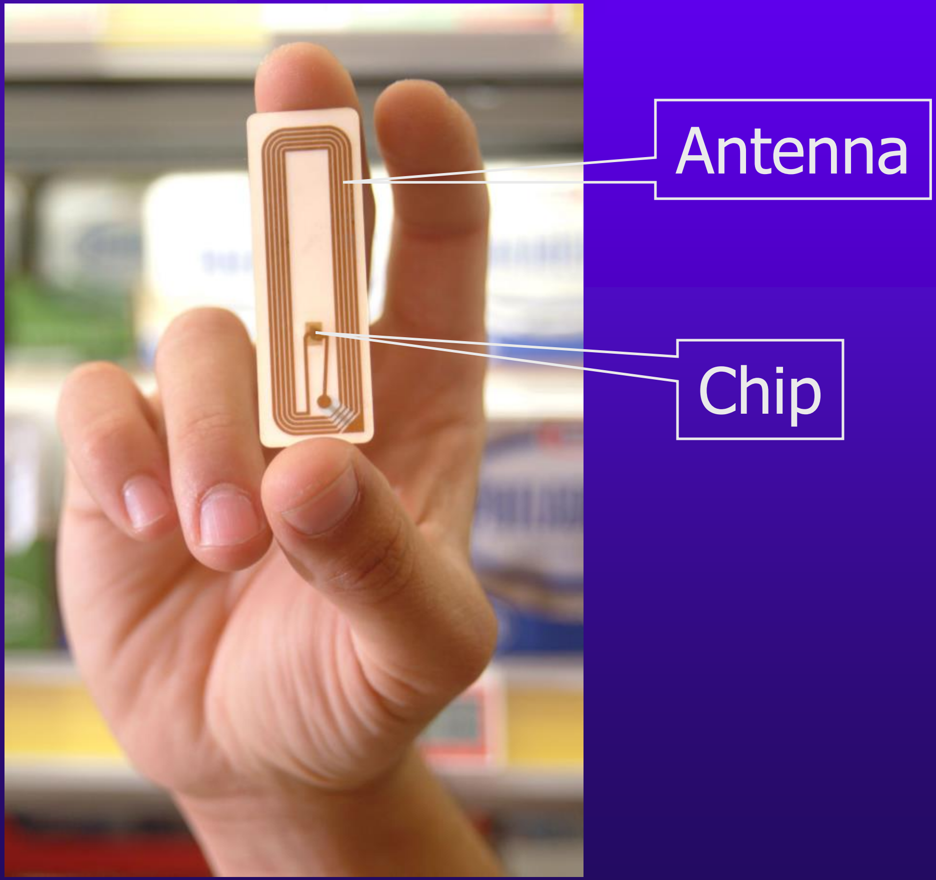
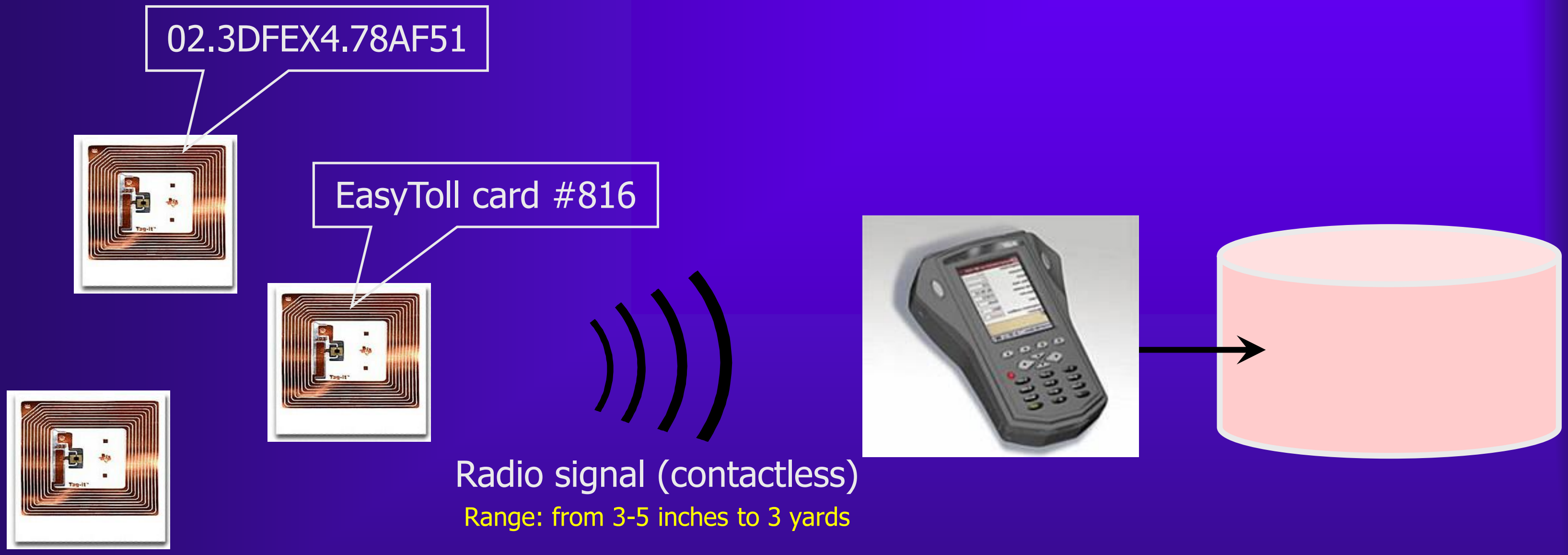
RFID Security and Privacy

What is RFID?

- Radio-Frequency Identification Tag



How Does RFID Work?



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EasyToll card #816

Radio signal (contactless)

Range: from 3-5 inches to 3 yards

Tags (transponders)

Attached to objects,
“call out” identifying data
on a special radio frequency

Reader (transceiver)

Reads data off the tags
without direct contact

Database

Matches tag IDs to
physical objects

RFID is the Barcode of the Future

Barcode

Line-of-sight reading

- Reader must be looking at the barcode

Specifies object type

- E.g., "I am a pack of Juicy Fruit"

RFID

Fast, automated scanning (object doesn't have to leave pocket, shelf or container)

Reading by radio contact

- Reader can be anywhere within range

Specifies <u>unique</u> object id

- E.g., "I am a pack of Juicy Fruit #86715-A"

Can look up this object in the database

Where Are RFID Used?

- Physical-access cards
- Inventory control
  - Gillette Mach3 razor blades, ear tags on cows, kid bracelets in waterparks, pet tracking
- Logistics and supply-chain management
  - Track a product from manufacturing through shipping to the retail shelf
- Gas station and highway toll payment
  - Mobil SpeedPass

Commercial Applications of RFID

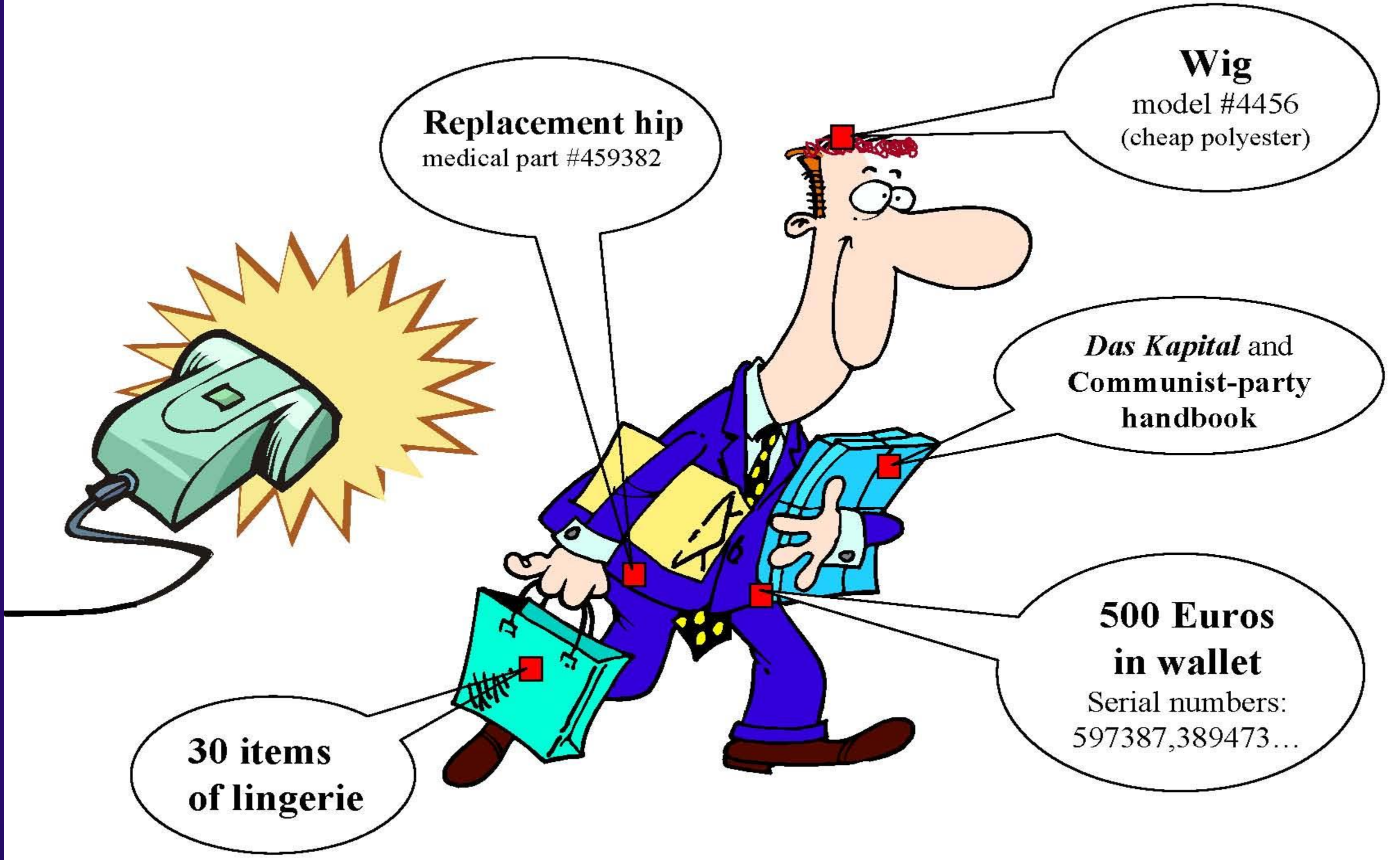
- RFID cost is dropping dramatically, making it possible to tag even low-value objects
  - Around 5c per tag, $100 for a reader
- Logistics and supply-chain management is the killer application for RFID
  - Shipping, inventory tracking, shelf stocking, anti-counterfeiting, anti-shoplifting
- Massive deployment of RFID is in the works
  - Wal-Mart pushing suppliers to use RFID at pallet level, Gillette has ordered 500,000,000 RFID tags

Futuristic Applications

- Prada store in New York City already uses RFID to display matching accessories on in-store screens
- Refrigerator shelves that tell when milk expires
- Airline tickets with RFIDs on them that help direct travelers through the airport
- Microwave ovens that read cooking directions from RFID tags on food packages
- RFID tags on postage stamps
- Businesses may attach RFID tags to invoices, coupons, and return envelopes

Privacy Issues (due to Ari Juels)

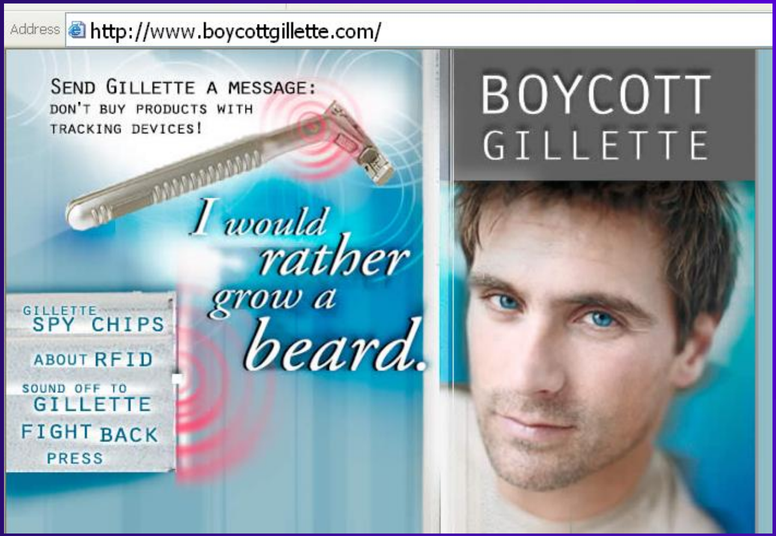
RFID tags will be *everywhere*…



Risks

- Personal privacy
  - FDA recommended tagging drugs with RFID “pedigrees”; ECB planned to add RFID tags to euro banknotes…
    - I’ll furtively scan your briefcase and learn how much cash you are carrying and which prescription medications you are taking
- Skimming: read your tag and make my own
  - In February 2005, JHU-RSA Labs team skimmed and cloned Texas Instruments’ RFID device used in car anti-theft protection and SpeedPass gas station tokens
- Corporate espionage
  - Track your competitor’s inventory

Consumer Backlash

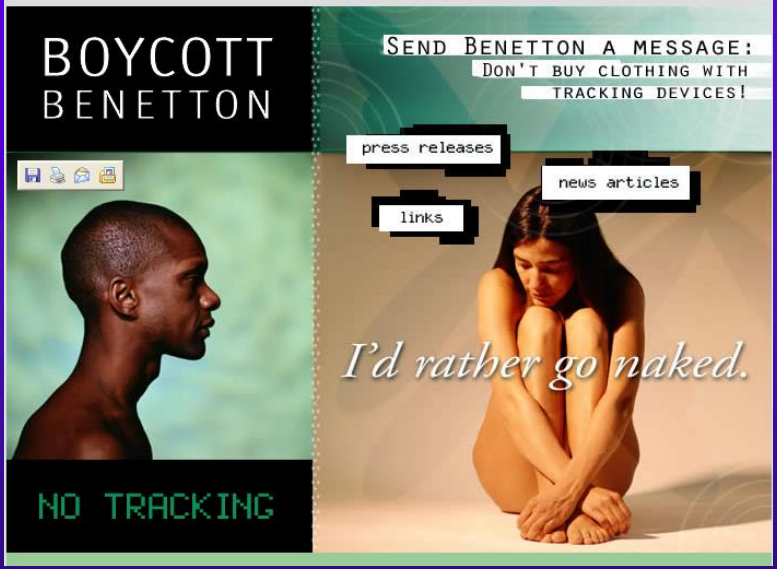


Address http://www.boycottgillette.com/

BOYCOTT GILLETTE

SEND GILLETTE A MESSAGE: DON'T BUY PRODUCTS WITH TRACKING DEVICES!

I would rather grow a beard.



BOYCOTT BENETTON

SEND BENETTON A MESSAGE: DON'T BUY CLOTHING WITH TRACKING DEVICES!

I'd rather go naked.

NO TRACKING

C.A.S.P.I.A.N.

Consumers Against Supermarket Privacy Invasion and Numbering

Is Big Brother in your grocery cart?

RFID Tag Power Sources

- Passive (this is what mostly used now)
  - Tags are inactive until the reader’s interrogation signal “wakes” them up
  - Cheap, but short range only
- Semi-passive
  - On-board battery, but cannot initiate communication
    - Can serve as sensors, collect information from environment: for example, “smart dust” for military applications
  - More expensive, longer range
- Active
  - On-board battery, can initiate communication

RFID Capabilities

- No or very limited power
- Little memory
  - Static 64- or 128-bit identifier in current 5-cent tags
- Little computational power
  - A few thousand gates at most
  - Static keys for read/write access control
- Not enough resources to support public- or symmetric-key cryptography
  - Cannot support modular arithmetic (RSA, DSS), elliptic curves, DES, AES; hash functions are barely feasible
    - Recent progress on putting AES on RFID tags

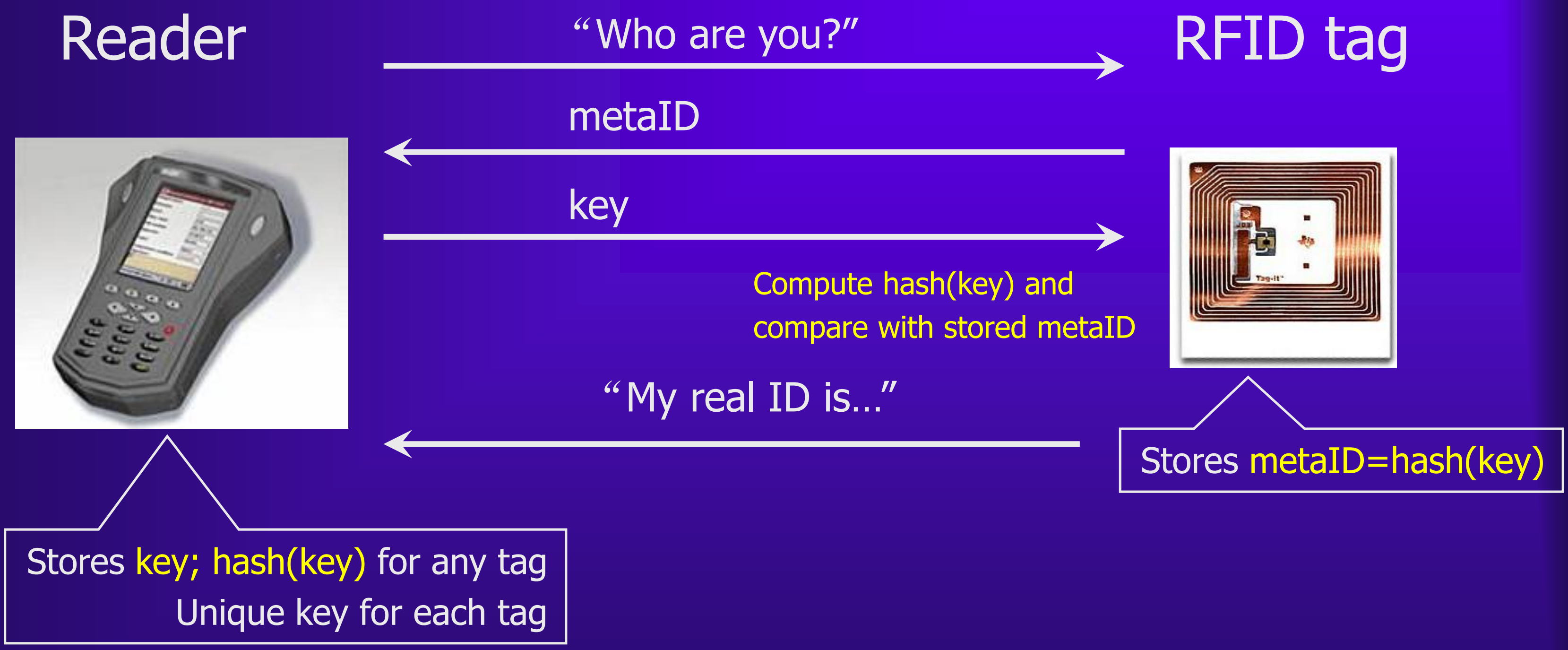
Blocking Unwanted Scanning

- Kill tag after purchase
  - Special command permanently de-activates tag after the product is purchased
  - Disables many futuristic applications
- Faraday cage
  - Container made of foil or metal mesh, impenetrable by radio signals of certain frequencies
    - Shoplifters are already known to use foil-lined bags
  - Maybe works for a wallet, but huge hassle in general
- Active jamming
  - Disables all RFID, including legitimate applications

Hash Locks

[Rivest, Weis, Sharma, Engels]

Goal: authenticate reader to the RFID tag



Reader

RFID tag

“Who are you?”

metaID

key

Compute hash(key) and compare with stored metaID

“My real ID is…”

Stores metaID=hash(key)

Stores key; hash(key) for any tag
Unique key for each tag

Why is this not a perfect solution?

Analysis of Hash Locks

- Relatively cheap to implement
  - Tag has to store hash implementation and metaID
- Security based on weak collision-resistance of hash function
- metaID looks random
- Problem: tag always responds with the same value
  - Attacker can track the same tag from place to place even if he cannot learn its real ID

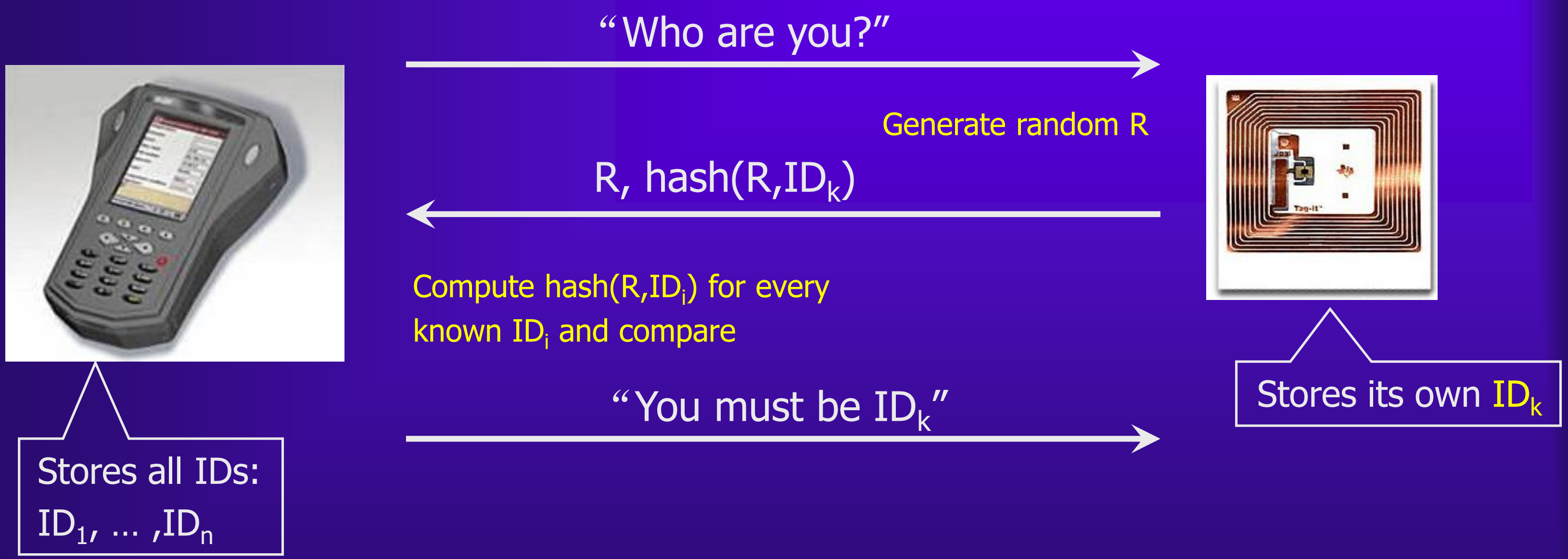
Randomized Hash Locks

[Weis et al.]

Goal: authenticate reader to the RFID tag

Reader

RFID tag



“Who are you?”

Generate random R

R, hash(R,ID_k)

Compute hash(R,ID_i) for every known ID_i and compare

“You must be ID_k”

Stores all IDs: ID_1, … ,ID_n

Stores its own ID_k

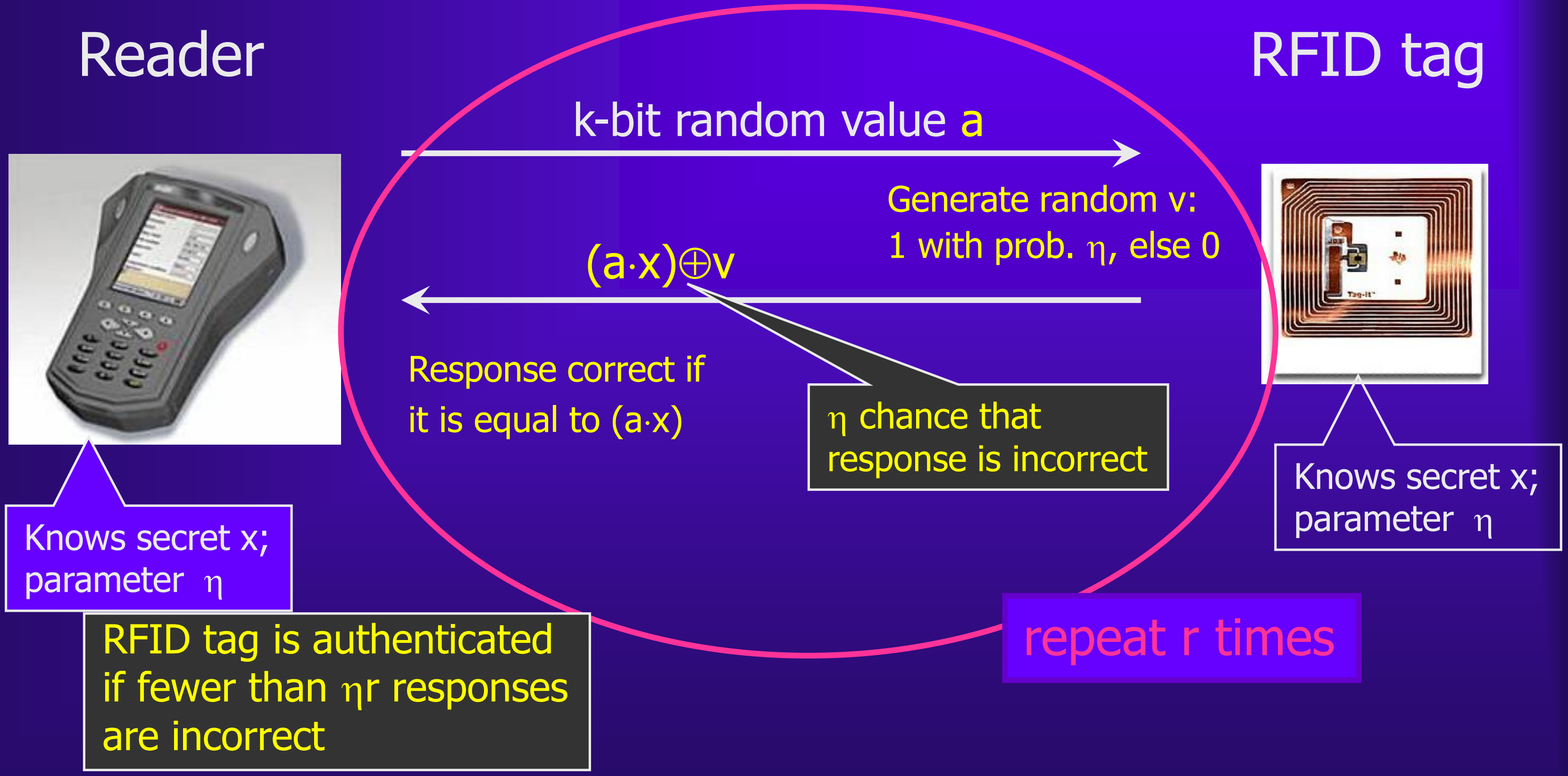
Analysis of Randomized Hash Locks

- Tag must store hash implementation and pseudo-random number generator
  - Low-cost PRNGs exist; can use physical randomness
- Secure against tracking because tag response is different each time
- Reader must perform brute-force ID search
  - Effectively, reader must stage a mini-dictionary attack to unlock the tag
- Alternative: use a block cipher
  - Need a very efficient implementation of AES

HB Protocol

[Juels and Weis, based on Hopper and Blum]

Goal: authenticate RFID tag to the reader



Reader

RFID tag

k-bit random value a

Generate random v:
1 with prob. η, else 0

(a·x)⊕v

Response correct if
it is equal to (a·x)

η chance that
response is incorrect

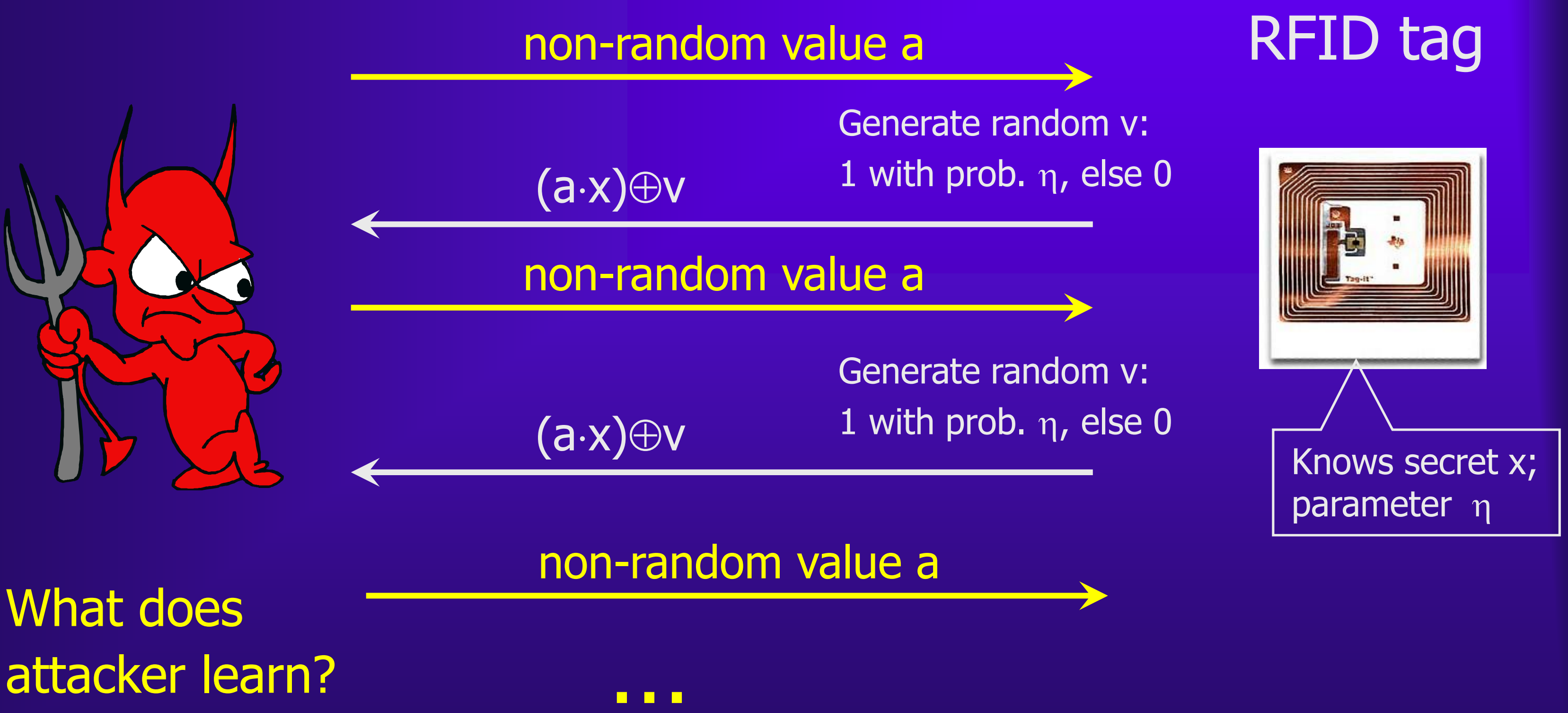
Knows secret x;
parameter η

Knows secret x;
parameter η

RFID tag is authenticated
if fewer than ηr responses
are incorrect

repeat r times

Active Adversary



non-random value a

$(a\cdot x)\oplus v$

Generate random v:
1 with prob. η, else 0

non-random value a

$(a\cdot x)\oplus v$

Generate random v:
1 with prob. η, else 0

non-random value a

…

RFID tag

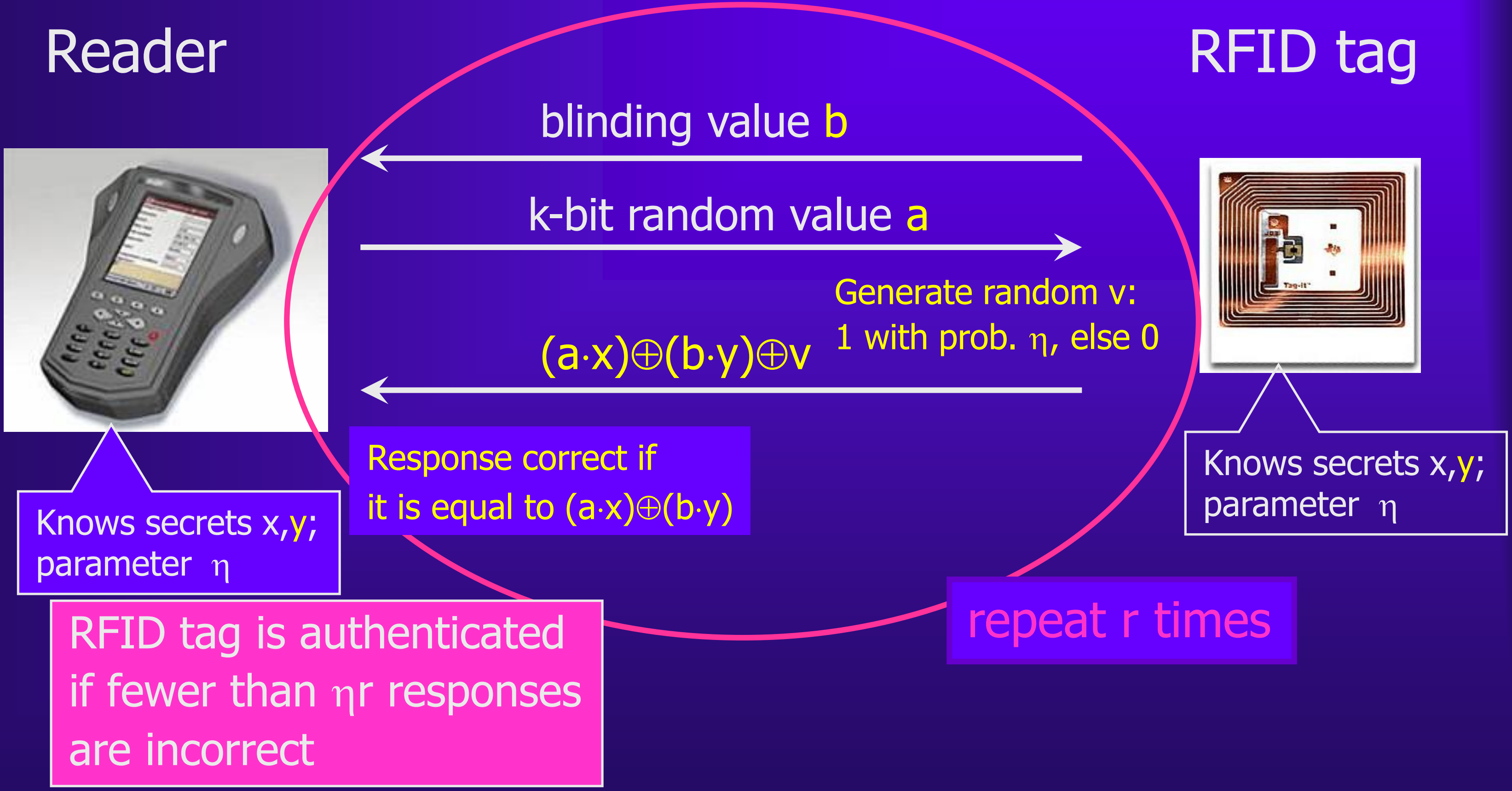
Knows secret x;
parameter η

What does attacker learn?

HB+ Protocol

[Juels and Weis]

Goal: authenticate RFID tag to the reader



Reader

RFID tag

blinding value b

k-bit random value a

Generate random v:
1 with prob. η, else 0

$(a\cdot x)\oplus(b\cdot y)\oplus v$

Response correct if
it is equal to $(a\cdot x)\oplus(b\cdot y)$

Knows secrets x,y;
parameter η

Knows secrets x,y;
parameter η

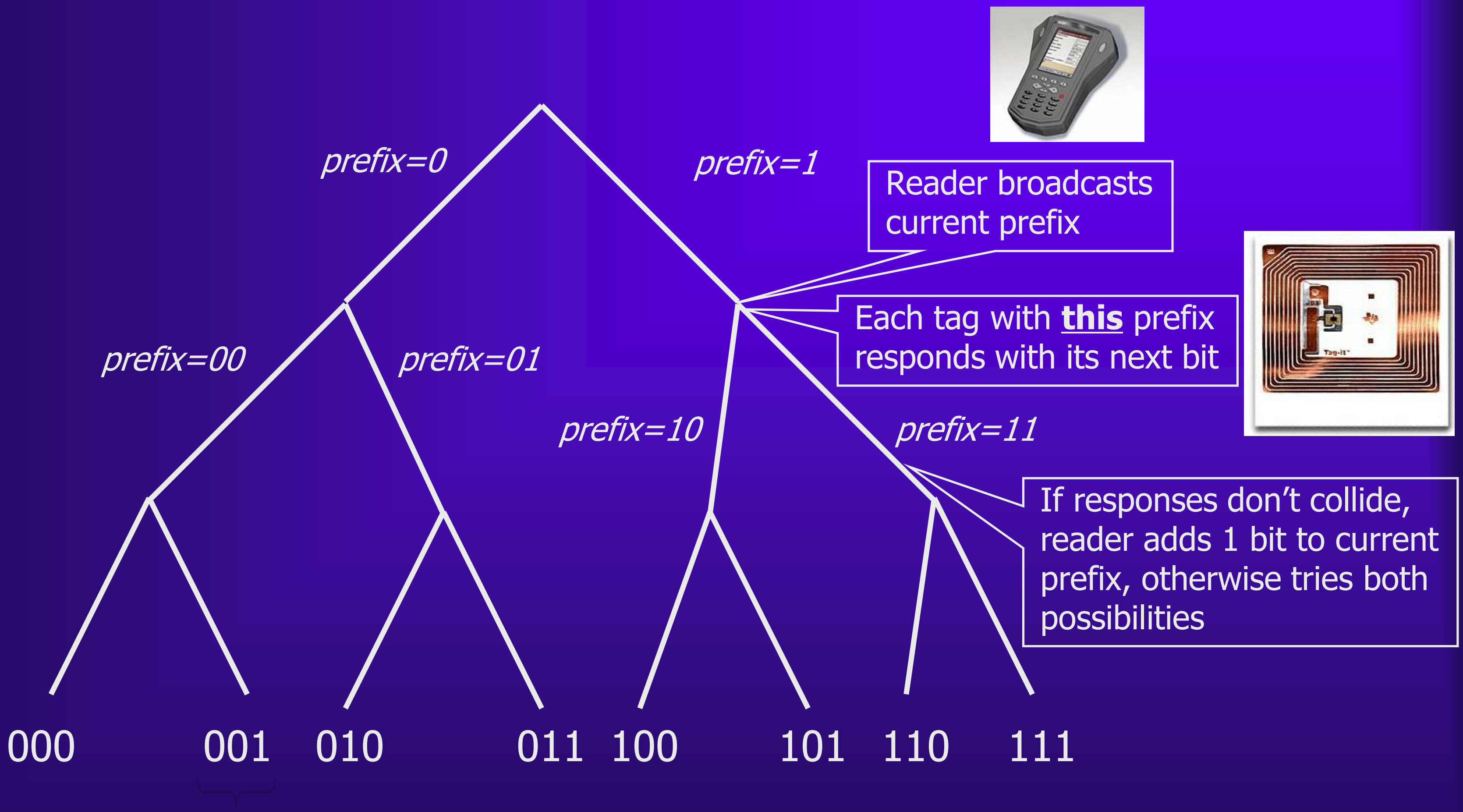
RFID tag is authenticated
if fewer than ηr responses
are incorrect

repeat r times

How Does the Reader Read a Tag?

- When the reader sends a signal, more than one RFID tag may respond: this is a collision
  - Reader cannot accurately read information from more than one tag at a time
  - Example: every tagged item in a supermarket cart responds to the cashier’s RFID reader
- Reader must engage in a special singulation protocol to talk to each tag separately
- Tree-walking is a common singulation method
  - Used by 915 Mhz tags, expected to be the most common type in the U.S.

Tree Walking



Reader broadcasts current prefix

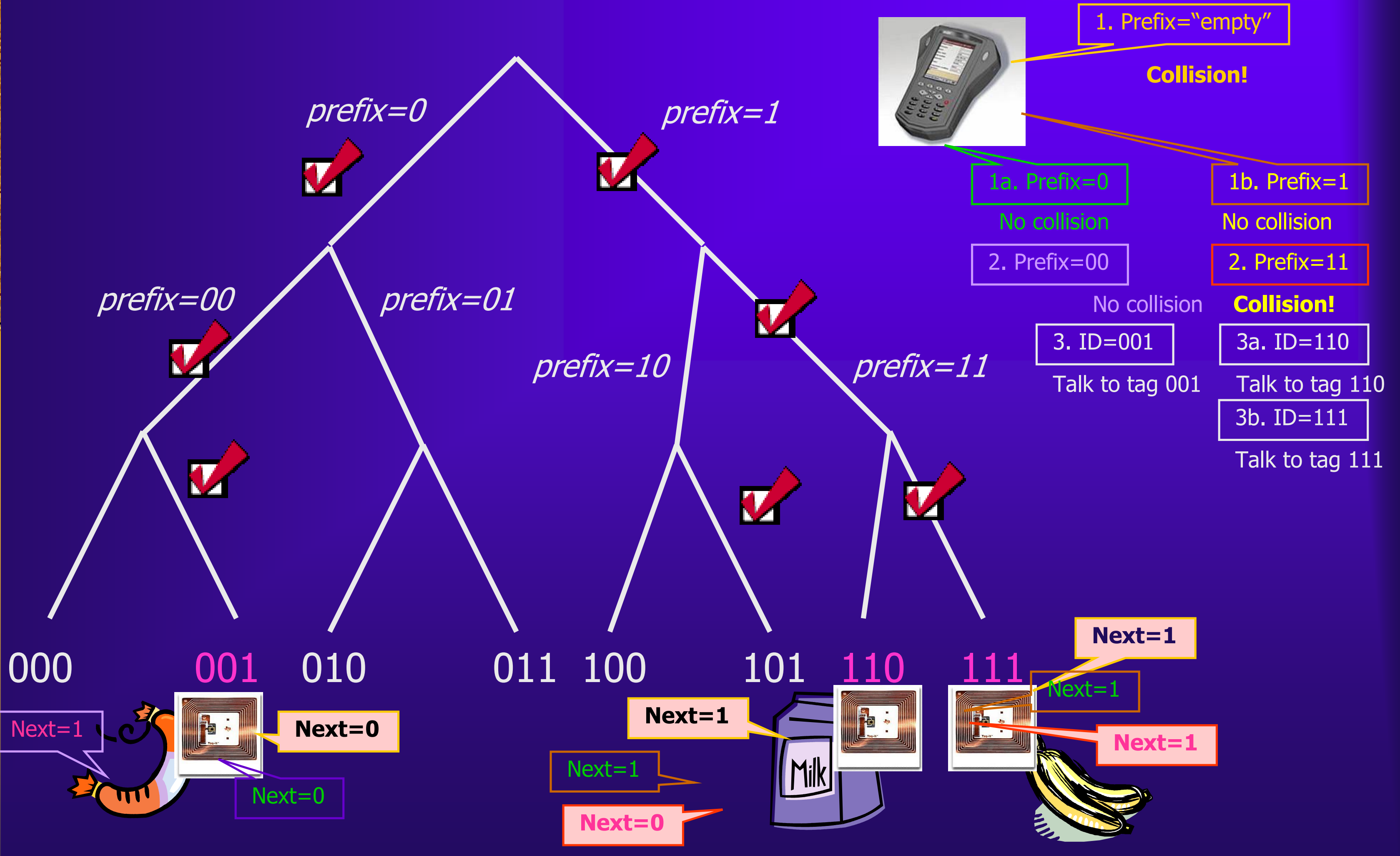
Each tag with **this** prefix responds with its next bit

If responses don’t collide, reader adds 1 bit to current prefix, otherwise tries both possibilities

Every tag has a k-bit identifier

This takes O(k • number of tags)

Example: Supermarket Cart



1. Prefix="empty"

Collision!

1a. Prefix=0

No collision

1b. Prefix=1

No collision

2. Prefix=00

No collision

2. Prefix=11

Collision!

3. ID=001

Talk to tag 001

3a. ID=110

Talk to tag 110

3b. ID=111

Talk to tag 111

Blocker Tag

[Rivest, Juels, Szydlo]

- A form of jamming: broadcast both "0" and "1" in response to any request from an RFID reader
  - Guarantees collision no matter what tags are present
  - To talk to a tag, reader must traverse every tree path
    - With 128-bit IDs, reader must try 2^{128} values – infeasible!
- To prevent illegitimate blocking, make blocker tag selective (block only certain ID ranges)
  - E.g., blocker tag blocks all IDs with first bit=1
  - Items on supermarket shelves have first bit=0
    - Can't block tags on unpurchased items (anti-shoplifting)
  - After purchase, flip first bit on the tag from 0 to 1

RFID References on the Website

- A couple of surveys on RFID privacy issues
- Hash locks paper by Weis et al.
- HB/HB+ paper by Juels and Weis
- Blocker tags paper by Juels et al.