Attacking RFID Systems

Exploiting ID and ticketing applications

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Power of Community 2006

Korea

Agenda

- What is RFID?
- How to exploit and attack RFID systems
- Attacks against the middleware
- Reader-emulation, soft-tags
- Unexpected risk middleware
- New ways to exploit the system
- Encrypted RFID Tags (14443, MRTD)

What is RFID?

- Radio Frequency Identification (RFID)
  - Wireless transmission of information between transponder and reader without visibility
  - Bidirectional transfer (read and write)
  - Transponder (tag) can be attached, embedded or implanted
  - Automatic correlation between object and saved data

Generic Terms

- RFID is often used as generic term for complete infrastructures.
  - A transponder (aka RFID-chip, -tag, -label, wireless label or simply chip)
  - A reader (in fact most of them can write to the tag too)
  - Some middleware, which connects the reader to a server
  - Some communication infrastructure
  - Integration with server farms, data warehouses, services and supporting systems

Variants

Different types of RFID transponders

Short range	Mid range	Long range
<= 15 centimeter	<= 5meter	Up to 500 meter
ISO 14443 A+B	ISO 15693	ISO 18000-xx
13.56 MHz, 125-134.2kHz	13.56 MHz, 125-135kHz	860-956 MHz (UHF) 2.4 GHz (Microwave) 5.8 GHz (Microwave)
E-field, magnetic field	EM-field	EM-field

Transponders

- There are different kinds of transponders:
  - Only transmitting a unique ID (serial-number)
    - Only passive
    - Identification
    - Tracking (Fast-track)
    - Only clear text communication

Transponders

- There are different types of transponders:
  - Storage of Data / Metadata R/W WORM
    - Most passive, some active
    - EPC
    - Smart Labels
    - Most use clear text communication, some are with encrypted communication

Transponders

- There are different types of transponders:
  - Act as Smart Card Interface
    - Most active, some passive
    - Biometric Passport (ICAO - MRTD)
    - Access Control System (Mifare DESFire)
    - Encryption, authentication, encrypted communication

Generic Attacks

- Sniffing of the communication between transponder and reader
  - Counterfeiting of the communication
  - Obtaining UID, user data and meta data
  - Basic attack on structures and tags
  - Replay attack to fool the access control systems

Generic Attacks

- Counterfeiting the identity of the reader and unauthorized writing to the tag
  - Change of UID via manipulation of the administrative block
  - Declare false identity
  - UID must be readable in clear text
  - Manipulation of product groups and prices

Generic Attacks

- Manipulation of data stored on the transponder
  - Manipulation of data
  - Manipulation of metadata
  - Swap of objects
  - Logical duplication of objects

Generic Attacks

- Deactivation of the transponder
  - Disable the traceability of objects
  - Disable the visibility of objects

Generic Attacks

- Attack the structures in the middleware and backends, manipulation of data structures.
  - Injection of malware into the backend and middleware systems
  - E.g. database worms
  - Manipulation of backend systems
  - Denial of Service attack against the infrastructure

Generic Attacks

- Jamming of the RFID frequencies
  - Use of “out-of-the-box” police jammer (broadband jamming transmitter)
  - Attack against anti-collision (RSA attack)
  - Prevent reading of the tag
  - Simple denial of service attack against the RFID System
  - Shut down production, sales or access

Encrypted RFID

- MIFARE are the most used RFID transponders featuring encryption
  - Technology is owned by Philips Austria GmbH
  - Technology is based on
    - ISO 14443
    - 13.56 MHz Frequency

MIFARE Tags

- MIFARE Standard
  - Proprietary high-level protocol
  - Philips proprietary security protocol for authentication and ciphering
  - MIFARE UltraLight: same tags without encryption

MIFARE Tags

- MIFARE Pro, ProX, and SmartMX
  - Fully comply to ISO 14443-4 standard
  - The different types of tags offer memory protected by two different keys (A and B)
  - Each sector could be protected with one of these keys.

Brute Force the Tag

- 2^6^8 bit for the keyspace
- 25 ms per try with a brute force perl script using Linux and a self written driver
- Using one RFID reader

$$\frac{6^{\left(2^{8}\right)} \bullet 0.025s}{3600s} \approx 81445305 \text{ Days} \approx 22623 Years$$

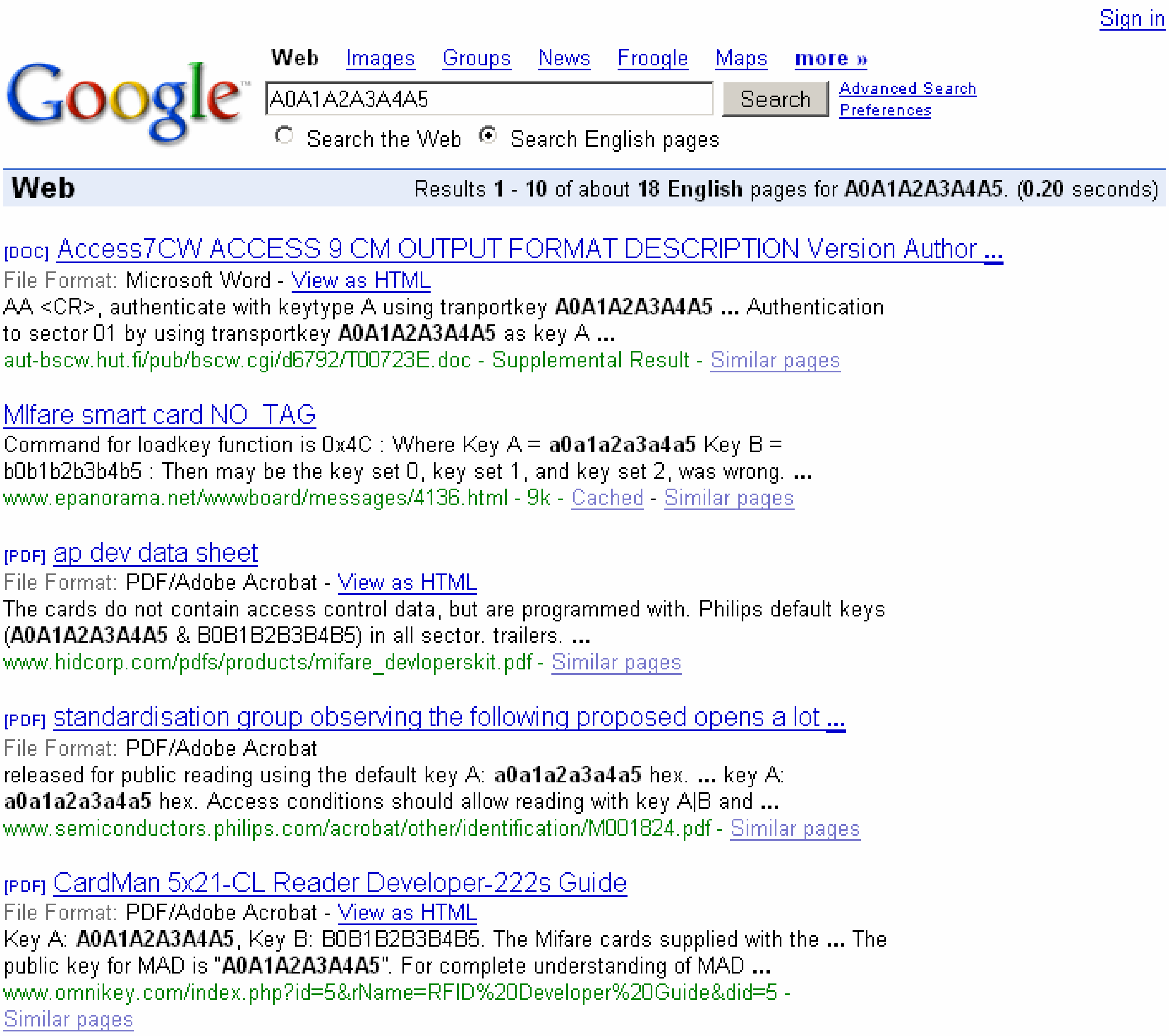
Brute Force the Tag

- 2^6^8 bit for the keyspace
- 25 ms per try with a brute force perl script using Linux and a self written driver
- Using 1.000 RFID readers

$$\frac{6^{\left(2^{8}\right)} \bullet 0.025s}{3600s \bullet 1000} \approx 81445\,\mathrm{Days} \approx 226\mathit{Years}$$

MIFARE Sector Keys

- Philips puts all information under NDA
- We are not interested to sign an NDA
- Extract information from RFID software via „UNIX strings“
- Google helps a lot, Google desktop search is very popular among smartcard developers´ PCs ;-)
- Look at the results


Sign in
Web Images Groups News Froogle Maps more »
Search
Advanced Search
Preferences
○ Search the Web ● Search English pages

A0A1A2A3A4A5

Web Results **1** - **10** of about **18 English** pages for **A0A1A2A3A4A5**. (**0.20** seconds)

[DOC] Access7CW ACCESS 9 CM OUTPUT FORMAT DESCRIPTION Version Author ...
File Format: Microsoft Word - View as HTML
AA <CR>, authenticate with keytype A using tranportkey **A0A1A2A3A4A5** ... Authentication to sector 01 by using transportkey **A0A1A2A3A4A5** as key A ...
aut-bscw.hut.fi/pub/bscw.cgi/d6792/T00723E.doc - Supplemental Result - Similar pages

MIfare smart card NO TAG
Command for loadkey function is 0x4C : Where Key A = **a0a1a2a3a4a5** Key B = b0b1b2b3b4b5 : Then may be the key set 0, key set 1, and key set 2, was wrong. ...
www.epanorama.net/wwwboard/messages/4136.html - 9k - Cached - Similar pages

[PDF] ap dev data sheet
File Format: PDF/Adobe Acrobat - View as HTML
The cards do not contain access control data, but are programmed with. Philips default keys (**A0A1A2A3A4A5** & B0B1B2B3B4B5) in all sector. trailers. ...
www.hidcorp.com/pdfs/products/mifare_devloperskit.pdf - Similar pages

[PDF] standardisation group observing the following proposed opens a lot ...
File Format: PDF/Adobe Acrobat
released for public reading using the default key A: **a0a1a2a3a4a5** hex. ... key A: **a0a1a2a3a4a5** hex. Access conditions should allow reading with key A|B and ...
www.semiconductors.philips.com/acrobat/other/identification/M001824.pdf - Similar pages

[PDF] CardMan 5x21-CL Reader Developer-222s Guide
File Format: PDF/Adobe Acrobat - View as HTML
Key A: **A0A1A2A3A4A5**, Key B: B0B1B2B3B4B5. The Mifare cards supplied with the ... The public key for MAD is "**A0A1A2A3A4A5**". For complete understanding of MAD ...
www.omnikey.com/index.php?id=5&rName=RFID%20Developer%20Guide&did=5 - Similar pages

Default Keys

- Found the following default keys:
  - Key A A0 A1 A2 A3 A4 A5
  - Key A FF FF FF FF FF FF
  - Key B B0 B1 B2 B3 B4 B5
  - Key B FF FF FF FF FF FF
  - About 60 keys from example applications
  - No protection 00 00 00 00 00 00

MAD

- Additional found the Mifare Application Directory.
- This PDF that shows how MIFARE are specifying the type of use of one of the transponders, each applications should have an entry to show the Type of Service.

Example Layouts

- In the datasheets and „googled“ documentation are a lot of examples.
- These examples include different keys and tag / memory layout and data structure for:
  - Ticketing
  - Access Control
  - Online Payment

Software developers are lazy

- Checking a couple of cards shows that more than 75% use one of these default keys!
- It compiles let's ship it !
- The programmers not only use the example layouts, they also use the example keys !

Attack the Tag

- Directory attacks are possible with found default and example keys
  - Variations of the directory are always possible
- „Smart“ brute-force attack to the tag are possible
  - never seen a lockout or false login counter
  - a delay for a false key does not exist

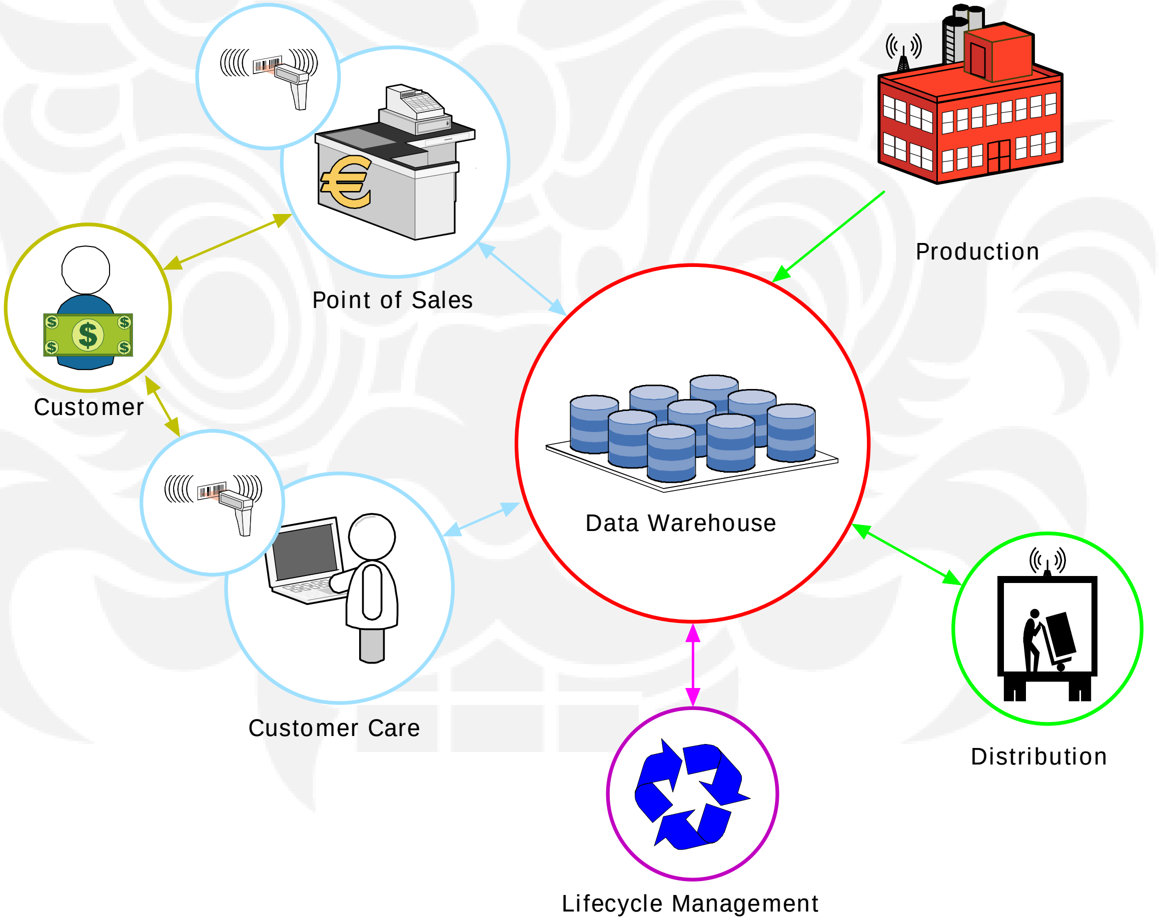
Attacks to the Backend

- The memory of a ISO 15693 tag acts like a normal storage
- RFDump (Black Hat 2004) could help to manipulate data like with a hex-editor
- SQL-Injection and other attacks are possible

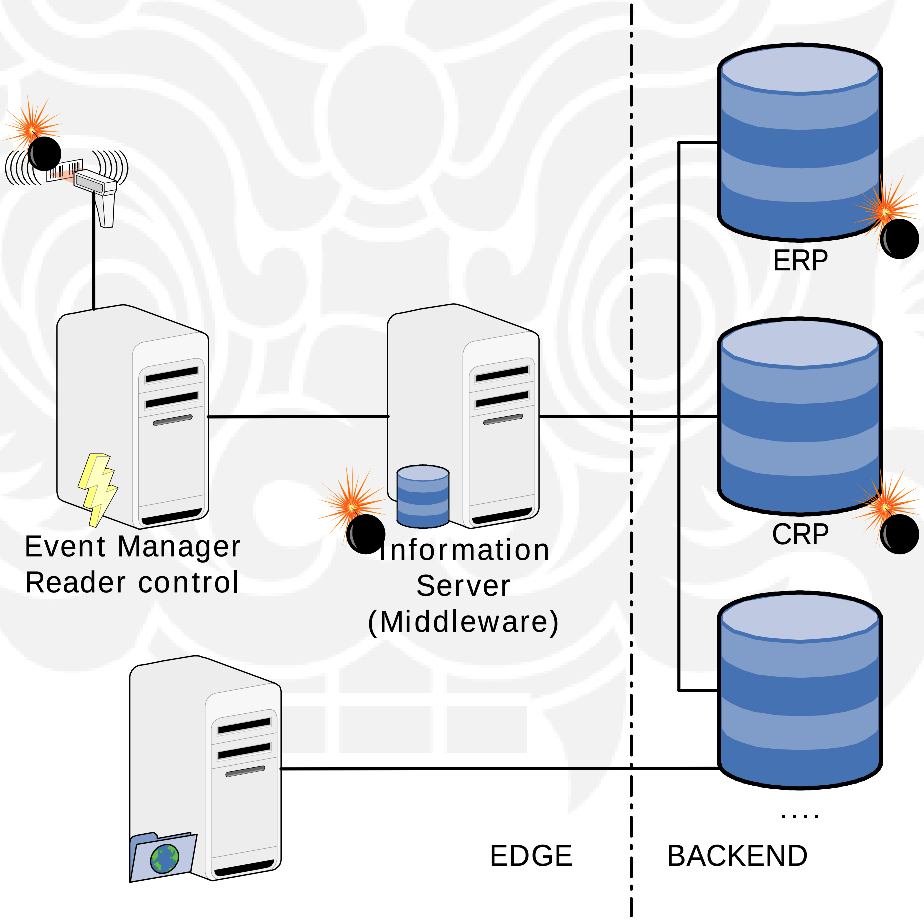
Preventing security functions

- If the tag is „read only“ read it with RFDump and write the manipulated data to an empty one
- Checksum, some implementations use the UID (Unique ID) as mirror block in the UD, both must be changed
- If the block is encrypted, the Sector Key must be broken

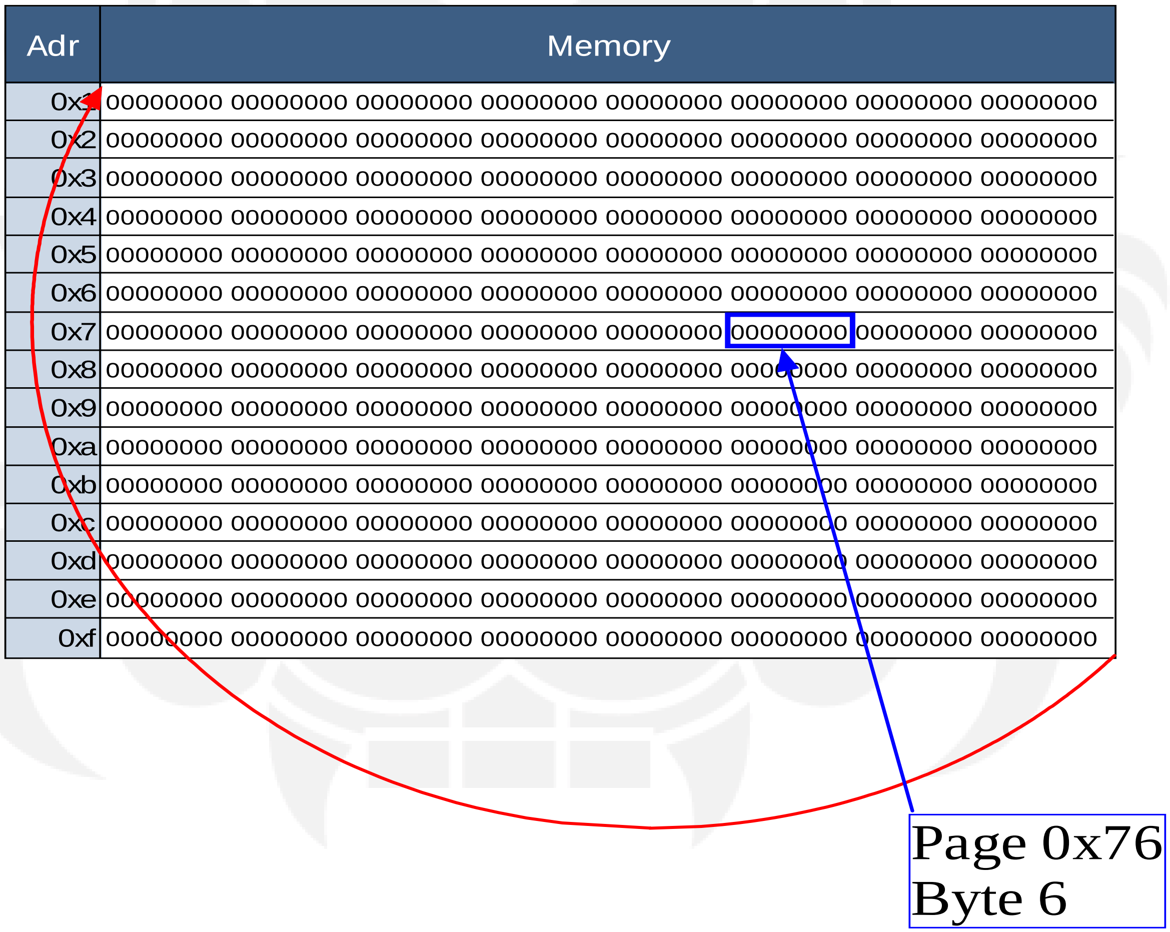
The RFID Supply chain



Break into the Systems



Problem Memory Size



Adr	Memory
0x1	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0x2	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0x3	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0x4	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0x5	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0x6	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0x7	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0x8	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0x9	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0xa	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0xb	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0xc	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0xd	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0xe	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0xf	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

Page 0x76
Byte 6

Representation to the Backend

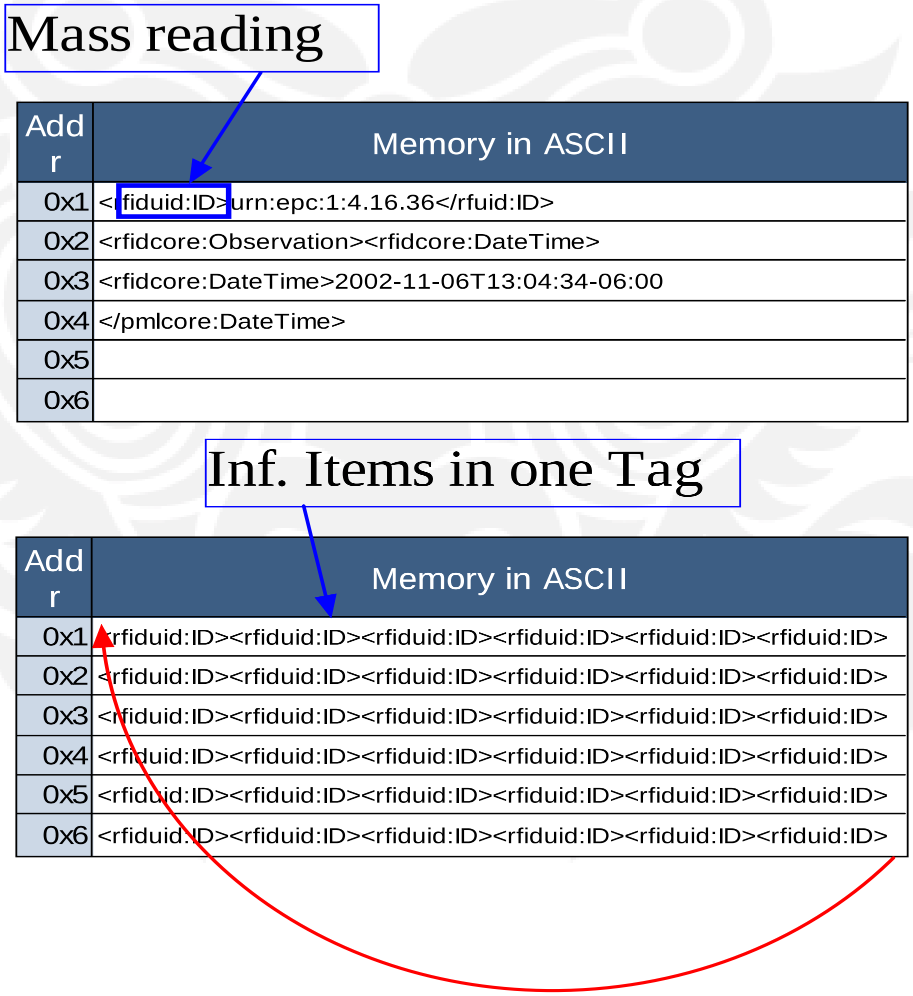
- Looks like unlimited space on the tag
  - E.g. RFDump uses a tag database to avoid reading over the boundary
- Normally reading is event-driven
  - Reading up to the EOF
  - Input is unchecked in all implementations we have seen

Tag DoS with C-Strings

End of String

Adr	Memory
0x1	68547369 69202073 6e616520 6178706d 656c6f20 20662061 616d696e 75706100
0x2	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0x3	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0x4	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0x5	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0x6	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0x7	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0x8	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0x9	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0xa	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0xb	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0xc	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0xd	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0xe	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF
0xf	FFFFFFF FFFFFFF FFFFFFF FFFFFFF FFFFFFFF FFFFFFF FFFFFFF FFFFFFF

Tag DoS with XML



Mass reading

Addr	Memory in ASCII
0x1	<rfiduid:ID>urn:epc:1:4.16.36</rfuid:ID>
0x2	<rfidcore:Observation><rfidcore:DateTime>
0x3	<rfidcore:DateTime>2002-11-06T13:04:34-06:00
0x4	</pmlcore:DateTime>
0x5	
0x6	

Inf. Items in one Tag

Addr	Memory in ASCII
0x1	<rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID>
0x2	<rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID>
0x3	<rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID>
0x4	<rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID>
0x5	<rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID>
0x6	<rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID><rfiduid:ID>

Soft-Tags

- Emulation of RFID-Tag and/or reader
- Serial-Emulation of any ISO 15693 tag
- Useful for testing backend and middleware
- Reads „backup“ from real tags
- Manipulation of any UID, User Data or administrative block.

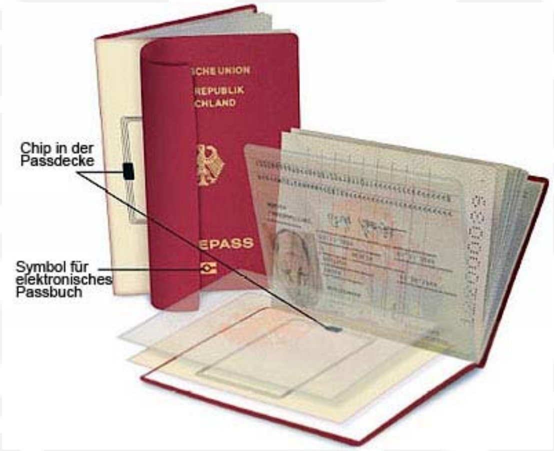
ePassports

This image is a work of a United States Department of Homeland Security employee, taken or made during the course of an employee's official duties.
As a work of the U.S. federal government, the image is in the public domain.

MRTD

- Machine Readable Travel Document aka Electronic Passports (ePassports)
- Specifications by ICAO
  - (International Civil Aviation Organization)
- Enrollment on a global basis

ePass from Germany



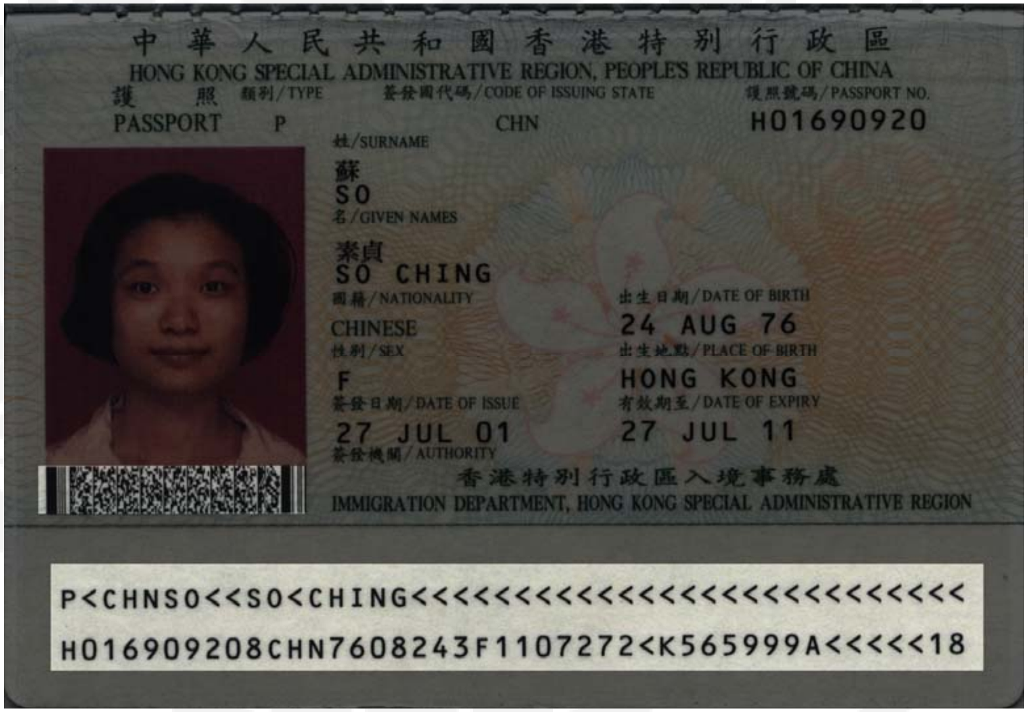
- RFID tag embedded into the cover
- Produced by the Bundesdruckerei GmbH

dn Systems

MRTD

- Store passport data and biometric information on an RFID transponder
  - Alternative storage methods like 2D barcodes also covered
  - Common standard for interoperability
  - Some features are mandatory, others are optional

2D Code and MRZ



中華人民共和國香港特別行政區
HONG KONG SPECIAL ADMINISTRATIVE REGION, PEOPLE'S REPUBLIC OF CHINA

護照 類別/TYPE 簽發國代碼/CODE OF ISSUING STATE 護照號碼/PASSPORT NO.
PASSPORT P CHN H01690920

姓/SURNAME
蘇
SO

名/GIVEN NAMES
素貞
SO CHING

國籍/NATIONALITY
CHINESE

出生日期/DATE OF BIRTH
24 AUG 76

性別/SEX
F

出生地點/PLACE OF BIRTH
HONG KONG

簽發日期/DATE OF ISSUE
27 JUL 01

有效期至/DATE OF EXPIRY
27 JUL 11

簽發機關/AUTHORITY
香港特別行政區入境事務處
IMMIGRATION DEPARTMENT, HONG KONG SPECIAL ADMINISTRATIVE REGION

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P<CHNSO<<SO<CHING<<<<<<<<<<<<<<<<<<<<<<<<<<<
H016909208CHN7608243F1107272<K565999A<<<<<18
```

Passport with 2D barcode and MRZ (machine readable zone)

MRTD Data-Layout

- LDS (Logical Data Structure)
  - Data is stored in DG (Data Groups)
    - DG1: MRZ information (mandatory)
    - DG2: Portrait Image + Biometric template (mandatory)
    - DG3-4: fingerprints, iris image (optional)
    - EF.SOD: Security Object Data (cryptographic signatures)
    - EF.COM: Lists with Data Groups Exist
- Data is stored in BER-encoded ASN.1
- DG2-DG4 uses CBEFF for encoding
  - common biometric file format, ISO 19785

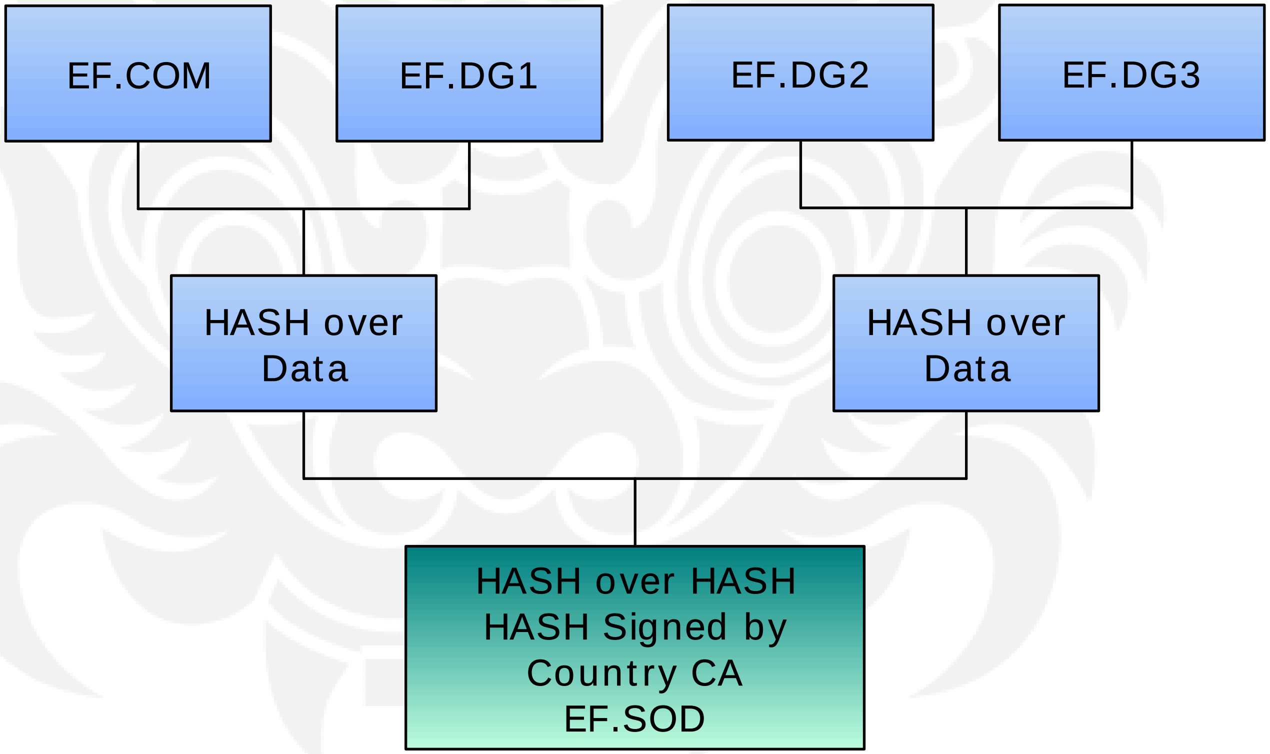
MRTD Security Features

- Random UID for each activation
  - Normally all ISO 14443 transponders have a fixed unique serial number
  - The UID is used for the anti collision
  - Prevent tracking of owner without access control
  - Problem: ICAO MRTD specs don't require unique serial number
  - Only some countries will generate random serial numbers

Passive Authentication

- This method is mandatory for all passports
- Method of proof that the passport files are signed by issuing country
- Inspection system to verify the hash of DG's
  - EF.SOD contains individual signatures for each DG
  - EF.SOD itself is signed
  - Document Signer Public Key from PKD / bilateral channels
  - Document Signer Public Key can be stored on the passport
  - Useful only if Country Root CA public key known

Signed Data


EF.COM

EF.DG1

EF.DG2

EF.DG3

HASH over Data

HASH over Data

HASH over HASH
HASH Signed by Country CA
EF.SOD

Basic Access Control

- Permits access to the data after the inspection systems are authorized
- Authorization through the Machine Readable Zone (MRZ)
  - Nine digit document number
  - In many countries: issuing authority + incrementing number
  - Six digit date of birth
    - Can be guessed or assumed to be a valid date
  - Six digit expiry date
  - 16 most significant bytes of SHA1-hash over MRZ_info are 3DES key used for S/M (ISO7816 secure messaging)

Extended Access Control

- Optional method
- Should prevent the unauthorized access to biometric data
  - Not internationally standardized
  - Implemented by individual issuers
  - Only shared with those countries that are allowed access

PKI Integration

- X.509 Certificates
  - Every issuer operates a self controlled CA
  - Signer keys are derived from CA root
  - Public keys are distributed via ICAO PKD
  - Everyone can verify
  - **Certificate revocation list (CRL)** not planned yet ☹

Cloning of passports

- Dual Interface Tags could act as MRTD Tag
- Data could be retrieved from an issued passport
- Personalization is possible via Smartcard Shell or other tools.
- Cloned tag behaves like an „Official“ ePassport

Chaos of Standarts

- TLV and ASN.1 not correctly implemented
- Redundant meta formats for biometric data
- If sign-key gets lost, the whole country is doomed
- First the data must be parsed, then it can be verified
- Design was made by politics and not by IT Security experts
- It is possible to manipulate data

Security Issues

- UID could be changed from the tag
- Passport-tag could act as Access-Control tag, if only UID is used, this tag could act as any access tag
- Manipulated DGs could crash the reader / terminal

Thank You

Questions ?