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SMART TREND-TRAVERSAL: A LOW DELAY AND ENERGY TAG ARBITRATION PROTOCOL FOR LARGE RFID SYSTEMS

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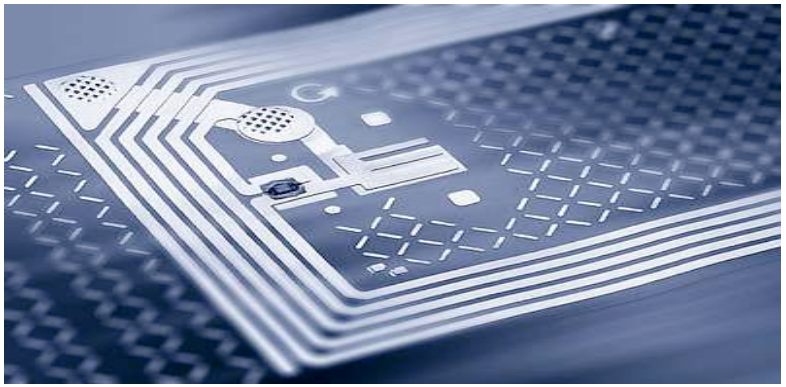
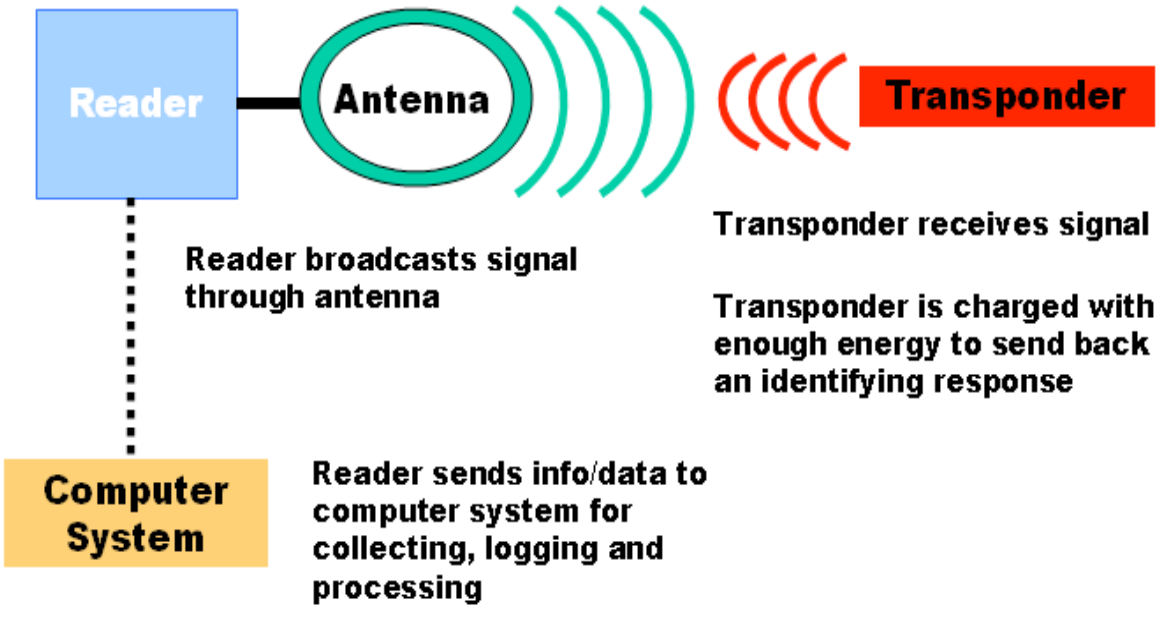
Outline

- Introduction
  - RFID systems
  - Problems and challenges
- Protocol Description
  - Motivation
  - Proposed protocol
  - Example and Algorithm
- Performance Evaluation
  - Distribution of tag IDs
  - Arbitration delay and energy consumption
  - Tree-based and Aloha-based comparison
- Conclusion

INTRODUCTION

Introduction: Radio Frequency Identification (RFID)





Features of RFID

- Low cost
- No line-of-sight
- Long life span
- Computation capability

Current standards

- EPC Class 1 Generation 1 (C1G1)
- EPC Class 1 Generation 2 (C1G2)

RFID System

- RFID reader: issue queries to communicate with the tags.
- Server: update information retrieved by the reader.
- RFID tags
  - Passive tag does not have its own power supply and solely relies on receiving energy from the reader to backscatter its data.
  - Active tag possesses its own battery for computation and communication.

PROTOCOL DESCRIPTION

RFID Tag Arbitration

Tag arbitration

- The reader identifies and retrieves information from the tags in its range
- Tag collision: multiple tags respond simultaneously
- Challenges
  - Excessive delay overhead and energy consumption due to collision
  - Impractical assumptions of uniform tag distribution and tag cardinality

Related protocols

- Query-tree based
  - Utilize the binary features of tag IDs
  - Memory-less
  - Deterministic
- Aloha based
  - Simple and low implementation cost
  - No guaranteed delay bound
  - Need to remember the state information

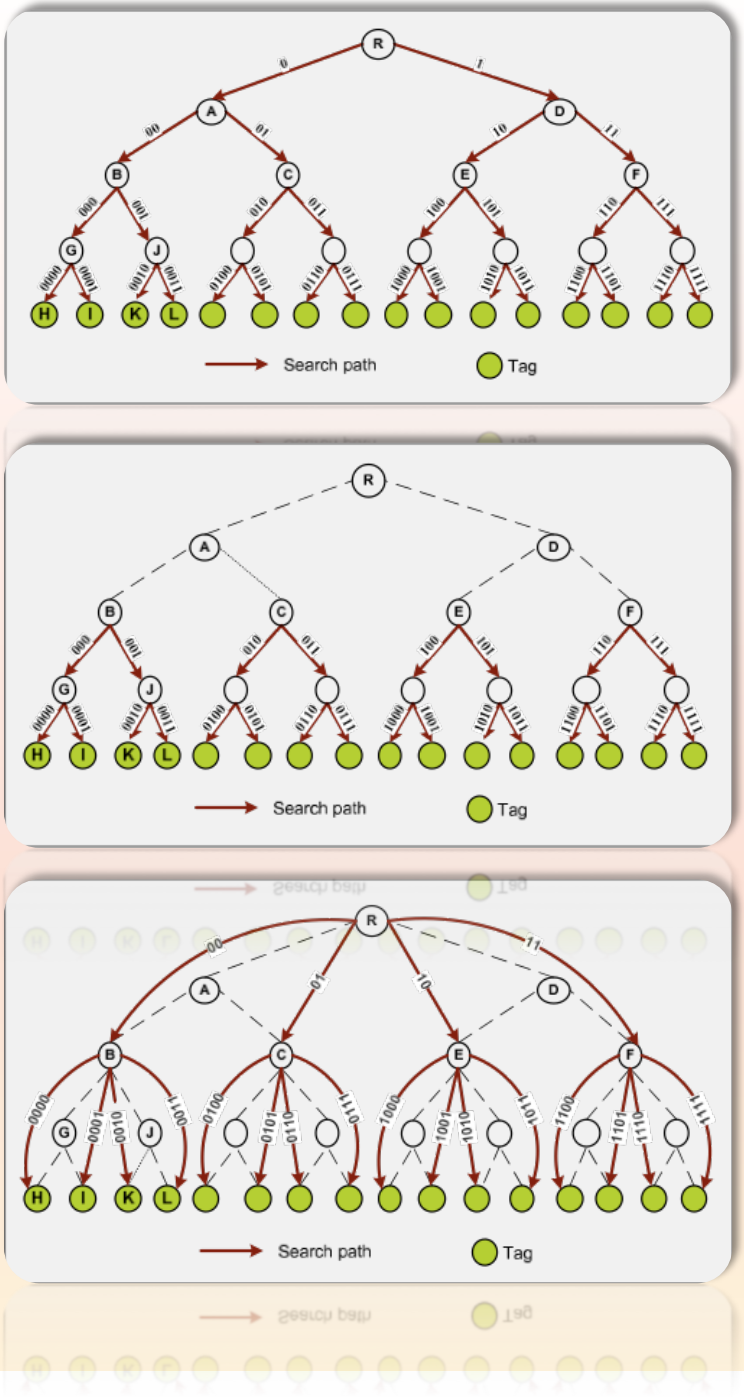
Tree-based Arbitration Protocols

Proposed:

- Query Tree: splitting the tags based on the IDs
- Enhancement: start the arbitration from an "optimal" point i/o root
- MAS: traverse multiple levels at a time

Assumptions

- Uniform distribution
- Number of tags



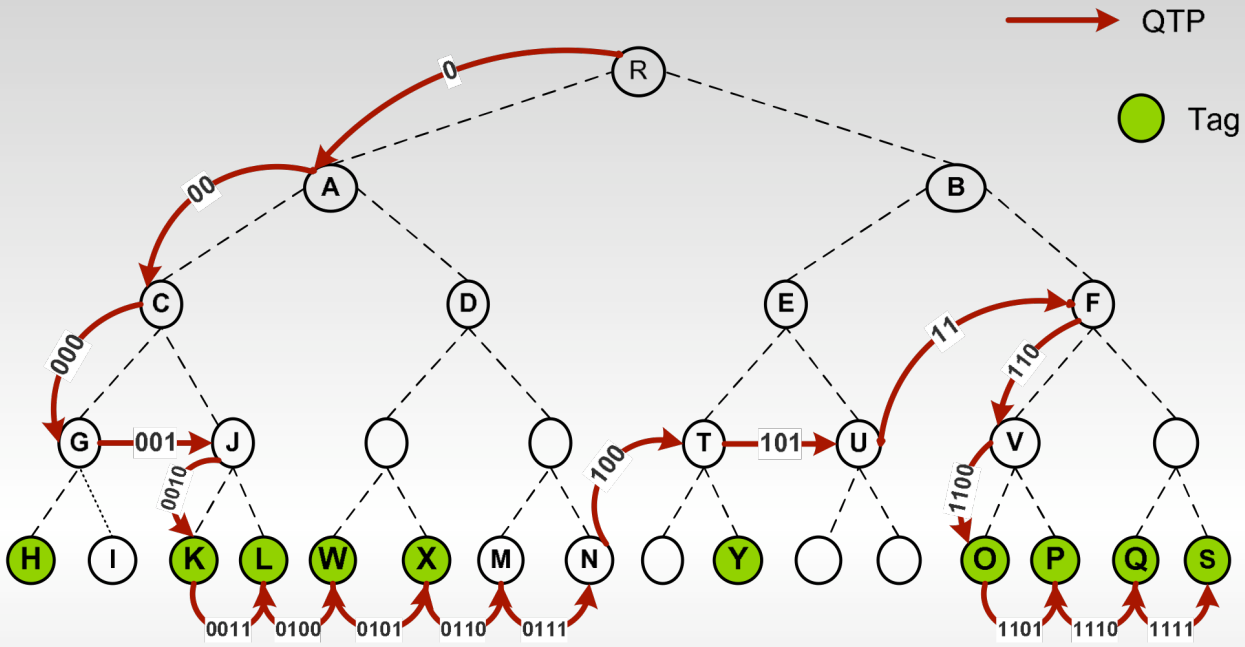
Motivation

- Goals
  - Reduce collision and empty slots
  - Hold no assumptions of the
- Proposed Smart Trend-Traversal (STT):
  - Query-tree based
  - Dynamically adjusted queries to avoid collision and empty slots
  - Close-to-optimal query traversal path
- QTP: query traversal path
  - A sequence of all queries used by the reader in the arbitration

Proposed STT protocol

- Reader starts arbitration from the root
  - Insert null value in the query
- Reader makes judgment according to the arbitration results:
  - Collision: current QTP is at a level too high
    - Traverse one level down
  - Empty: current QTP is at a level too low
    - Traverse one level if the node is the right sibling
    - Traverse to the right if the node is the left sibling (to guarantee all the leafs are covered)
  - Single tag response: current QTP overlaps with ideal QTP
    - Traverse to the immediate right node horizontally

Example of STT



Algorithm: Construct QTP

Let $q_c=b_1b_2...b_h$ be the current query prefix used.

m is the number of consecutive 1's from the least significant bit in q_c.

q_n is the prefix in the next query to be issued.

\IF The reader detects a collision slot

$q_n = q_c0$;

\ELSE

$q_n = b_1b_2...b_{h-m-1}1$;

\IF The reader detects an empty slot

\FOR i=1 to m-1

$q_n = q_n0$;

\ELSE //singleton node

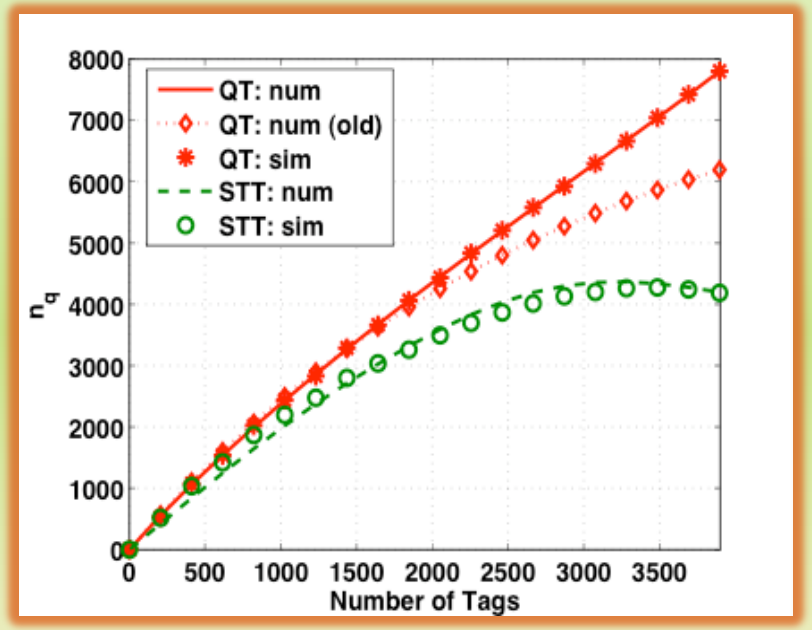
\FOR i=h-m+1 to h

$q_n = q_n0$;

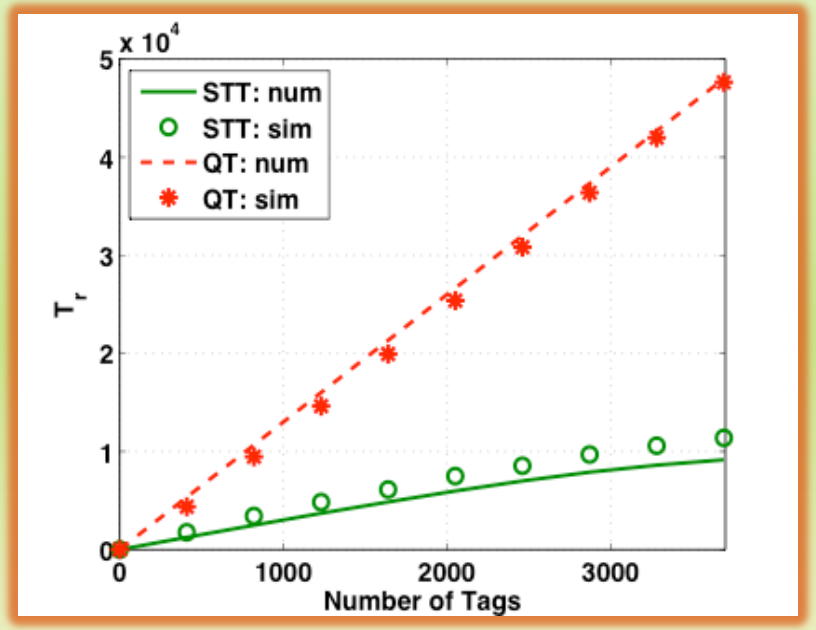
PERFORMANCE EVALUATION

STT vs QT

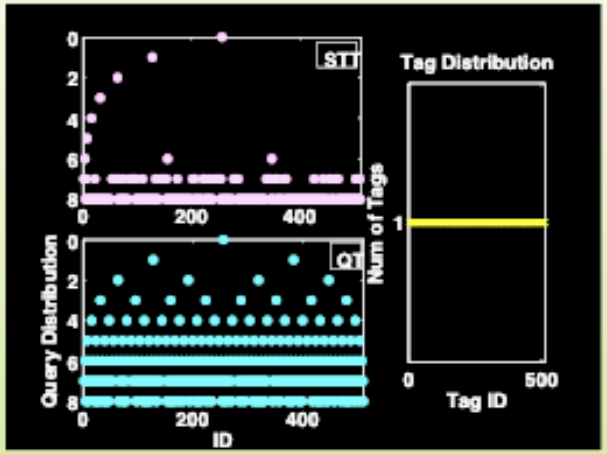
Number of slots (delay)



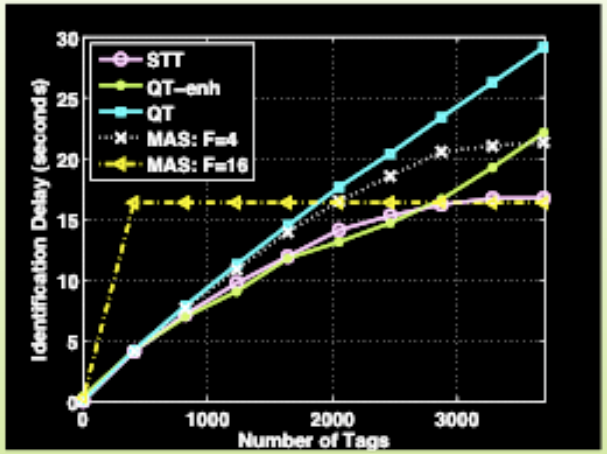
Number of tag replies (energy consumption)



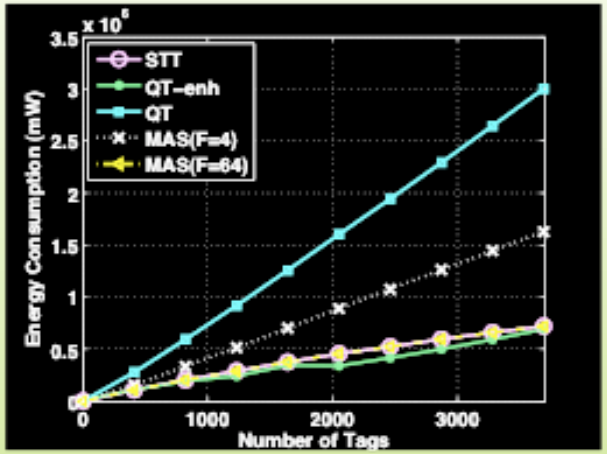
Uniform/Normal distribution



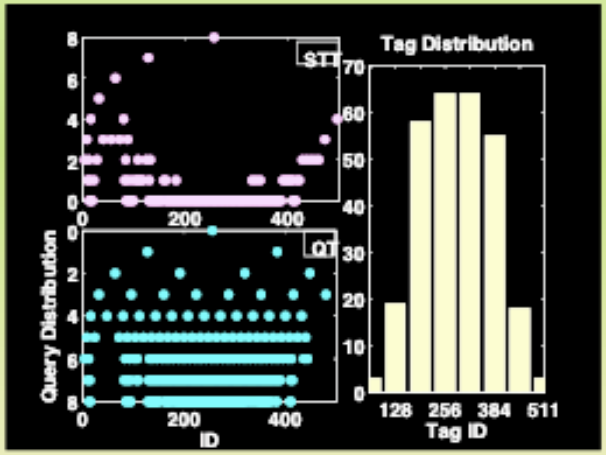
(a) Uniform distribution.



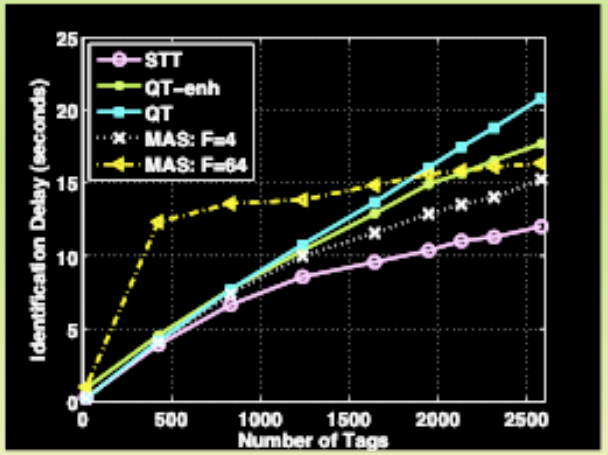
(b) Identification delay.



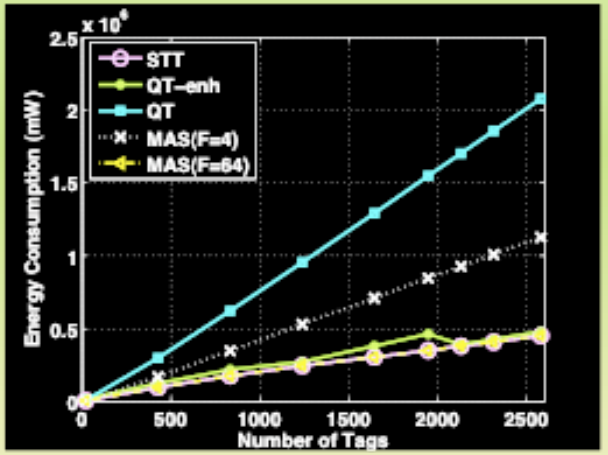
(c) Energy consumption.



(d) Normal distribution.

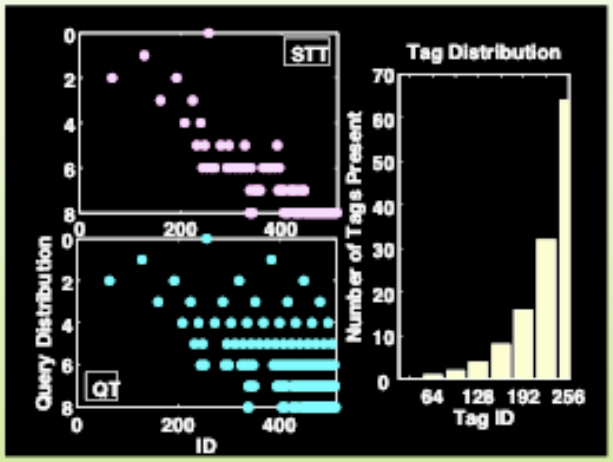


(e) Identification delay.

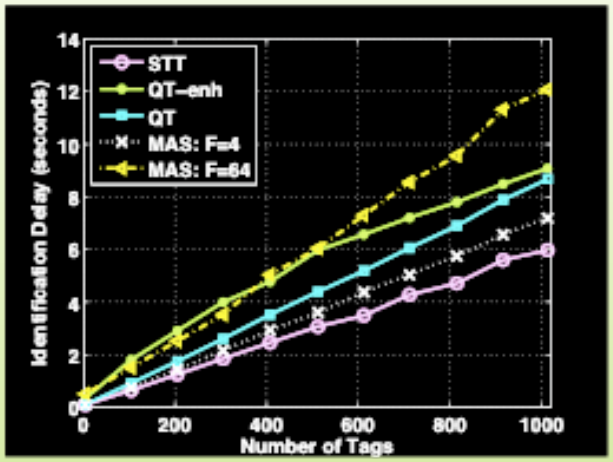


(f) Energy consumption.

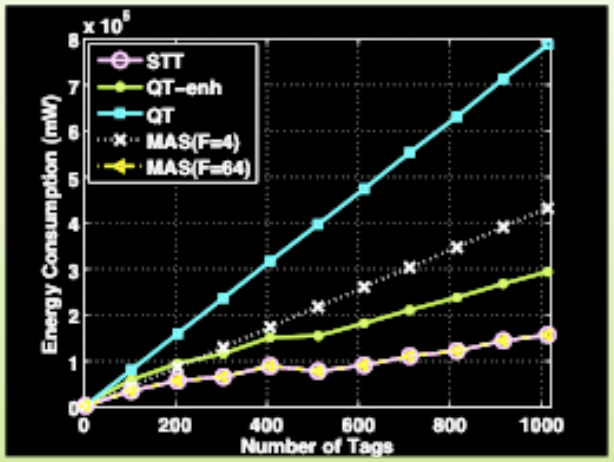
Geometric/Local-uniform distributions



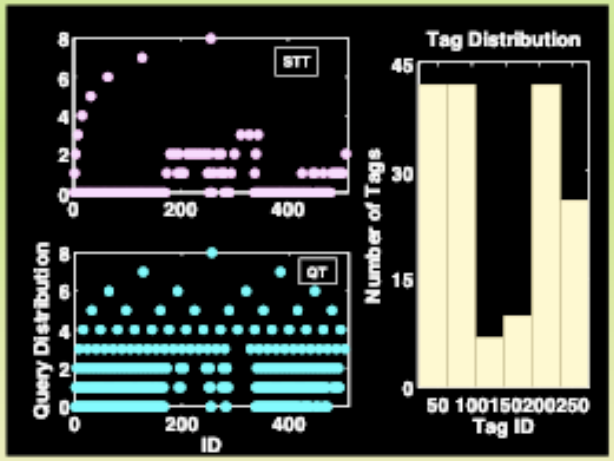
(g) Geometric distribution.



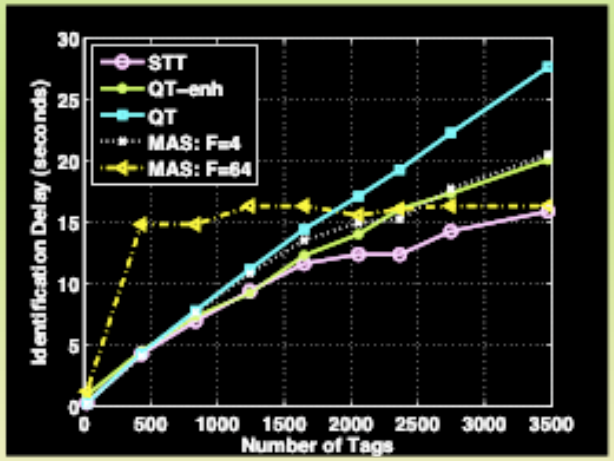
(h) Identification delay.



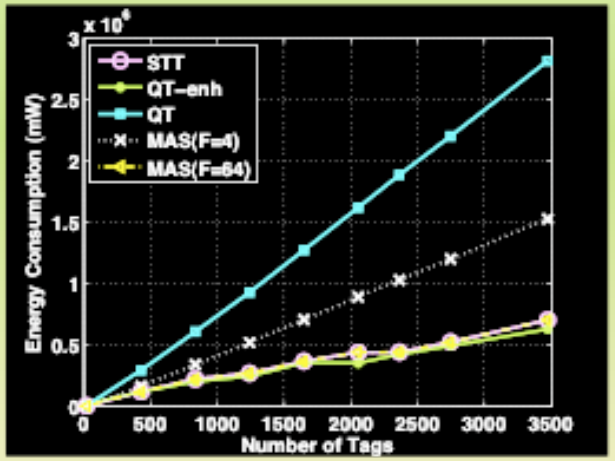
(i) Energy consumption.



(j) Special Categories.

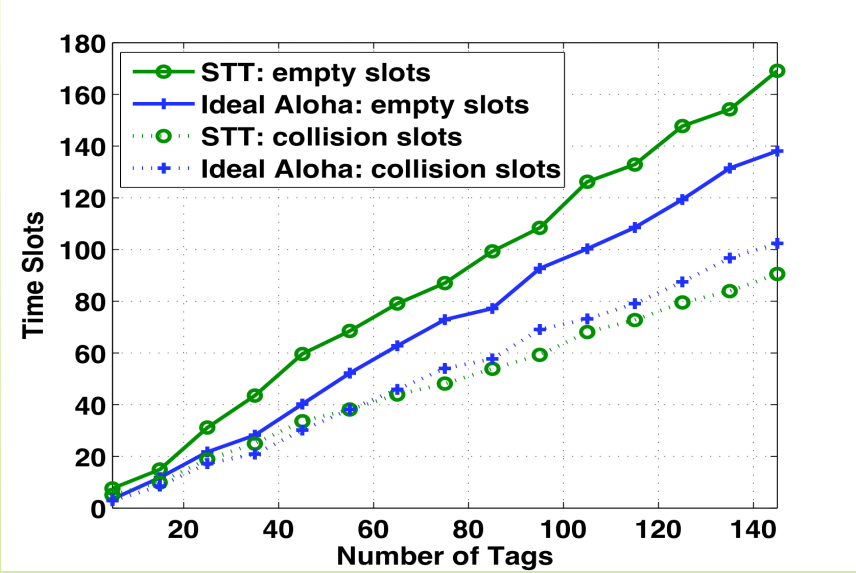


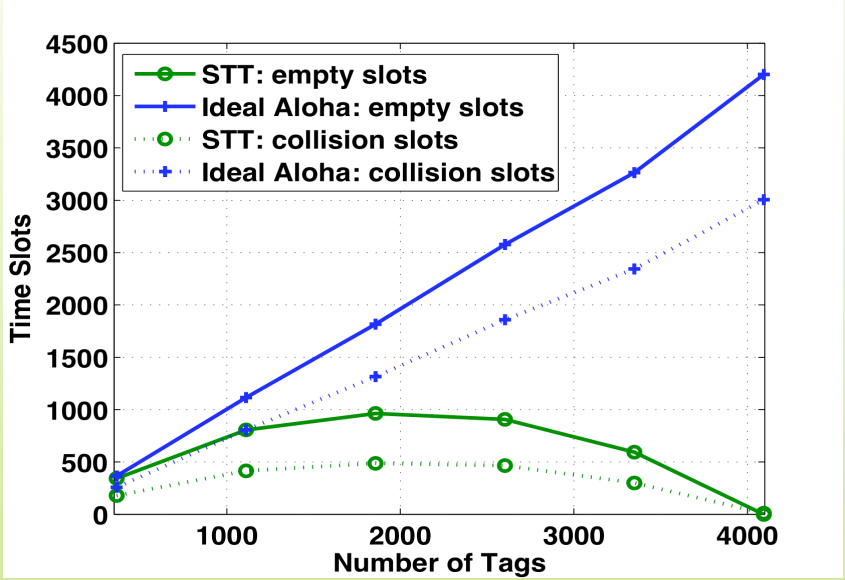
(k) Identification delay.

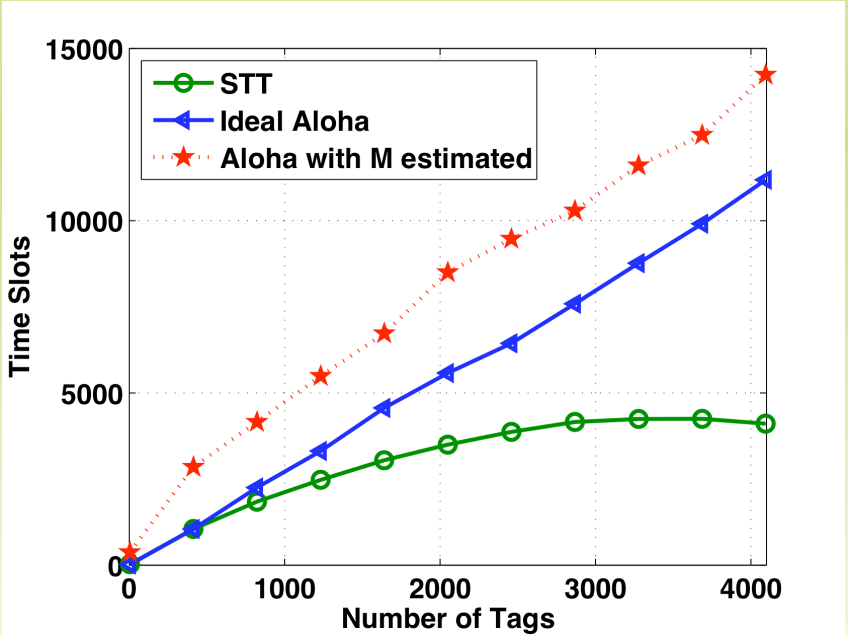


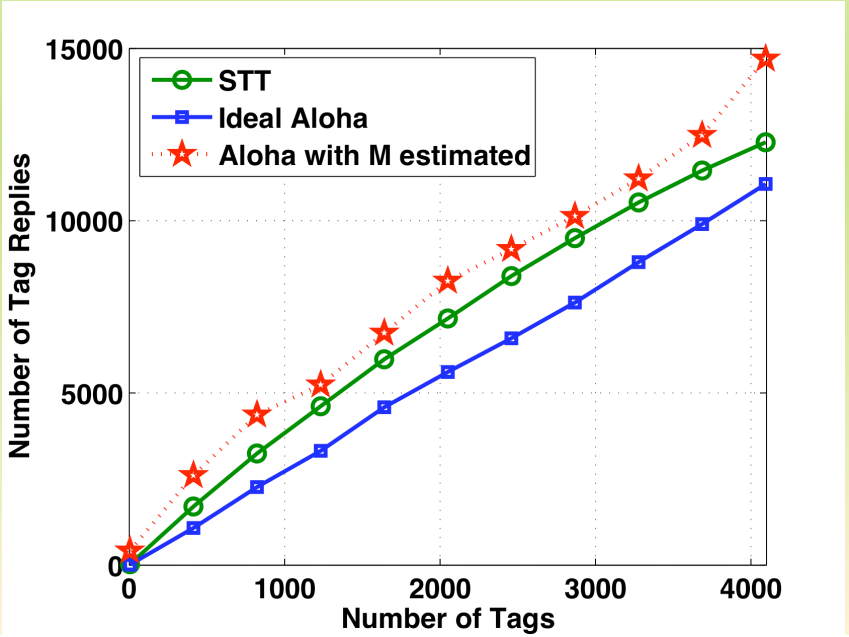
(l) Energy consumption.

STT vs. Frame Slotted Aloha









FURTHER DISCUSSION

Analytical Model

The average number of time slots used:

- h: traversal level
- K: number of bits in tag ID
- $V_{h,i}$: The probability of a i^{th} node at level h being visited

$$n_q = \sum_{h=0}^{K} \sum_{i=1}^{2^h} V_{h,i}.$$

The average number of tag replies:

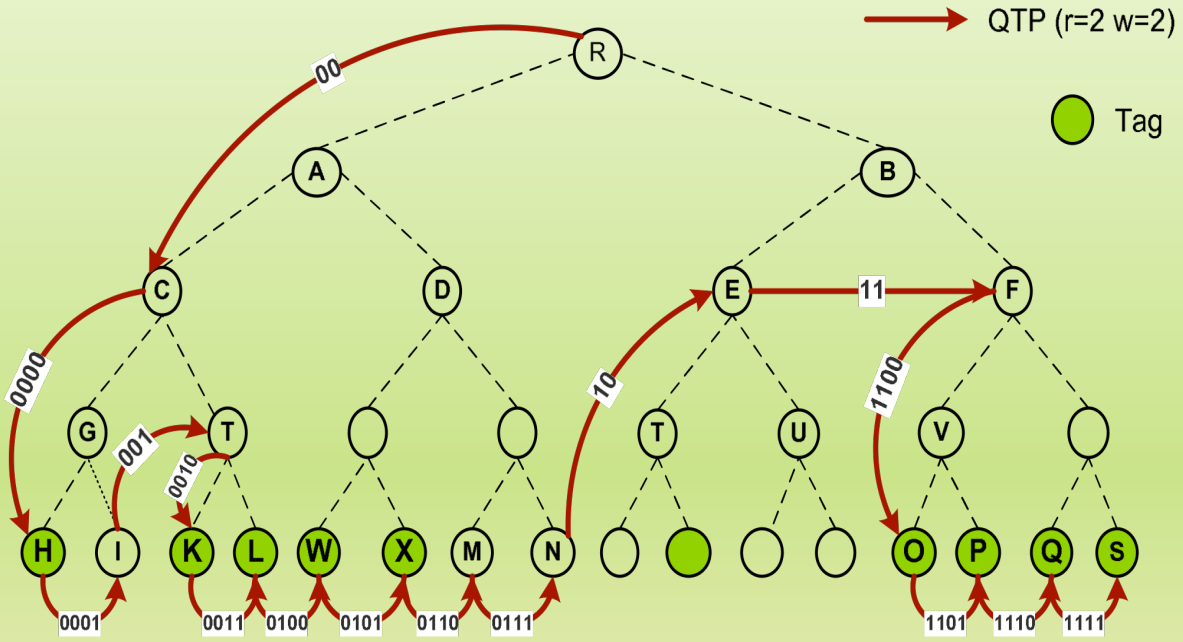
- M: number of tags in the reader's interrogation region

$$T_r = \sum_{h=0}^{K} \sum_{i=1}^{2^h} \frac{M}{2^h} V_{h,i},$$

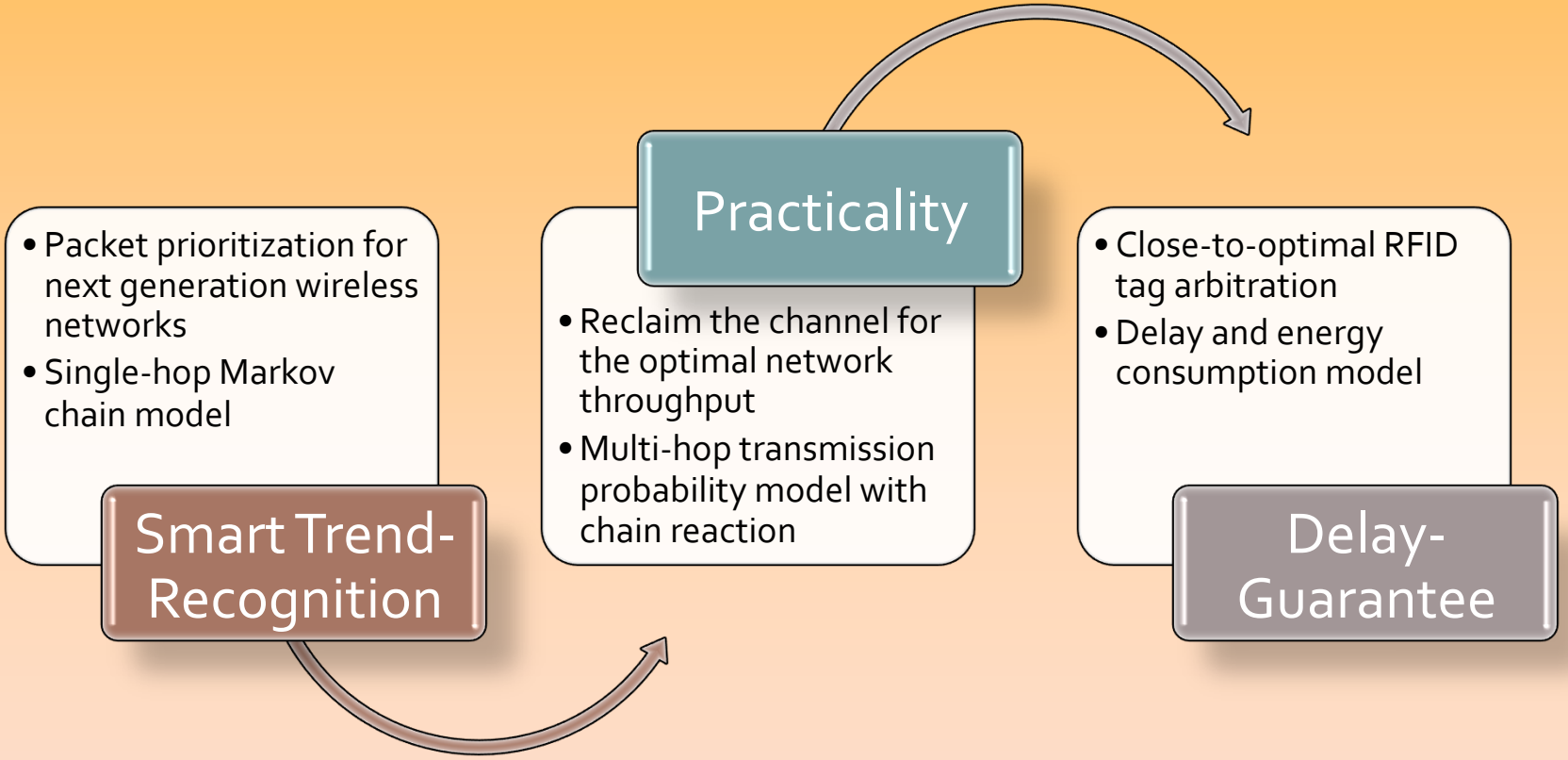
Fine-tune STT

1. Set initial traversal level r

2. Set buffer size w to record the continuous traversal failures



Conclusion


Smart Trend-Recognition
• Packet prioritization for next generation wireless networks
• Single-hop Markov chain model
Practicality
• Reclaim the channel for the optimal network throughput
• Multi-hop transmission probability model with chain reaction
Delay-Guarantee
• Close-to-optimal RFID tag arbitration
• Delay and energy consumption model

Thank you