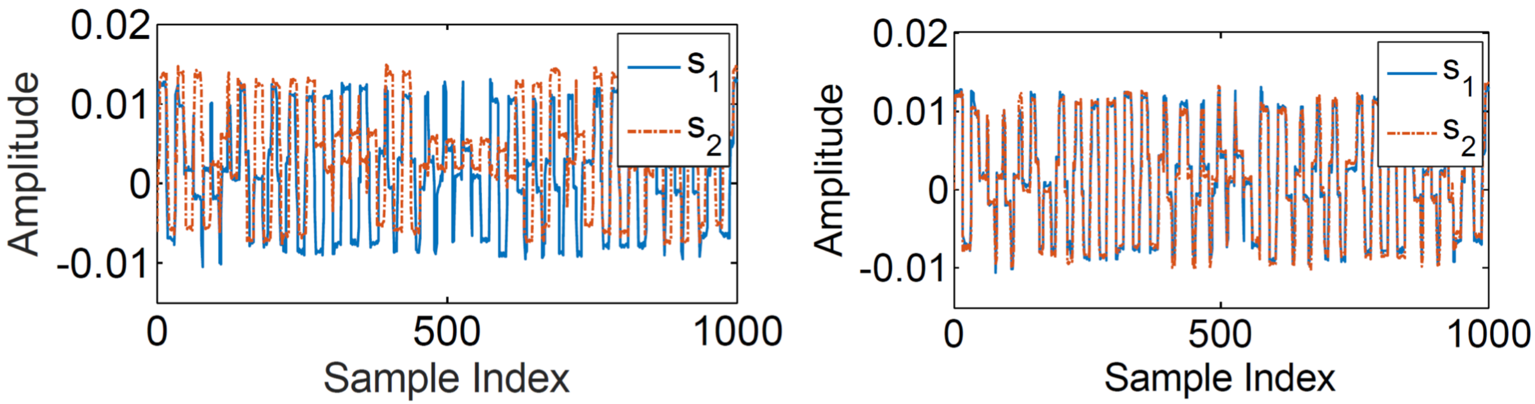
(b) abnormal waveforms

- Inconsistent signal caused by hardware

System Design: Signal preprocessing

Signal preprocessing:

- Cut EPC segment
- Tag categorization
- Noise elimination



(a) Before performing ASP

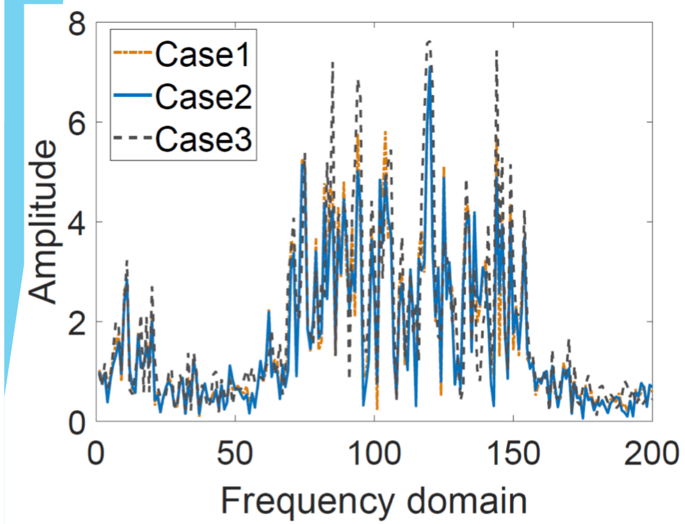
(b) After performing ASP

- Effectiveness of ASP

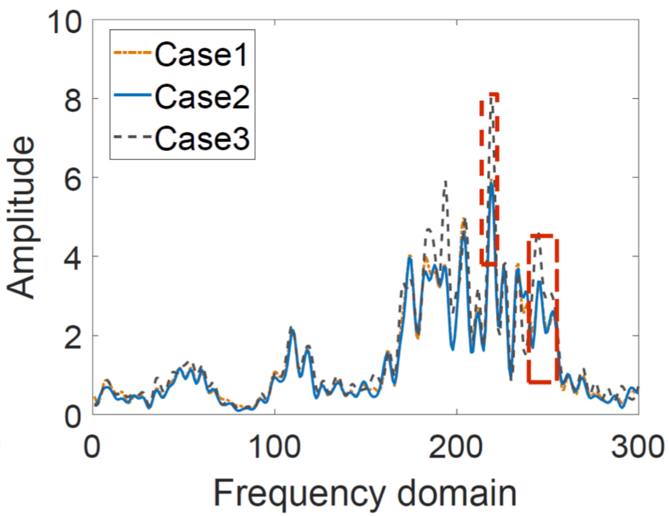
System Design: Feature extraction

Feature extraction:

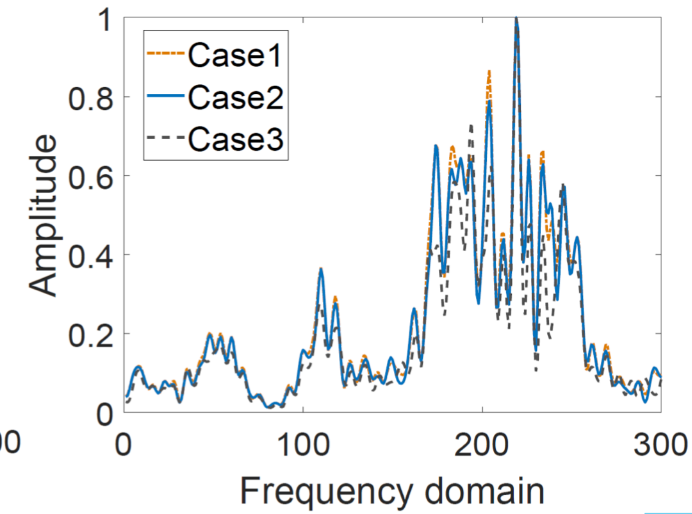
- FFT
- Low-pass filter
- Normalization



- After FFT



- After Low-pass Filter

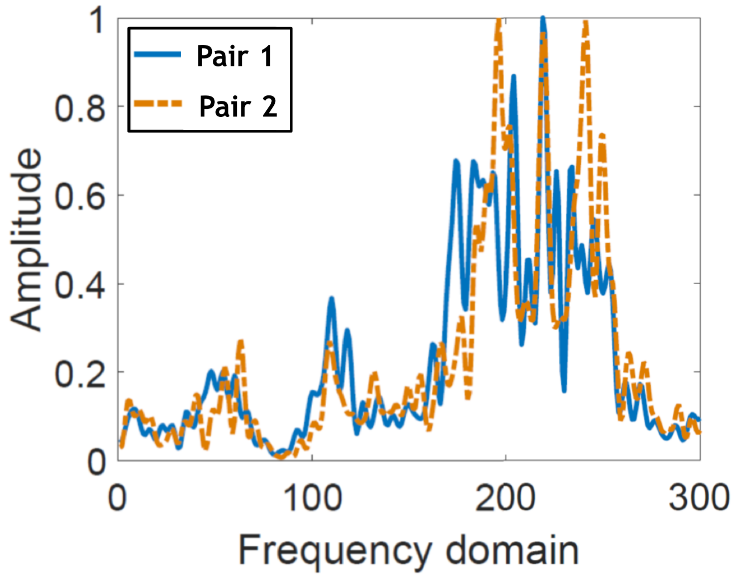


- After normalization

System Design: Feature matching

Feature extraction:

- Overlapped rate *R*: $$R = \frac{\varphi(F_c) \bigcap \varphi(F_t)}{\varphi(F_c) \bigcup \varphi(F_t)}$$



The features of different tag pairs

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Experiments and Evaluation

Hardware:

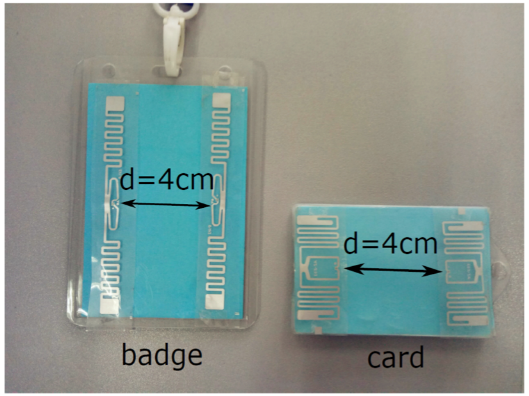
- Impinj R220 Reader
- USRP N210 plus SBX daughterboard
- 3 types of tags:Impinj E41-B, E41-C,Alien-9640

Deployment:

- The distance between the reader antenna and the monitor antenna: D=0.5m ~1.5m
- The distance between two tags: 4cm

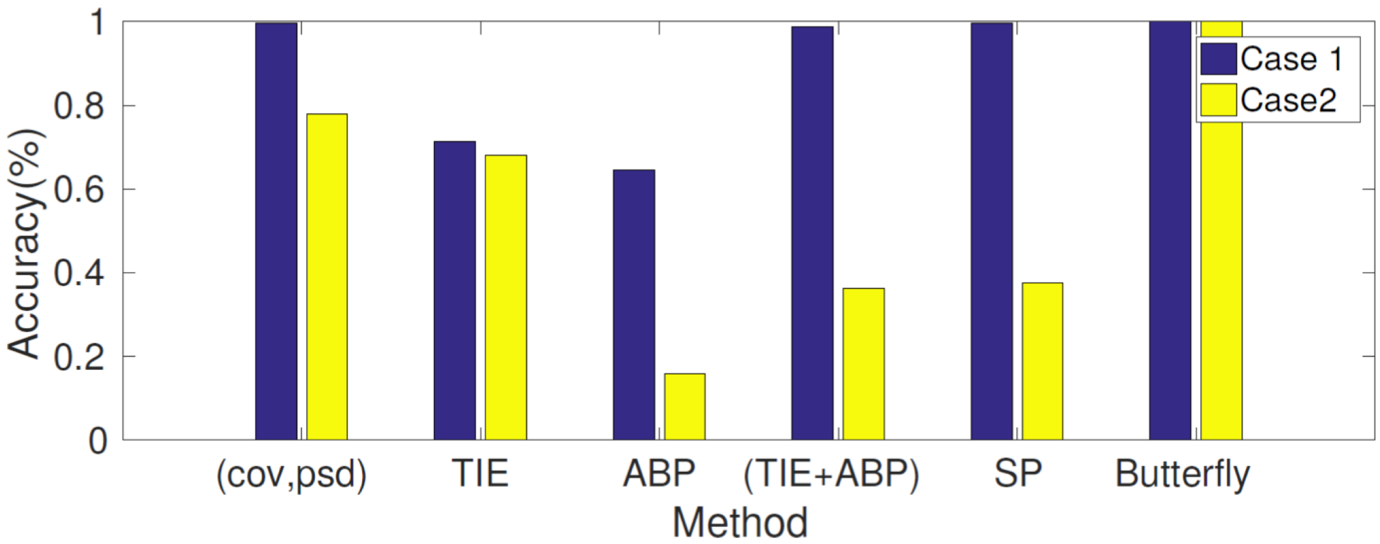
Metrics:

- False accept rate (FAR)
- False reject rate (FRR)
- Accuracy



Experiments and Evaluation

Case 1: The same authentication position.
Case 2: Different authentication position in the same room.
Case 3: Different authentication position in the different room.



- Comparison between Butterfly and prior solutions in two cases

Experiments and Evaluation

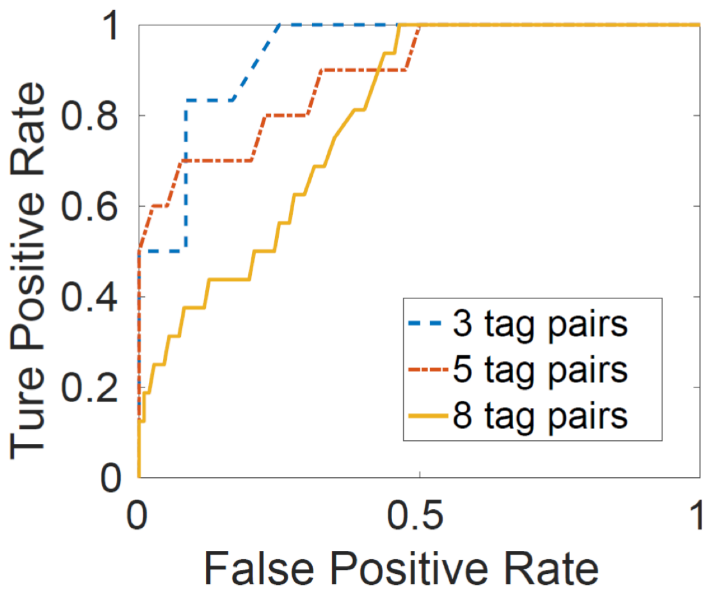
Changing the authentication devices:

Table 2. Accuracy after changing devices

	Room 2	Room 3	Room 4
Accuracy	98.5%	93.3%	91.5%

Experiments and Evaluation

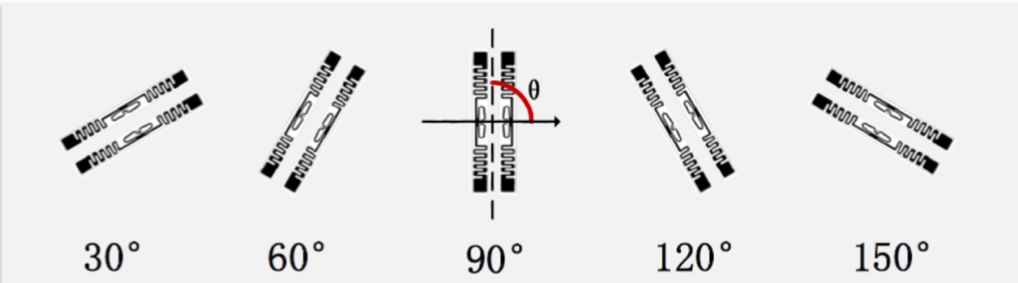
Authenticate multiple tags:



- The ROC curve of multiple pairs

Experiments and Evaluation

Other factors: Tag rotation



Rotations of tag pairs

Table 3. The accuracy when tag pairs rotate

Angle(○)	30	60	90	120	150
Accuracy(%)	91.7	96.7	100	95	93.3

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Conclusion

- In this paper, we present an **environment-independent** physical layer authentication scheme for passive RFID tags, called Butterfly.

- The main advantage of Butterfly is the **resilience to environments, locations, and device changes,** which are major problems in prior solutions.

- We implement a prototype Butterfly and conduct extensive experiments for evaluation. The results show that Butterfly is very effective and accurate in authentication (up to 96.7%).

Thank you!

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