

Adaptive Confidence-Aware Multi-Antenna RFID Anti-Collision Method for Precision Livestock Monitoring

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Abstract: Radio Frequency Identification (RFID) enables automatic livestock identification in precision agriculture, but simultaneous tag replies can cause collisions and increase reading delay. Earlier work combined multiple receiving antennas with Dynamic Frame Slotted ALOHA (DFSA) to improve bulk tag reading. This paper proposes a confidence-aware extension, called CA-MA-DFSA, that combines slot-outcome feedback, antenna-level response confidence, and a bounded frame-size update. The reader estimates the remaining tag population from idle, successful, and collided slots, then adjusts the next frame conservatively. Antenna observations are used to prioritize repeated interrogation of uncertain tags rather than assuming that every antenna independently identifies a new tag. A simulation plan is specified for comparison with conventional DFSA and multi-antenna DFSA. No experimental results are claimed in this draft; performance must be established through implementation and reproducible testing.

Keywords: RFID, anti-collision, precision agriculture, livestock monitoring, DFSA, multi-antenna, adaptive frame, tag estimation.

I. INTRODUCTION

Precision livestock monitoring uses electronic identification to support animal traceability, movement records, and herd counting. RFID tags attached to animals communicate with a reader when energized. At a farm gate, several animals may pass close together, causing many tags to reply in the same communication interval. When replies overlap, the reader may not decode all identifiers. Repeated inventory rounds then consume time and energy.

Alotaibi et al. (2023) studied a multi-antenna RFID reader with DFSA and reported simulation-based throughput gains over a single-antenna arrangement. The present draft does not reproduce that paper. It proposes a different control layer: use a confidence indicator from repeated antenna observations together with slot statistics to adapt the next interrogation frame.

II. PROBLEM STATEMENT AND RESEARCH GAP

A fixed or coarse frame adjustment may be inefficient when the number of tags changes quickly or when interference makes slot outcomes uncertain. A reader may observe collisions but still lack a reliable estimate of how many tags remain. In a multi-antenna system, combining observations also requires care: the same tag may be heard by more than one antenna, so raw antenna detections cannot simply be added.

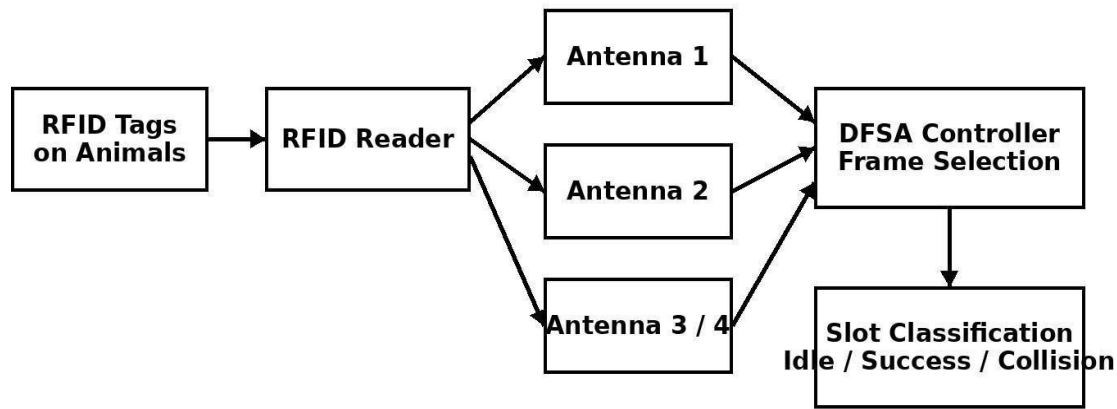


Research question: Can a bounded, confidence-aware frame update reduce total inventory slots and missed-tag rate compared with baseline DFSA under varying tag density and interference? The claimed contribution is a testable algorithmic proposal, not a proven improvement.

III. EXISTING SYSTEM

The existing system uses a multi-antenna RFID reader with Dynamic Frame Slotted ALOHA (DFSA). RFID tags attached to animals transmit their identifiers after receiving an inventory query. Multiple antennas receive the responses. The reader classifies each slot as idle, successful, or collided and uses these slot statistics to select the next frame length. The architecture improves tag observation using multiple antennas, but it does not explicitly use antenna-level confidence, duplicate-aware fusion, or an uncertain-slot revisit mechanism.

EXISTING SYSTEM ARCHITECTURE - MULTI-ANTENNA DFSA



Multi-antenna reception improves observation, while DFSA uses slot statistics

Figure 1. Existing System Architecture – Multi-Antenna DFSA.

Working of Existing System:

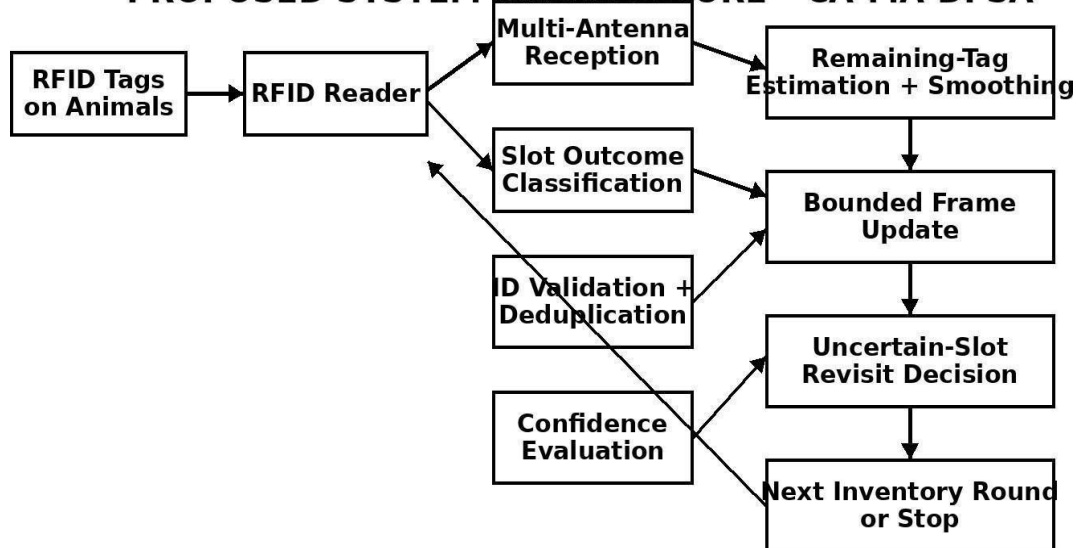
1. RFID tags are attached to animals for unique identification.
2. The RFID reader sends an inventory/query command to the tags.
3. Multiple RFID tags respond using different time slots.
4. When more than one tag responds in the same slot, a collision occurs.
5. Multiple antennas receive the responses from different directions.
6. The system classifies each slot as Idle, Successful, or Collision.
7. The DFSA controller uses these slot statistics to select the frame size for the next inventory round.
8. The process continues until the required tags are identified.

IV. PROPOSED SYSTEM

The proposed CA-MA-DFSA architecture extends the existing system with confidence-aware antenna fusion and bounded adaptive frame control. The reader collects observations from multiple antennas, validates decoded identifiers, removes duplicate IDs, evaluates confidence, estimates the remaining unread-tag population, and updates the next frame within configured limits. When observations are weak or inconsistent, the corresponding slot can be revisited in a later inventory round.



PROPOSED SYSTEM ARCHITECTURE - CA-MA-DFSA



Confidence-aware fusion + deduplication + bounded adaptive DFSA control

Figure 2. Proposed System Architecture – CA-MA-DFSA.

Working of Proposed System:

1. The RFID reader initializes an inventory round and selects an appropriate frame size.
2. RFID tags attached to animals respond in randomly selected time slots.
3. Multiple antennas simultaneously receive the tag responses.
4. The system identifies Idle, Successful, Collision, and Uncertain slot conditions.
5. Valid RFID IDs are checked using response quality and CRC/validation information.
6. Duplicate IDs received through different antennas are removed.
7. The system calculates the number of successful, idle, collision, and uncertain slots.
8. The remaining unread tag population is estimated from the observed slot statistics.

V. PROPOSED CA-MA-DFSA METHOD

The proposed Confidence-Aware Multi-Antenna Dynamic Frame Slotted ALOHA (CA-MA-DFSA) method is designed to improve RFID tag identification in precision livestock monitoring environments. The method extends the conventional DFSA approach by combining multi-antenna reception, confidence evaluation, duplicate-tag removal, remaining-tag estimation, smoothing, and bounded frame-size adaptation. In a livestock monitoring environment, a large number of RFID-tagged animals may pass through an RFID interrogation area at the same time. When several tags transmit their responses in the same time slot, collisions occur, which can increase the number of inventory rounds and communication slots required for complete identification. The proposed method attempts to address this problem by using information collected from multiple antennas and by dynamically adapting the frame size according to the estimated number of remaining tags.

1.1 Multi-Antenna RFID Reception

The system uses multiple receiving antennas positioned around the RFID interrogation area. Each antenna can observe tag responses from a different direction or location. This improves the opportunity to detect tags that may have weak or partially obstructed responses at another antenna. During every inventory round, the reader collects the responses



received by all available antennas. The observations from different antennas are then combined before deciding the final identification status of a tag.

1.2 Slot Classification

Each time slot is classified according to the received RFID responses. The major slot conditions are:

- Idle Slot: No valid tag response is detected.
- Successful Slot: A single valid tag response is detected.
- Collision Slot: Multiple tag responses overlap in the same slot.
- Uncertain Slot: A response is detected, but its reliability or validity is insufficient for confident identification.

The slot statistics are used by the proposed controller to estimate the current tag population and determine the next frame size.

1.3 Confidence-Aware Tag Identification

A major feature of CA-MA-DFSA is the use of confidence information during tag identification. Instead of treating every received response equally, the system considers the reliability of the observation.

For example, a response can be considered more reliable when:

- the RFID ID is successfully decoded,
- the CRC/check information is valid,
- the signal quality is sufficient,
- the response is consistently observed by the antennas.

When the response quality is weak or inconsistent, the observation can be marked as uncertain instead of immediately being treated as a reliable identification.

1.4 Duplicate ID Removal

Since multiple antennas may receive the response of the same RFID tag, the system may obtain duplicate observations. Therefore, the proposed method performs ID validation and deduplication.

If the same RFID tag ID is detected by two or more antennas during the same inventory round, it is counted only once in the final identified-tag list. This prevents multiple observations of one animal from being incorrectly interpreted as multiple different tags.

VII. REMAININGTAG ESTIMATE

REMAINING TAG ESTIMATE:

Remaining Tag Estimation is an important component of the proposed CA-MA-DFSA method. Its main purpose is to estimate the number of RFID tags that have not yet been successfully identified after each inventory round. Since the reader does not always know the exact number of active tags, an estimation based on slot observations is used to select a suitable frame size for the next round.

A. During an inventory round, the RFID reader observes three main types of slots:

B. Idle slots (I): No tag responds.

C. Successful slots (S): One tag responds successfully.

D. Collision slots (C): More than one tag responds in the same slot.

E. If the current frame contains L slots and there are approximately n remaining tags, the probability of an idle slot can be represented as:

$$P_{idle} \approx \left(1 - \frac{1}{L}\right)^n$$

G. The observed idle-slot ratio is calculated as:

$$H. \frac{p_{obs}}{idle} = \frac{I}{L}$$

I. The system then compares the observed idle-slot ratio with the theoretical probability to estimate the number of remaining tags.



VIII. CONFIDENCE-AWARE ANTENNA FUSION

• Confidence-Aware Antenna Fusion:

Confidence-aware antenna fusion is an important component of the proposed CA-MA-DFSA method. In a multi-antenna RFID environment, the same tag may be detected by more than one antenna. However, the quality of the received response may be different at each antenna. Therefore, the proposed method combines the observations from multiple antennas while considering their confidence or reliability. Each antenna provides an observation of a tag response. The observation may include the RFID tag ID, signal quality, CRC/validation status, and response consistency. Instead of treating all antenna observations equally, the system assigns a confidence value to each observation.

• Confidence Evaluation

For an antenna a , the confidence of a received response can be represented as:

$$C_a = w_1 Q_a + w_2 V_a + w_3 R_a$$

where:

- C_a = confidence value of antenna a
- Q_a = response/signal quality
- V_a = ID or CRC validation result
- R_a = response reliability or consistency
- w_1, w_2, w_3 = weighting factors

IX. ALGORITHM

Algorithm 1: CA-MA-DFSA

The Confidence-Aware Multi-Antenna Dynamic Frame Slotted ALOHA (CA-MA-DFSA) algorithm is designed to improve RFID tag identification by combining multi-antenna observations with confidence-aware processing and adaptive frame-size control. The algorithm operates in repeated inventory rounds until all readable tags are identified or a predefined maximum number of rounds is reached.

Input

- N : Number of RFID tags
- A : Number of receiving antennas
- L : Initial frame size
- L_{min} : Minimum frame size
- L_{max} : Maximum frame size
- α : Smoothing factor
- β : Frame scaling factor
- τ : Confidence/uncertainty threshold
- Δ : Maximum allowed frame-size change

Output

- Set of successfully identified RFID tags
- Number of inventory rounds
- Total number of slots used
- Missed or uncertain tag information
- Final identification status



X. EXPERIMENTAL DESIGN

Experimental Design

The proposed CA-MA-DFSA method can be evaluated using a MATLAB or Python-based RFID simulation environment.

- Tag Population: 50, 100, 250, 500, and 1000 RFID tags.
 - Number of Antennas: 1, 2, and 4 antennas.
 - Channel Conditions: Low, medium, and high response-error conditions.
 - Compared Methods:
 1. Single-Antenna DFSA
 2. Multi-Antenna DFSA
 3. Proposed CA-MA-DFSA
 - Performance Metrics:
 - o Total number of slots
 - o Identification throughput
 - o Tag completion rate
 - o Missed-tag rate
 - o Number of inventory rounds
 - o Computational overhead
 - Evaluation: The proposed method is compared with existing methods under different tag densities and antenna configurations.
 - Ablation Study: The effect of confidence fusion, remaining-tag estimation, smoothing, and bounded frame adaptation can be evaluated separately.
- Expected purpose: The experiment is designed to determine whether CA-MA-DFSA can reduce unnecessary slots and missed-tag events while improving RFID identification efficiency.

XI. CONCLUSION

This paper introduced CA-MA-DFSA, a proposed confidence-aware extension for multi-antenna RFID identification in precision livestock monitoring. It specifies the control logic and a fair evaluation plan. Future work is to implement the simulator, publish the parameter settings and code, compare against established baselines, and validate the approach with real RFID equipment. Numerical performance claims should be added only after experiments are completed.

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REFERENCES

- [1] M. Alotaibi et al., "Anti-Collision Algorithm for Identification in Precision Agriculture Applications," IEEE Access, vol. 11, pp. 130197–130205, 2023. doi: 10.1109/ACCESS.2023.3334636.



- [2] X. Zhang, Y. He, H. Yi, et al., "A Novel Anti-Collision Algorithm for Large Scale of UHF RFID Tags Access Systems," *Computers, Materials & Continua*, vol. 80, no. 1, pp. 897–912, 2024. doi: 10.32604/cmc.2024.050000.
- [3] S. A. H. Alhuthali, M. Murad, I. A. Tasadduq, M. H. Awedh, A. M. Rushdi, et al., "An Effective Tag Estimation Method Based upon Artificial Neural Networks and Signal Strength for Anticollision in Radio Frequency Identification Systems," *International Journal of Computational Intelligence Systems*, vol. 17, article 200, 2024. doi: 10.1007/s44196-024-00587-5.
- [4] X. Xiong, W. Wang, T. Yang, and G. Mao, "A survey on RFID anti-collision strategies: From avoidance to recovery," *Computer Networks*, 2024. doi: 10.1016/j.comnet.2024.110897.
- [5] Chih-Chung Lin, Yuan-Cheng Lai, and Zelalem Legese Hailemariam, "A distinguished-bit tracking knowledge-based query tree for RFID tag identification," *Computer Communications*, vol. 218, pp. 166–175, 2024. doi: 10.1016/j.comcom.2024.01.017.
- [6] "A Review of Tags Anti-Collision Identification Methods Used in RFID Technology," *Electronics*, vol. 12, no. 17, article 3644, 2023. doi: 10.3390/electronics12173644.
- [7] "A Dynamic Multi-ary Query Tree Protocol for Passive RFID Anti-collision," *Computers, Materials & Continua*, vol. 72, no. 3, pp. 4931–4944, 2022. doi: 10.32604/cmc.2022.026654.
- [8] Zhimei Ling and Chaoying Wei, "An adaptive RFID anti-collision algorithm for network intrusion detection," *Journal of Reliable and Intelligent Environments*, vol. 14, no. 2, 2024. doi: 10.3233/RFT-230057.
- [9] "Research on the RFID Anticollision Strategy Based on Decision Tree," *Wireless Communications and Mobile Computing*, 2022. doi: 10.1155/2022/2913157.
- [10] "An ALOHA-Based Algorithm Based on Grouping of Tag Prefixes for Industrial Internet of Things," *Security and Communication Networks*, 2022, article 1812670.

