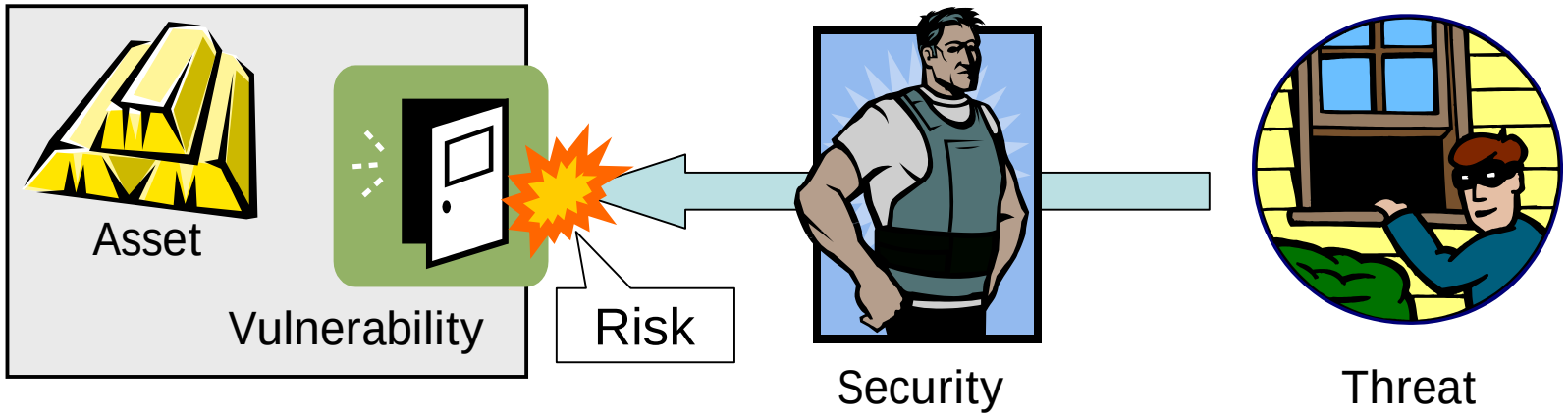
Recent security features and issues in embedded systems

NEC OSS Promotion Center

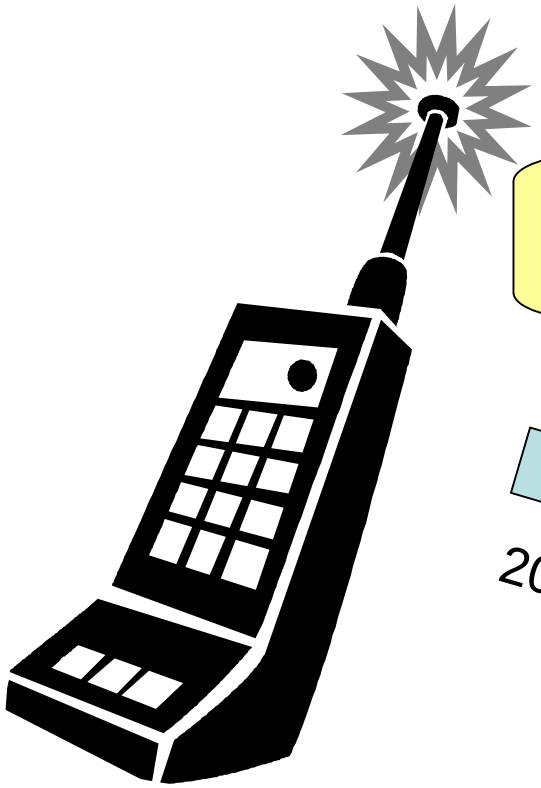
KaiGai Kohei <kaigai@ak.jp.nec.com>

Security Overview



- Asset and Vulnerability should be considered as a pair.
- Threat intend to attack vulnerabilities.
- Risk means possibilities the threat to be actualized.
  - more worthwhile asset, weaker vulnerability has its risk grow.
  - risk depends on environmental factors, organization policy.
- Security is a way to reduce risk.

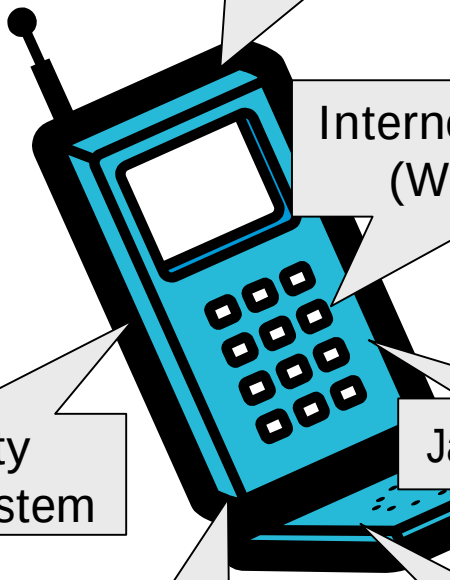
Evolutions of Cellular-Phone in the last 20 years



The first generation cellular-phones (1987)

Value of Assets ⇧
Vulnerability ⇧

20 years later



electronic money, Credit card

Internet connectivity (Web,mail,…)

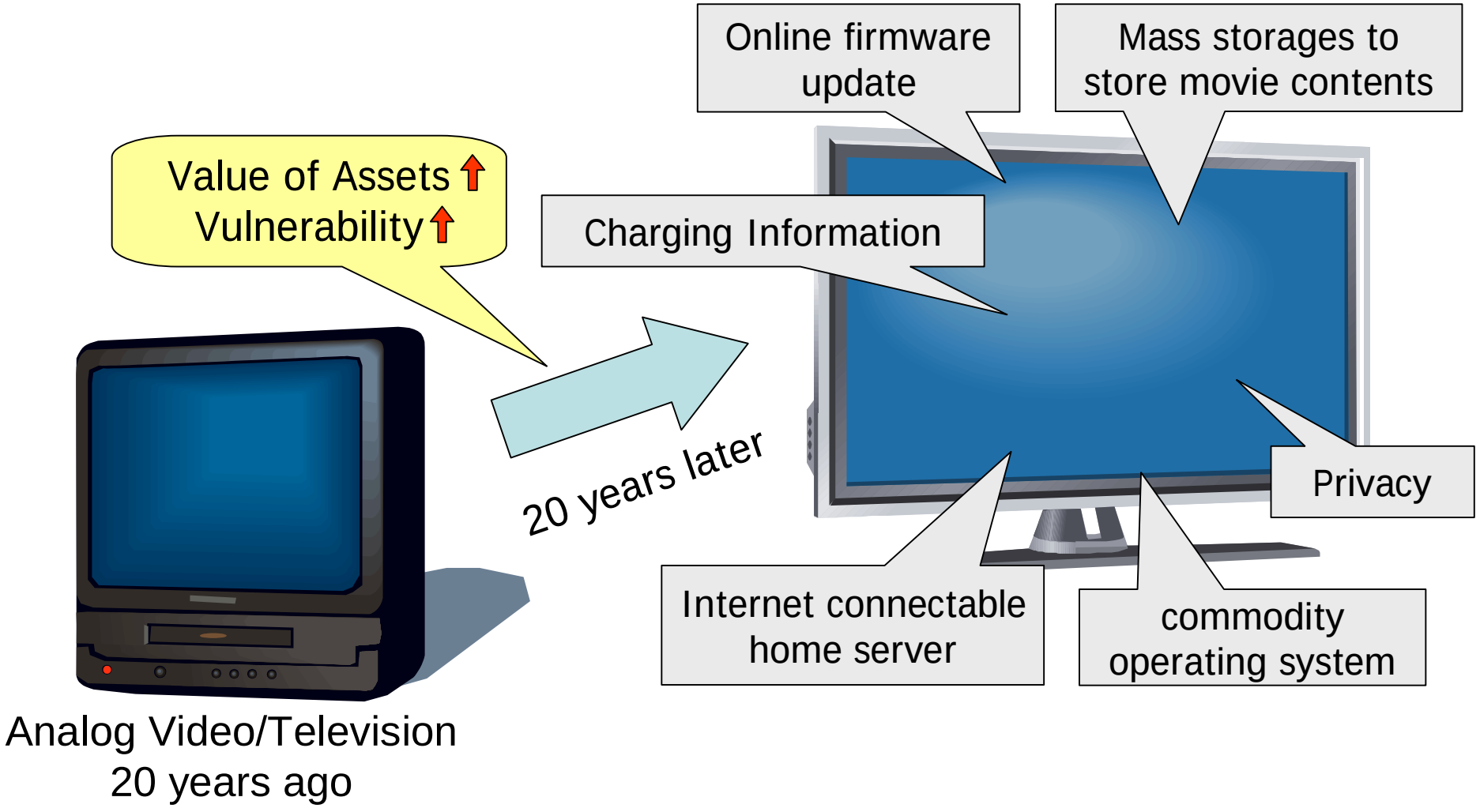
Java application

stored privacy, individual info

Mass storage & Data exchange

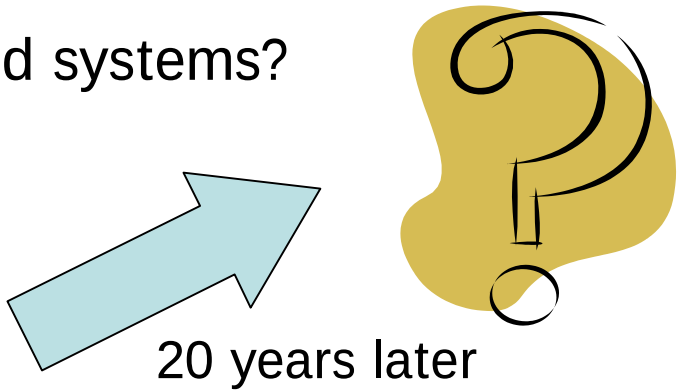
commodity operating system

Evolutions of Video/Television in the last 20 years



Evolutions of OS security in the last 20 years

- What kind of security features are currently available within the operating system?
  - SELinux, Cryptograph, ACL, ...
- Can we apply them on embedded systems?
- Is it really comprehensive?



20 years later

Traditional UNIX permission

```
[kaig     @mailsv ~]$ ls -l /etc
-rw-r--r--   1 root root 23954 Apr  1 18:21 /etc/aliases
-rw-r--r--   1 root root    17 Jul 24  2000 /etc/host.conf
-rw-r--r--   2 root root   147 Nov 30  2005 /etc/hosts
-rw-r--r--   1 root root   161 Jan 13  2000 /etc/hosts.allow
-rw-r--r--   1 root root   347 Jan 13  2000 /etc/hosts.deny
-rw-r--r--   1 root root  1666 Aug 29  2005 /etc/inittab
-rw-r--r--   1 root root  5553 Mar 19 08:46 /etc/passwd
drwxr-xr-x  10 root root  4096 Nov 13 14:10 /etc/rc.d/
-r--------   1 root root  5563 Mar 19 08:46 /etc/shadow
     :          :    :     :     :     :          :
```

Today's Topics

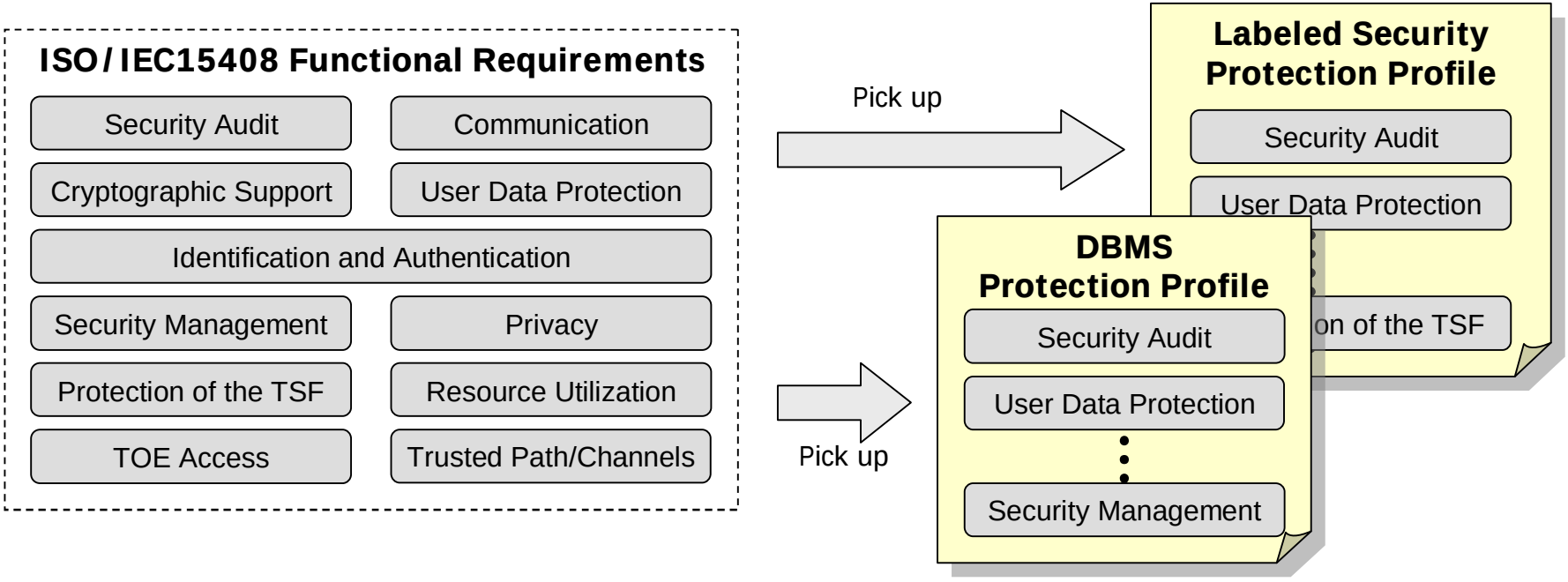
- Sorting out security requirements
  - ISO15408 framework makes it clearly categorized.
  - Recent security futures can be mapped on the categories.
- Recent security feature and its issue
  - Introductions/Overviews of recent security features
  - Possible difficulty in applying security features to embedded systems
  - Why? differences in CPU, Filesystem, Memory size, ...
- This session shows the issues to be resolved when we apply recent security features on embedded systems.

ISO/IEC15408

- The purpose of ISO/IEC15408
  - Common criteria to evaluate security functionalities of IT products, not only software
- Essentials
  - more than 20 years history since TCSEC, ITSEC
  - 11 functional categories, 8 assurance ones
    - Developers can select functional ones suitable for them.
  - We can use it as a comprehensive catalog of security functionalities.

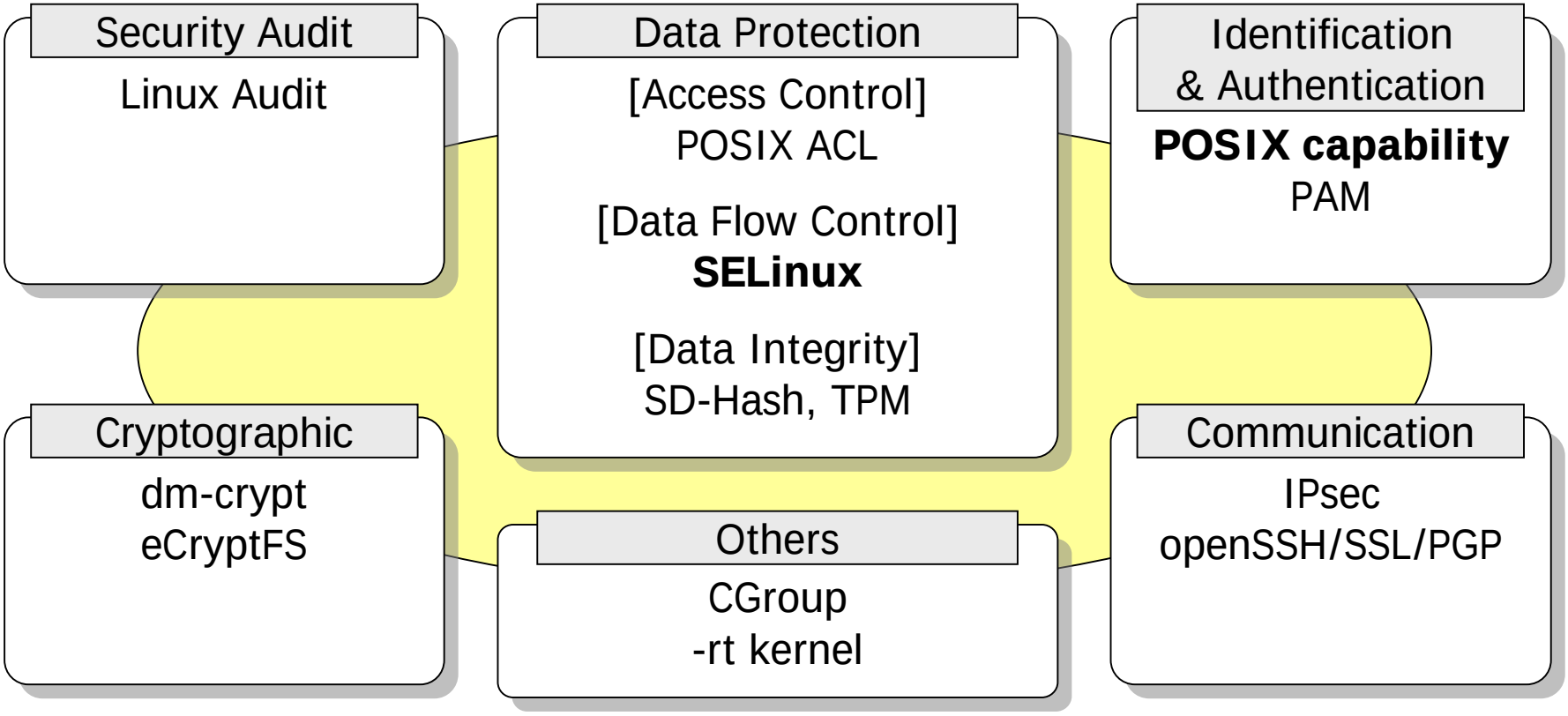
Protection Profile

- What is Protection Profile?
  - A set of requirements for specific categories
    - OS, RDBME, Firewall, SmartCard, Digital-Copier, etc...
  - Example:
    - CAPP, LSPP, MLOSPP for OS, DBMSPP for RDBMS



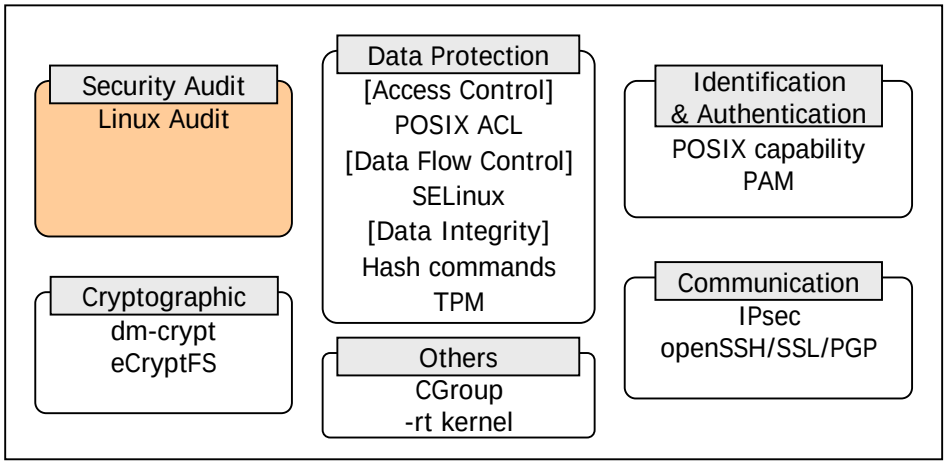
Technology map of Recent Security Features

- Re-organized major categories of security functionalities required by protection profiles for operating system.



Security Audit

- What is the purpose?
  - To confirm what has happened later, when we get security incidents
    - Unified event logging for both operating system and applications
    - Well formalized audit logs, In-kernel event filter
  - To alert system administrators
- Related components
  - linux-audit



linux-audit features (1/2)

- Designed for ISO15408 requirements
  - System call audit
  - In-kernel event filters
  - Selective audit review
  - Event notification for administrators
- Utilities
  - auditd
  - auditctl
  - ausearch, aureport

linux-audit features (2/2)

```
[root@saba ~]# auditctl -a exit,always -S open ¥
                        -F path=/etc/shadow -F exit!=0
[root@saba ~]#
```

```
[kaigai@saba ~]$ less /etc/shadow
/etc/shadow: Permission denied
[kaigai@saba ~]$
```

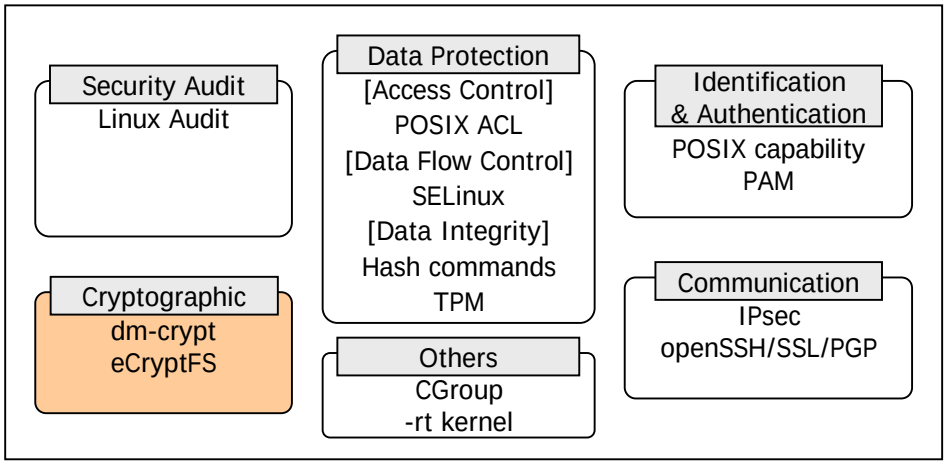
```
[root@saba ~]# ausearch --file /etc/shadow
----
time->Mon Mar 24 19:19:05 2008
type=PATH msg=audit(1206353945.330:3541): item=0 name="/etc/shadow"
          inode=6111049 dev=08:06 mode=0100400 ouid=0 ogid=0 rdev=00:00
          obj=system_u:object_r:shadow_t:s0
type=CWD msg=audit(1206353945.330:3541):  cwd="/home/kaigai"
type=SYSCALL msg=audit(1206353945.330:3541): arch=40000003 syscall=5
          success=no exit=-13 a0=806d010 a1=8000 a2=0 a3=8000 items=1
          ppid=3638 pid=18234 auid=1001 uid=1001 gid=100 euid=1001
          suid=1001 fsuid=1001 egid=100 sgid=100 fsgid=100 tty=pts6 ses=52
          comm="less" exe="/usr/bin/less"
          subj=unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023
          key=(null)
```

linux-audit issues in embedded systems

- Architecture Limitation
  - It hooks the entry-point of system call
    - Implemented in assembler code
  - Unsupported architectures
    - Only x86, ppc, ppc64, s390, ia64, UML, sparc64 are supported now.
    - Super-H coming soon (2.6.25)
    - Where is ARM, MIPS?
- Storage size limitation
  - smaller storage than server/desktop

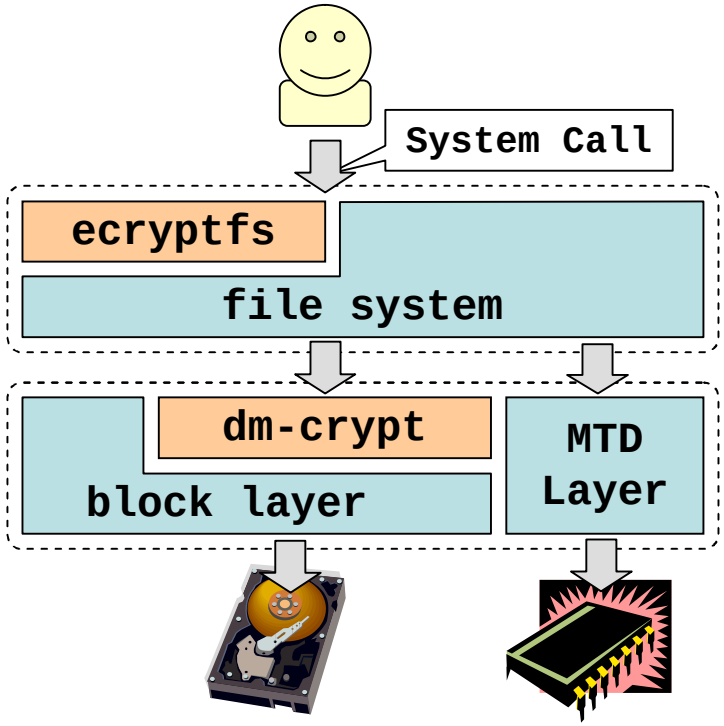
Cryptographic Support

- What is the purpose?
  - Crypto-key operations based on standard algorithms.
  - Encryption/Decryption based on standard algorithms.
- Related components
  - dm-crypt
  - eCryptFS
    - based on in-kernel crypt API



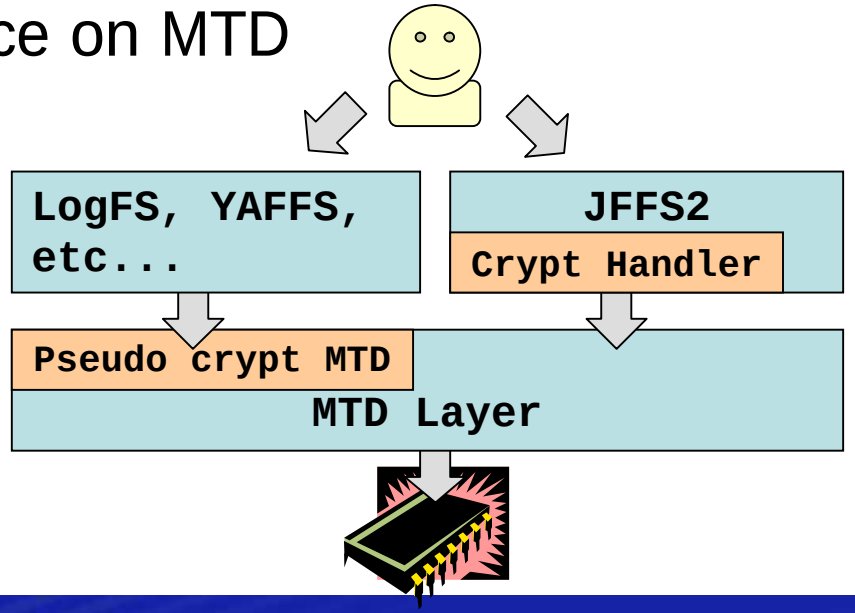
dm-crypt / eCryptFS features

- dm-crypt
  - One of the device-mapper modules
  - Works in Block Layer
  - Per-device encryption
- eCryptFS
  - One of the pseudo filesystem works as NFS doing
  - Per-file encryption
    - Metadata as containts of files
    - Encryption is done before compression in jffs2



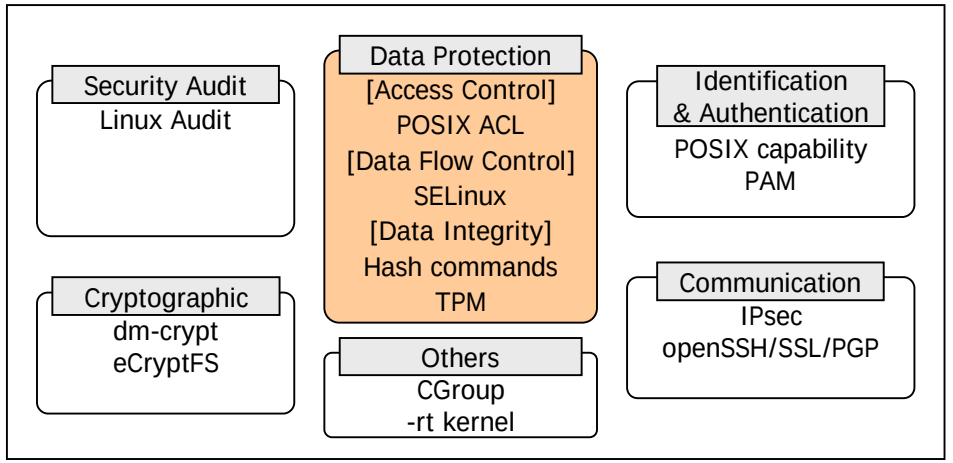
dm-crypt / eCryptFS issues in embedded systems

- dm-crypt and MTD devices
  - I/O traffic on MTD devices don't go through block layer.
  - Cryptographic Support on JFFS2, LogFS and so on?
- Feasible ideas
  - Utilization of JFFS2 compress handlers
  - Pseudo cryptographer device on MTD



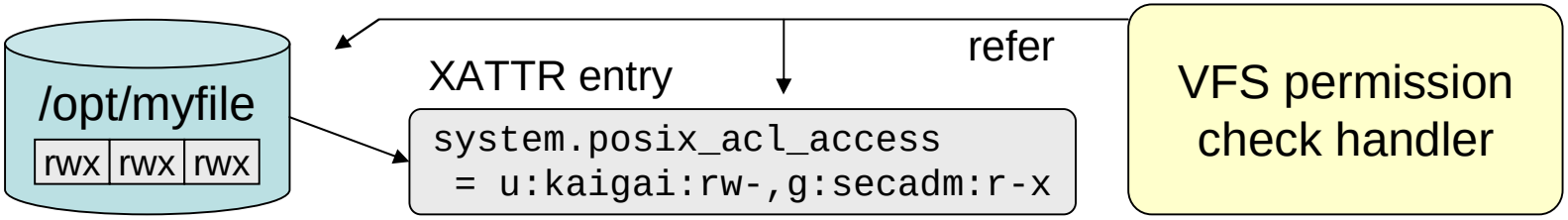
Data Protection

- Essentials
  - Access Control
  - Data Flow Control
  - Data Integrity
- What is the purpose?
  - To protect data (including metadata) from leaking, manipulation and destruction.
- Related components
  - POSIX ACL
  - SELinux



POSIX ACL

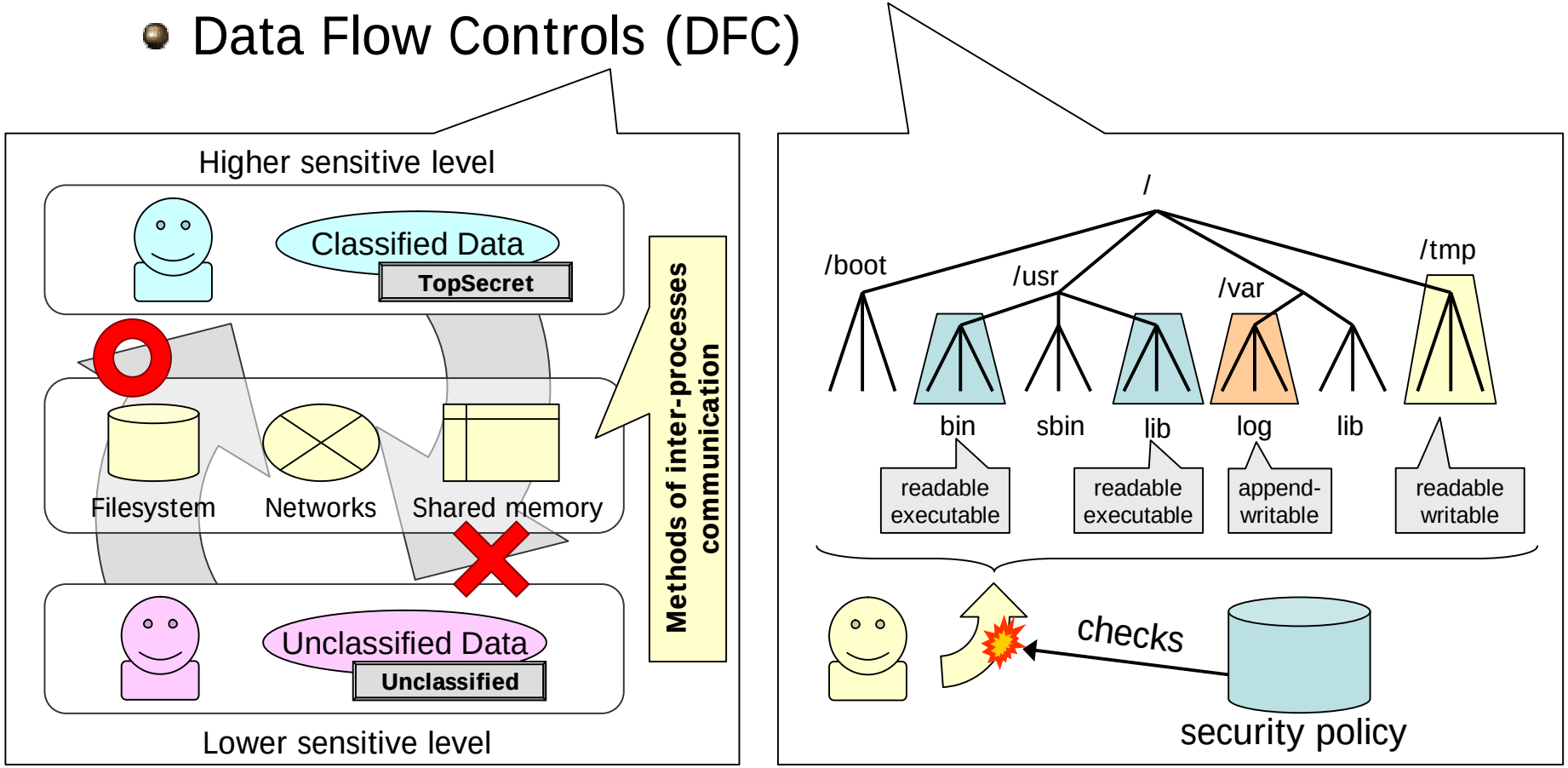
- The limitation in traditional permission model
  - 'rwx' permission for owner, a group and others
- How POSIX ACL works
  - It stores ACL within xattrs, used in permission checks.



  - Default ACL supports
- POSIX ACL Issues in embedded systems
  - XATTR supports in filesystems are needed.
  - Busybox supports are needed.

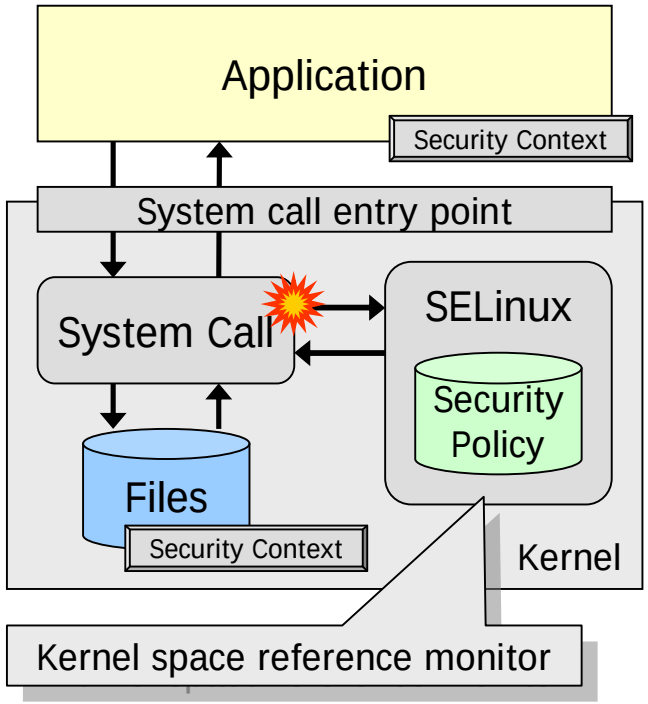
SELinux (1/3)

- What is the purpose of SELinux?
  - Mandatory Access Controls (MAC)
  - Data Flow Controls (DFC)



SELinux (2/3)

- Features
  - It associates a security attribute for each subject/object.
    e.g) "**`root:object_r:var_log_t:Unclassified`**"
  - SELinux hooks any system-call invocation to apply its decision based on its security policy.
- Why we need SELinux?
  - root can be a single-failure point
  - Fine-grained access control
  - A single unified security policy
  - Generally, fewer checks are better
  - If SELinux is disabled?
    - Massive checks in userspace
    - or, Quality degrading

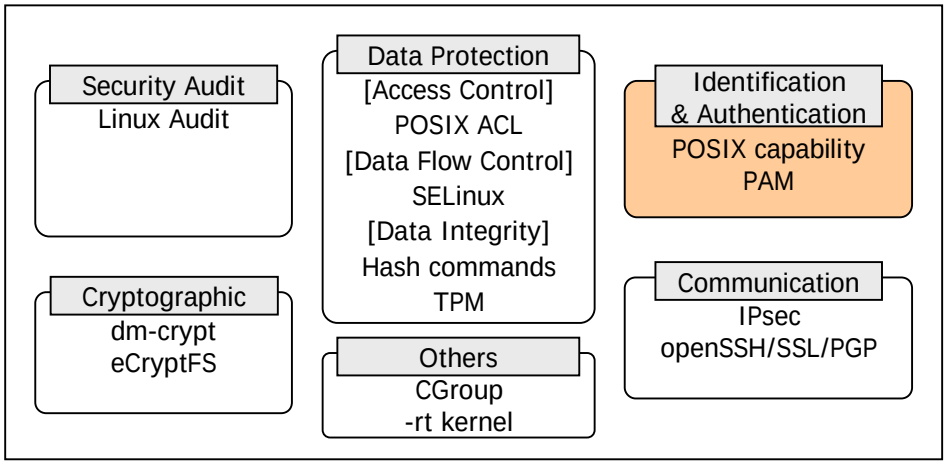


SELinux (3/3)

- SELinux issues on embedded systems
  - Filesystem XATTR support
    - security context of files are stored within xattr field.
    - cramfs, LogFS, yaffs, etc...
  - Userland utilities support
    - Now busybox has 12 applets, 12 extensions for SELinux
      - load_policy, setenforce, restorecon, ...
      - '-Z' option support, preserving security context, ...
    - libselinux provides fundamental facilities to userland.
    - pam_selinux.so associate a user with its security context.
  - Security Policy
    - Different application, environment from server/desktop
    - Distributors should provide its suitable base security policy

Identification and Authentification

- What is the purpose?
  - To ensure a process works with correct identifier.
  - To associate a user with correct authorities.
  - These features are foundation for other security facilities to work correctly.
    - Security-Audit, Access Controls, ...
- Related components
  - POSIX Capabilities
  - PAM



POSIX Capabilities (1/4)

- The purpose of POSIX Capabilities
  - Least privileged set
- Features
  - It enables to associate a part of 'root privileges'
    - E.g) Using network port < 1024, Ignoring DAC permission
  - Linux kernel has this feature from 2.4.x series, however, it has been hard to utilize.
- Recent updates
  - Filesystem POSIX Capability
  - Per-process Capability Bounding Set

POSIX Capabilities (2/4)

The calculation rule of capabilities on execve()

```
P'(permitted)  = (F(permitted) & cap_bset)
               | (P(inheritable) & F(inheritable))
P'(effective)  = F(effective) ? P'(permitted) : 0
P'(inheritable)= P(inheritable)
```

- Pseudo File POSIX capability bits
  - If euid = 0 -> F(*) is set to All-1 (0xfff...fff)
  - If euid != 0 -> F(*) is set to All-0 (0x00...00)
  - We had no way to represent F(*) bitmasks.
- Filesystem POSIX Capability stores F(*) information within xattr of executable files.
  - We can run privileged programs with more restricted power.
  - E.g) /bin/ping with only CAP_NET_RAW

POSIX Capabilities (3/4)

comes from filesystem XATTR

The calculation rule of capabilities on execve()

```
P'(permitted)   = (F(permitted) & cap_bset)
                | (P(inheritable) & F(inheritable))
P'(effective)   = F(effective) ? P'(permitted) : 0
P'(inheritable)= P(inheritable)
```

- Example
  - /bin/ping with CAP_NET_RAW on F(permitted), not SetUID'ed
    - P'(permitted) = CAP_NET_RAW & 0xfff...fff | 0 & 0
    - P'(effective) = (true) ? CAP_NET_RAW : 0
- Features
  - It stores F(*) bits within filesystem XATTR region
  - It enables to replace SetUID programs.
  - Available on 2.6.24 or later

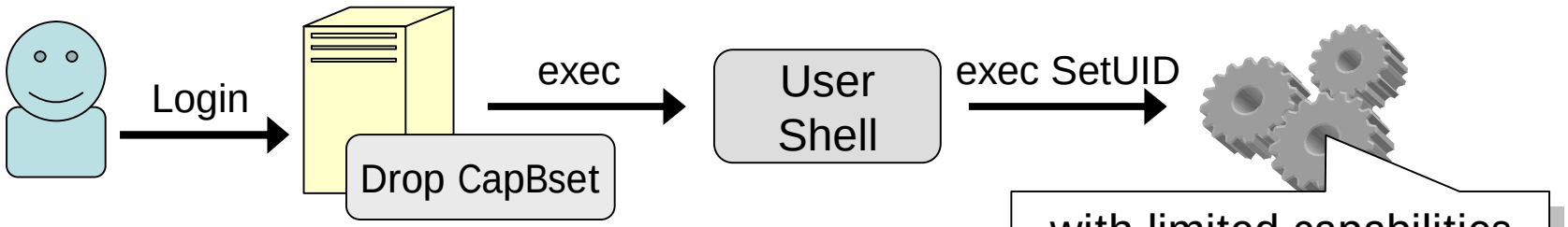
POSIX Capabilities (4/4)

The calculation rule of capabiliti

Capability bounding-set

```
P'(permitted)   = (F(permitted) & cap_bset)
                | (P(inheritable) & F(inheritable))
P'(effective)   = F(effective) ? P'(permitted) : 0
P'(inheritable)= P(inheritable)
```

- Features
  - Capability bounding-set can mask root privileges
  - F(permitted) is 0xfff...fff when euid = 0
  - In 2.6.24 or former, cap_bset is system wide variable
    - In the next kernel, we can set per-process capability bounding set, as follows.

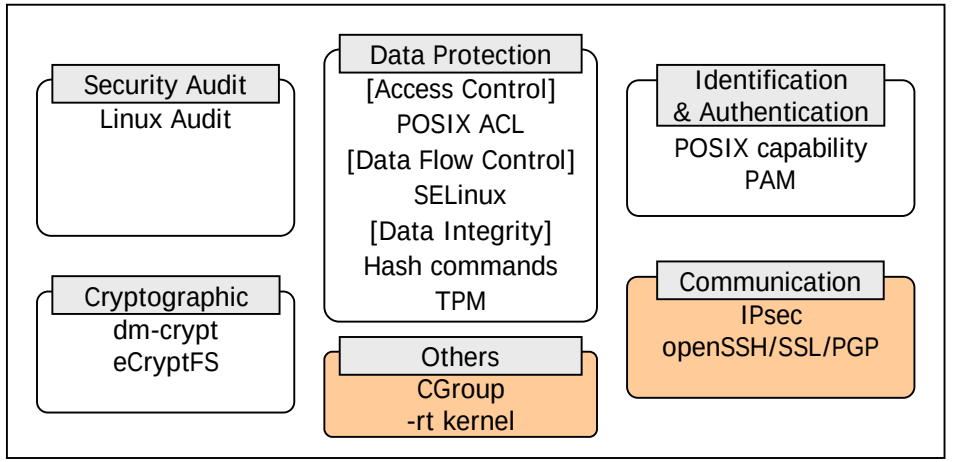


PAM

- PAM (Pluggable Authentication Module)
  - A framework of authentication modules
- PAM Issues in Embedded systems
  - Widely used to set up initial users security attribute
    - security context of SELinux
    - per-process capability bounding set
  - It means these 'secure initial state' depends on PAM
  - How tinylogin handle it?

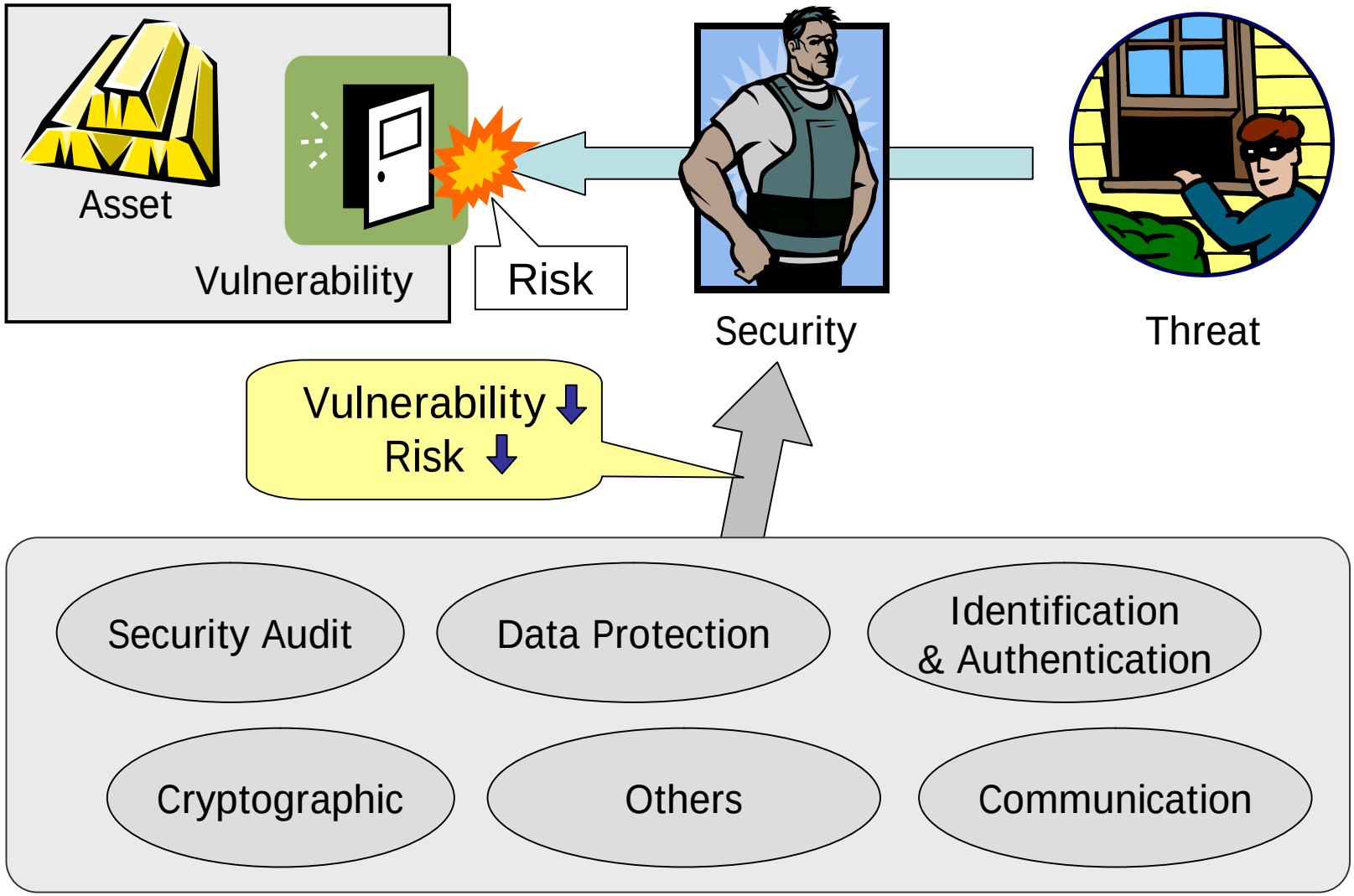
Communication & Others

- What is the purpose?
  - To provide secret, trusted and separated communication channel
  - Resource utilization, trusted timestamp, ...
- Related components
  - SSH/SSL/PGP
  - IPsec
    - Sensitivity and Integrity on communication channels
  - Cgroups/-rt kernel
    - Resource availabilities are also required to security aspect



- Give us issues in this region, if you have anything.

Summary (1/2)


Asset
Vulnerability
Risk
Security
Threat
Vulnerability ⬇
Risk ⬇
Security Audit
Data Protection
Identification & Authentication
Cryptographic
Others
Communication

Summary (2/2)

- These issues should be solved to provide 'secure' embedded systems.
- Filesystem XATTR support
  - Common requirement for selinux, ACL, capabilities
  - It is now available on most of regular filesystems, but ...
- Utilities support
  - busybox
    - Now, about 70% of SELinux utilities are merged into upstream
    - Features of ACLs and capabilities are also necessary
- Cryptograph support on MTD devices
- Linux-audit support for embedded architecture

Any Question?

Thank you!