RFID Multiple Access Methods

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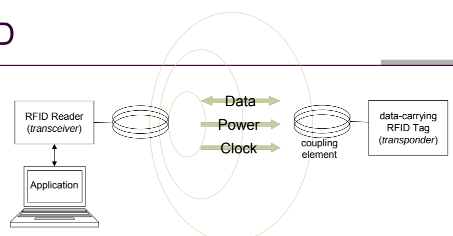
Overview

- RFID and Motivation
- Aloha and Collision Resolution
- Commercial Offerings
- Comparative Analysis
- Conclusion

RFID



3 main components:

- (passive/active) **RFID Tag** (*trans*mitter/res*ponder*)
  microchip+coiled antenna; **stores data**; power from interrogation signal;
- RFID Reader (*trans*mitter/re*ceiver*)
  RF module, control unit;
- Data Processing Subsystem
  application, database, ...

RFID Challenges

Goal is to reliably identify multiple objects, in as short a time as possible

However, requirements to drive RFID Tags size and cost down limit ressources

- Limited memory and computation capabilities
  - Little calculation possible at Tag
- Lack of internal power source
  - state information unreliable
- Collisions difficult to detect (varying signal strengths)
- Transponders can‘t be assumed to hear one-another
  - Special case of multiple channel access communication problem
- Strong FCC regulations on Readers „maximum in Band allowed field strength“
  - ex ISO18000-3: 6,6kbps Tag→Reader >> 1,6kbps Reader→Tag
  - Reader -> Tag messages must be minimized

➢ Many standard collision-resolution protocols non-applicable or difficultly implemented

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- Aloha and Collision Resolution
  - (Pure) Aloha
  - Slotted Aloha
  - Framed-slotted Aloha
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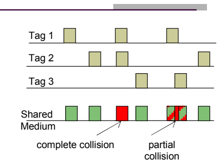
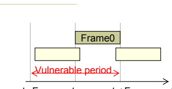
(Pure) Aloha

- Tag transmits upon data ready
- Detect success or collision
- Tag retransmits after **random backoff time** following collision



Vulnerable period:
Collision occurs if t_0-F ≤ t_1 ≤ t_0+F



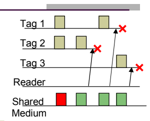
RFID: Tags can‘t detect/sense carrier.
Collision is:

- ➢ determined by listening for Reader‘s „(N)ACK“
- ➢ ...undetected

Aloha - 2

Switch-off

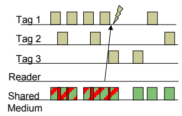
- If Tag response successfully decoded, Tag automatically enters Quiet state
- More later under Slotted-Aloha



Slow-down

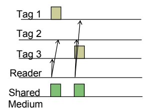
compromise between Aloha and Swith-off

- Reader overwhelmed by responses
- „Slow-down" command sent,
  Tag adapts its (random) backoff algorithm
- Goal is to diminish Tags' reply frequency



„Carrier Sense"

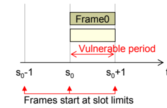
- MUTE signal to all Tags when start of transmission is detected.



Slotted Aloha

Aloha with an additional constraint:

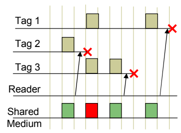
- Time is divided into discrete time intervals **(slots)**
- A Tag can transmit **only** at the **beginning** of a slot
- Packets either collide completely or do not collide at all
- Synchronization overhead:
  Reader SOF, EOF
- Vulnerable period reduced to size F:



Slotted Aloha - 2

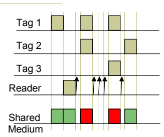
„Terminating"

- If Tag response successfully decoded, Tag automatically enters Quiet state
- Avoids collisions due to Tags replying indefinitely
- Tags re-enter Active state upon next "Wake-up" from Reader
  - Failure to recognize "Wake-up" a problem:
    Tags time-out of sleep mode automatically
- Also called "Muting"



„Early End"

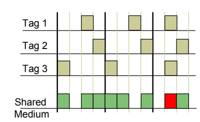
- Slot delimited by Reader SOF, EOF
- Reader issues „Next-Slot" command on no responses received



Framed Slotted Aloha

Further discretisation of time:

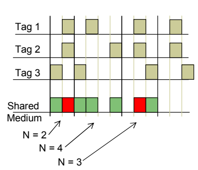
- Medium access grouped into Frames, with N slots per frame
- Tags transmit at most **once** in a randomly selected slot, within maximum N
- Little extra synchronization overhead:
  . Reader SOF, EOF for slots
  . maximum slot number N set in Tag as default



Framed Slotted Aloha - 2

Adaptive

- Reader can temporarily expand / contract number of slots for upcoming round
  - Number of slots in a round varies with number of Tags in field
- Previous extensions also applicable:
  - Terminating / Muting
  - (slotted) „Early End"



Perspective

Aloha	
+ easily / quickly adapts to varying number of Tags + simplest Reader design: „listen"	- worst case: never finishes - theoretically proven maximum channel utilisation 18.4% [1]
Slotted-Aloha	
+ less of a „free-for-all" + doubles the channel utilisation of Aloha	- still only 36.8% medium utilisation [1] - requires synchronisation (overhead) - Tgas need to count slots
Frame-Slotted Aloha	
+ (automatically) diminishes each Tag's repeat rate to once per frame	- requires synchronization - „frame size" needs to be known / transmitted - Tag needs to count frames / slots

[1] Theoretical test data, which is based on the assumption of a Poisson arrival

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- **Commercial Offerings**
  - Philips I*Code
  - ISO 18000 „MODE 1“
  - ISO 18000 „MODE 2“
- Comparative Analysis
- Conclusion

Philips I*Code

- „Reader talks first“: first the Reader sends a command
- „Timeslot anticollision principle“ – variant of slotted Aloha
- Number of timeslots adjustable by Reader with „Timeslot Index“ command

Timeslot Index	0	1	2	3	4	5	6	7
Number of timeslots	1	4	8	16	32	64	128	256
Timeslot Mask (hex) at Tag	00	03	07	0F	1F	3F	7F	FF

- Timeslot position :=
  hashvalue AND TimeslotMask
  - where Tag „Randomness“ is hash value of defined offset (8bit) in serial number (ID)

(„I*CODE1“ System Design Guide [SL048611])

ISO18000 „MODE 1“

No default collison management --can be considered as Pure Aloha

Protocol Extensions (optional)

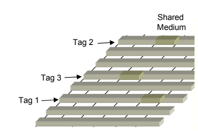
- Extension 1: „non-slotted non-terminating aloha protocol“ [6.1.10.2]
  - Tags reply at random with self-determined intervals
  - Reply as long as in energizing field
  - Reader doesn't influence interrogation process
- Extension 2: „slotted terminating adaptive round protocol“ [6.1.10.4]
  - Continuing dialog between Reader and Tag
  - Tags select reply-slot number, from a maximum slot number
  - Number of slots in round expands/contracts with number of Tags in field (temporarily overridden by Reader)

(„RFID for Item Management – Air Interface Part 3“ – ISO 18000-3 MODE 1)

ISO18000-3 „MODE 2“

Combination of Frequency and Time division multiple Access (FTDMA)

- Tags can select from 8 reply channels (multi-frequency operation)
  (Subcarriers derived by division of powering field's frequency)
- Freq. Hop Rate: 0 (whole reply transmitted one one frequence)
  Freq. Hop Sequence: random (in response to valid Reader command)
- In all other aspects, Slotted Aloha
  on each subcarrier
  - Muting: „mute ratio“
    (unmuted, ½, ¾, $^{31}/_{32}$, ..., $^{511}/_{512}$, fully muted)



(„RFID for Item Management – Air Interface Part 3“ – ISO 18000-3 MODE 2)

Summary

		Reader/Tag-Talk-First	Aloha	Slotted-Aloha	Framed-slotted Aloha	Switch-off	Slow-down	Terminating / Muting	Reader „Carrier Sense“	Early-End	Adaptive	Multiple reply channels
SuperTag		TTF	■			✓	✓		✓			
Philips I*CODE		RTF			■			✓			✓	
ISO18000 MODE1	ext1	RTF	■									
	ext2				■			✓		✓	✓	
ISO18000 MODE2				■				✓				✓
Auto-ID C1_G2		RTF		■							✓	

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How they stack

Performance metrics:
- Mean access time ?
- Transaction speed (Tags/sec) ?
- Time to last Tag (worst-case) ?

RFID system characteristics:
- Tag ID length ?
- Different data rates ?

- Trade litterature information often **misleading** or **incomplete**
- Manufacturers‘ websites light on technical details: **marketing**

  ➢ Comparing systems to one-another very difficult even meaningless in some cases

Comparison Attempt

ISO 18000 „MODE 1“ and ISO18000 „MODE 2“

Test Setup: Several operational conditions experimented
- randomly oriented, same fixed orientation
- randomly numbered, randomly numbered

Test Goal: Identify all 500 Tags, and read 100bytes of data from each Tag

Ex.: Tags randomly orientated, randomly numbered

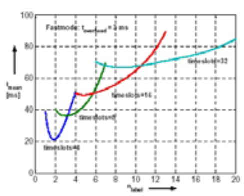
Protocol saturation	500 Tags	10'000 Tags
Time to identify 500 Tags:	4.911 sec	0.3396 sec
Time to read 100B from 500 Tags:	17.755 sec	0.5397 sec
Total identification and read time:	**22.666 sec**	**0.8793 sec**

(A comparison of ISO15693 and ISO18000-3,Magellan, 2001)

Comparison Counter-Example

Philips I*Code

Mean access time:
- depends heavily on **optimal** number of timeslots, for given number of Tags
- $2^{current-1} \leq$ optimal $\leq 2^{current}$
- optimum number of timeslots depends on number of Tags in field
- only 8 bits of ¨hashed Tag ID transmitted



mean_time as f(num_labels)

➢ No **one** measure for I*Code can be taken as „**the**“ measure to compare against other systems

(„I*CODE1“ System Design Guide [SL048611])

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Conclusion

- Accessing as many Tags‘ information, in as little a time as posssible
- Qualitative description of collision-resolution algorithms
- Quantative comparison of implementations
- Comparisons difficult, meaningful?

- *Probabilistic* collision detection algorithms
  vs.
  Deterministic anti-collision algorithms
  → ex. Binary Tree Walking

- More than 40 patents, for what amounts to „known“ methods