IoT: lecture 2

Gaia Maselli
Dept. of Computer Science

Course info

- Course web page

twiki.di.uniroma1.it/twiki/view/Reti_Avanzate/InternetOfThings1718

- Additional lecturers will come to give lectures

Radio Frequency Identification (RFID)
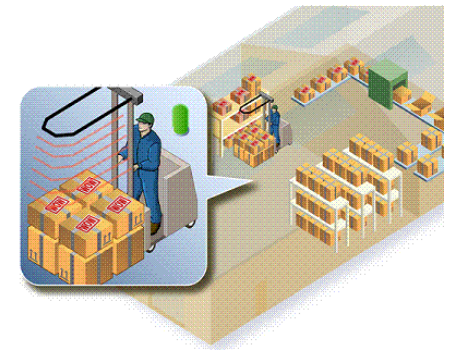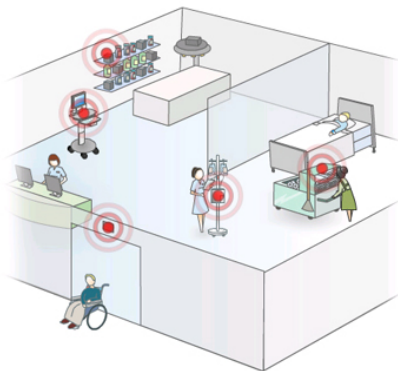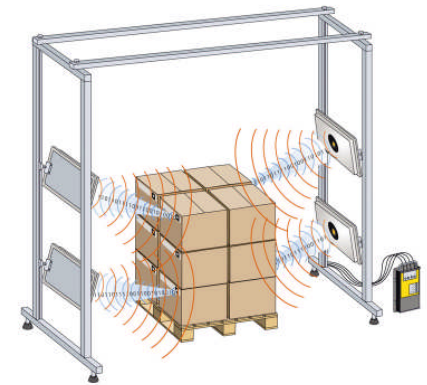
- Key role as enabling technology in IoT

TAGS

READER

Applications

➤ Inventory and logistics
➤ Acces controll object tracking
  ➤ Libraries
  ➤ Airport luggages
➤ Domotics e Assisted Living
  ➤ Intelligent appliances
 ➤ Daily assistance to people with disabilities

RFID system

- RFID is the traditional and most widely used technology that harvests power from RF signals.

- In RFID, the tags — battery free devices — reflect the high-power constant signal generated by the reader — a powered device — to send it their unique ID.

- A variety of applications whose common required functionality is **object identification** — to get the unique ID associated to each tag.

- Tag **identification** and **counting** are the main functionalities so far implemented by RFID systems
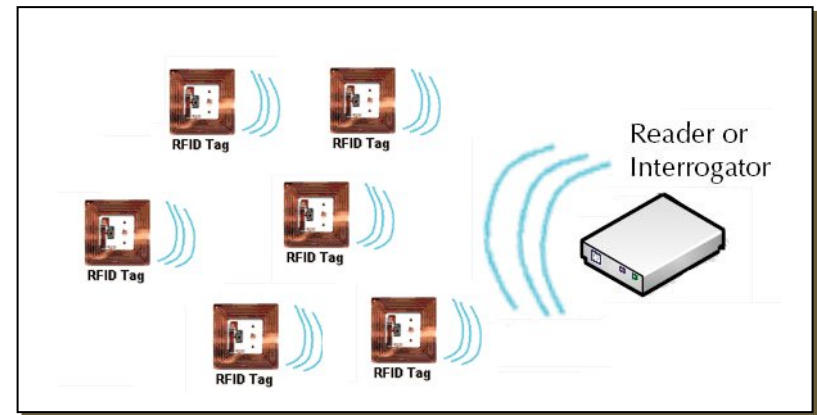
Tag identification

- Single-reader systems with passive tags
    - Reader queries tags
    - Tags respond with their ID by back-scattering the received signal
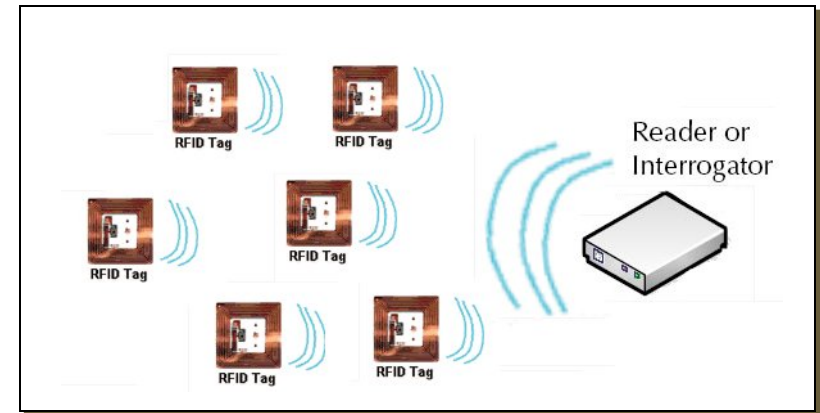
Key Issues

▸ Tags cannot ear each other

▸ Simultaneous tag responses cause collision

▸ Channel access must be arbitrated by the reader

Goal → Fast arbitration of massive tags

Tag identification through a MAC protocol

- Several MAC protocols have been proposed to identify tags in a RFID system

- **Sequential** protocols (aim at singulating tag transmissions)
  - Aloha based
  - Tree based

- **Concurrent** protocols (exploit tags collisions)
  - Buzz
  - TIANC

Transmission time model

- Derived from EPCglobal Specification Class 1 Gen 2
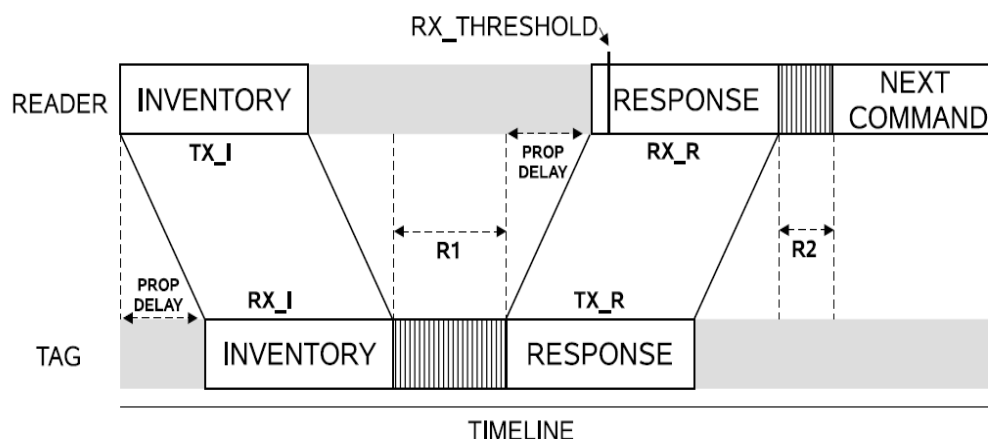
- ▸ R1: tag reaction time
- ▸ R2: reader reaction time
- ▸ RX_threshold: time at which the reader should receive the first bit of tag transmission

- Framed Slotted Aloha

- Tree Slotted Aloha

(blackboard)

Dy_TSA: Motivation

- Tree Slotted Aloha (TSA) has been shown to outperform previous ones with respect to rate or system efficiency (but also time and transmitted bits)

- Almost half of time needed by TSA for identifying tags is spent in collisions

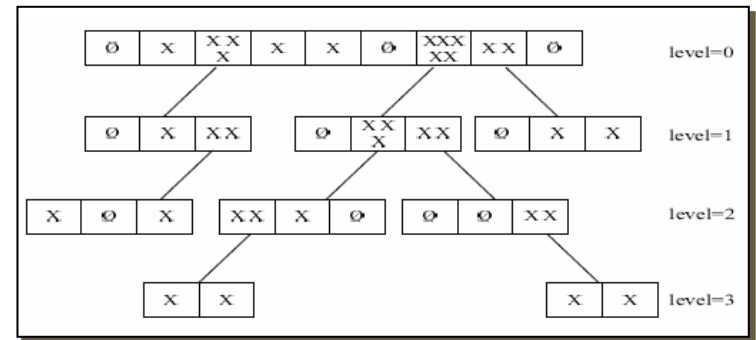- TSA **weakness** is **accuracy in estimating tag population**

Work Contribution

Optimize the identification process by dynamically estimating tags and consequently reducing collisions

Tree Slotted Aloha

Tree Slotted Aloha (TSA)

■ A new child frame is issued for each collision slot: only tags replying to the same slot participate

Main Issue

Estimating tag population to properly tune frame sizes

Estimating tag population

- The number of tags to be identified is not known
  - The initial frame size is set to a predefined value (i.e., 128)
  - The size of the following frames is estimated

$$\text{tags per collision slot} = \frac{(\text{estimated total num of tags}) - (\text{identified tags})}{\text{collision slots}}$$

- The total number of tags is estimated according to the outcome of the previous frame (based on Chebyshev's inequality)

$$\varepsilon(N, c_0, c_1, c_k) = \min_n \left| \begin{pmatrix} a_0^{N,n} \\ a_1^{N,n} \\ a_k^{N,n} \end{pmatrix} - \begin{pmatrix} c_0 \\ c_1 \\ c_k \end{pmatrix} \right|$$

- ▸ N: size of completed frame
- ▸ $<c_0,c_1,c_k>$ triple of observed values
- ▸ $<a_0,a_1,a_k>$ triple of estimated values

▸ Given N and a possible value of n, the expected number of slots with r tags is estimated as

$$a_r^{N,n} = N \times \binom{n}{r} \left(\frac{1}{N}\right)^r \left(1 - \frac{1}{N}\right)^{n-r}$$

Inaccuracy of tag estimation for large networks

- The estimator does not capture the possibly high variance of the number of tags

- The minimum is computed over n ranging in $\left[c_1 + 2c_k, 2\left(c_1 + 2c_k\right)\right]$

- The upper bound 2(c1+2ck) is not adequate for network composed of thousands of nodes

  - Example: 5000 tags, N=128, it is highly likely that c1=0

    n is estimated 2(c1+2ck) = 512 ➡ definitively too small

X	X	X	X	----	X	X	X	X

X	X	X	X		X	X	X	X		----		X	X	X	X
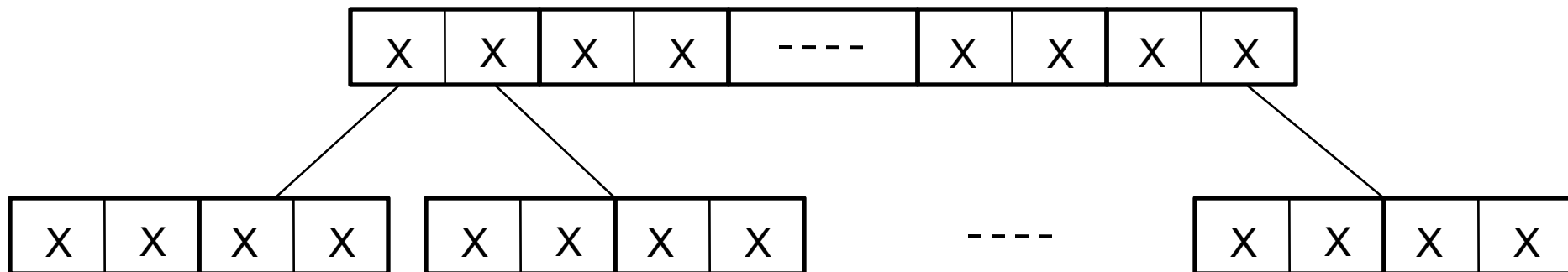
Only 4 slots for an expected number of colliding tags around 40!

Unbounded estimator

- Let us search for a better upper bound

- Let us not stop at 2(c1+2ck)

- For N=128 and $<c_0,c_1,c_k>$ = $<0,0,128>$, the table shows the triple of estimated values and their distance from observed value by varying n
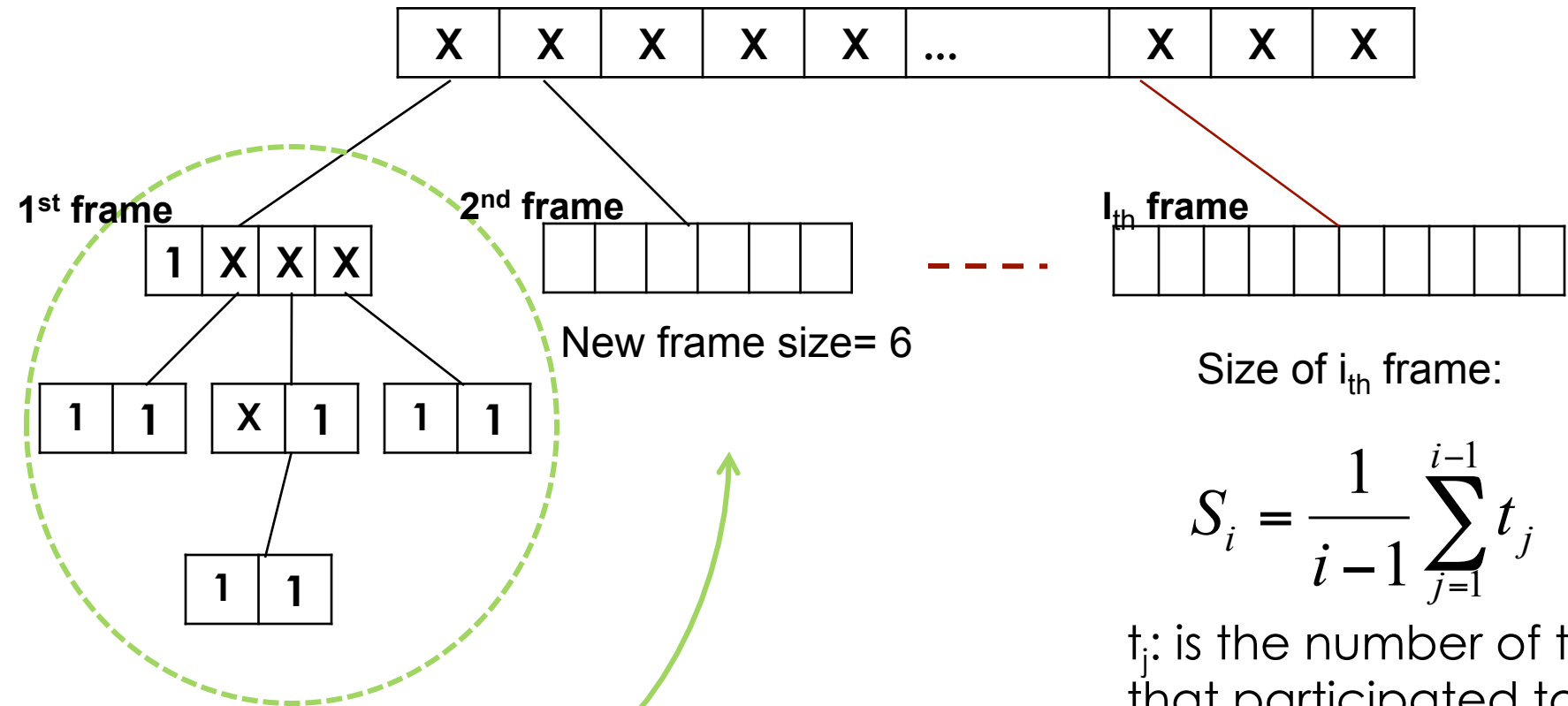
Varying n

n	vect. distance	a_0	a_1	a_k
256	64.671	17.187	34.645	76.167
500	16.211	2.536	9.983	115.482
700	4.537	0.528	2.912	124.560
800	2.337	0.241	1.519	126.240
900	1.188	0.110	0.780	127.110
1000	0.598	0.050	0.396	127.554
1500	0.017	0.001	0.012	127.987
2000	0.0005	0.00002	0.0003	127.9997

still not accurate!

Dynamic Tree Slotted Aloha (Dy_TSA)

- Dynamic tag estimation that exploits the knowledge gained during previously completed frames

- Assumption: tags are uniformly distributed among all slots
  - The expected number of tags in a slot is

  $$E[X] = \frac{n}{N}$$

  - Satisfied for when n>>N

Dy_TSA: dynamic tag estimation

X X X X X ... X X X

1st frame   **2nd frame**   I$_{th}$ **frame**

1 X X X

1 1 X 1 1 1

1 1

New frame size= 6

Size of i$_{th}$ frame:

$$S_i = \frac{1}{i-1}\sum_{j=1}^{i-1} t_j$$

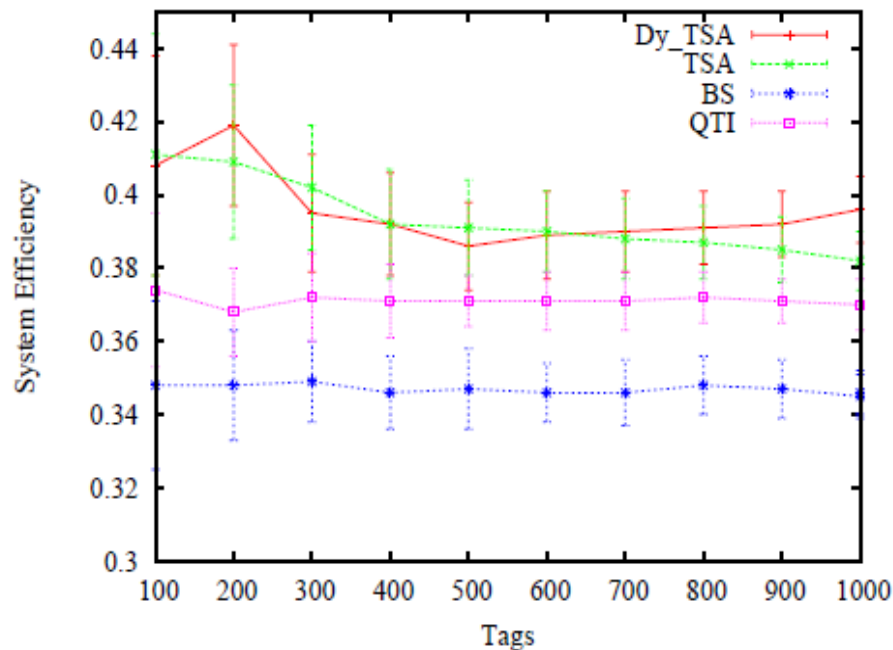t_j: is the number of tags that participated to frame j

- 8 tags found!

- As TSA proceeds in depth-first order, the estimation method can be recursively applied on deeper levels of the tree

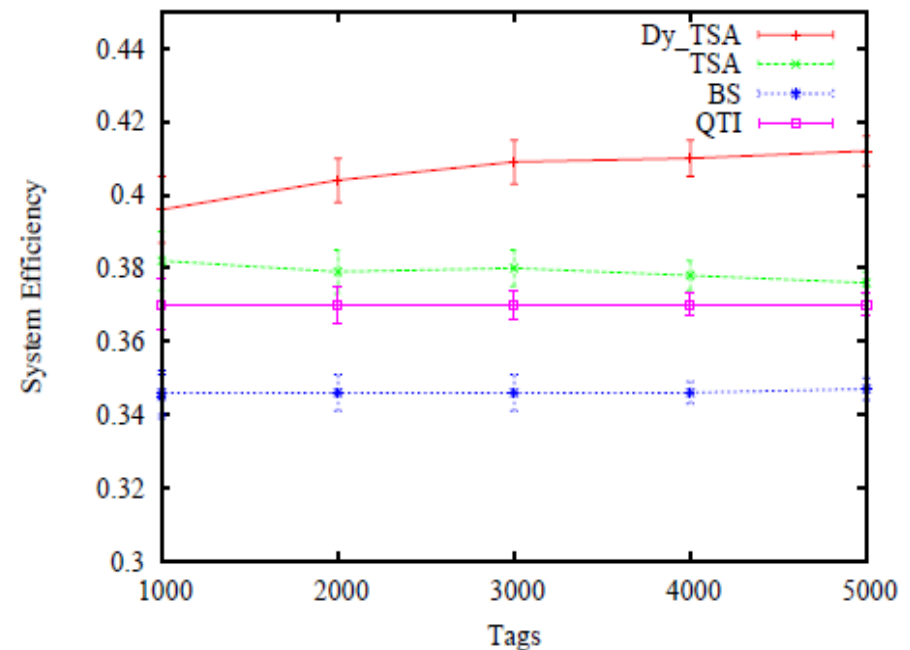# Accuracy of dynamic tag estimation
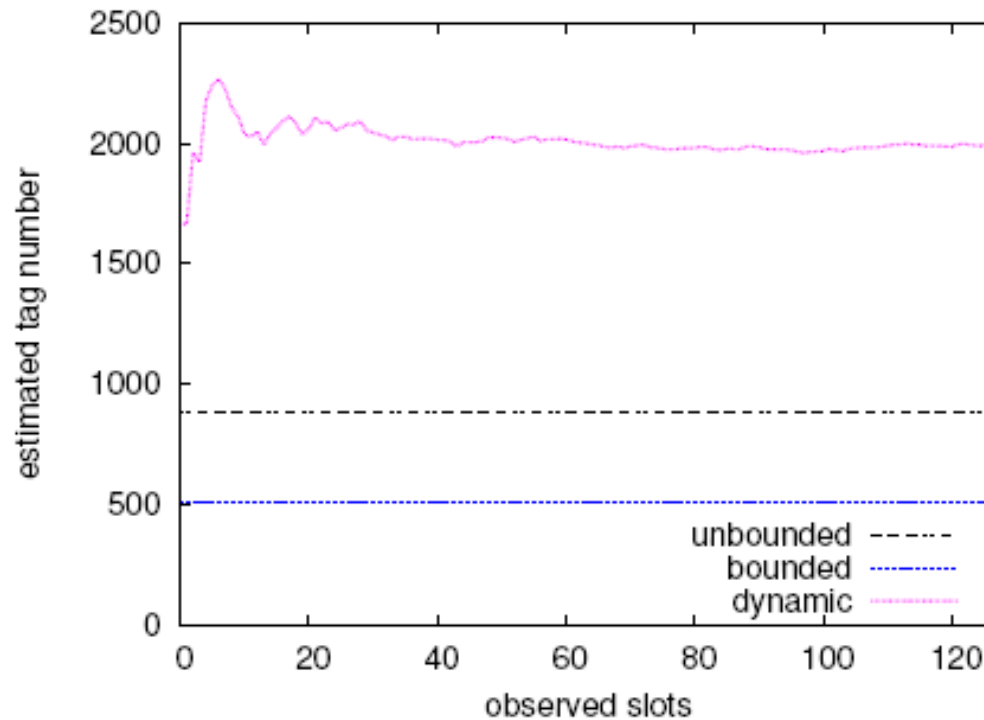
Estimated number of tags as slots of the first frame are resolved (n=2000)
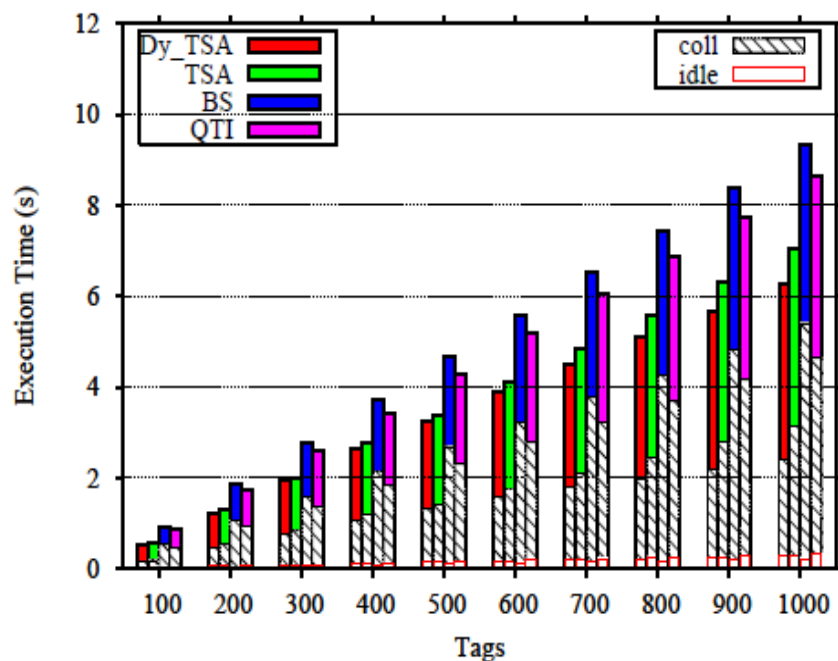
Protocol evaluation: rate
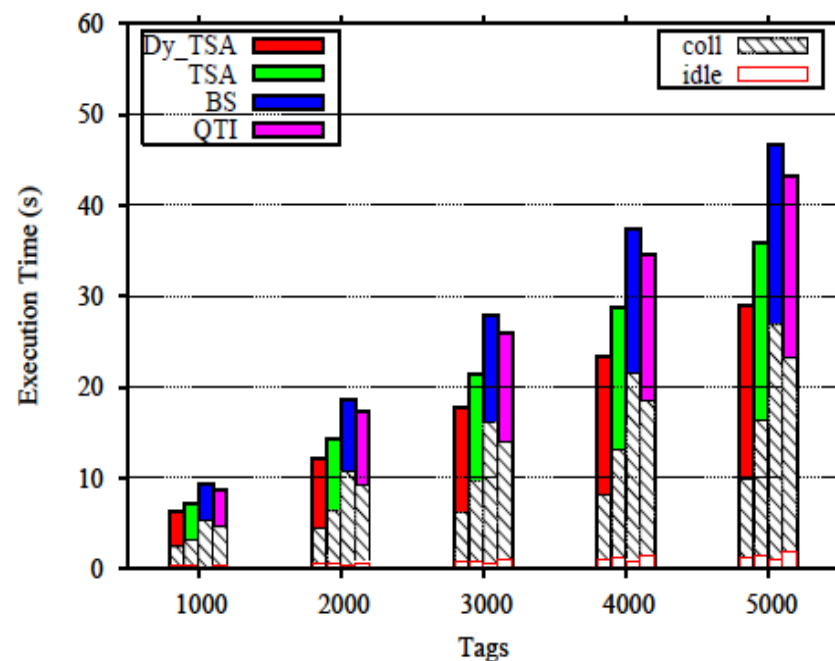

(a) System efficiency: 100-1000 nodes.

(b) System efficiency: 1000-5000 nodes.
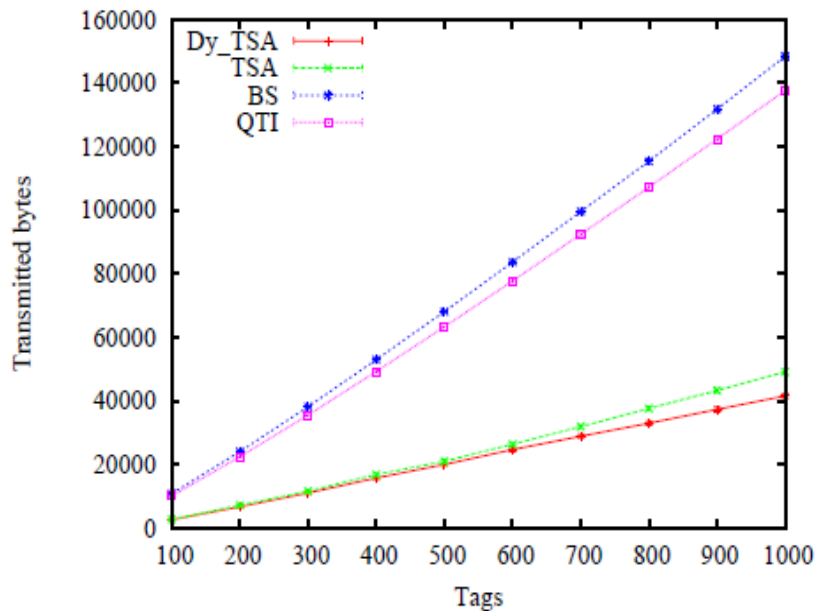
Results: latency

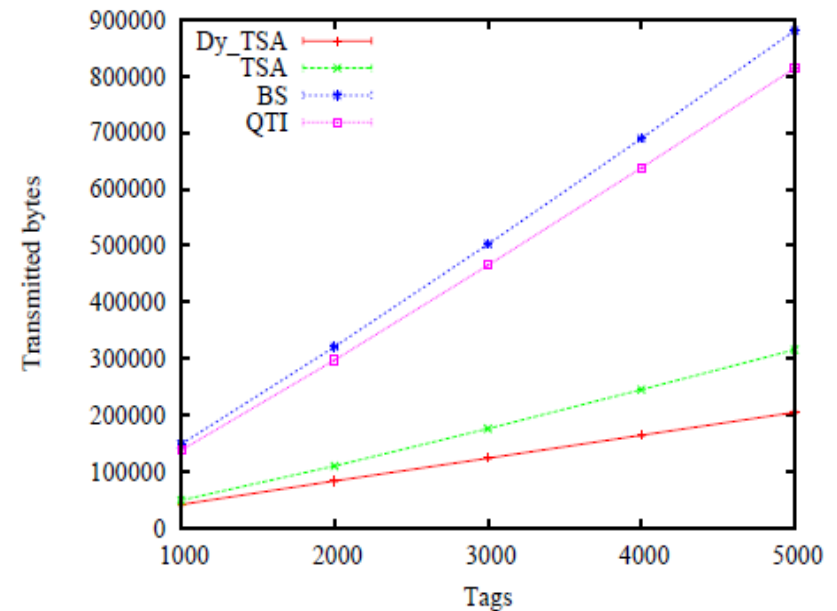(a) Execution time: 100-1000 nodes.

(b) Execution time: 1000-5000 nodes.

Results: transmitted bits

(a) Transmitted bits: 100-1000 nodes.

(b) Transmitted bits: 1000-5000 nodes.

Comments

- Dy_TSA fixes the TSA inability to estimate the tag population and properly tune the size of reading frames

- **Open issue:** How to properly tune the initial frame size

Readings

- Papers available on IEEE and ACM digital libraries:

- G. Maselli, C. Petrioli, and C. Vicari, "**Dynamic Tag Estimation for Optimizing Tree Slotted Aloha in RFID Networks,** *ACM MSWIM 2008,* Vancouver, Canada.

- T.F. La Porta, G. Maselli, C. Petrioli, "**Anti-collision Protocols for Single-Reader RFID Systems: Temporal Analysis and Optimization"**, *IEEE Transactions on Mobile Computing,* vol.10, no.2, pp.267,279, Feb. 2011.