An Efficient RFID Tag Estimation Method Using Biased Chebyshev Inequality for Dynamic Frame Slotted ALOHA

Hazem Elsaid

Smart SysTech 2014, 02.07.2014

LIKE
Lehrstuhl für Informationstechnik
Schwerpunkt KommunikationsElektronik

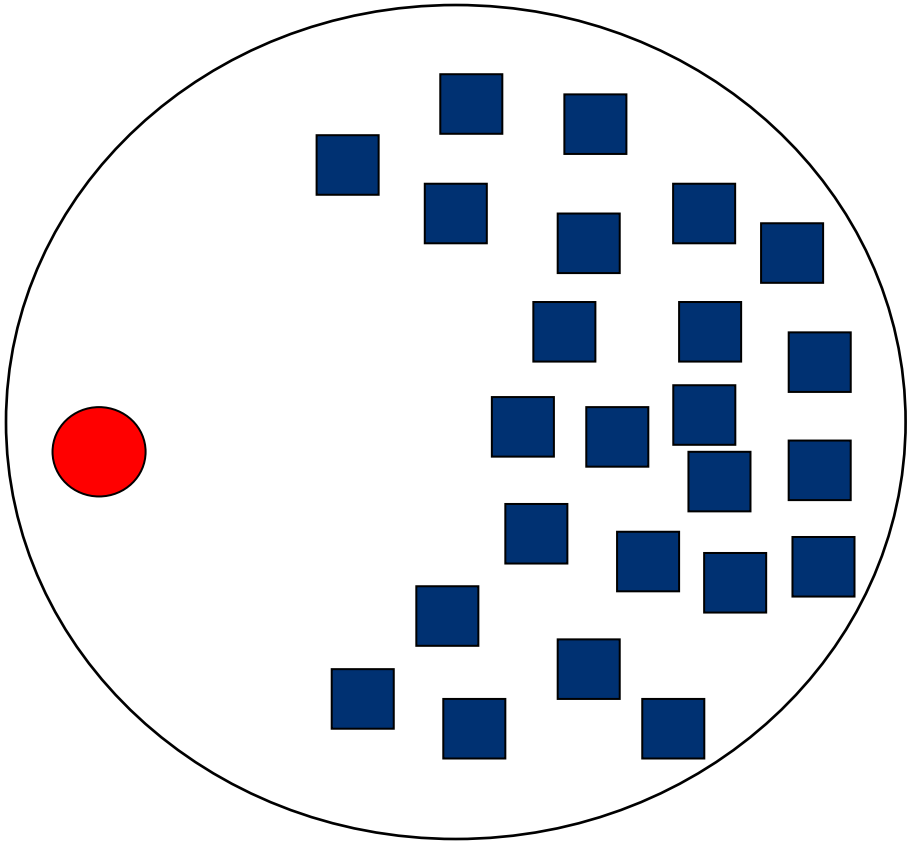
FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

Agenda

- Motivation
- Classical Tag Estimation Methods
- Proposed Biased Chebyshev Tag Estimation
- Conclusion and Future Work

Motivation

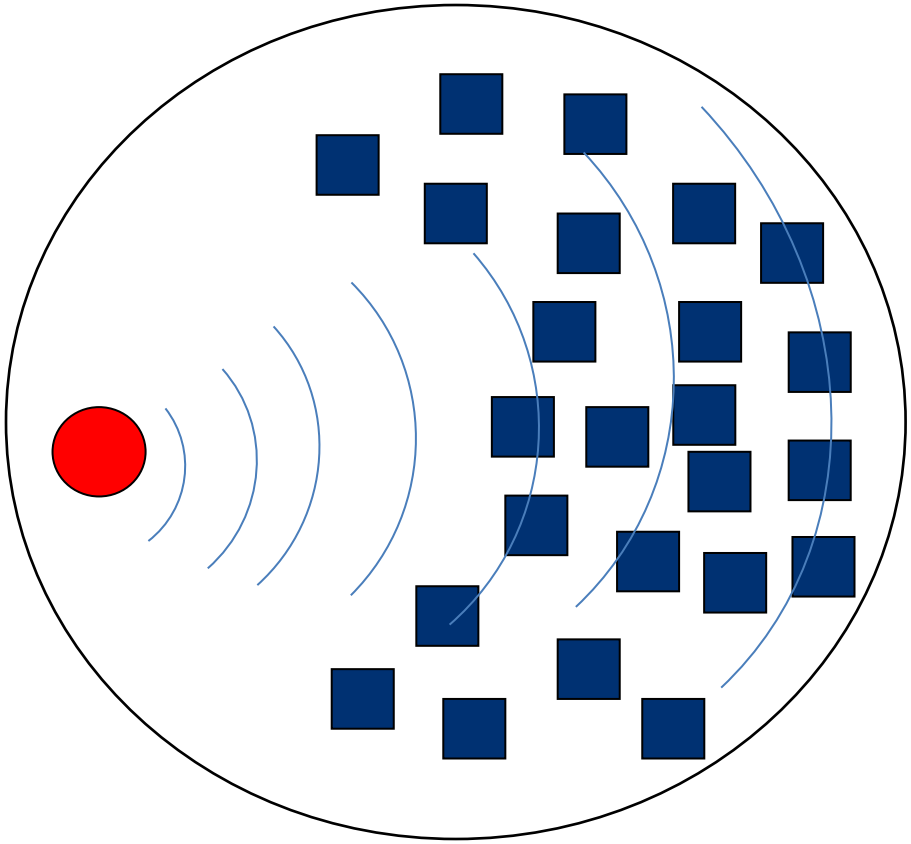
- System Model:
  - Single RFID Reader.
  - Dense RFID network with unknown number of passive tags.
  - Tags should be identified in the minimum possible time.



Motivation

- System Model:
  - Single RFID Reader.
  - Dense RFID network with unknown number of passive tags.
  - Tags should be identified in the minimum possible time.

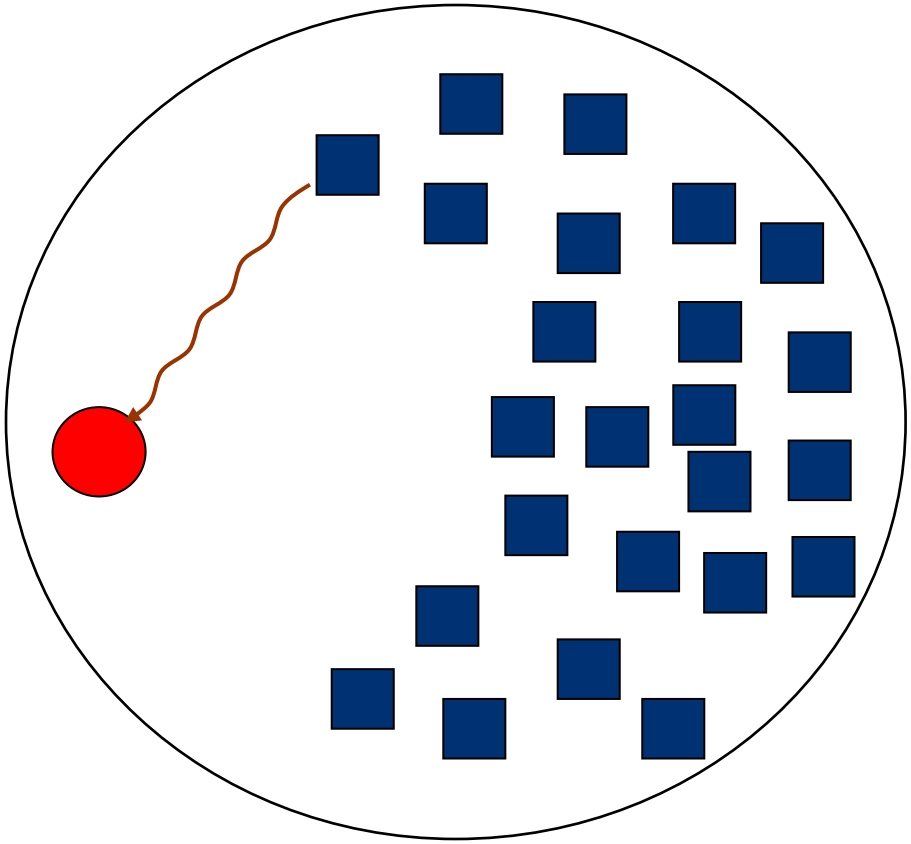
- Identification Process:
  - Reader asks the tags for there EPC code.



Motivation

- System Model:
  - Single RFID Reader.
  - Dense RFID network with unknown number of passive tags.
  - Tags should be identified in the minimum possible time.

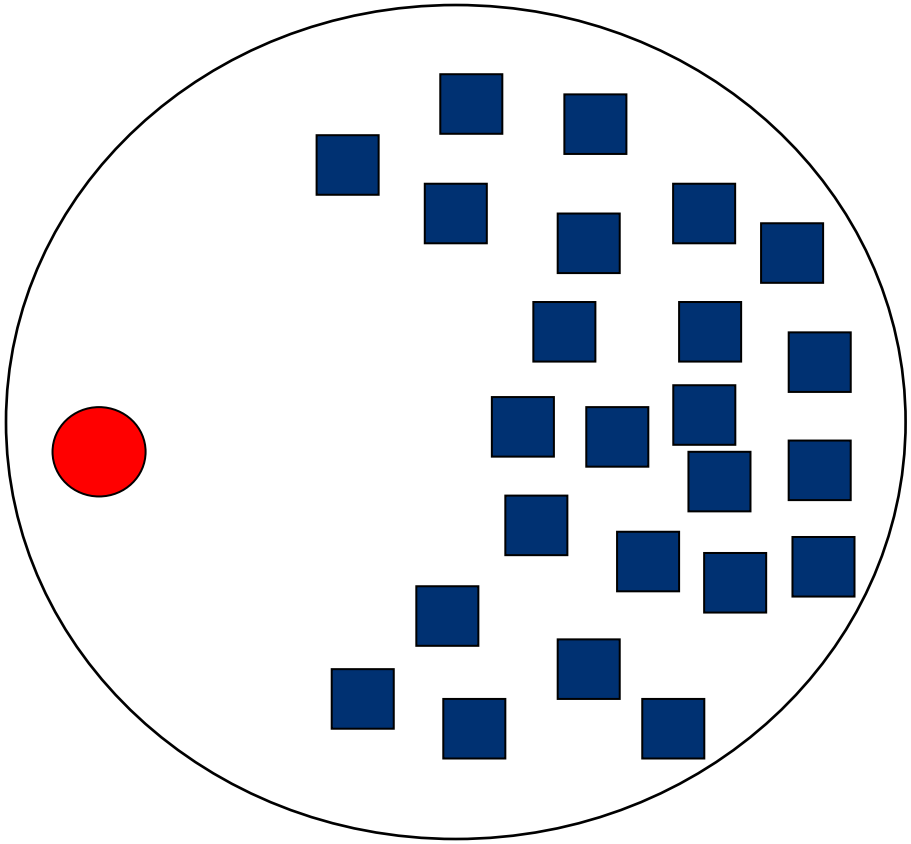
- Identification Process:
  - Reader asks the tags for there EPC code.
  - Single answer (Successful).



Motivation

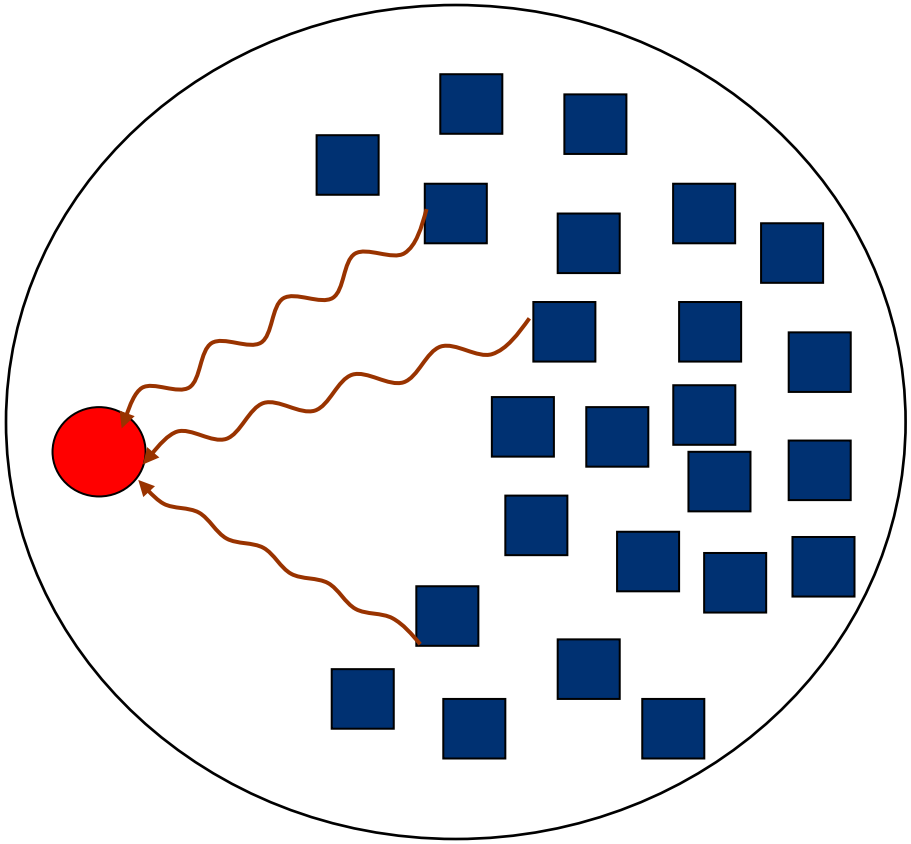
- System Model:
  - Single RFID Reader.
  - Dense RFID network with unknown number of passive tags.
  - Tags should be identified in the minimum possible time.

- Identification Process:
  - Reader asks the tags for there EPC code.
  - Single answer (Successful).
  - No answer.



Motivation

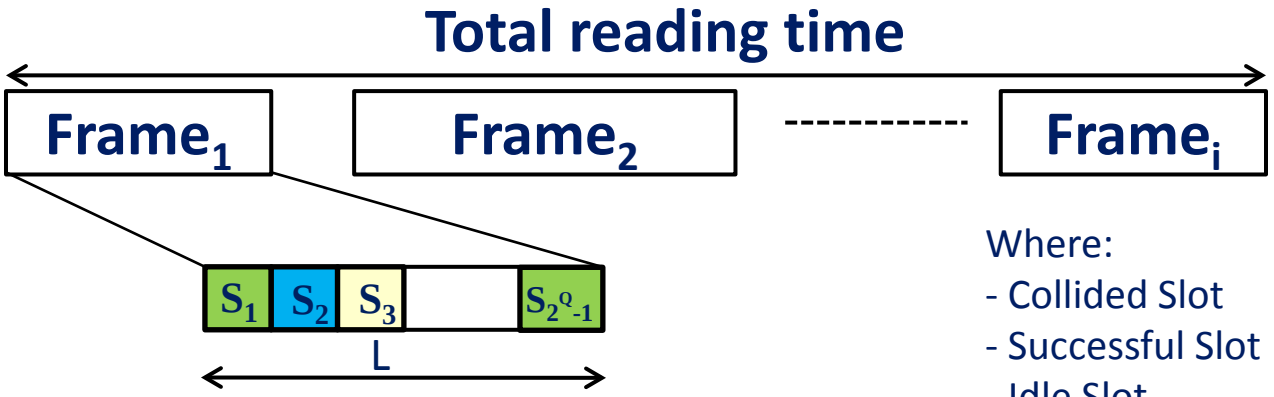
- System Model:
  - Single RFID Reader.
  - Dense RFID network with unknown number of passive tags.
  - Tags should be identified in the minimum possible time.



- Identification Process:
  - Reader asks the tags for there EPC code.
  - Single answer (Successful).
  - No answer.
  - Multiple answers. (Collision)

➢ **What is the maximum achievable identification efficiency?**

Motivation

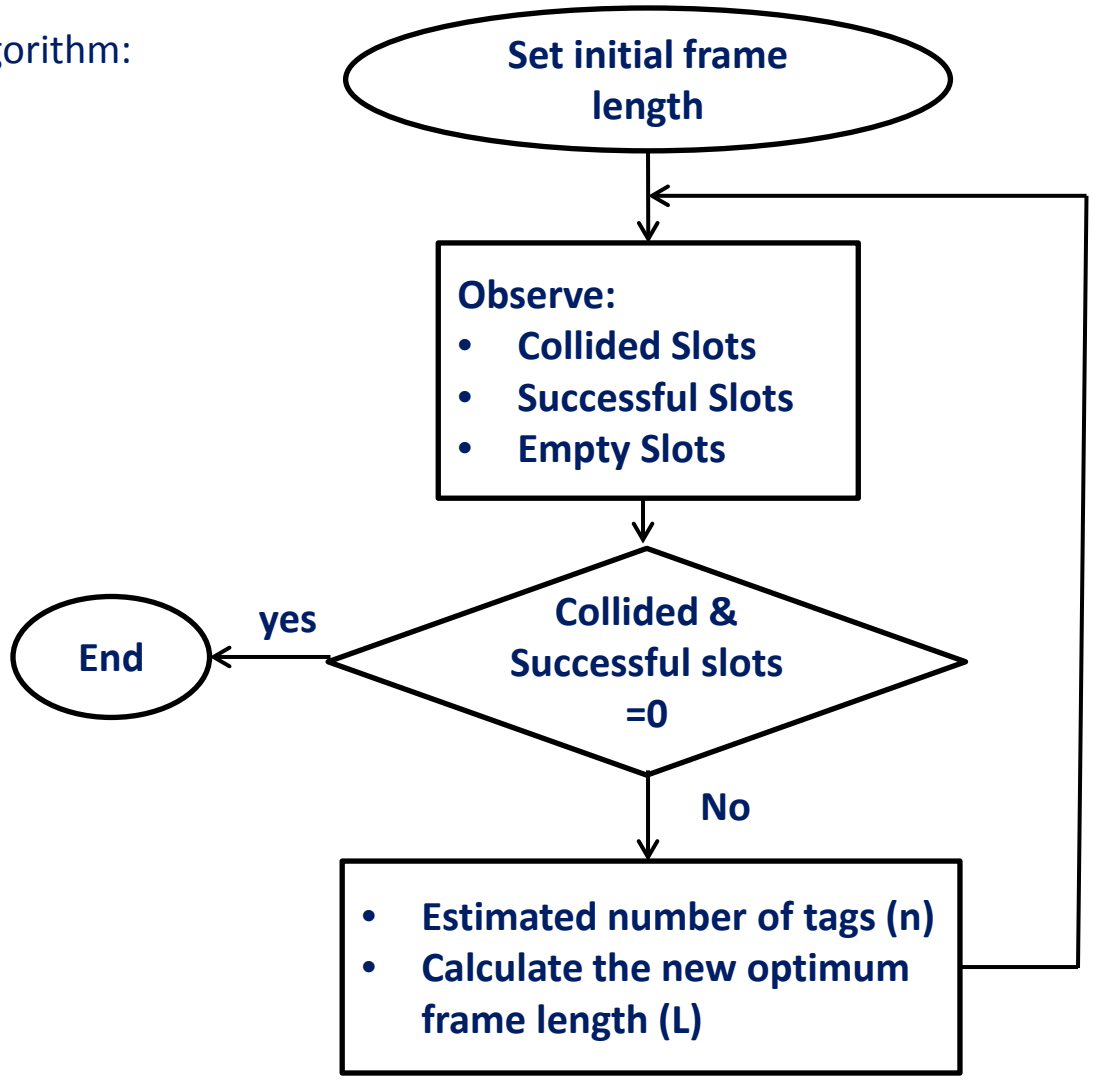


- Dynamic Framed Slotted ALOHA:
  - Time divided into multiple frames.
  - Each frame has different length (number of slots).
  - Reader has to inform the tags with the frame size (Q value).
  - Each tag chooses only one random slot per frame.
- Maximum reading efficiency: $\eta_{\max} = 36\% \quad \text{if } L = n$ → **Unknown number of tags n=?**

Robust number of tags estimation

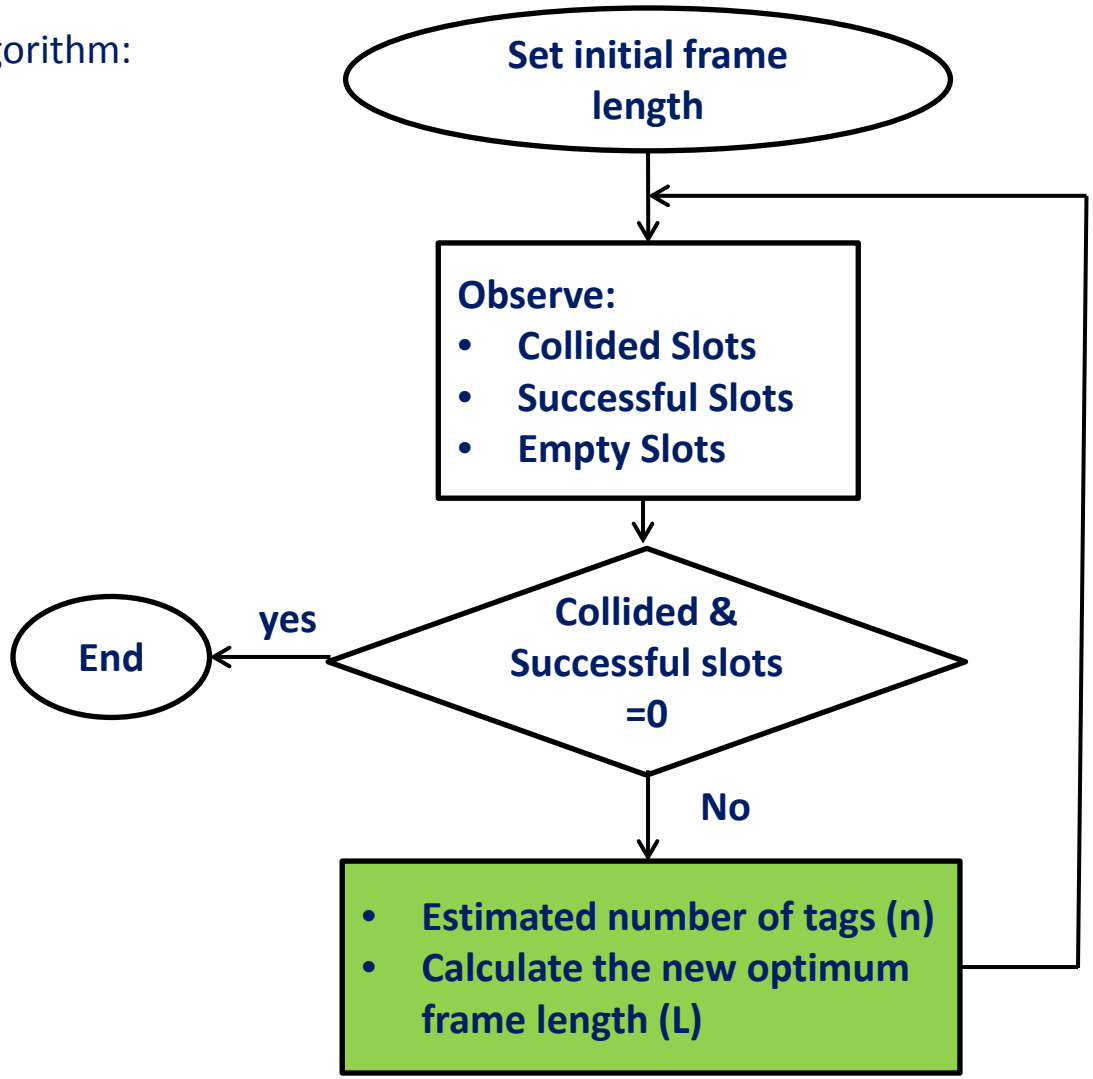
Motivation

- Complete anti-collision algorithm:



Motivation

- Complete anti-collision algorithm:



Agenda

- Motivation
- **Classical Tag Estimation Methods**
- **Proposed Biased Chebyshev Tag Estimation**
- **Conclusion and Future Work**

Classical Tag Estimation Methods

- Lower bound:
  - Assumes two tags collided per collided slot (Lower bound of collision).

$$n_{est} = 2 \times \text{Number of collided slots}$$

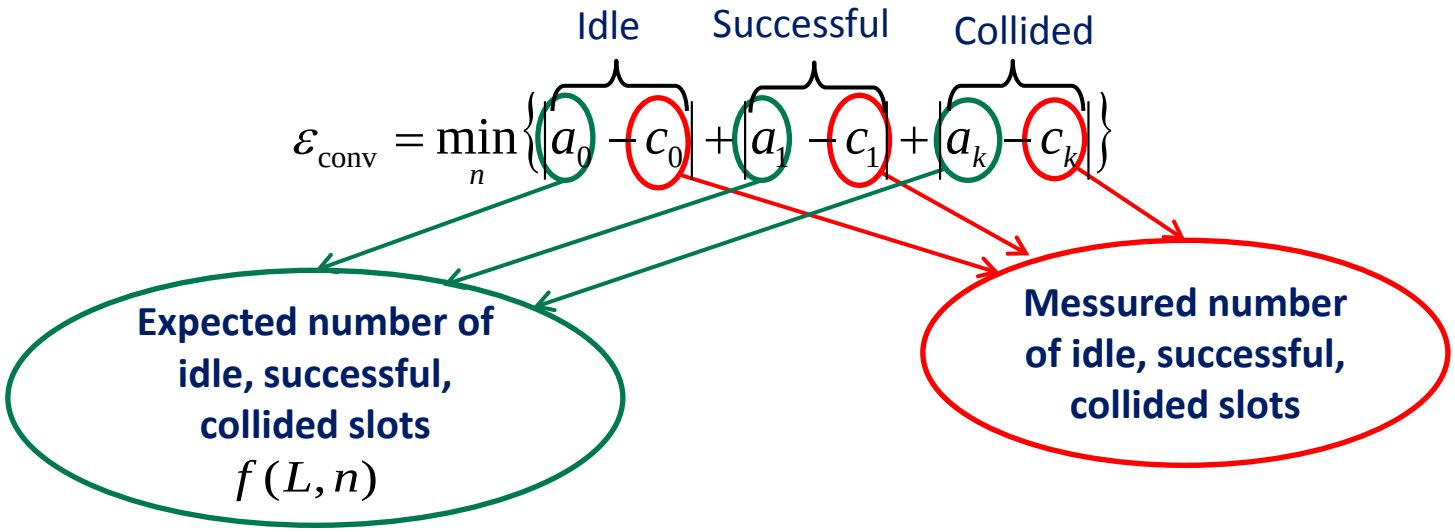
- Schoute:
  - Assumes Poisson distribution, then calculates the expected number of collisions per slot.

$$n_{est} = 2.39 \times \text{Number of collided slots}$$

→ Both these methods depends only on one information (number of collided slots)

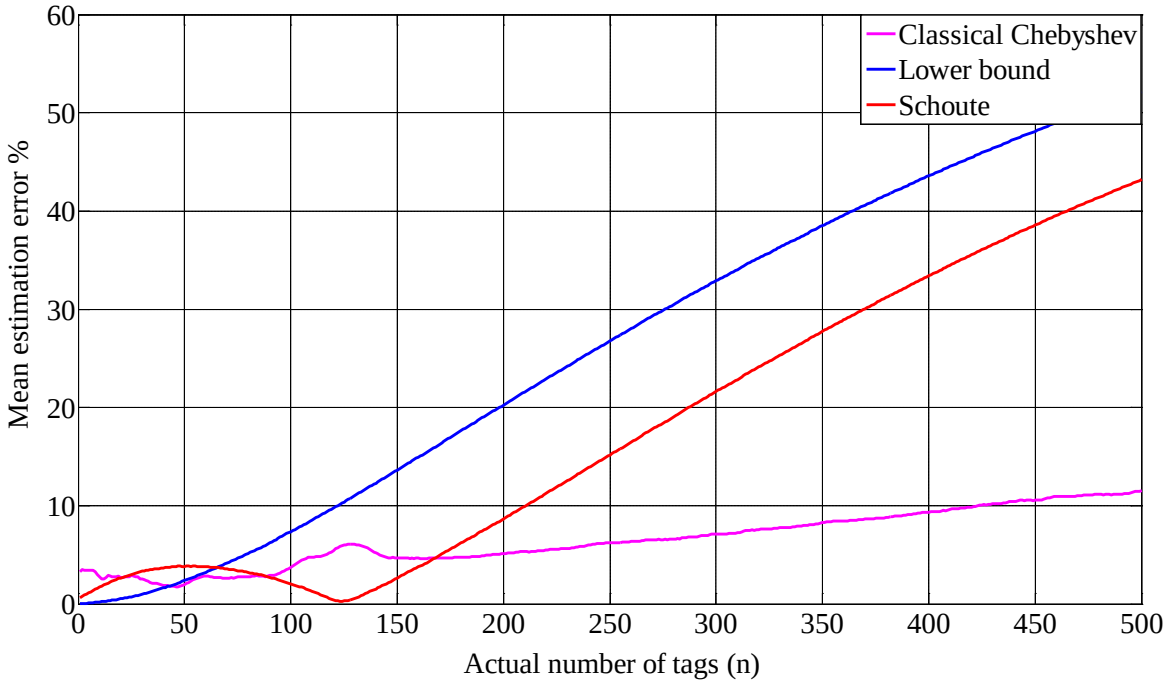
Classical Tag Estimation Methods

- Classical Chebyshev Tag estimation methods



Classical Tag Estimation Methods

- Estimation error for the classical tag estimation methods
  - Frame length L=128.
  - Classical Chebyshev is the most promising tag estimation method.
  - The estimation error increase when the actual number of tags increases.



Agenda

- Motivation
- Classical Tag Estimation Methods
- **Proposed Biased Chebyshev Tag Estimation**
- **Conclusion and Future Work**

Proposed Biased Chebyshev Tag Estimation

- Classical Chebyshev Tag estimation :

$$\varepsilon_{\text{conv}} = \min_{n}\left\{\left|a_0 - c_0\right| + \left|a_1 - c_1\right| + \left|a_k - c_k\right|\right\}$$

- Numerical example:
  - $|a_0\text{-}c_0| = k$ → error = k tags.
  - $|a_1\text{-}c_1| = k$ → error = k tags.
  - $|a_k\text{-}c_k| = k$ → error ≥ 2*k tags. (depends on the existing number of tags).

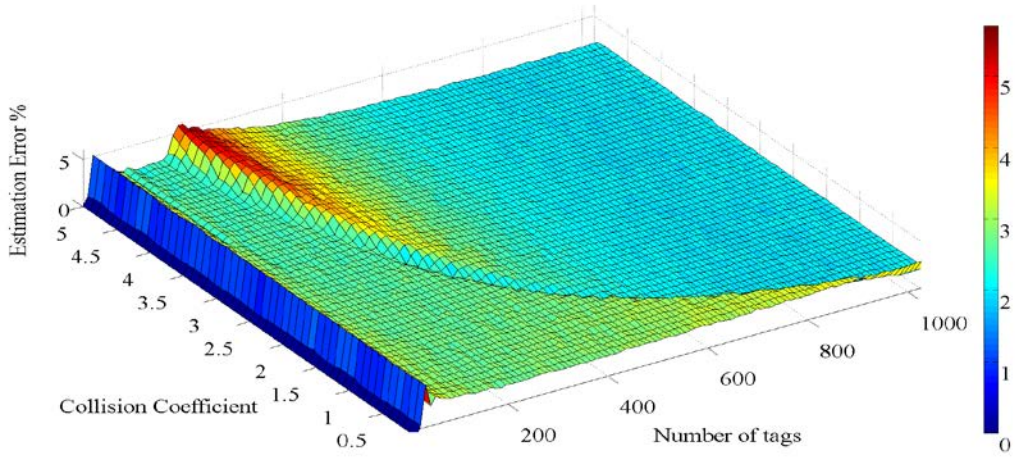
- Proposed biased Chebyshev Tag estimation:

$$\varepsilon_{\text{Biased}} = \min_{n}\left\{\left|a_0 - c_0\right| + \left|a_1 - c_1\right| + \gamma_c\left|a_k - c_k\right|\right\}$$

Collision Coefficient

Proposed Biased Chebyshev Tag Estimation

- Estimation error curve:
  - Frame length L=512
  - Number of tags >> L →Number of collided slots is dominant.
  - Number of tags << L →Number of collided slots is very small.
  - L/2< Number of tags <2L → Variable collision coefficient (γ_c) for minimum estimation error.

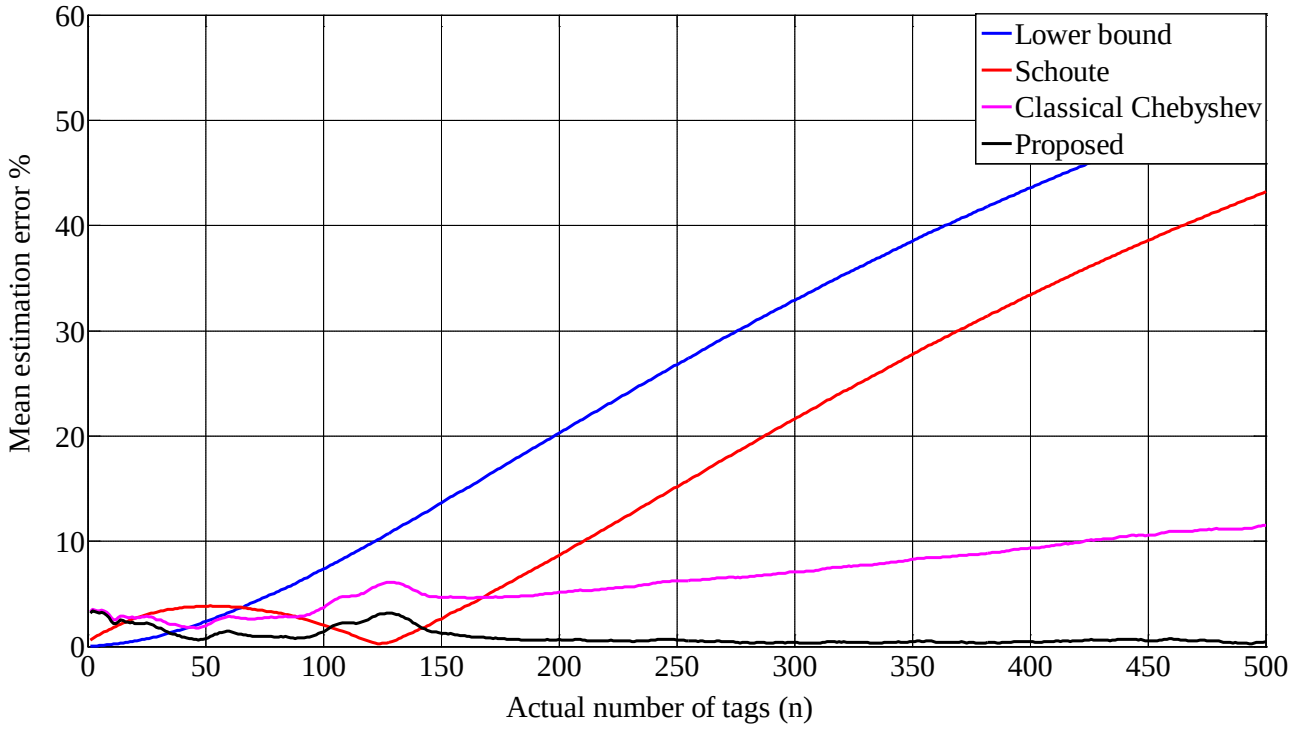


- Using simulations the proposed collision coefficient equation:

$$\gamma_c(L,n) = (1.2\times10^{-4} n \ -0.09)\cdot L + (0.0016\times n + 8.36)$$

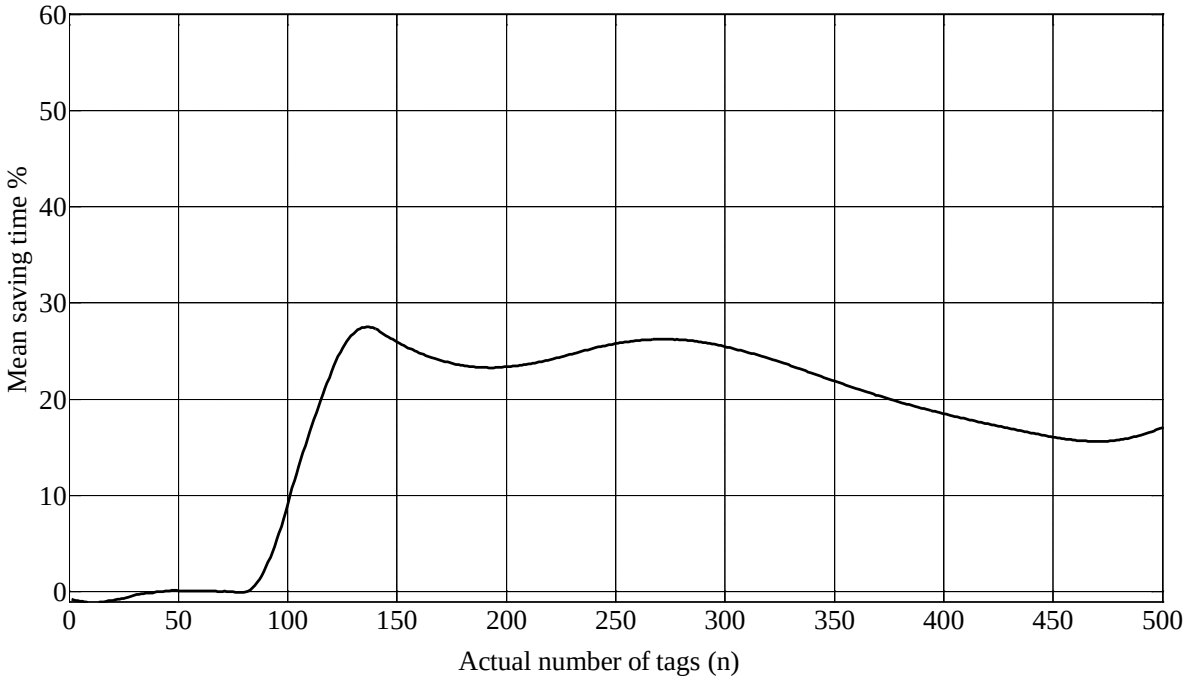
Proposed Biased Chebyshev Tag Estimation

- Estimation error for the proposed tag estimation compared to the classical methods:
  - Frame length L=128
  - The proposed collision coefficient compensates the increase of the mean estimation error with the increase of the number of tags.



Proposed Biased Chebyshev Tag Estimation

- Percentage of saving time using the proposed algorithm compared to the classical Chebyshev algorithm:
  - Starting frame length L=128
  - Oscillations in the curve are due to the frame length takes only discrete values 2^Q.
  - Negative value at with a tag populations less than 25 tags has a very small effect.



Agenda

- Motivation
- Classical Tag Estimation Methods
- Proposed Biased Chebyshev Tag Estimation
- **Conclusion and Future Work**

Conclusion and future work

- Conclusion
  - A new biased Chebyshev inequality tag estimation method is proposed.
  - The proposed method is compared with the classical tag estimation methods and gives better results with dense RFID networks.
  - A new biased Chebyshev inequality anti-collision algorithm is presented.
  - The new algorithm compared with the classical Chebyshev inequality anti-collision and the reading time is reduced by 25%.

- Future work
  - The successful and empty coefficients should be also calculated and added to the main estimation equation.
  - Compare the new estimation performance with the current performance in terms of estimation error and saving time.

Thanks for your kind attention!

FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG
FACULTY OF ENGINEERING

Hazem.a.elsaid@fau.de