FINDERS: A Featherlight Information Network With Delay-Endurable RFID Support

ZHIPENG YANG AND HONGYI WU

Center for Advanced Computer Studies

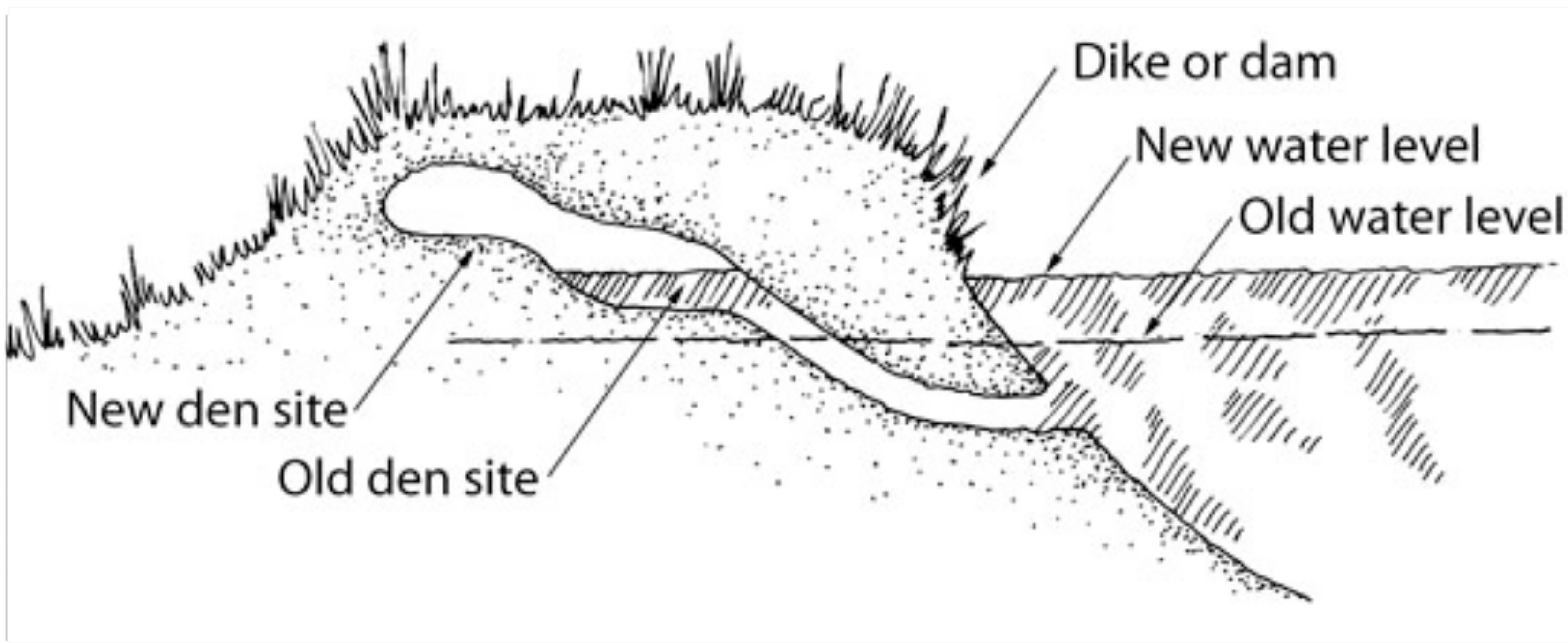
University of Louisiana at Lafayette

This work is supported in part by the National Science Foundation under grant CNS-0831823.

OUTLINE

- ☐ MOTIVATION
- ☐ SYSTEM ARCHITECTURE
- ☐ PRINCIPLES
- ☐ PROTOCOL
- ☐ IMPLEMENTATION

Biological Research at National Wetlands Research Center



Damages made by nutria

WHAT WE SHOULD DO

- ☐ Observe many problems caused by nutrias
- ☐ Track them
- ☐ Understand their habitat
- ☐ Build models to predict their behavior, population, and potential damage
- ☐ Develop strategies to control them and protect our property

What we do in field experiments ......

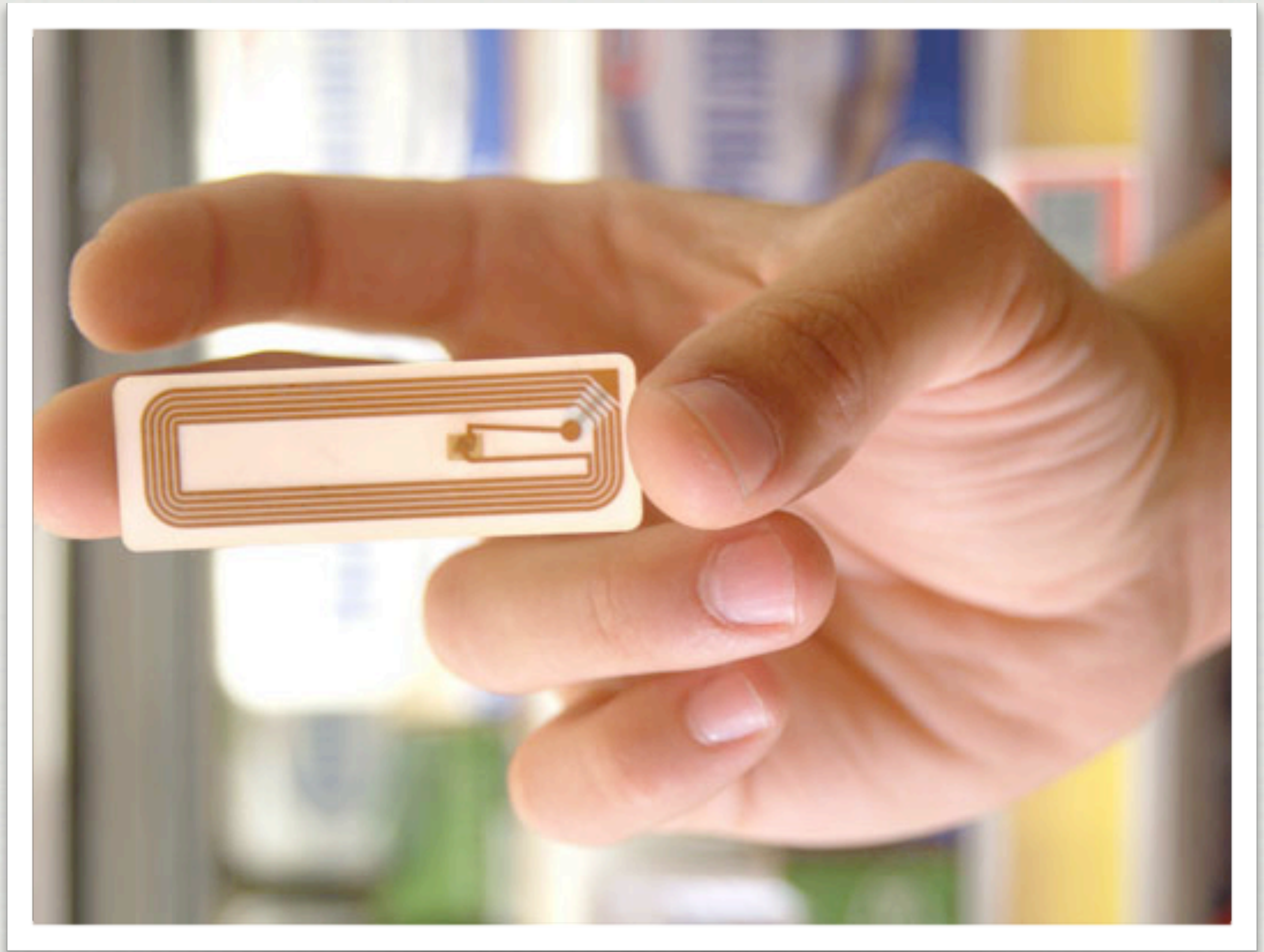
Mark it, attach GPS, let it go ....

Days later ....

DEAD!

LESSONS LEARNT

- Weight constraint
  - the weight of the sensor must be under 5% of the weight of the animal to avoid hindering its movement or welfare
- The lowest weight of active device is bounded by
  - battery: to power the device
  - casing: must be heavy-duty for the protection of power source and powered electronic circuits under harsh environments
  - 80% of the nutria cannot carry any active devices
- Similar problems for investigating most small animals
  - frog migration, penguins habitat tracking, ...



POSSIBLE SOLUTIONS

Passive RFID Tags

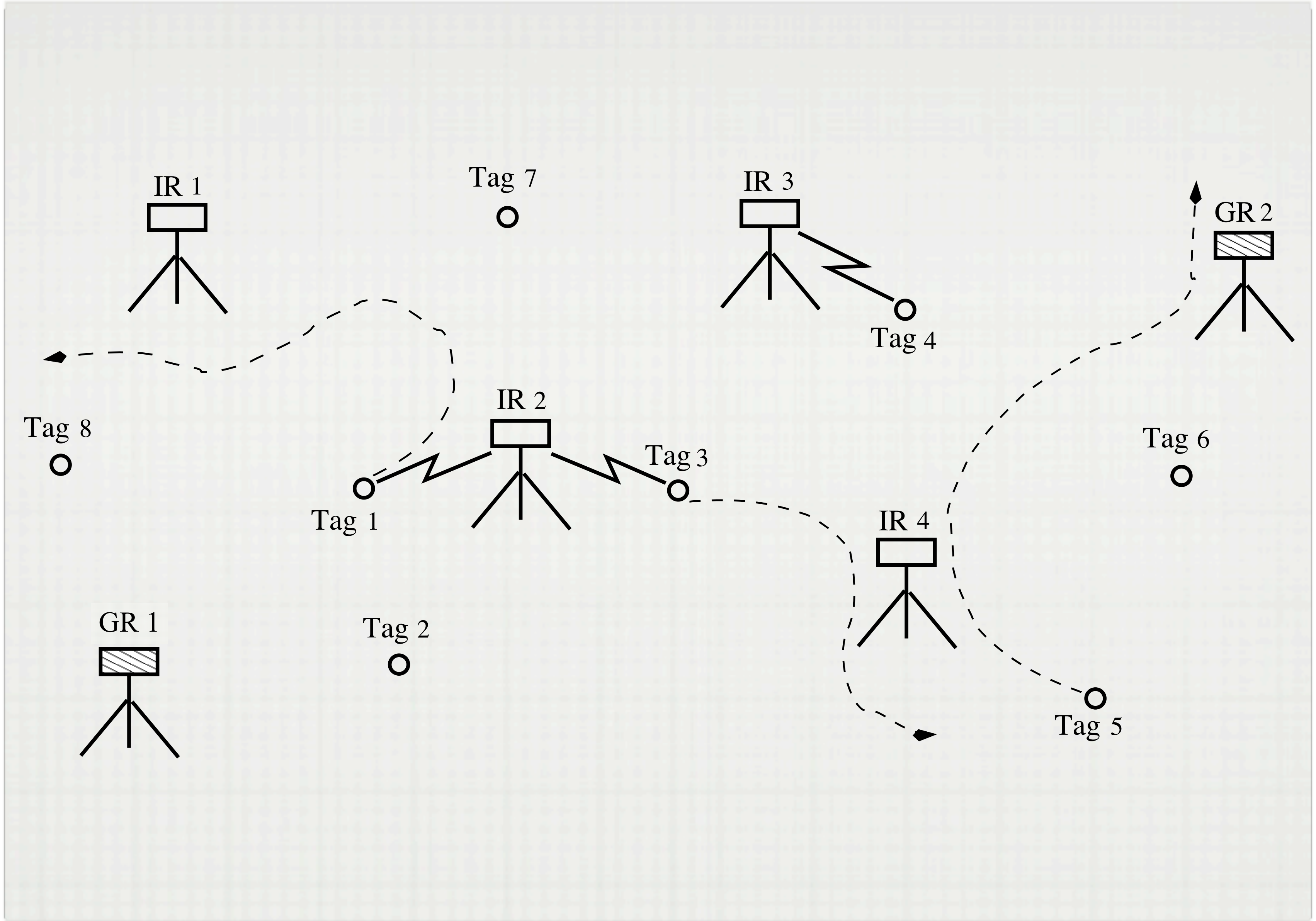
PASSIVE TAGS

- Nice properties
  - No battery
  - No need for casing
  - very thin and light (less than 1 gram)
  - Low cost
  - Durable: survivable under very harsh environments (underwater, underground tunnels, and extreme temperatures)

POSSIBLE SOLUTIONS

Passive RFID Tags on Nutria

SYSTEM ARCHITECTURE



ARCHITECTURE OF FINDERS

IR: Isolated Reader

GR: Gateway Reader

UNIQUE CHALLENGES

- 1. Intermittent connectivity:
  - The connectivity of FINDERS is very low and intermittent, forming a sparse network where a tag is connected to a reader only occasionally.
  - A special DTN with unique communication and storage constraints.
- 2. Intermittent computation:
  - The computation at the tag is also intermittent. It is available only when the tag is powered up by a nearby reader.
  - Such continuous functions necessary to many protocols as counters and timers cannot be implemented here.

UNIQUE CHALLENGES

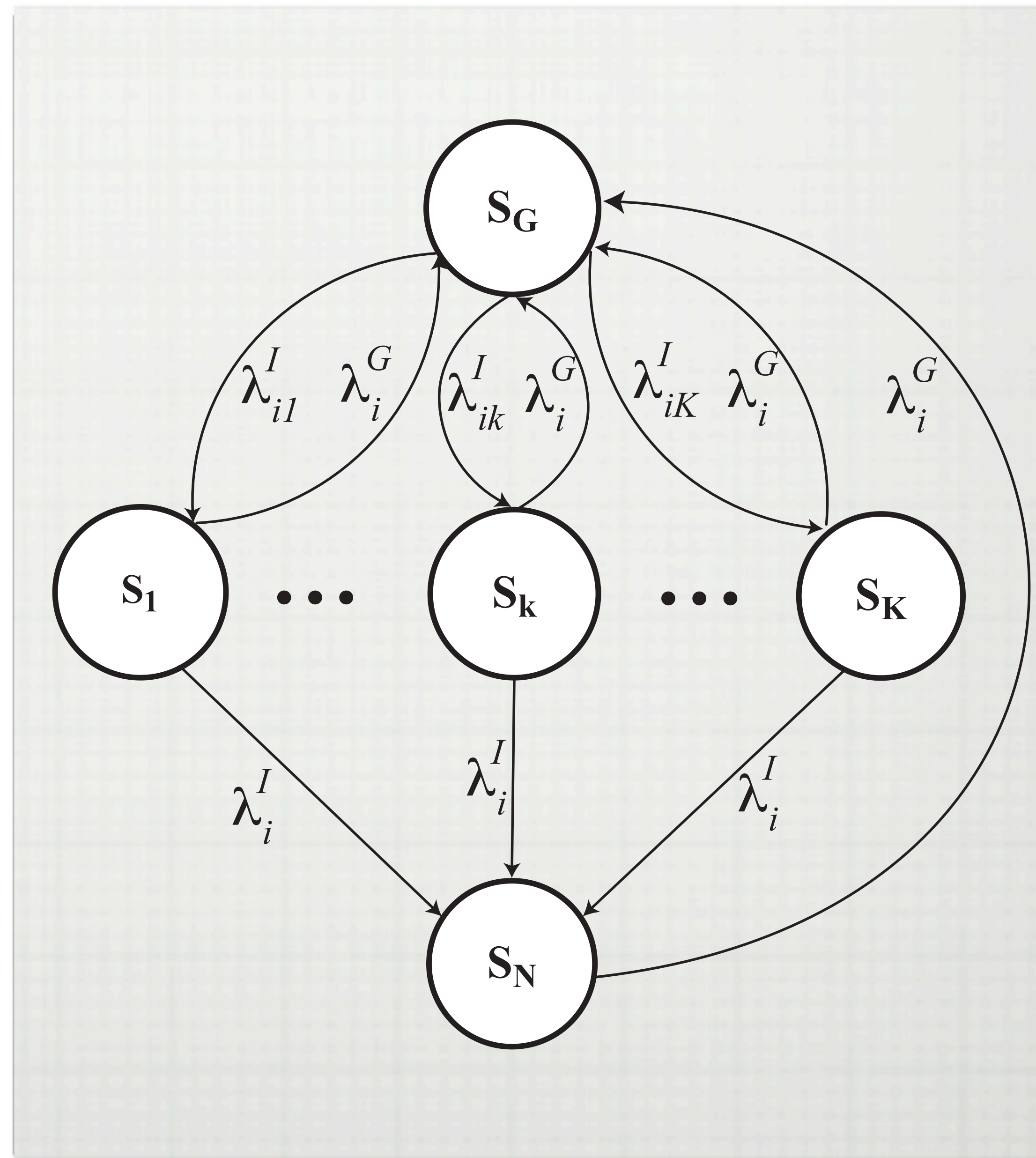
- 3. Critical network resource:
  - the buffer space of the tags (the main vehicle for data transportation) is so limited that it may become the critical network resource and communication bottleneck
- 4. Nodal heterogeneity:
  - a reader is a static and powerful device, with large storage, high computing power, and long-lasting battery power
  - the tag can be mobile and has extremely limited resource
- 5. Asymmetric communication:
  - The communication can be established between a tag and a reader only, but not tags to tags or readers to readers

UNIQUE OPPORTUNITIES

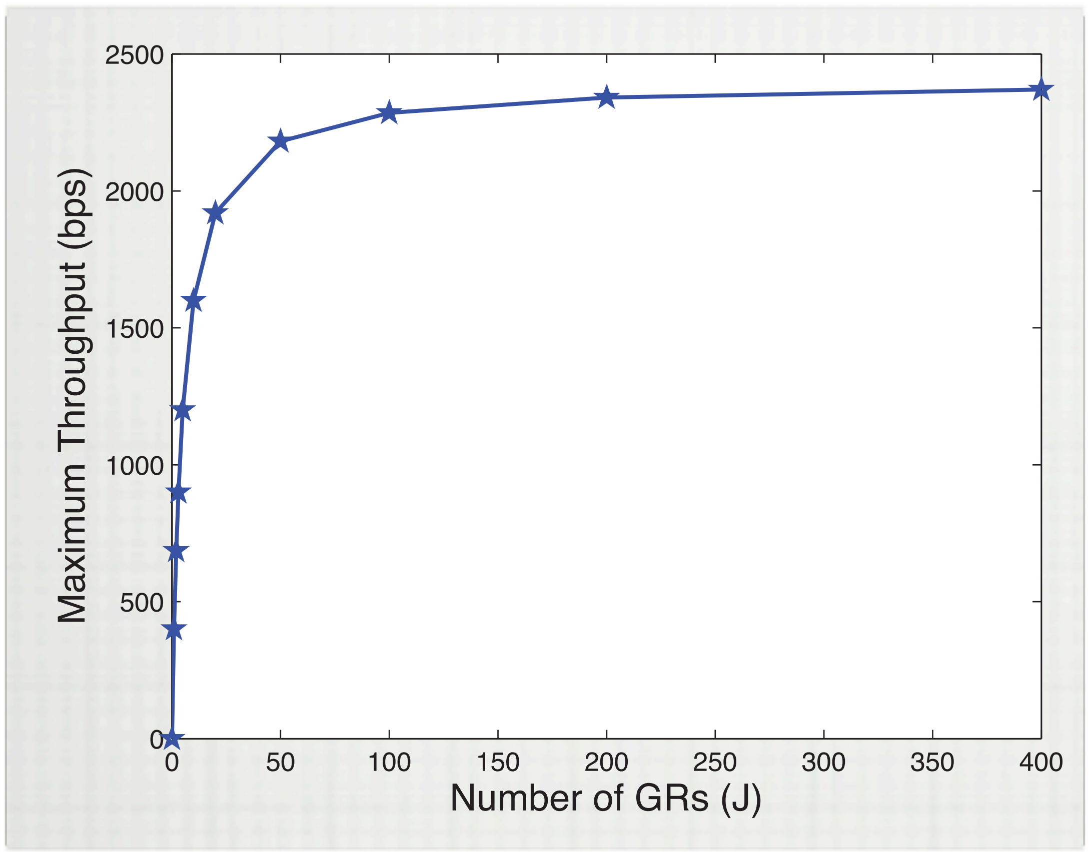
- 1. Delay tolerability:
  - Data delivery delay in FINDERS is potentially high,
  - However, such delay, though not desirable, is usually tolerable by the applications which aim at pervasive information gathering from a statistical perspective
- 2. Fault tolerability:
  - Redundancy may exist during data acquisition and delivery.
  - Thus, a data packet may be lost without degrading information gathering performance.

IS FINDERS FEASIBLE?

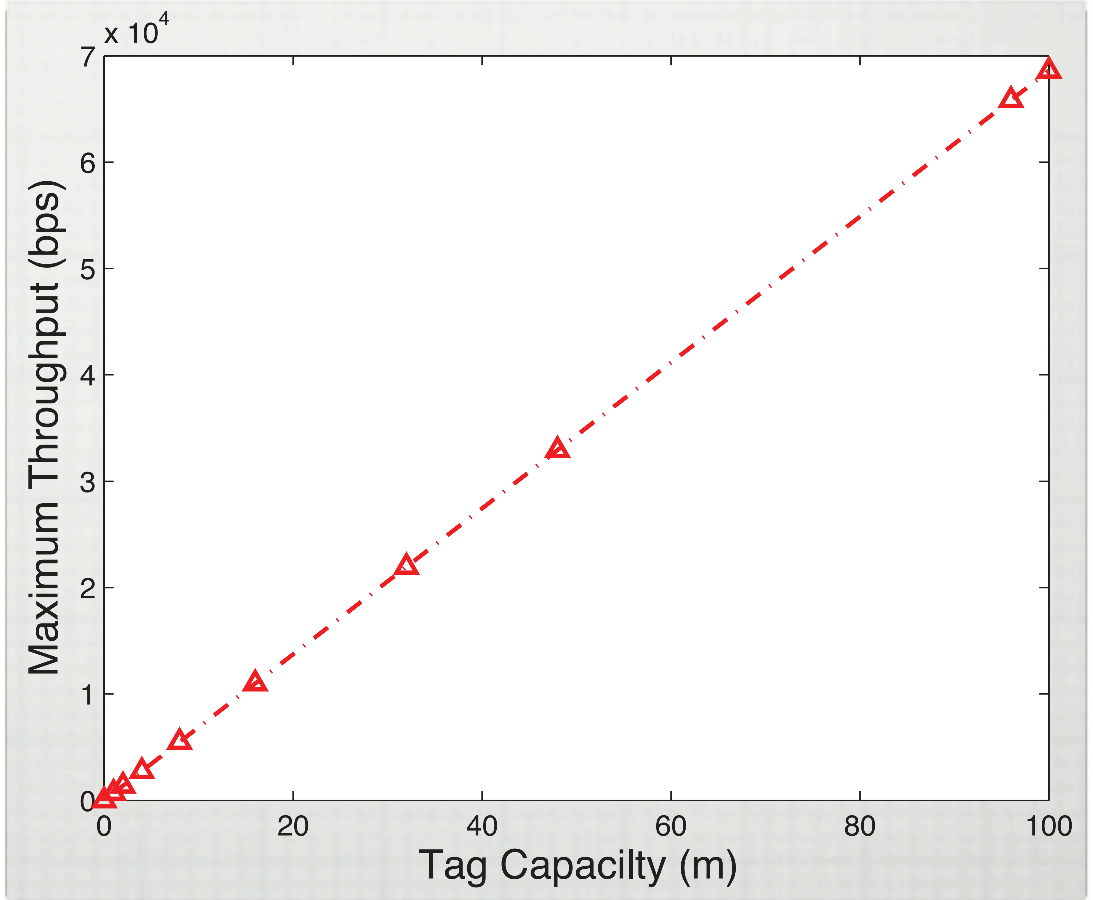
- General feasibility study to estimate the network capacity
  - No data loss at tag if physical failure ignored
  - To model the reader
    - G/G/1 queue
    - Service rate
    - Arrival rate
    - Network capacity



ANALYTIC RESULTS



- Multiple kbps throughput can be achieved in a typical FINDERS



- IR's: 5
- GR's: 2
- Tags: 100
- Tag capacity: 96 bits

PRINCIPLES

PRELIMINARY OBSERVATIONS

- Little earlier studies have ever been conducted on information networks composed of RFID gears with sporadic communication between moving tags and nearby readers.
  - Sensor network solutions are not directly applicable.
    - End-to-end communications, which are the basis of mainstream sensor network technologies
  - DTN technologies are not applicable either
    - The fundamental principle of DTN: ample buffering is employed under the intermittent connectivity to alleviate the needs of immediate transmission
    - Asymmetric communication paradigm, the intermittent computation capability and the extremely small buffer size of a passive tag

KEY ISSUES (I)

- Routing metrics
  - An indicator of the available resource of a given path or link.
  - Hop count and delay used in conventional networks.
  - These metrics, however, do not reflect the unique network resource of FINDERS, and thus may lead to poor network performance or even failure if used for routing.
  - In this research, we investigate effective routing metrics based on meeting probabilities between tags and readers, and devise mechanism that consumes insignificant storage space for maintaining and updating such metrics.

EFFECTIVE DELIVERY CAPABILITY (EDC)

- FINDERS is an opportunistic network, where the communication links exist with certain probabilities
- EDC indicates the likelihood that a node can deliver data messages to the GR's.
  - Initial value: 0 for tags and IR's; 1 for GR's
  - Update (EWMA): when two nodes meet

$$\xi_i = (1-\eta)^{\lfloor \frac{t_1 - t_o}{\Delta} \rfloor} [\xi_i] + \eta \hat{\xi}$$

Constant employed to keep partial memory of historic status

EDC of Node *i* before it is updated

EDC of the other node

KEY ISSUES (2)

- Duplication control: a system-wide optimization problem
  - In DTN networks, replication is necessary during data delivery for achieving a given success ratio.
  - Increases overhead, and worse yet, excessive replication may degrade the delivery ratio due to frequent buffer overflow.
- Queue management:
  - Limited communication resource and relatively high loading factor
  - Differentiate the packets in the queue by a simple and efficient parameter which signifies their importance and determines which packet to transmit or drop.

MESSAGE FAULT TOLERANCE DEGREE (FTD)

- For duplication control and queue management
- Fault tolerance: the probability that at least one copy of the message is delivered to GR's by other nodes in the network.
- Initial value: 0 for a new message
- Update: when a message is transmitted

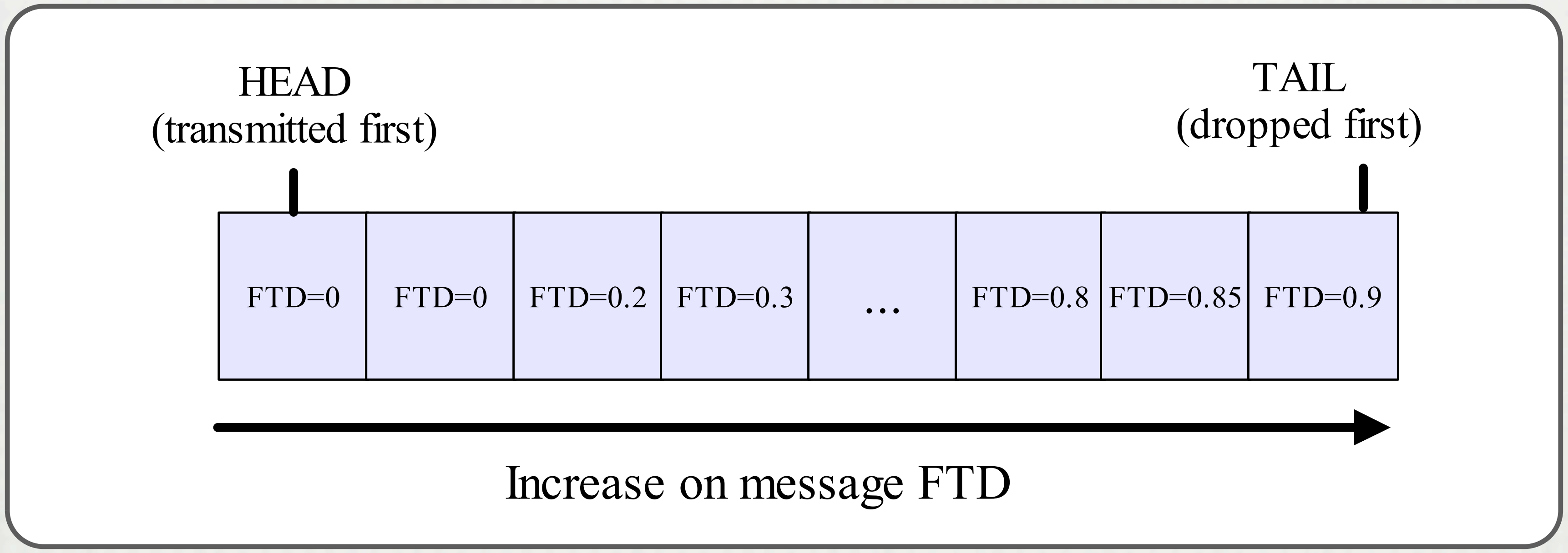
$$\mathcal{F}_j^M = 1 - (1 - [\mathcal{F}_i^M])(1 - \xi_i)$$

Old fault tolerance degree

Nodal delivery probability

QUEUE MANAGEMENT

- The queue management scheme is based on message fault tolerance



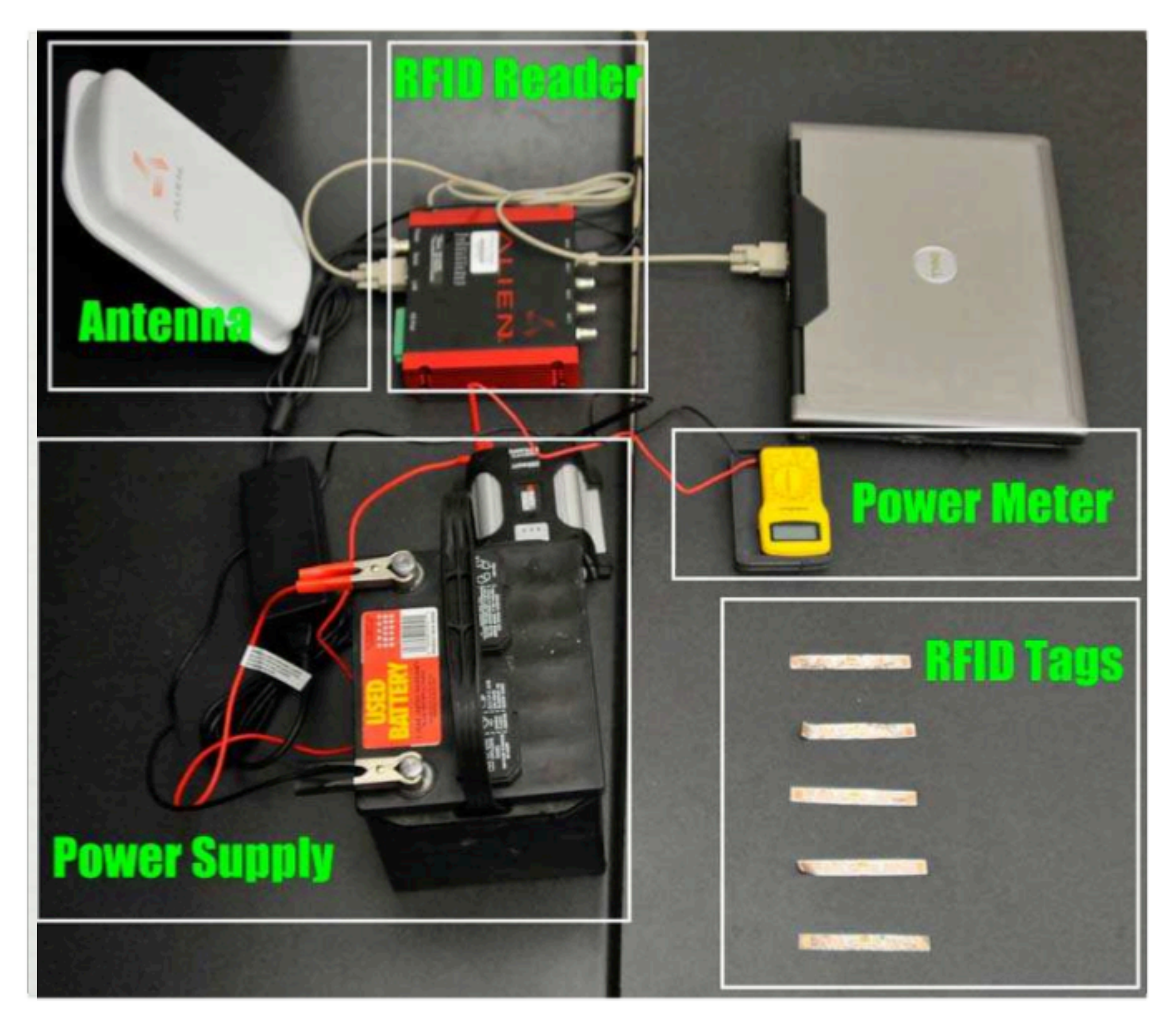
- Message dropping happens in two situations:
  - If the queue is full
  - if the FTD of a message is higher than a threshold

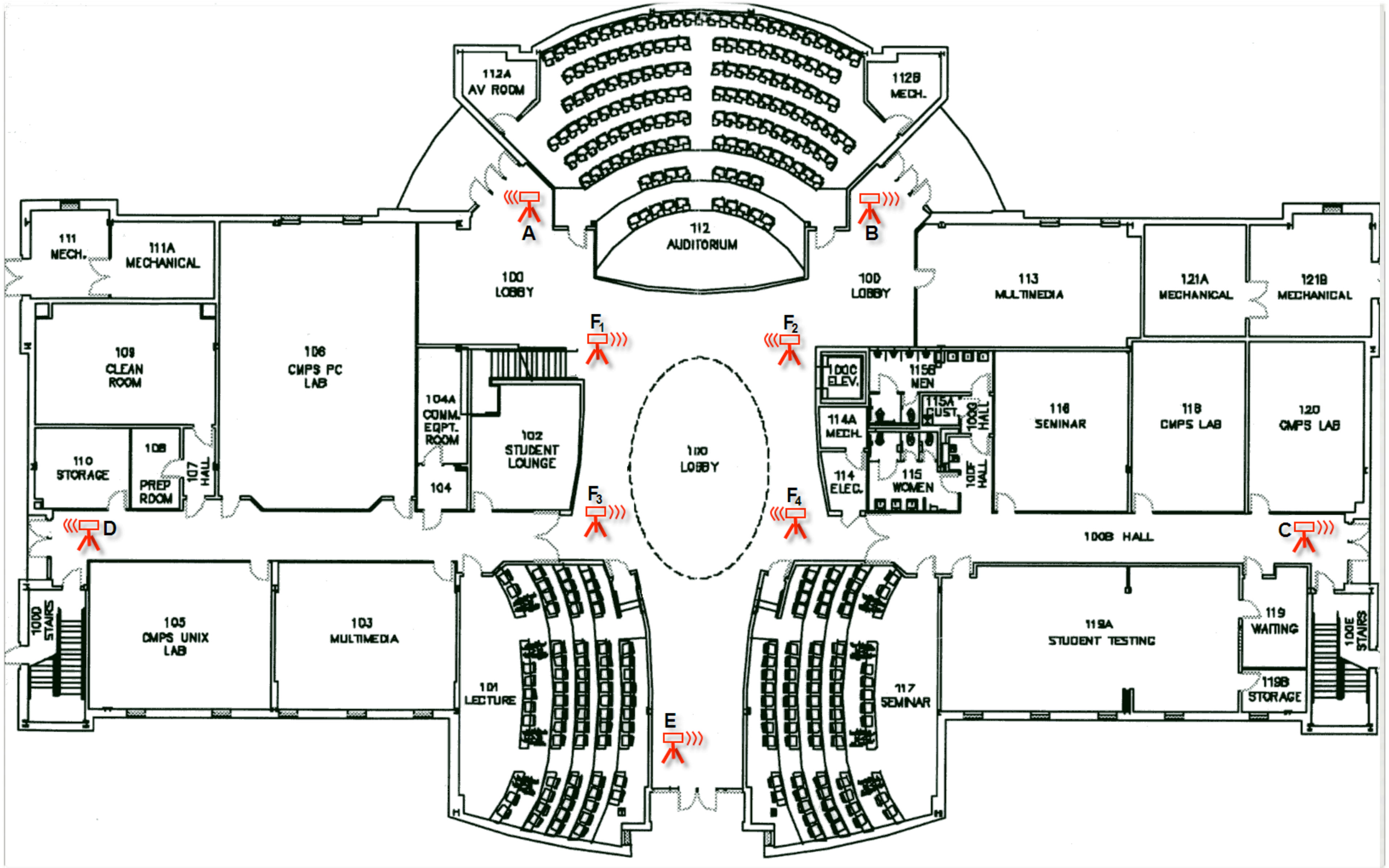
PROTOCOL OVERVIEW

- When a reader detects a tag:
  - Step 1: Data Generation and Retrieval.
  - Step 2: Update of EDC for both reader and the tags
  - Step 3: Data Queuing. The reader inserts the data into its queue, which is sorted according to FTD.
  - Step 4: Receiver Identification. One or multiple nearby tags will be identified for data transportation.
  - Step 5: Data Duplication (including the update of their FTD's).
  - Step 6: Data Transmission. Data are written into selected tags.

RFID GEARS

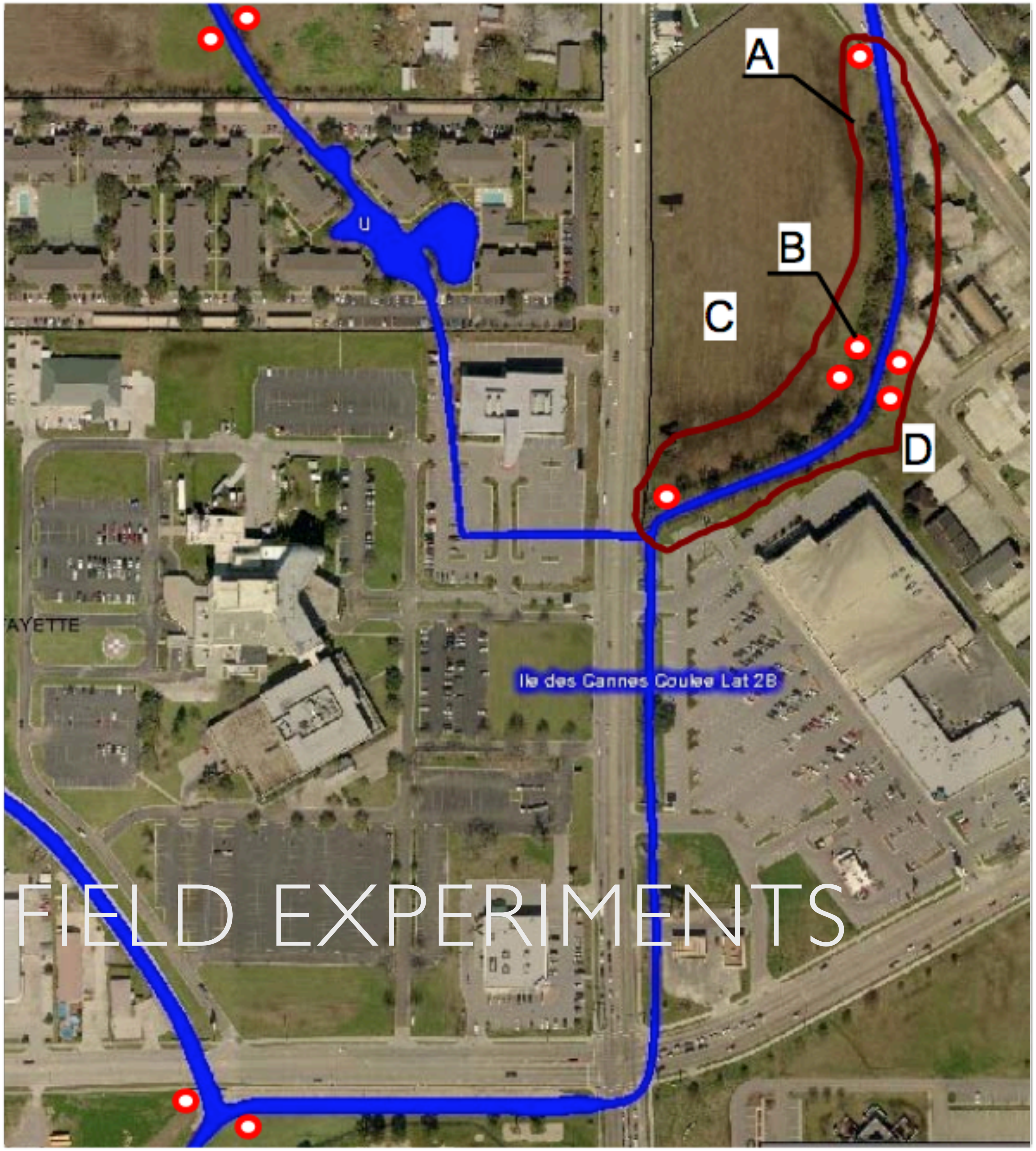
- Alien passive Class1Gen2 RFID tags (ALN-9540)
  - 8.15 × 94.8 × 0.05 mm
  - Less than one gram
  - 14 bytes
- ALR-9900 readers
  - 64 MB RAM
  - 64 MB flash memory
  - 4 antennae and 50 channels



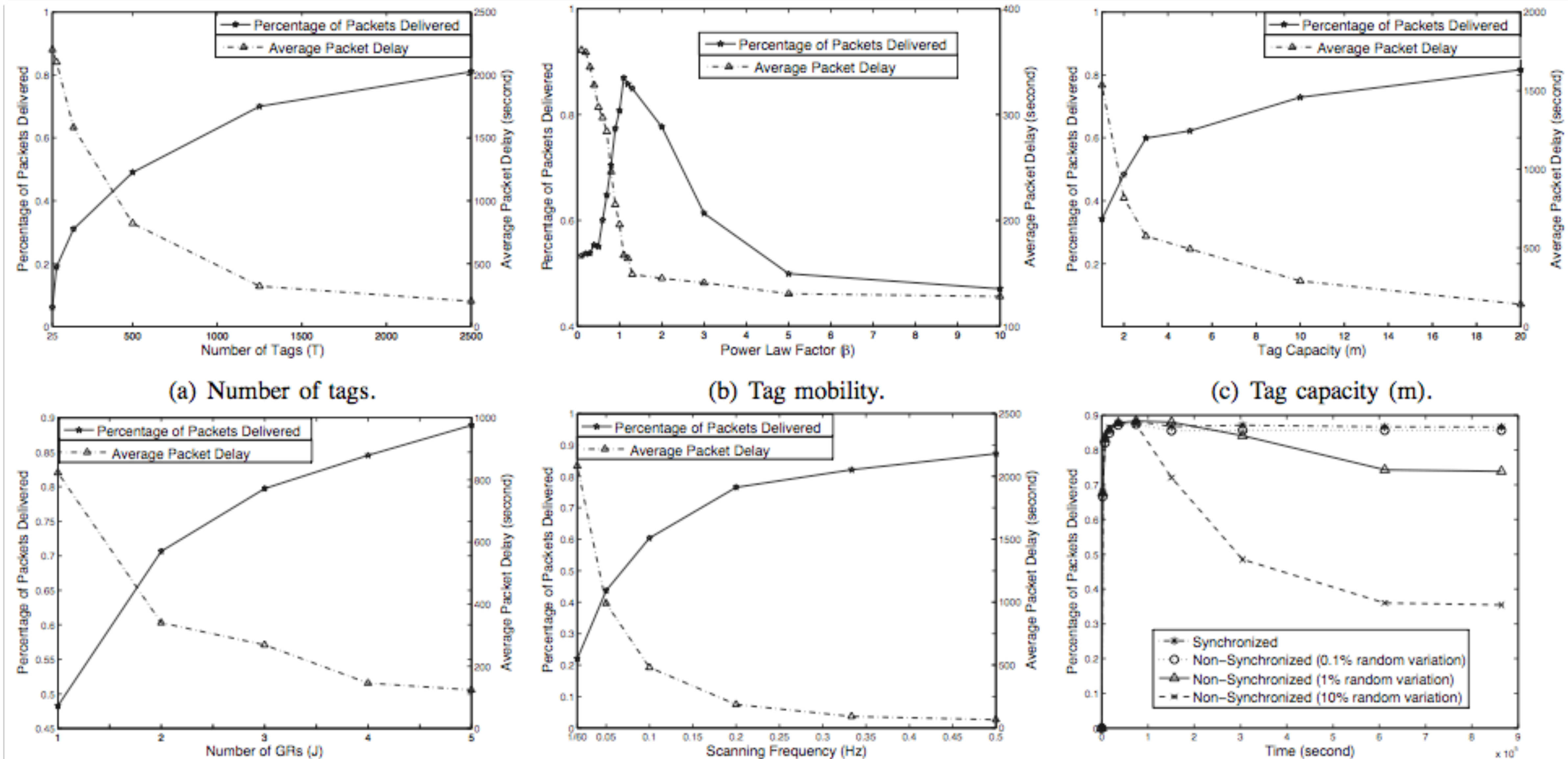


PLANNED EXPERIMENTAL SETUP

ON CAMPUS



PLANNED FIELD EXPERIMENTS



(a) Number of tags. (b) Tag mobility. (c) Tag capacity (m).

(d) Number of GR's. (e) Scanning frequency. (f) Synchronization errors.

Simulation Results

SUMMARY

Motivation: Weight Constraint

↓

Solution: Passive RFID Tags

↓

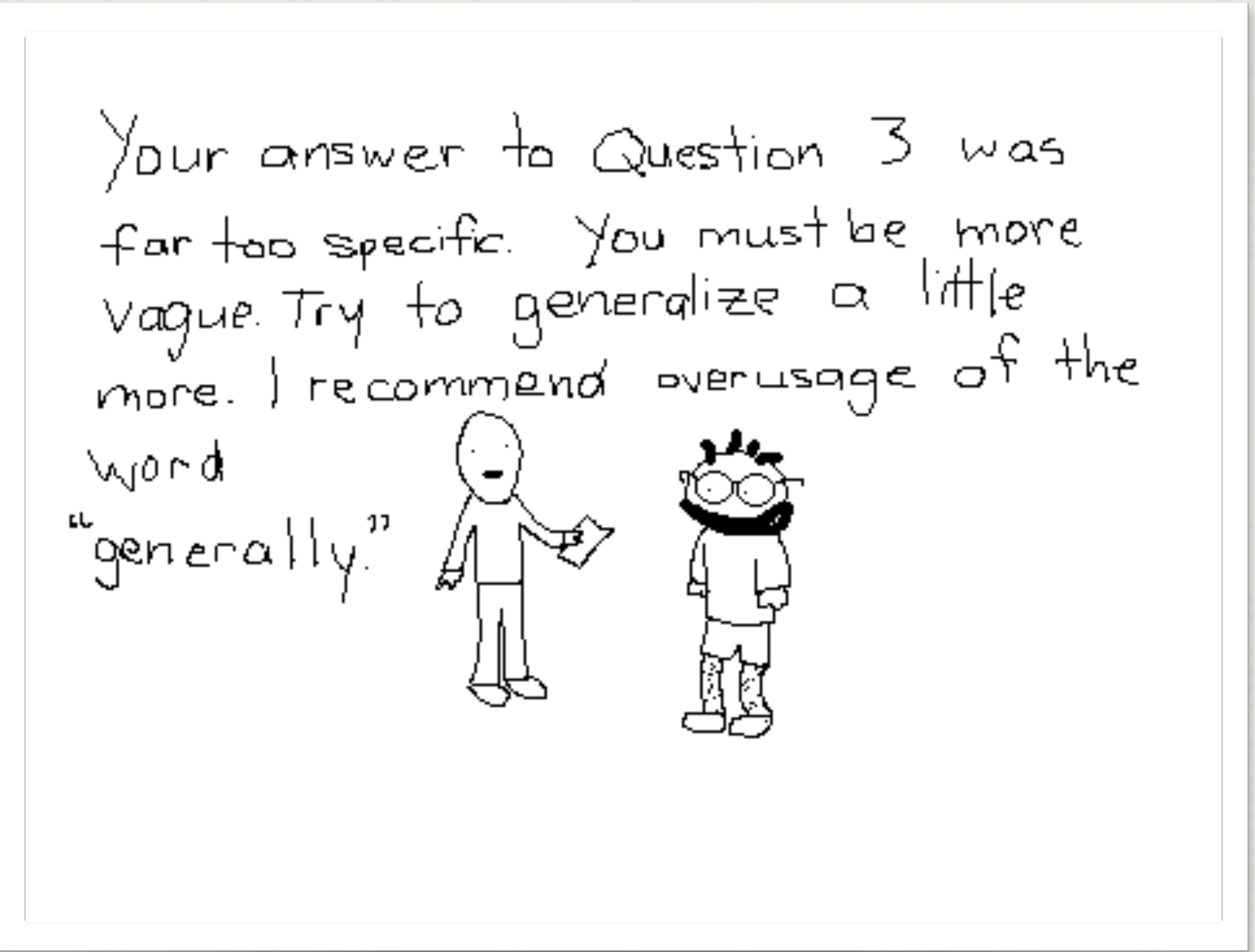
Challenges: Limited Resource

↓

Contribution: Protocol Development

↓

Future Work: Experiments and Enhancement


Your answer to Question 3 was far too specific. You must be more vague. Try to generalize a little more. I recommend overusage of the word "generally."

QUESTIONS ?