

Poster Abstract: Accurate and Fast Detection of Tag Antenna Damage for RFID Sensing

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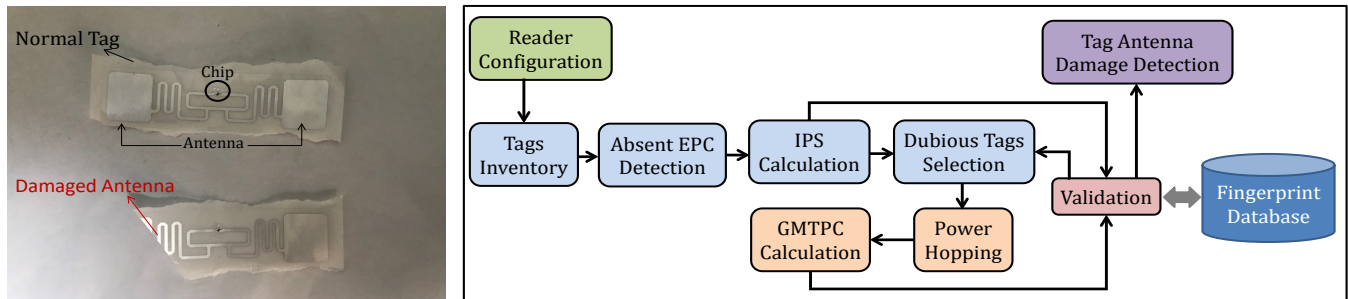


Figure 1: Antenna damage of commodity RFID tag (left) and system overview of RFANT-Checker (right).

ABSTRACT

Tag antenna damage is a common phenomenon in real-world RFID systems, which incurs severe changes of antenna impedance and antenna gain. Existing RFID sensing systems leveraging signal features (e.g., phase readings) related to antenna impedance or gain are vulnerable to such tag antenna damage jeopardizing sensing accuracy and reliability.

In this poster, we introduce RFANT-Checker, the first automatic system that provides accurate and fast detection of tags with damaged antenna. Impedance-induced phase shift and gain-induced minimum transmission power coefficient are jointly exploited as fingerprints for selection and validation. We implement RFANT-Checker with COTS devices and evaluate it on 84 examples of commodity tag. Experiment results demonstrate the high detection accuracy of up to 97% and low time overhead of at most 10s.

CCS CONCEPTS

• Networks → Cyber-physical networks; • Computer systems organization → Sensor networks.

KEYWORDS

RFID; Tag Antenna Damage; Fingerprint-based Detection

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1 INTRODUCTION

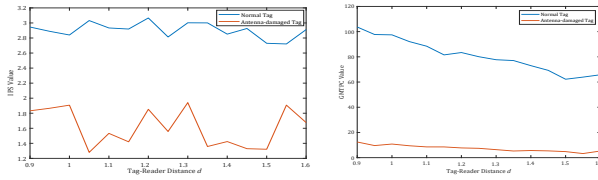
RFID tags may suffer from physical damage (e.g., deformation, breakage) caused by man-made and external factors in real-world applications [4]. Tag antenna damage occurs more frequently than chip damage¹, in general, since the size of tag chip is relatively small, as shown in Figure 1 (left). With respect to widely-used meandered dipole commodity tags, antenna damage leads to changes of antenna gain and antenna impedance incurring impedance mismatch, thereby resulting in severe changes of collected phase readings by reader and minimum transmission power of reader to activate the tag. Consequently, the reliability of past RFID sensing systems will be jeopardized, resulting in very low sensing accuracy, especially those systems utilizing differential signal feature values of dual-tags [1] or impedance changes caused by materials [3] or temperature [2] for sensing.

In this poster, we present RFANT-Checker to detect tags with damaged antenna automatically, accurately and fast by exploiting distance-independent impedance-induced phase shift (IPS) extracted from phase readings and gain-induced minimum transmission power coefficient (GMTPC) as fingerprints. RFANT-Checker can be easily integrated into past sensing systems as precursor module. Note that even though tag antenna is partially damaged, this tag is probably still readable. Otherwise, we can simply find it by searching absent tag ID (i.e., EPC).

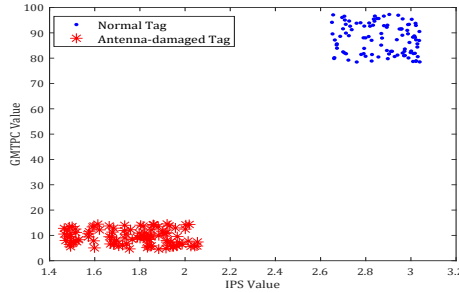
2 SYSTEM DESIGN

Figure 1 (right) shows the workflow of RFANT-Checker. We first set the transmission power of reader antenna to the

¹Note that tag chip damage is always caused by high heat, static electricity, but not mechanically.



(a) IPS values. (b) GMTPC values.

Figure 2: Fingerprint values under various d .

Figure 3: Fingerprint values of 100 tests when $d=1m$.

maximum value and inventory mode to FM0, and then start the tag inventory. If any EPC is absent, the corresponding tag antenna is damaged. Otherwise, we *calculate IPS* and select the dubious tags, and then utilize power hopping to *calculate GMTPC* for jointly validating the dubious tags, and finally pinpoint these tags and handle them.

2.1 IPS Calculation

The phase readings of each tag can be expressed as

$$\theta = (\theta_T + \theta_R + \theta_{Tag} + 2\pi \times 2d/\lambda) \bmod 2\pi \quad (1)$$

where θ_T and θ_R are constants introduced by reader antenna, d denotes the tag-reader distance measured beforehand, λ denotes the wavelength of RF signals, θ_{Tag} denotes the impedance-induced phase shift introduced by tag and is relevant to antenna damage.

Then, we can obtain the distance-independent IPS:

$$IPS = \{\theta - 4\pi d/\lambda + 2\pi \lfloor 2d/\lambda \rfloor\}^+ \quad (2)$$

where $\{x\}^+ = \begin{cases} x, & \text{if } x \geq 0 \\ x + 2\pi, & \text{if } x < 0 \end{cases}$ due to phase unwrapping and Figure 2(a) shows the IPS values of normal tag and antenna-damaged tag under different d .

Finally we utilize *SELECT* command in Gen2 standard to select dubious tags based on similarity matching and filter out other tags, since the time overhead of power hopping in next step is high, thereby accelerating the detection speed.

2.2 GMTPC Calculation

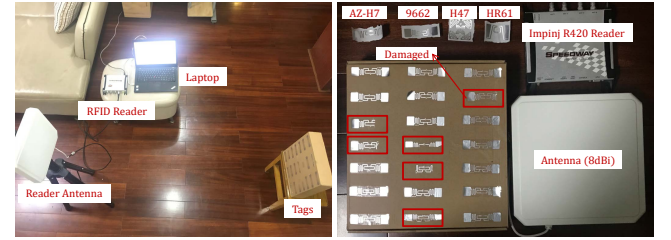
We can utilize power hopping to obtain the minimum transmission power of reader antenna to activate each tag, which can be expressed as

$$P_{threshold} = \delta \cdot d^2 / ((1 - |\Gamma_{tag}|^2) G_{tag}) \quad (3)$$

where δ is constant not influenced by antenna damage, Γ_{tag} is introduced by impedance mismatch [2] and G_{tag} denotes

Table 1: Performance evaluation of 84 tag examples.

Tag Model	ADA	FAR	FRR	ATO	ATO (w/o SEL)
Alien 9962	97.5%	0.88%	3.64%	7.8s	17.9s
Impinj H47	90.8%	3.67%	3.85%	5.6s	12.4s
Impinj HR61	85.6%	7.75%	2.25%	9.6s	21.6s
NXP AZ-H7	95.4%	1.02%	3.20%	7.5s	16.8s


Figure 4: System deployment in indoor environment. the tag antenna gain. Generally, damaged tag antenna with shape changes lead to lower antenna gain.

Afterwards, we can obtain the GMTPC:

$$GMTPC = d^2 / P_{threshold} \quad (4)$$

Figure 2(b) shows the GMTPC values of normal tag and antenna-damaged tag under different d and Figure 3 demonstrates the feasibility of exploiting IPS and GMTPC as fingerprints. Finally, we can confirm the antenna-damaged tags by comparing registered fingerprint values.

3 IMPLEMENTATION

Setup. RFANT-Checker contains one Impinj Speedway R420 reader connected to one Thinkpad laptop through LLRP protocol, single circular polarized antenna with 8dBi gain, as shown in Figure 4. The operated transmission power range is 10.0-30.0 dBm. The software is developed using Java.

Evaluation. We evaluate RFANT-Checker on 4 types of commodity tags respectively (shown in Table 1) with 6 common forms of antenna damage and 15 normal tags (84 examples in total). Table 1 shows the results of average detection accuracy (ADA), false accept rate (FAR), false reject rate (FRR), average time overhead (ATO) and ATO without selection operation, which verify the **accurate** and **fast** detection.

4 CONCLUSION

We present an automatic system RFANT-Checker to detect tags with damaged antenna accurately and fast for reliable RFID sensing, regardless of tag models or tag numbers.

5 ACKNOWLEDGMENTS

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