# Miscellaneous Topics

Buy a rifle, encrypt your data, and wait for the revolution

## Smart Cards

Invented in the early 1970's

Technology became viable in early 1980's

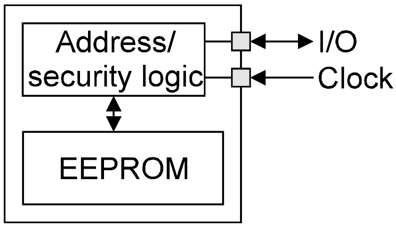
Major use is prepaid telephone cards (hundreds of millions)

- Use a one-way (down) counter to store card balance

Other uses

- Student ID/library cards
- Patient data
- Micropayments (bus fares, photocopying, snack food)

## Memory Cards




Usually based on I$^2$C (serial memory) bus

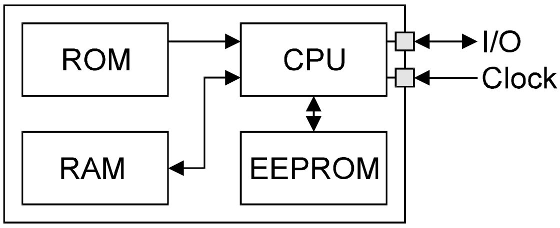
Typical capacity: 256 bytes

EEPROM capabilities

- Nonvolatile storage
- 10,000 write/erase cycles
- 10ms to write a cell or group of cells

Cost: $5

## Microprocessor Cards




ROM/RAM contains card operating system and working storage

EEPROM used for data storage

## Microprocessor Cards (ctd)

Typical specifications

- 8-bit CPU
- 16K ROM
- 256 bytes RAM
- 4K EEPROM

Size ratio of memory cells:

RAM = 4× EEPROM size
= 16× ROM size

Cost: $5-50 (with crypto accelerator)

## Smart Card Technology

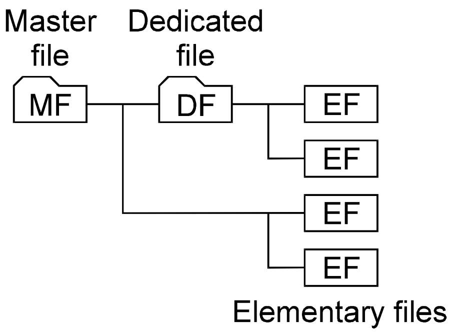
Based on ISO 7816 standard, which defines

- Card size, contact layout, electrical characteristics
- I/O protocols
  - Byte-based
  - Block-based
- File structures

Terminology alert: Vendor literature often misuses standard terms

- “Digital signature” = simple checksum or MAC
- “Certificate” = data + “digital signature”

# File Structures




Files addressed by 16-bit file ID (FID)

- FID is often broken into DF:EF parts (MF is always 0x3F00)

Files are generally fixed-length and fixed-format

# File Types

Transparent

- Binary blob

Linear fixed

- $n \times$ fixed-length records

Linear variable

- n records of fixed (but different) lengths

Cyclic

- Linear fixed, oldest record gets overwritten

Execute

- Special case of transparent file

## File Attributes

EEPROM has special requirements (slow write, limited number of write cycles) which are supported by card attributes

- WORM, only written once
- Multiple write, uses redundant cells to recover when some cells die
- Error detection/correction capabilities for high-value data
- Error recovery, ensures atomic file writes
  - Power can be removed at any point
  - Requires complex buffering and state handling

## Card Commands

Typical commands are

- CREATE/SELECT/DELETE FILE
- READ/WRITE/UPDATE BINARY
  - Write can only change bits from 1 to 0, update is a genuine write
- ERASE BINARY
- READ/WRITE/UPDATE RECORD
- APPEND RECORD
- INCREASE/DECREASE
  - Changes cyclic file position

## Card Commands (ctd)

Access control

- Based on PIN of chip holder verification (CHV)
- VERIFY CHV
- CHANGE CHV
- UNBLOCK CHV
- ENABLE/DISABLE CHV

Authentication

- Simple challenge/response authentication protocol
- INTERNAL AUTHENTICATE
  - Authenticate card to terminal
- EXTERNAL AUTHENTICATE
  - Authenticate terminal to card

## Card Commands (ctd)

Encryption: Various functions, typically

- ENCRYPT/DECRYPT
- SIGN DATA/VERIFY SIGNATURE

Electronic purse instructions

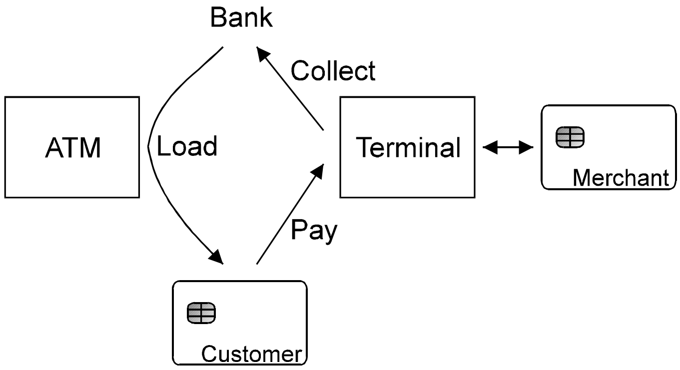
- INITIALISE/CREDIT/DEBIT

Application-specific instructions

- RUN GSM ALGORITHM

# prEN 1546

Inter-sector electronic purse (IEP) standard, 1995




Both customer and merchant use smart-card based electronic purses to handle payment transactions

# prEN 1546 (ctd)

Defines the overall framework in some detail, but leaves algorithms, payment types and parameters, and other details to implementors

- Specifies the file layout and data elements for the IEP
- Defines commands INITIALISE IEP, CREDIT IEP, DEBIT IEP, CONVERT IEP CURRENCY, and UPDATE IEP PARAMETER
- Specifies exact payment routines in a BASIC-like pseudolanguage
- All messages are "signed" (typically with a 4-byte DES MAC)
- Handles everything but purse-to-purse transactions

Includes many variants including a cut-down version for phonecards and extra acknowledgements for transactions

## Credit IEP Transaction

| IEP | | Bank |
|---|---|---|
| INITIALISE bank for load (amount and currency) | → | Verify currency and balance |
| Verify details | ← | INITIALISE IEP for load |
| Sign( DEBIT account ) | → | Verify details<br>Debit account |
| Verify details<br>Update card state | ← | Sign( CREDIT IEP ) |
| Sign( Load acknowledgement ) | → | Verify acknowledgement |

## Credit Merchant Transaction

| IEP | | Merchant |
|---|---|---|
| | ← | INITIALISE IEP for purchase |
| Sign( INITIALISE merchant for purchase) | → | Verify details |
| Verify details<br>Update card state | ← | Sign( DEBIT IEP) |
| Sign( CREDIT Merchant ) | → | Verify details<br>Record transaction for transmission to bank |
| | ← | Sign( Purchase acknowledgement) |

## TeleQuick

Austrian CEN 1546 Quick electronic purse adapted for online use

- Merchant ↔ customer = Internet
- Merchant ↔ bank = X.25

All communications uses strong SSL encryption and server certificates

Conceived as a standard Quick transaction with terminals a long way apart

- Transaction rollback in case of communications faults
- Virtual ATM must handle multiple simultaneous transactions
  - Handled via host security modules (HSM's)
- Windows PC is an insecure platform
  - Move functionality into read (LCD, keypad, crypt module)

## Working with Cards

ISO 7816 provides only a standardised command set, implementation details are left to vendors

- Everyone does it differently

Standardised API's are slow to appear

PKCS #11 (crypto token interface) is the most common API

- Functionality is constantly changing to handle different card/vendor features
- Vendors typically only implement the portions which correspond to their products
- For any nontrivial application, custom handling is required for each card type

## Working with Cards (ctd)

The Smart Card Problem

- No cards
- No readers
- No software

Installation of readers and cards is too problematic

- Keyboard and mouse (or all of Windows) may stop working
- Installing more than one reader, or reinstalling/updating drivers, is a recipe for disaster
  - Drivers need to be installed in exactly the right order
  - PC operations may be affected (eg other peripherals stop working, system functions are disabled)
  - Drivers/readers may cease to function entirely
- USB readers seem to be the safest bet

## Working with Cards (ctd)

Even finding basic DES encryption which works is tricky

- Schlumberger Cryptoflex: Doesn’t make DES user-accessible
- Schlumberger Multiflex: Returns only 6 of 8 encrypted bytes
- IBM MFC: Encrypts a random number
- Maosco MULTOS: Uses a fixed, known key “for security reasons”
- General Information Systems OSCAR: XOR’s the DES key with a random number “for security reasons”
- Gemplus GPK: Restricts keys to 40 bits

## PKCS #11

Object-oriented interface to any type of crypto token

- Smart card
- Crypto hardware accelerator
- Fortezza card
- USB-based token
- Handheld PC (eg PalmPilot)
- Software implementation

Programming interface is (in theory) completely independent of the underlying token type

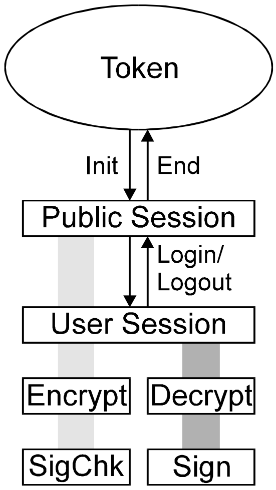
## PKCS #11 (ctd)

Token provides various services to the caller

- Store public/private keys, certificates, secret keys, authentication values, generic data
- Encrypt/decrypt
- Sign/signature check
- Wrap/unwrap key
- Generate key, generate random data
- Find object in token

# PKCS #11 (ctd)

Services can be restricted until the user has logged on using a PIN/password




# PKCS #11 Token Objects

Token objects are structured in a hierarchical manner

- Object
  - Key
    - Public Key
      - RSA Public Key
      - DSA Public Key
      - DH Public Key
      - KEA Public Key
    - Private Key
      - RSA Private Key
      - DSA Private Key
      - DH Private Key
      - KEA Private Key
    - Secret Key
      - DES Key
      - 3DES Key
      - RC2/RC4/RC5 Key
      - Skipjack Key
  - Certificate
    - X.509 Certificate
  - Data

## PKCS #11 Token Objects (ctd)

Each object has a collection of attributes, eg RSA private key has:

- Object attributes

| | |
|---|---|
| CKA_CLASS = CKO_PRIVATE_KEY | |
| CKA_TOKEN = TRUE | (persistent object) |
| CKA_PRIVATE = TRUE | (needs login to use) |
| CKA_MODIFIABLE = FALSE | (can't be altered) |
| CKA_LABEL = "My private key" | (object ID for humans) |

- Key attributes

| | |
|---|---|
| CKA_KEY_TYPE = CKK_RSA | |
| CKA_ID = 2A170D462582F309 | (object ID for computers) |
| CKA_LOCAL = TRUE | (key generated on token) |

## PKCS #11 Token Objects (ctd)

- Private Key attributes

| | |
|---|---|
| CKA_SENSITIVE = TRUE | (attributes can't be revealed outside token) |
| CKA_EXTRACTABLE = FALSE | (can't be exported from token) |
| CKA_DECRYPT = TRUE | (can be used to decrypt data) |
| CKA_SIGN = TRUE | (can be used to sign data) |
| CKA_UNWRAP = TRUE | (can be used to unwrap encryption keys) |

- RSA Private Key attributes

  CKA_MODULUS = …
  CKA_PUBLIC_EXPONENT = …
  CKA_PRIVATE_EXPONENT = …
  CKA_PRIME_1 = …
  CKA_PRIME_2 = …
  CKA_EXPONENT_1 = …
  CKA_EXPONENT_2 = …

Like a rubber screwdriver or styrofoam broadsword, PKCS #11 trades some utility in exchange for flexibility

## JavaCard

Standard smart card with an interpreter for a Java-like language in ROM

- Card runs Java with most features (multiple data types, memory management, most class libraries, and all security (via the bytecode verifier)) stripped out
  - Can run up to 200 times slower than card native code

Provides the ability to mention both "Java" and "smart cards" in the same sales literature

## JavaCard (ctd)

Card contains multiple applets

- External client sends `select` command to card
- Card selects applet and invokes its `select` method
- Further commands sent by the client are forwarded to the applets `process` method
- Applet is shut down via `deselect` method when a new select command is received

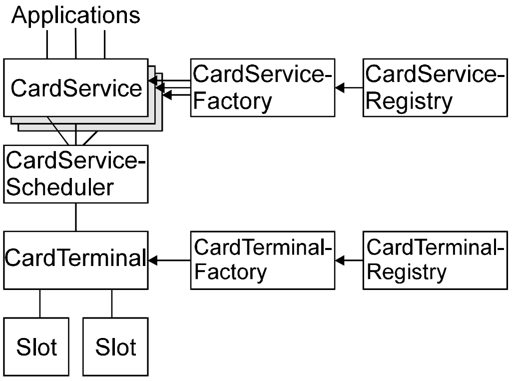
Applet can access packages and services from other applets

- How to do this securely is still under debate

# OCF

Open Card Framework, object-oriented framework for smart card developers

- Class contains a blueprint for an object
- Object is an instance of a class




# OCF (ctd)

## class SmartCard

### CardID

– Information identifying the card

### CardServiceFactory

CardService: PurseCardService

CardService: FileSystemCardService

CardService: …

### CardServiceRegistry

– Looks up requested CardService in CardServiceFactory

– Instantiates a new CardService object for the caller

### CardServiceScheduler

– Communicates with the card terminal

– Coordinates access to card services

# OCF (ctd)

## class CardFile

- Attributes
  - – TRANSPARENT, LINEAR FIXED, …
- CardFilePath, CardFileInputStream, CardFileOutputStream

## class Terminal

- Slot
  - – Information on reader slot + optional display, keyboard
- CardTerminalFactory
  - CardTerminal
- CardTerminalRegistry
  - – As CardServiceRegistry

# PC/SC

Interoperability Specification for ICC's and Personal Computer Systems

- Microsoft's attempt to kill PKCS #11 (c.f. PCT vs SSL)
- Goes a long way towards solving the Smart Card Problem

PC/SC spec defines

- Physical and electrical characteristics as ISO 7816
- Interface device (IFD) handler
  - – Common software interface for card readers
  - – Sets out minimal IFD requirements (command handling, card insertion check)
- Integrated circuit card (ICC) resource manager
  - – Controls all IFD's attached to the system

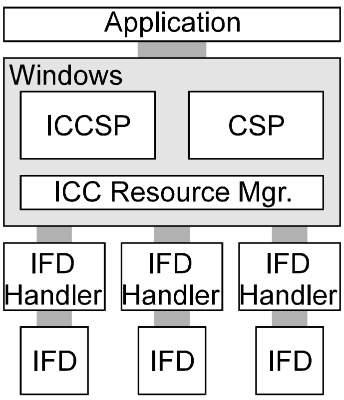
# PC/SC (ctd)

PC/SC spec (ctd)

- ICC service provider (ICCSP)
  - Maintains context of a card session
- Crypto service provider (CSP)
  - Optional manager for crypto functionality
  - Separated out for export control purposes

Getting it all to work properly was a remarkable achievement

# PC/SC (ctd)




Provided as part of newer Windows releases

- ~~Simon~~ Bill says smartcards

## PKCS #11 vs OCF vs PC/SC

| | Language | OS | Abstraction Level |
|---|---|---|---|
| PKCS #11 | Any | Any | High |
| OCF | Java | JVM | Low |
| PC/SC | Any | Windows | Low (ICCSP)<br>High (CSP) |

PKCS #11: Powerful but complex to implement → slow to appear

OCF: By Java programmers for Java programmers

PC/SC: Any platform you want as long as it's Windows (limited availability under Linux)

## Smart Card Limitations

Typical cards have the following limits

- 9600bps only (~1K/sec communication rate)
  - A single public-key operation can take seconds just to communicate the data
  - Many card CPU's are also used for I/O, card can't do anything else while communicating
- 3.5 MHz clock (slow 8-bit CPU)
- No on-board battery (power analysis attacks)
- Limited chip size (5mm$^2$) and thickness due to packaging constraints

Other crypto token form factors (USB token, PCMCIA card, iButton, Datakey) avoid these problems

# Dallas iButton

Avoids most smart card problems by changing the packaging

Device is contained in 16×5mm microcan

- Stainless steel case is much stronger than smart card
- Case contains built-in battery and clock
- I/O doesn't tie up a serial port
  - $10 iButton interface is cheaper than $50 card reader

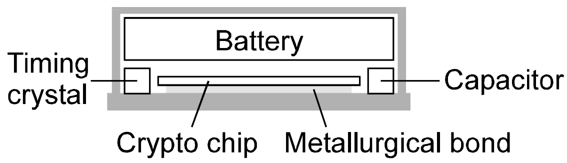
Capabilities range from simple serial-number ID, real-time clock, and data storage to crypto iButton

- 8051 processor, 32K ROM, 6K NVRAM
- 1024-bit crypto accelerator
- Real-time clock

# iButton Security

iButton package allows for much better security measures than smart cards

- Various triggers erase memory if tampering is detected




- Active face of chip is metallurgically bonded to base of can

Energy reservoir capacitor is used to zeroise memory

Timing crystal drives on-board clock

## iButton Security (ctd)

Zeroisation can be triggered by

- Opening the case
- Disconnecting the battery
- Temperatures below -20º C or above 70º C
- Excessive voltage levels
- Attempts to penetrate the case to get to the chip
  - Chip contains screen to prevent microprobing

## iButton Programming

The device recognises two roles

- Crypto officer initialises the device
  - Create transaction group(s)
  - Set up information (keys, monetary value, etc)
  - Set initial user PIN
  - Lock transaction group(s)
- User utilises it after initialisation by crypto officer

Device contains one default group (Dallas Primary Feature Set) initialised at manufacture

- Allows crypto officer to initialise the device
- Allows user to verify that crypto officer hasn’t altered certain initial options

## iButton Programming (ctd)

Dallas Primary contains default private key generated by device at manufacture

- Corresponding public key is certified by the manufacturer
- Guarantees to a third party that a given initial key belongs to a given iButton
- Users can generate further keys as required

## iButton Special Features

Device provides enhanced signature capabilities using on-board resources

- Signing time
- Transaction counter (incremented for each signature, used to detect trojan signing software)
- Device serial number

Signing process

- User hashes data with MD5, SHA-1, RIPEMD-160, …
- iButton hashes user-supplied hash with device serial number, transaction counter, and timestamp
- iButton signs hash using private key
- User retrieves serial number, transaction counter, timestamp, and signature from iButton

## Contactless Cards

### Several levels of contactless cards

- Contact, ISO 7816
- Close-coupled, 0-2mm, ISO 10536
  - Abandoned in favour of proximity cards
- Proximity, 0-10cm, ISO 14443
  - Typical use: MIFARE, transport applications
- Vicinity, ~1m, ISO 15693
  - Typical use: RFID

### Terminology and specs mirror ISO 7816

- Card = Proximity Integrated Circuit Card, PICC
- Reader = Proximity Coupling Device, PCD

## Contactless Cards (ctd)

### Contactless card issues

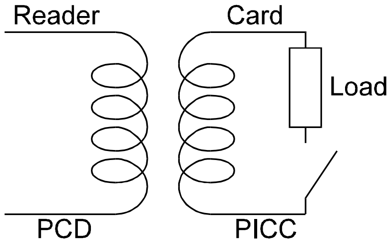
- Power and communications link is unstable
- Background noise problems
- Low power levels available
  - Boosting power increases RFI caused by carrier sidebands
  - Maximum range determined by level at which RFI still complies with emission laws
- Transaction must be rapid (100-200ms)
  - Move as many people through as few turnstiles as possible

## Contactless Card Communications

Power and data transmitted at 13.56 MHz

- Card coil requires only a few turns
- Coil can be printed circuit or a standard wire coil
- Card and reader communicate at 106 Kbps (13.56MHz/128)

Card communicates with reader using load modulation

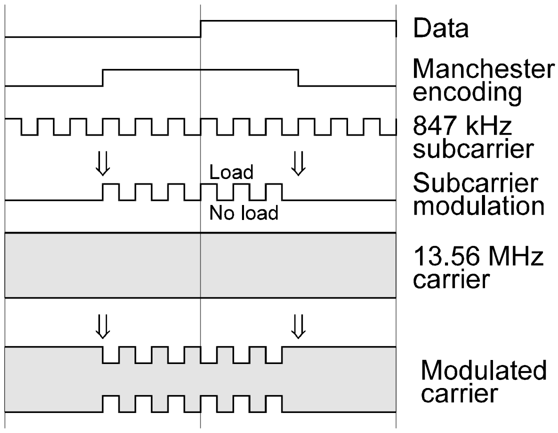



- Switches a load resistor in and out of circuit
- Reader detects changes in load

## Contactless Card Communications (ctd)

Load modulation types

- Type A, simple and efficient




- Type B, complex and inefficient — included for political reasons

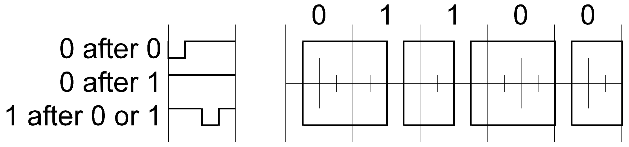
## Contactless Card Communications (ctd)

Reader communicates with card using ASK

- 100% amplitude shift keying = turn carrier on and off
- CMOS circuits in card consume no power when not switched

Encoding uses a modified Miller code

- Carrier pauses at different positions
- To decode, card measures distance between pauses

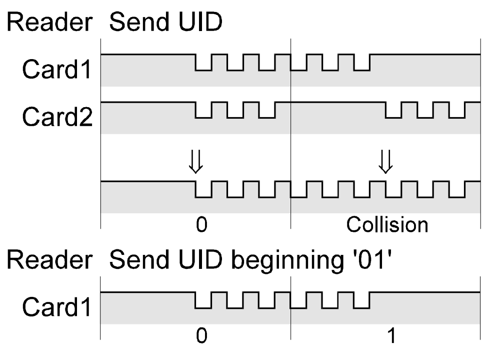



- Detecting errors like dropped bits is very simple

## Initialisation and Anticollision Handling

Card initialisation

- Reader actives all cards using wakeup frame
  - Wakeup frame has special format to distinguish it from normal frames
- Extraneous cards weeded out using collision detection



## Vicinity Cards

Extend proximity card ideas

- PCD → VCD (Vicinity card device)
- PICC → VICC (Vicinity integrated circuit card)

Vicinity card requirements

- Low-cost, high volume, long range, simple cards

More commonly use type B modulation

- Less RFI allows operation over longer ranges
- Use PPM (pulse position modulation) for VCD → VICC, FSK for VICC → VCD
  - Communication rate 6.6 Kbps
  - Variations on modulation, coding, and baud rate for different applications (speed vs distance vs noise immunity vs emission levels)

## Attacks on Smart Cards

Use doctored terminal/card reader

- Reuse and/or replay authentication to card
- Display $*x* transaction but debit $*y*
- Debit account multiple times

Protocol attacks

- Card security protocols are often simple and not terribly secure

Fool CPU into reading from external instead of internal ROM

Manipulating supply voltages can affect security mechanisms

- Picbuster
- Clock/power glitches can affect execution of instructions

## Attacks on Smart Cards (ctd)

Erasing an EEPROM cell requires a high voltage (12 vs 5V) charge

- Don't provide the power to erase cells
- Most cards now generate the voltage internally
  - Destroy the (usually large) on-chip voltage generator to ensure the memory is never erased

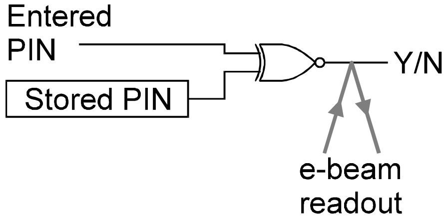
## Physical Attacks

Erase onboard EPROM with UV spot beam

Remove chip from encapsulation with nitric acid

- Use microprobing to access internal circuit sections
- Use electron-beam tester to read signals from the operational circuit

Example: PIN recovery with an e-beam tester



## Physical Attacks (ctd)

Modify the circuit using a focused ion beam (FIB) workstation

- Disable/bypass security circuitry (Mondex)
- Disconnect all but EEPROM and CPU read circuitry

## Attacking the Random Number Generator

Generating good random data (for encryption keys) on a card is exceedingly difficult

- Self-contained, sealed environment contains very little unpredictable state

Possible attacks

- Cycle the RNG until the EEPROM locks up
- Drop the operating voltage to upset analogue-circuit RNG's
- French government attack: Force manufacturers to disable key generation
  - This was probably a blessing in disguise, since externally generated keys may be much safer to use

## Timing/Power Analysis

Crypto operations in cards

- Take variable amounts of time depending on key and data bits
- Use variable amounts of power depending on key and data bits
  - Transistors are voltage-controlled switches which consume power and produce electromagnetic radiation
  - Power analysis can provide a picture of DES or RSA en/decrypt operations
  - Recovers 512-bit RSA key at ~3 bits/min on a PPro 200

Differential power analysis is even more powerful

- Many card challenge/response protocols are DES-based → apply many challenge/response operations and observe power signature

## Voice Encryption

Built from three components


Hardware-based

- DSP with GSM or CELP speech compression
- DSP modem

Software-based

- GSM or CELP in software
- External modem or TCP/IP network connection

Mostly built from off-the-shelf parts (GSM DSP, modem DSP, software building blocks)

# TCSEC/Orange Book

## Trusted Computer Security Evaluation Criteria

- Based on 10-15 years of security research
- Usage model: multiuser mainframes, terminals/users cleared at a single level
- “Make it simple enough that even a general can understand it”
- Attempts to apply it to other areas (eg networks) via increasingly tortuous “interpretations”

# Applying the Orange Book

| Maximum sensitivity | Rmax |
|---|---|
| Unclassified (U) | 0 |
| Unclassified but sensitive (N) | 1 |
| Confidential (C) | 2 |
| Secret (S) | 3 |
| Top Secret (TS) | 5 |

| Minimum user clearance | Rmin |
|---|---|
| Uncleared (U) | 0 |
| Uncleared, allowed access to sensitive information (N) | 1 |
| Confidential (C) | 2 |
| Secret (S) | 3 |
| Top Secret (TS)/Background Investigation | 4 |
| Top Secret (TS)/Special Background Investigation | 5 |

Risk Index = Rmin – Rmax

## Applying the Orange Book (ctd)

| Risk index | Operating Mode | Orange Book class |
|---|---|---|
| 0 | Dedicated | None |
| 0 | System high | C2 |
| 1 | Limited access, controlled, compartmented, multilevel | B1 |
| 2 | Limited access, controlled, compartmented, multilevel | B2 |
| 3 | Controlled, multilevel | B3 |
| 4 | Multilevel | A1 |
| 5 | Multilevel | ? |

## Applying the Orange Book (ctd)

Operating modes

| | |
|---|---|
| Dedicated | System exclusively used for one classification |
| System high | Entire system operated at and all users cleared at highest sensitivity level of information |
| Limited access | All users not fully cleared or authorised access to all data |
| Controlled | Limited multilevel |
| Compartmented | At least one compartment requiring special access to which not all users have been cleared, but all users cleared to highest level |
| Multilevel | Two or more classification levels, not all users cleared for all levels |

## Typical Voice Encryption System

Speech compression

- GSM compression (high-bandwidth)
- CELP compression (low-bandwidth)

Security

- DH key exchange
- DES (larger manufacturers)
- 3DES, IDEA, Blowfish (smaller manufacturers, software)
- Password/PIN authentication

## Typical Voice Encryption System (ctd)

Communications

- Built-in modem (hardware)
- Internet communications (software)

Speak Freely, `http://www.fourmilab.ch/netfone/windows/speak_freely.html`

- Typical software implementation
- Uses standard software components
- Portable across several operating systems

## Problems

Latency issues (dropped packets)

Authentication/MITM attacks

No standardisation

## GSM

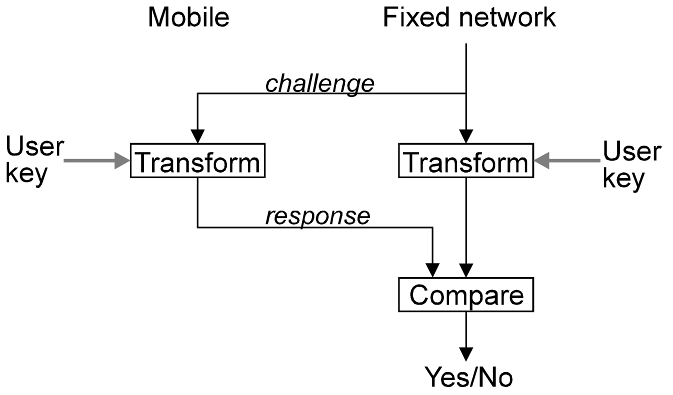
GSM subscriber identity module (SIM) contains

- International Mobile Subscriber Identity (IMSI)
- Subscriber identification key $K_i$

Used for authentication and encryption via simple challenge/response protocol

- A3 and A8 algorithms provide authentication (usually combined as COMP128)
- A5 provides encryption

# GSM (ctd)

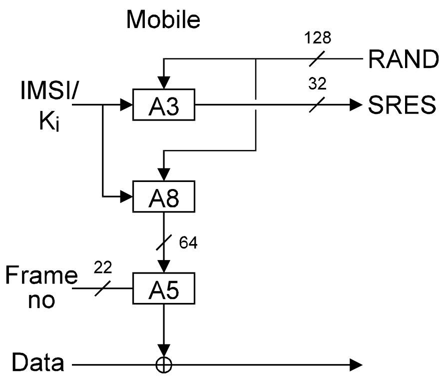



Authentication is simple challenge/response using A3 and IMSI/$K_i$

# GSM Security

A3 used to generate response

A8 used to generate A5 key



## GSM Security (ctd)

1. Base station transmits 128-bit challenge RAND
2. Mobile unit returns 32-bit signed response SRES via A3
3. RAND and $K_i$ are combined via A8 to give a 64-bit A5 key
4. 114-bit frames are encrypted using the key and frame number as input to A5

## GSM Security (ctd)

GSM security was broken in April 1998

- COMP128 is weak, allows IMSI and $K_i$ to be extracted
  - Direct access to SIM (cellphone cloning)
  - Over-the-air queries to phone
- Some cards were later modified to limit the number of COMP128 queries
- A5 was deliberately weakened by zeroing 10 key bits
  - Even where providers don't use COMP128, all shorten the key
- Claimed GSM fraud detection system doesn't seem to exist
- Affects 80 million GSM phones

## GSM Security (ctd)

Key weakening was confirmed by logs from GSM base stations

```
BSSMAP GSM 08.08 Rev 3.9.2  (BSSM) HaNDover REQuest (HOREQ)
-------0 Discrimination bit D BSSMAP
0000000- Filler
00101011 Message Length    43
00010000 Message Type      0x10
Channel Type
00001011 IE Name           Channel type
00000011 IE Length         3
00000001 Speech/Data Indicator    Speech
00001000 Channel Rate/Type Full rate TCH channel Bm
00000001 Speech encoding algorithm      GSM speech algorithm
Encryption Information
00001010 IE Name           Encryption information
00001001 IE Length         9
00000010 Algorithm ID      GSM user data encryption V.1
******** Encryption  Key   C9 7F 45 7E 29 8E 08 00
Classmark Information Type 2
```

## GSM Security (ctd)

Many countries were sold a weakened A5 called A5/2

- A5 security: Breakable in real time with $2^{40}$ precomputations
- A5/2 security: None (5 clock cycles to break)
- Another attack is to bypass GSM entirely and attack the base station or land lines/microwave links

GSM security was compromised at every level

- Deliberately weakened key generation
- Broken authentiction
  - GSM MoU knew of this nearly a decade ago but didn’t inform its members
- A5/1 was known to be weak, A5/2 was deliberately designed to be weak

GSM represents well-designed multiple-redundant compromise

## GSM Security (ctd)

Most other cellphone security systems have been broken too

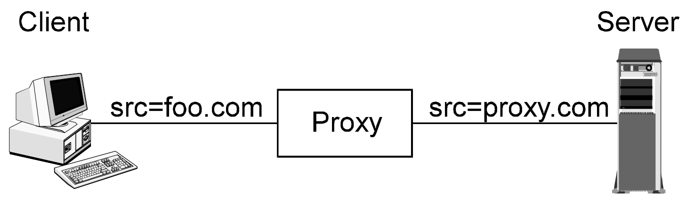
- Secret design process with no public scrutiny or external review
- Government interference to ensure poor security

## Traffic Analysis

Monitors presence of communications and source/destination

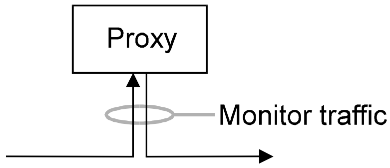
- Most common is analysis of web server logs
- Search engines reveal information on popularity of pages
- The mere presence of communications can reveal information

## Simple Anonymiser Proxy




HTTP version at `http://www.anonymizer.com`

Fairly easy to defeat:

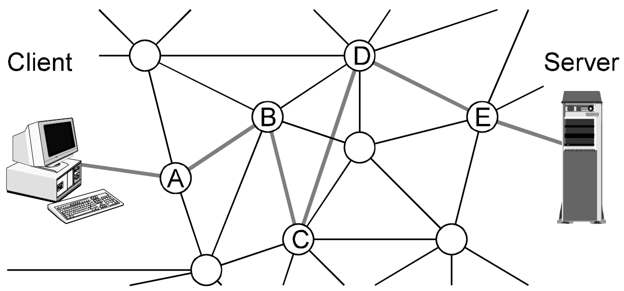



## Mixes

Encrypted messages sent over user-selected route through a network

- Packet = A( B( C( D( E( data )))))
- Each server peels off a layer and forwards the data

Servers can only see one hop




Sender and receiver can’t be (easily) linked

## Attacks on Mixes

Incoming messages result in outgoing messages

- Reorder messages
- Delay messages

Message sizes change in a predictable manner

Replay message (spam attack)

- Many identical messages will emerge at some point

## Onion Routing

Message routing using mixes, `http://www.itd.nrl.navy.mil/ITD/5540/projects/onion-routing`

Routers have permanent socket connections

Data is sent over short-term connections tunnelled over permanent connections

- 5-layer onions
- 48-byte datagrams
- CREATE/DESTROY for connection control
- DATA/PADDING to move datagrams
- Limited form of datagram reordering
- Onions are padded to compensate for removed layers

## Mixmaster

Uses message ID's to stop replay attacks

Message sizes never change

- 'Used' headers are moved to the end, remaining headers are moved up one
- Payload is padded to a fixed size
- Large payloads are broken up into multiple messages
- All parts of the message are encrypted

Encryption is 1024 bit RSA with triple DES

Message has 20 headers of 512 bytes and a 10K body

## Crowds

Mixes have two main problems

- Routers are a vulnerable attack point
- Requires static routing

Router vulnerability solved via jondo (anonymous persona)

Messages are forwarded to a random jondo

- Can't tell whether a message originates at a given jondo
- Message and reply follow the same path

## LPWA

Lucent Personalised Web Assistant

- Provides access to web sites via LPWA proxy
- Automatically generates per-site pseudonymous personas
  - User name
  - Password
  - Email address
- Filters sensitive HTTP headers

## LPWA (ctd)

Protects users from profile aggregation, spamming

- User connects to LPWA using email address and password
- When web site asks for identification information, user types `\u` (user name), `\p` (password), `\@` (email address)
- Proxy translates these to per-site pseudonymous personas

Email forwarder forwards mail to users real email address

- Spam sources can be blocked on a per-persona basis

## Steganography

From the Greek for “hidden writing”, secures data by hiding rather than encryption

- Encryption is usually used as a first step before steganography

Encrypted data looks like white noise

Steganography hides this noise in other data

- By replacing existing noise
- By using it as a model to generate innocuous-looking data

## Hiding Information in Noise

All data from analogue sources contains noise

- Background noise
- Sampling/quantisation error
- Equipment/switching noise

Extract the natural noise and replace it with synthetic noise

- Replace least significant bit(s)
- Spread-spectrum coding
- Various other modulation techniques

Examples of channels

- Digital images (PhotoCD, GIF, BMP, PNG)
- Sound (WAV files)
- ISDN voice data

## Generating Synthetic Data

Usually only has to fool automated scanners

- Needs to be good enough to get past their detection threshold

Two variants

- Use a statistical model of the target language to generate plausible-looking data
  - "Wants to apply more or right is better than this mechanism. Our only way is surrounded by radio station. When leaving. This mechanism is later years".
  - Works like a text compressor in reverse
  - Can be made arbrtrarily close to real text

## Generating Synthetic Data (ctd)

- Use a grammatical model of actual text to build plausible-sounding data
  - "{Steganography|Stego} provides a {means|mechanism} for {hiding|encoding} {hidden|secret} {data|information} in {plain|open} {view|sight}".
  - More work than the statistical model method, but can provide a virtually undetectable channel

Problems with steganography

- The better the steganography, the lower the bandwidth

Main use is as an argument against crypto restrictions

# Watermarking

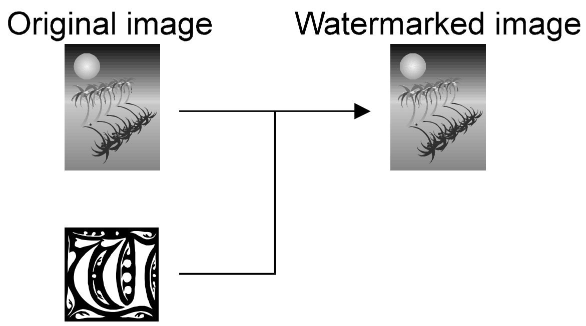
Uses redundancy in image/sound to encode information

Requirements

- Invisibility
- Little effect on compressability
- Robustness
- High detection reliability
- Security
- Inexpensive

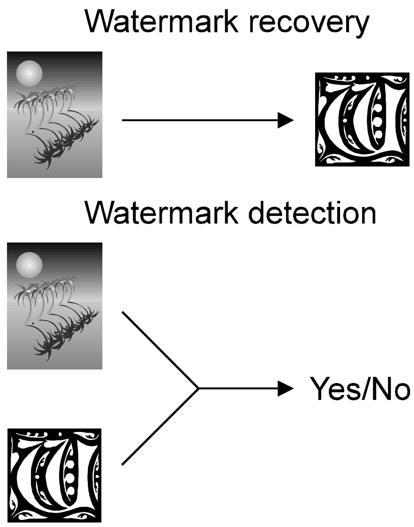
# Watermarking (ctd)

Watermark insertion



## Watermarking (ctd)

Watermark detection/checking




## Watermarking (ctd)

Public watermarking

- Anyone can detect/view the watermark (and try to remove it)

Private watermarking

- Creator can demonstrate ownership using a secret key

Copy Protection Working Group (CPTWG) looking at standardisation, `http://www.dvcc.com/dhsg`

## Defeating Watermarking

Lossy compression (JPEG)

Resizing

Noise insertion (print+scan)

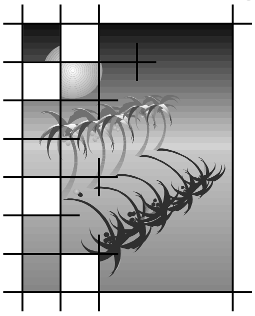
Cropping

Interpretation attacks (neutralise ownership evidence)

Automated anti-watermarking software available (eg UnZign)

## Defeating Watermarking (ctd)

Presentation attacks (segmented images)



Watermarking is still in its infancy

- No watermarking standards
- No indication of security/benchmarks
- No legal recognition

## Other Crypto Applications

### Hashcash

- Requires finding a collision for *n* bits of a hash function
  - "Find a message for which the last 16 bits of the SHA-1 hash are 1F23"
- Forces a program to expend a (configurable) amount of effort before access is granted to a system or service
- Useful for stopping denial-of-service attacks
  - *n* varies as the system load goes up or down
  - Can be used as a spam-blocker

## Other Crypto Applications (ctd)

### PGP Moose

- Signs all postings to moderated newsgroups
  - Signature is added to the message as an `X-Auth` header
- Unsigned messages (spam, forgeries) are automatically cancelled
- Has so far proven 100% effective in stopping newsgroup spam/forgeries