# Intelligent MAC Design for RFID Networks

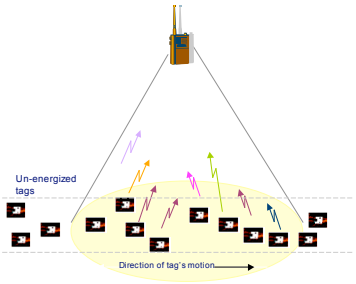
**Girish Khandelwal, Kyounghwan Lee, Min Chen, Semih Serbetli, Aylin Yener**

PENNSTATE 1855

## Introduction

- RFID tags are envisioned to be mounted on virtually everything in the near future!
- Development very much driven by potential applications: Identify individual components, inventory control, sensory information reports, security…
- Reader is designed to read one tag at a time: multiple tags lead to "collisions".
- Solution: Design of collision reduction/avoidance transmission schemes to achieve low identification time and high throughput of the system.

## System Model




## Current Proposals & Motivation

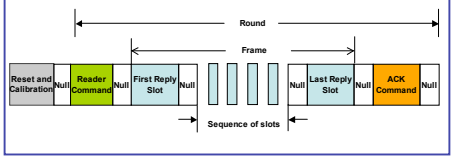
- Framed Slotted ALOHA
  - Fixed round size: performance limitation
  - Small frame size and high tag count
    - *excessive collisions*
  - Large frame size and low tag count
    - *under-utilization of the resources*
    - → Need for an intelligent MAC protocol
- Binary Tree Search
  - Entire EPC is exchanged between tag and reader in both directions.
    - waste of time and bandwidth
    - →No attempt to use the received bit string

## ASAP-General Description

- ASAP *(Adaptive Slotted ALOHA Protocol)* is based on framed slotted-ALOHA with enhancements to original 13.56 MHz band STAC.
- Designed for 900MHz UHF band RFID system.
- Exploitation of the statistical information collected at the reader.
- Performance improvement by adaptively proposing the appropriate round size for dynamic change of tag density.
- Slight modification to the current standard without additional complexity.

## ASAP-Round Structure

- ASAP is time-slotted random access protocol.
- The communications take place in "rounds".
- Key is "*to adjust the round size"* for dynamic tag density.




## Design of Optimum Frame Size

- Reader proposes the optimum frame size (*N*) by exploiting the statistical information collected at the reader.
- ML- Estimator for tag count.
- $\beta^*$ = 1.943 is determined by maximizing the efficiency function:

$$P_{eff} = \frac{E[S]\cdot T_B}{E[U]\cdot T_B + E[I]\cdot T_I}$$

$Z_I$: No. of Idle slots
$Z_S$: No. of successful slots
$Z_U$: No. of unsuccessful slots
N : No. of slots

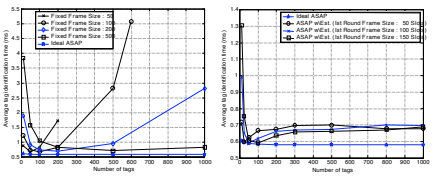
ML-Tag Count Estimator ($\hat{k}$)

Maximize Efficiency Function

$$N = \beta^* \hat{K}$$

## Simulation Results-ASAP

- Trend for average number of bits as D varies



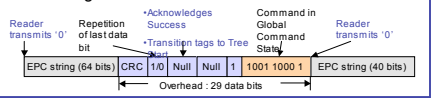

- ASAP shows ***significant improvement*** over fixed frame size protocol.

## OPT-General Description

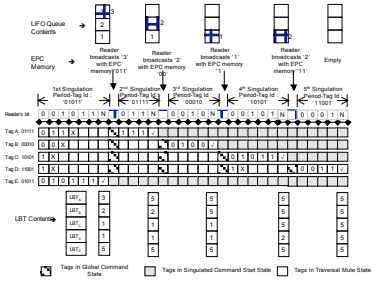
- Optimum Protocol Tree (OPT) is based on Binary Tree Search.
- Take advantage of the similarities in the EPC strings:
  - Utilize the partial data stream received from the tags in previous unsuccessful transmission attempts
  - Selective transition of unsuccessful tags for participation in subsequent rounds
  - Cost : Slight modifications to recommended state machine implementation in Binary Tree search algorithm.

## OPT-Working Principle

- LBT (Last Bit Transmitted) Register
  - Each tag stores the index of the last transmitted bit
- LIFO (Last In First Out) Queue
  - Reader stores and updates the index of the collisions
- EPC Buffer Memory
  - Reader stores the EPC string of the last identified tag
- Reader-Tag Communication Structure

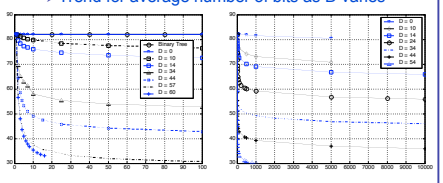



## Identification in OPT




## Simulation Results-OPT

- Trend for average number of bits as D varies




- OPT shows ***significant improvement*** over Binary Tree Search, especially for large D, i.e., the *degree of correlation*.

## Conclusions

- Envisioned application of RFID systems requires the efficient MAC protocol in order to reduce the collision and minimize the identification time.
- Two intelligent MAC protocols for RFID systems have been proposed: ASAP & OPT.
- ASAP exploits the statistical information at the reader in order to provide the optimum frame size.
- OPT takes advantage of the similarities in the EPC strings.
- ASAP and OPT provide the significant performance improvement with virtually no additional complexity.

Sponsored by The Technology Collaborative **(Vocollect, 3eTI, Phillips, IBM, Adcus, Steel River, Identifi)**