Development of Embedded SELinux

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1. What is SELinux?

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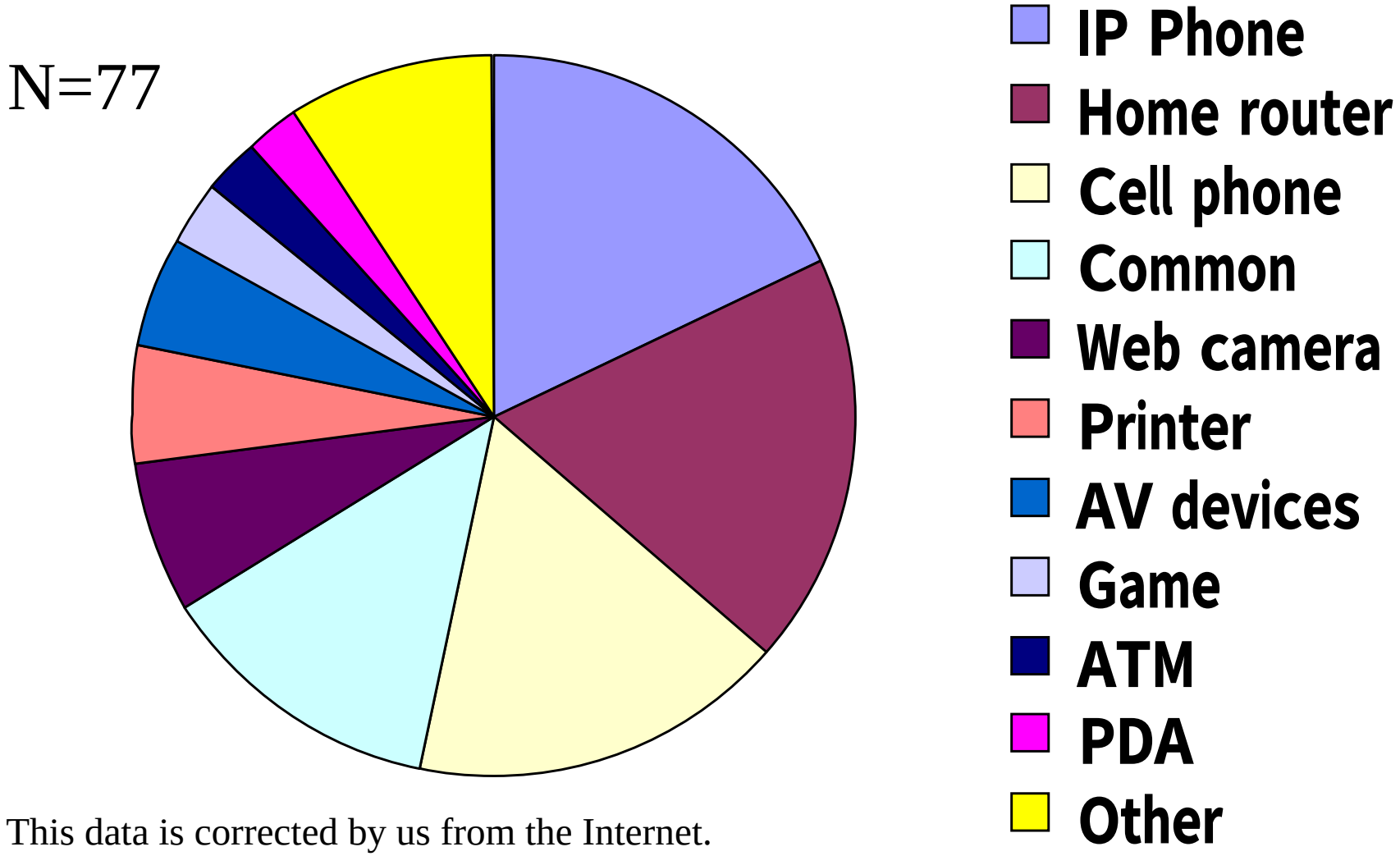
Vulnerabilities do exist in embedded devices

Statistics of vulnerabilities found in embedded devices



* This data is corrected by us from the Internet.

Often reported: In a mailing list, 30 vulnerabilities are reported a year.

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Security is needed for embedded Linux

- Linux based embedded devices are increasing
  - TV, DVD recorder, Cell phone, Home gateway, STB
- Connected to the Internet
- Exposed to attacks
- Once exploited:
  - System is destroyed, used as spring board.
  - Device-makers have to recall to fix vulnerabilities.
- Security technology suitable for embedded devices is needed.

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Difficulties in security technologies

- Update and Virus scan are common in PCs.
- Update
  - PC: OS vendors take care of all updates
  - Embedded devices
    - Device-makers have to prepare update
    - Heavy task
      - Watch all bugfix
      - Backport patch
      - Provide update software
    - Update will be delayed, or not prepared…
- Virus scan
  - Heavy (Pattern file: 30Mbyte in PC)

- Security technology effective even with no update is required.
- -> SELinux

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What is SELinux?

- Security-Enhanced Linux
  - Developed by NSA(http://www.nsa.gov/selinux)
  - Implemented in kernel
  - Merged to 2.6
- Access Control Feature
  - Least privilege (Type Enforcement)
  - Mandatory Access Control(MAC)
    - No one (including root) can avoid
- SELinux can confine behavior of attackers
    - Very difficult to do harm
  - Effective before update
- Widely used for PCs
  - Enabled on Redhat, Fedora by default

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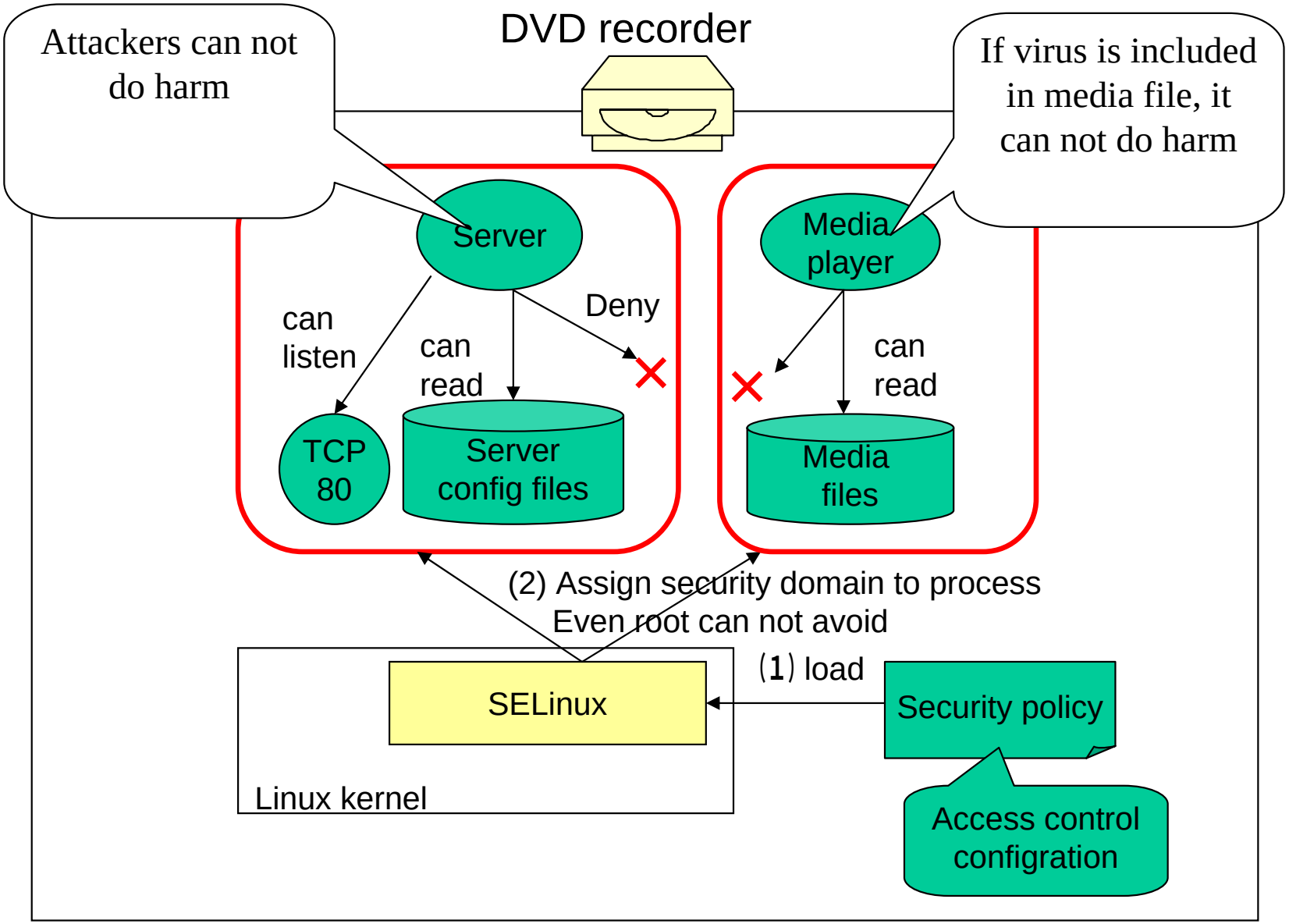
The feature of SELinux



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TE (Type Enforcement): The access control model

- Label based access control

- *Domain* label is assigned to processes
- *Type* label is assigned to resources
- Domain is not allowed nothing by default
- Allow necessary access permissions

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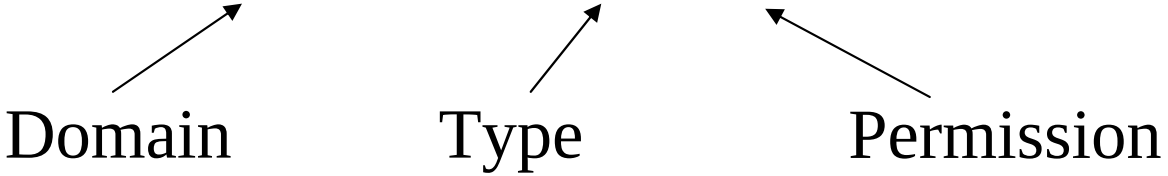
Security policy

Domain is allowed nothing by default

- Need to allow necessary accesses
- Configuration for access control rules
- Allow domains to access types

allow httpd_t web_contents_t file:{ read };



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2. Issues in Embedded SELinux

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Issues to port SELinux to embedded devices

#1. Extended attribute(xattr)

#2. Difficulties in security policy

#3. Performance

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Issue #1 Extended attirubtes(xattr)

- Xattr
  - Data structure in file system used to stores labels and other attributes
- In SELinux, filesystem must support xattr!
- Xattr support in filesystem
  - Ext3, ext2 : OK
  - Jffs2 : OK
    - Merged to 2.6.18 by KaiGai
  - LogFS, yaffs: Not yet
- We have to use jffs2 for flash ROM

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Issue #2 :Difficulty in security policy(1)

- 3 Steps to configure policy for embedded devices
  - 1) Obtain sample policy (called refpolicy)
  - 2) Tuning: remove unnecessary rules
  - 3) Add necessary rules

- For PC servers, refpolicy is good
  - refpolicy is well-written for PC distros.

- Difficult to write small, precise policy for embedded devices
  - Have to remove too many rules
  - Dependencies in policy
  - Tons of macros

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Difficulty in policy: Remove many lines

- Refpolicy is intended for PC usage
  - Included configuration for Fedora, Debian, SUSE
  - Large
    - File size: more than 2M, memory consumption more than 5M
  - To use for embedded need tuning
    - remove unnecessary rules

- Example: To configure simple Apache server
  - We removed more than 400 rules
  - For each rules,
    - You have to understand what you are removing,...
  - It is only a part
    - Base system is not included

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Difficulty in policy: Dependency

- Dependency within policy
  - After removing part of policy, error appears because of dependency.
    - Have to declare label when using label.
    - If only declaration is removed, error appears.
    - Sometimes labels are declared in macro, declaration is hidden..
  - Example:
    - After removing policy related to sendmail, error appears in policy of apache

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Difficulty in policy: Tons of macros

- Macros are traditionally used to write policy
- Macros are increasing:
  - More than 1000
  - Difficult to understand

- Also a lot of labels

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Issue #3: Problems in performance

- Overhead on system call
- Memory usage
- File usage

- Ported SELinux to SH based device and measured
  - Target board
    - Renesas **R0P751RLC0011RL (R2DPlus)**
      - SH 7751R(SH4 240Mhz)
      - RAM 64 Mbyte
  - SELinux before tuning
    - kernel 2.6.22
    - File system
      - ext3 on CF card
      - jffs2 on FLASH ROM
    - Policy : refpolicy in Fedora 6 without tuning
    - Userland: Userland as of Mar 2007

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Overhead on system call(Before tuning)

- lmbench
- The SELinux overhead

lmbench	Overhead (%) (Pentium 4 PC)	Overhead(%) SH7751R, before tuning
read	12.3	130.0
write	14.0	146.6
stat	33.0	96.8
create	101.7	163.4
unlink	45.6	86.4
open/close	25.8	93.0
Pipe	20.6	66.8
Unix domain socket	12.3	31.1
TCP	87.0	22.0
UDP	63.3	27.7

Overhead is bigger in embedded environment

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Memory usage (Before tuning)

- Security policy, SELinux itself consumes memory
- Memory usage by SELinux: B-A
  - A= SELinux disabled kernel, output of free command
  - B= SELinux enabled, output of free command
    - Policy is taken from Fedora Core 6
- Result: 5365 kbyte
- For embedded, it is big.

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File size increase(Before tuning)

	Size in crease (kbyte)
Kernel (zImage)	73.7
library	482.1
Commands	374.6
Policy	1,356.2
Total	**2,286.6**

Big for Flash ROM system

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3. Development of Embedded SELinux

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Our work

- Issues to port SELinux to embedded devices
  - #1. Extended attribute(xattr)
  - #2. Difficulties in security policy
  - #3. Performance

Our work

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Resolving difficulty in policy

- Used SELinux Policy Editor instead of refpolicy.

- Refpolicy
  - Removing rules from existing policy file, to write small policy
  - Difficult

- SELinux Policy Editor
  - Write only rules that is necessary.
  - Easy to write small policy.

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SELinux Policy Editor

- Tool to configure SELinux policy

- Main feature: SPDL(Simplified Policy Description Language)
  - Hide labels and dependency internally

- Developed by Hitachi Software
- GPL
  - http://seedit.sourceforge.net/

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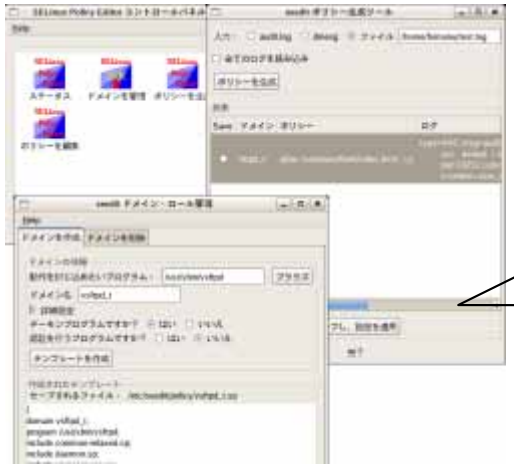
Components of SELinux Policy Editor

Hides detail of SELinux
(SPDL)

Simplified Policy

seedit-converter

SELinux Policy



GUI, Command line tools
Policy generator,
template maker

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The SPDL

* Example of SPDL: policy for Web server program

```
{
domain httpd_t;
program /usr/sbin/httpd;
...
allow /etc/httpd/** r,s;
allow /var/log/httpd/** r,a,s;
allow /var/www/** r,s;
allownet -protocol tcp -port 80,443 server;
}
```

- Hide labels
  - Name based configuration: Can use file name, port number
  - Resolve dependency internally
- Simplified permissions

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Benefits of SELinux Policy Editor

- Do not have to use sample policy
  - no macros, dependencies
- Can write custom policy for embedded devices
  - SPDL is easy to understand
- Can write small policy
  - can describe only what you need
  - Policy size :about 60k byte for 10 apps
- http://seedit.sourceforge.net/

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Tuning SELinux

- Overhead
- Memory footprint
- File size

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Reducing overhead

- Mainly reduced read/write overhead
  - It was big (about 150%)

- Other tuning
  - Hand optimization
  - Removed logics about unused permission
    - such as NIC, IP address

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Reducing read/write overhead

- Duplicated permission checks in file read/write
  - In open and read/write system call
- Permission check can be removed at read/write
  - Need check only policy is changed after open
- Made patch, merged in 2.6.24
  - http://lkml.org/lkml/2007/9/13/373

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Result of lmbench(After tuning)

lmbench	Overhead before tuning (%)	Overhead after tuning(%)
read	130.0	12.5
write	146.6	14.9
stat	96.8	58.8
create	163.4	146.1
unlink	86.4	69.6
open/close	93.0	61.9
pipe	66.8	30.6
UNIX socket	31.1	6.1
TCP	22	10.5
UDP	27.7	11.7

- Good in read/write!
- Need work in “create”

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Improving memory footprint

- Development of policy by SELinux Policy Editor
  - can write small policy easily
  - Wrote policy for 10 apps

- Removing big buffers in kernel
  - Buffers for 32768 policy rules : 252K byte
  - Modified to allocate dynamically depending of policy size
  - Only 1kbyte is allocated when small policy is loaded
    - Merged to 2.6.24
      - http://marc.info/?t=118767097300001&r=1&w=2

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Memory usage (After tuning)

Before tuning (kbyte)	After tuning(kbyte)
5365	465

- Small policy contributed a lot (about 4.6M)

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Reducing file size

- (1) Writing small policy by SELinux Policy Editor
- (2) Reducing size of library: small libselinux
  - separate libselinux and libsepol
  - Remove unneccesary functions from libselinux
  - Merged to SELinux community
    - http://marc.info/?l=selinux&m=118064545200576&w=2
    - 「make EMBEDDED=y」 build option
  - 482k -> 66k
- (3) Reducing size of commands
  - a) Integrated commands to BusyBox
    - With Japanese community
    - Merged to BusyBox
  - b) Choose least set of commands
    - load_policy, setfiles, restorecon, ls –Z, ps –Z, setenforce, getenforce, is_selinux_enabled
  - 375k -> 11k

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File size increase(After tuning)

	Before tuning (kbyte)	After tuning(kbyte)
Kernel (zImage)	73.7	73.7
Library	482.1	66.3
Command	374.6	10.8
Policy	1,356.2	60.4
Total	**2,286.6**	**211.2**

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4. Application to various devices

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SELinux applied devices

- SH based
  - L-Box (NTT Comware)
    - SH7751R
    - Originally 2.4 based
    - Without modifying userland
  - CAT 760 (Silicon Linux)
    - SH7760 based small board
    - Rootfs on 16Mbyte Flash ROM

- ARM based
  - Zaurus(Angstrom)
  - Android on Zaurus

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Porting to Android

- Not yet to Android on QEMU
  - Yaffs2 does not support xattr

- We ported SELinux to Android on Zaurus
  - File system is ext3

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SELinux on Android Zaurus

- Two domains can be assigned
  - Android_init_t : Programs run from init
  - Android_java_t: Programs run from “app_process”

- Can not assign domains for separate java apps
  - All run as “android_java_t”
    - They are launched from “app_process”

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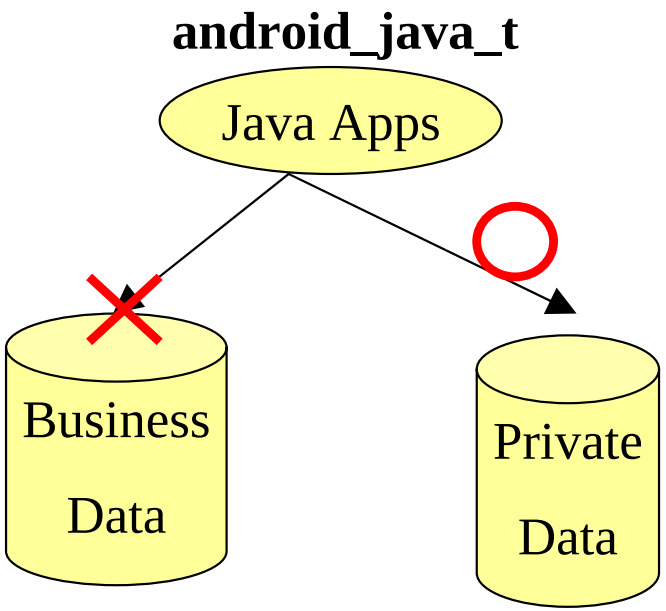
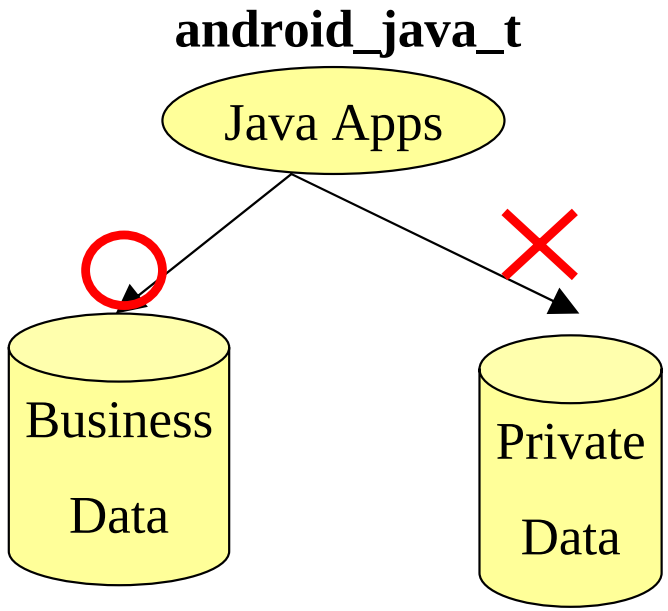
Example application of SELinux on Android

- Multi-mode phone
- Private mode/Bussiness mode in one phone
- Security policy switches between mode

Private Mode



Business Mode



Demo is from 17:00 !

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Remaining issues for Android SELinux

- Assigning domains to each java apps
  - We should be able to do..
  - We want source of “app_process”!!!

- Xattr for yaffs
  - Planning to do

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5. Related works

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Audit for SH

- What is Audit?
  - Framework to obtain system call logs
- Can obtain logs useful to develop SELinux policy
  - Full path name
- Not mandatory, but useful
- CPU dependent because entry.S has to be modified.
  - Supports x86,Power PC,MIPS
  - SH not supported
- Submitted audit for SH patch , merged to 2.6.25

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Contributions from Japanese community

- xattr support for jffs2
  - By KaiGai merged to 2.6.18
- Improvement of latency in security check
  - By KaiGai merged to 2.6.24
    - http://marc.info/?t=119078657600002&r=1&w=2
- BusyBox for SELinux
  - SELinux Applets
  - Assigning domains to BusyBox applet
    - By Shinji: Merged to 1.8.2
    - http://www.busybox.net/lists/busybox/2007-August/028481.html

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Remaining issues

- Strict policy
- More tuning
  - We can reduce more
    - Example
      - we can remove MLS support, booleans from kernel
- xattr for yaffs, logfs

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Summary

- Difficulties in Embedded SELinux
  - Difficulty in policy
  - Performance problem
- Development of Embedded SELinux
  - Policy by SELinux Policy Editor
  - Tuning
- Application to some devices
- SELinux is suitable security technology for embedded !
  - Effective without update
  - Architecture independent
  - Lightweight

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Thanks

- People in seBusyBox project
  - KaiGai
    - General advices, hosted project site, ml
- SELinux community
  - Stephen Smalley
    - Advices/ideas about implementation of tuning SELinux
- BusyBox community
  - Denis Vlasenko
    - Advices about BusyBox
- Renesas solutions
  - Yusuke Goda : flash ROM boot support for evaluation board

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Patches & sources

- See http://elinux.org/SELinux
- SELinux Policy Editor
  - http://seedit.sourceforge.net/
- Reducing read/write overhead
  - Merged to 2.6.24
  - http://lkml.org/lkml/2007/9/13/373
- Removing big fixed size buffer
  - Merged to 2.6.24
  - http://marc.info/?t=118767097300001&r=1&w=2
- Reducing size of library
  - Merged to libselinux 2.0.35
  - http://marc.info/?l=selinux&m=118064545200576&w=2
- SELinux'ed BusyBox
  - Many applets merged
  - Assigning domain to applets
    - http://www.busybox.net/lists/busybox/2007-August/028481.html
- Improving latency in permission check
  - Merged to 2.6.24
  - http://marc.info/?t=119078657600002&r=1&w=2
- Audit for SH
  - Merged to 2.6.25
  - http://lkml.org/lkml/2007/11/7/3

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