Examining Linux Kernel Size

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- **Facts**
  - Embedded engineers need small kernel.
  - To make small kernel,
    you need to configure your kernel very carefully.
  - Num of config items $>$ 3000

- **Issues**
  - Kernel size and memory usage impacts of config items are unknown.
  - Trial-and-error approach is impractical.
  - Trend of kernel footprint along versions is unknown.

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- **Objective**
  - Making clear impact of config items
    for kernel size and memory usage.

- **Output**
  - Size impact of config items
    - Derived from kernel file size measurement
  - Memory usage impact of config items
    - Derived from memory usage measurement just after boot

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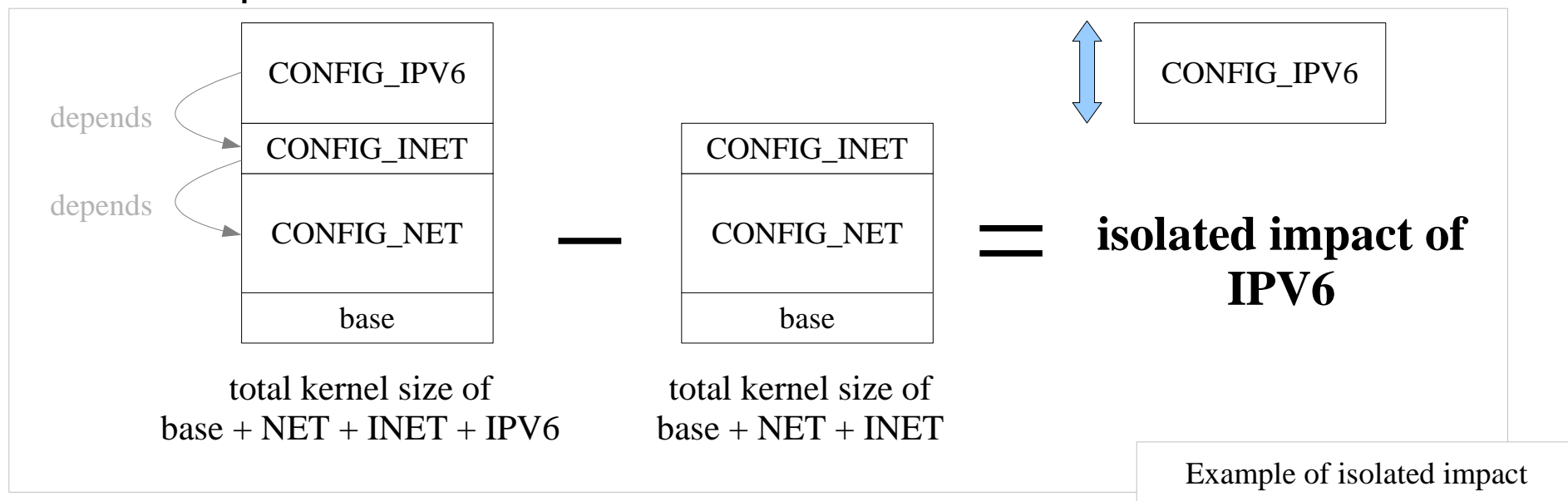
2. Project scope (2)

- ## Approach
  - ## – Automatic measurement
    - Generate .config files from selected config item list.
    - Make kernels and measure file size of kernel image.
    - Install, reboot, and measure memory usage just after booting.
  - ## – Impact calculation
    - Calculate impacts for each config item from measured result.
    - "Impact" means ISOLATED IMPACT shown as below.

depends → CONFIG_IPV6
CONFIG_INET
depends → CONFIG_NET
base

total kernel size of
base + NET + INET + IPV6

—

CONFIG_INET
CONFIG_NET
base

total kernel size of
base + NET + INET

=

isolated impact of IPV6

CONFIG_IPV6

Example of isolated impact

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- **Goal**
  - Publishing / providing data
    - Covering many versions.
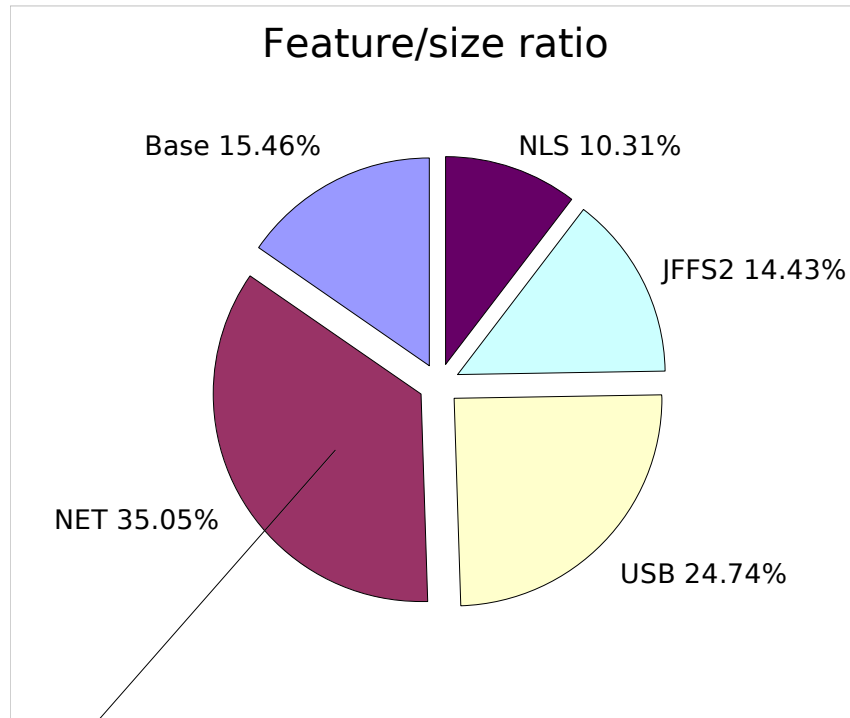   - Covering many architectures.

- **Benefits**
  - For embedded engineers
    - You can estimate size and memory usage before building kernel.
    - If all isolated impacts are known, kernel size can be predicted by summing-up size of each config item.
  - For kernel developers
    - Version comparison helps to point out which part of kernel is bloating and to be improved.
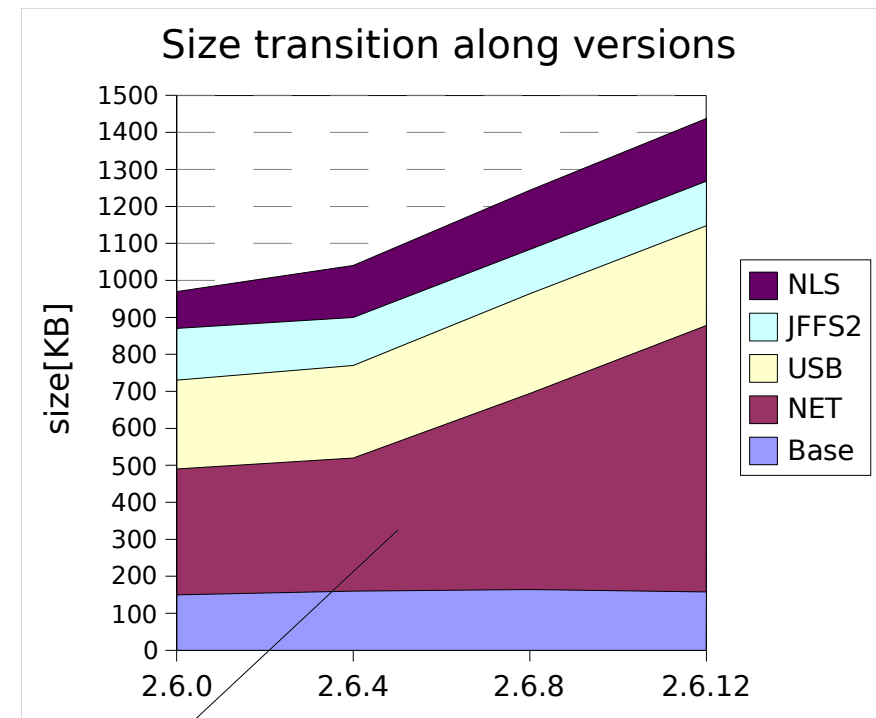
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- # Expected deliverable

Feature/size ratio

Base 15.46%

NLS 10.31%

JFFS2 14.43%

NET 35.05%

USB 24.74%

It shows impact of this part is large

Size transition along versions

Legend:
- NLS
- JFFS2
- USB
- NET
- Base

size[KB]

1500, 1400, 1300, 1200, 1100, 1000, 900, 800, 700, 600, 500, 400, 300, 200, 100, 0

2.6.0 2.6.4 2.6.8 2.6.12

It shows this part is bloating

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2. Project scope (5)

- I have a dream ...

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• Plan and status

repeated

4. More architectures

Plan to utilize **CELF Test Lab.**

current step

3. More versions

200 config items

6 versions

2 archs

2. Trial exam

200 config items

Single version

2 archs

＊ Reported at
Japan Tech Jam #6(Jan. 2006)

1. Developed automated examination tool

⋮

2.6.15

2.6.12

2.6.10

2.6.8

2.6.4

2.6.0

| i386 | arm | mips | ppc | sh | ⋯ |

examination target versions & archs

- **Tool overview**

input

| target config item list |
| kernel source tree |

Function components

- .config generator
- kernel builder
- size measurement
- install and reboot
- memory measurement

.config

kernel

output

measurement result

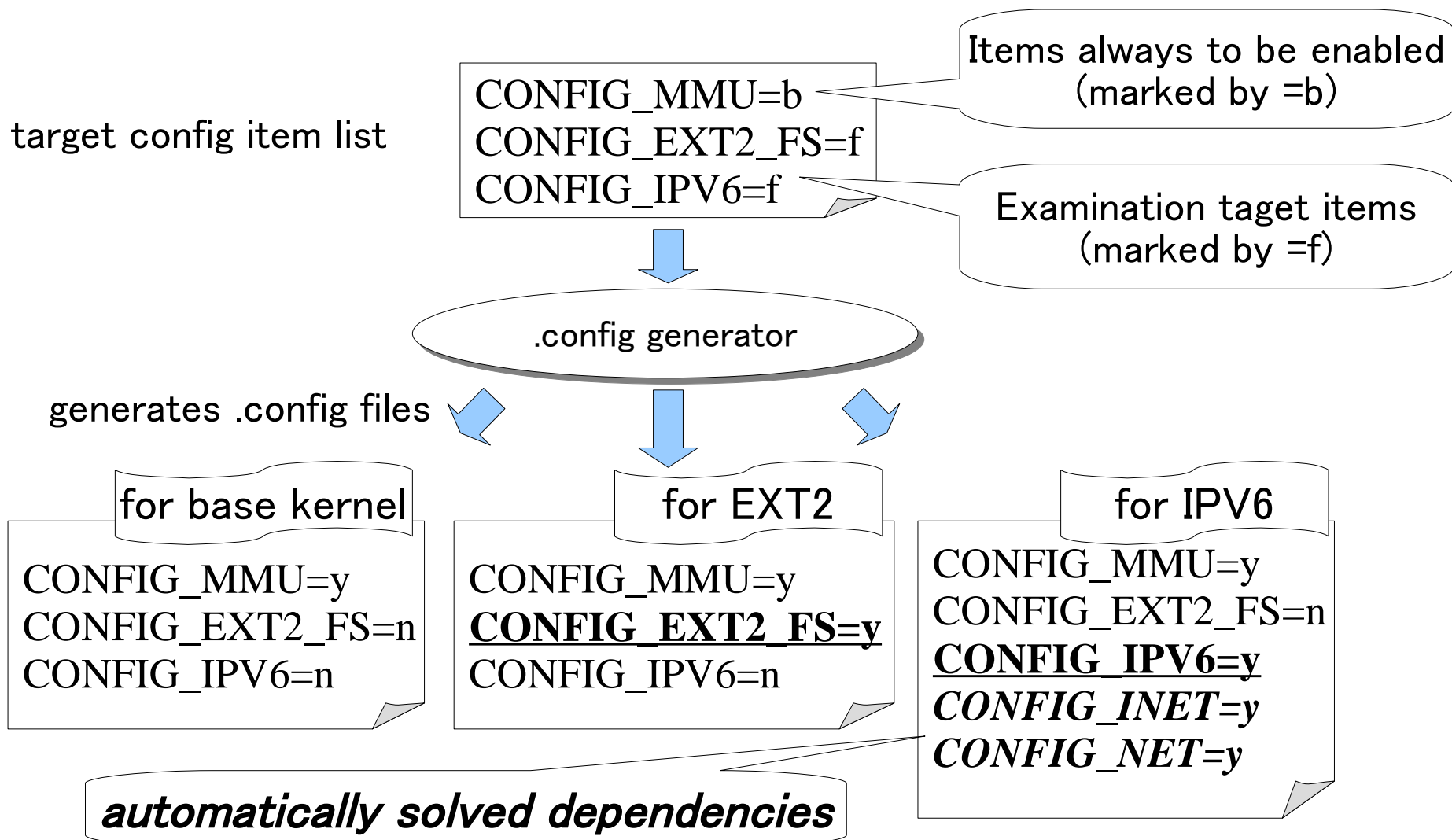Empowered by Innovation **NEC**

- **How .config files are made**
  - .config generator generates .config files from target config item list.

Items always to be enabled (marked by =b)

target config item list

```
CONFIG_MMU=b
CONFIG_EXT2_FS=f
CONFIG_IPV6=f
```

Examination taget items (marked by =f)

.config generator

generates .config files

for base kernel

```
CONFIG_MMU=y
CONFIG_EXT2_FS=n
CONFIG_IPV6=n
```

for EXT2

```
CONFIG_MMU=y
CONFIG_EXT2_FS=y
CONFIG_IPV6=n
```

for IPV6

```
CONFIG_MMU=y
CONFIG_EXT2_FS=n
CONFIG_IPV6=y
CONFIG_INET=y
CONFIG_NET=y
```

automatically solved dependencies

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3. Examination tool (3)

- **What you need to set-up for your examination**
  - Remote-type environment
    - Connect host and target via Ethernet and serial line.
      - Target downloads kernel via Ethernet.
      - Host communicates with target via serial console.
    - Connect host and reset device which can reset the target.
      - Host can force target to reset by reset device.
    - Communicating and reset method can be configurable so that our tool is flexible about environment.

ether

host

serial

parallel

target

reset device
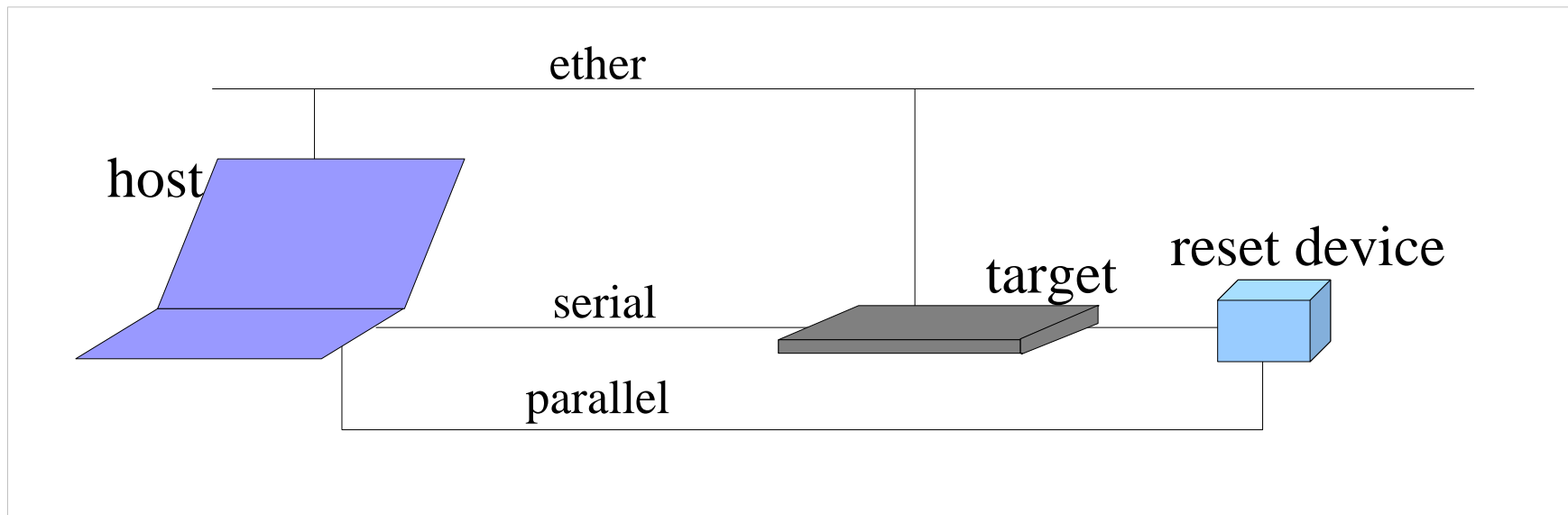
  - Self-type environment is also available

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- **Conditions**
  - Base-config-set for "base kernel"
    - Minimal configuration to boot.
    - UP kernel
    - ext3, sysfs, procfs
  - Target config items : About 200
    - Select popular items for embedded.
    - Except for items which have global effect. (ex : smp, pm, printk support etc.)
  - Target versions : 2.6.0, 2.6.4, 2.6.8, 2.6.10, 2.6.12.6, 2.6.15.6
  - Target architectures : i386, ARM

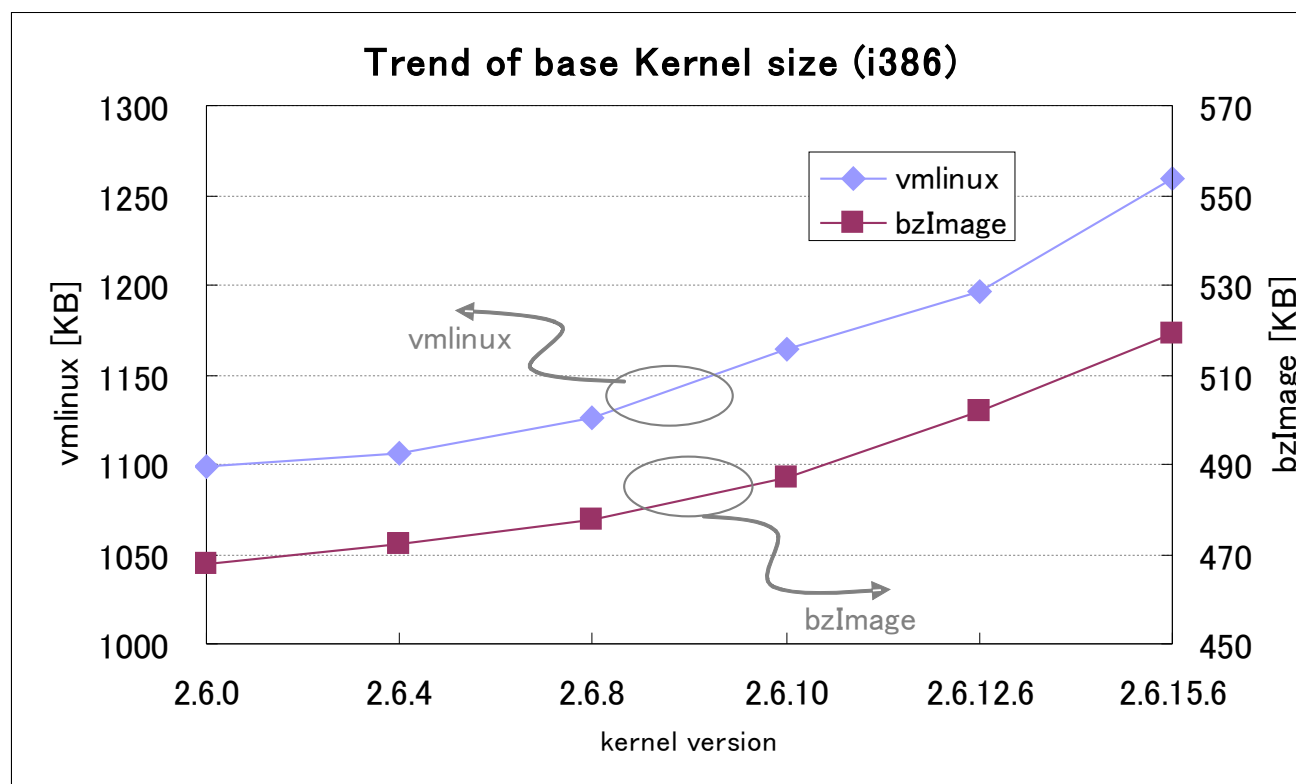Empowered by Innovation **NEC**

4. Current examination result (2)

- **Result about size : Base Kernel**
  - Size increase is about 10% from 2.6.0 to 2.6.15.
    - vmlinux : 150[KB]
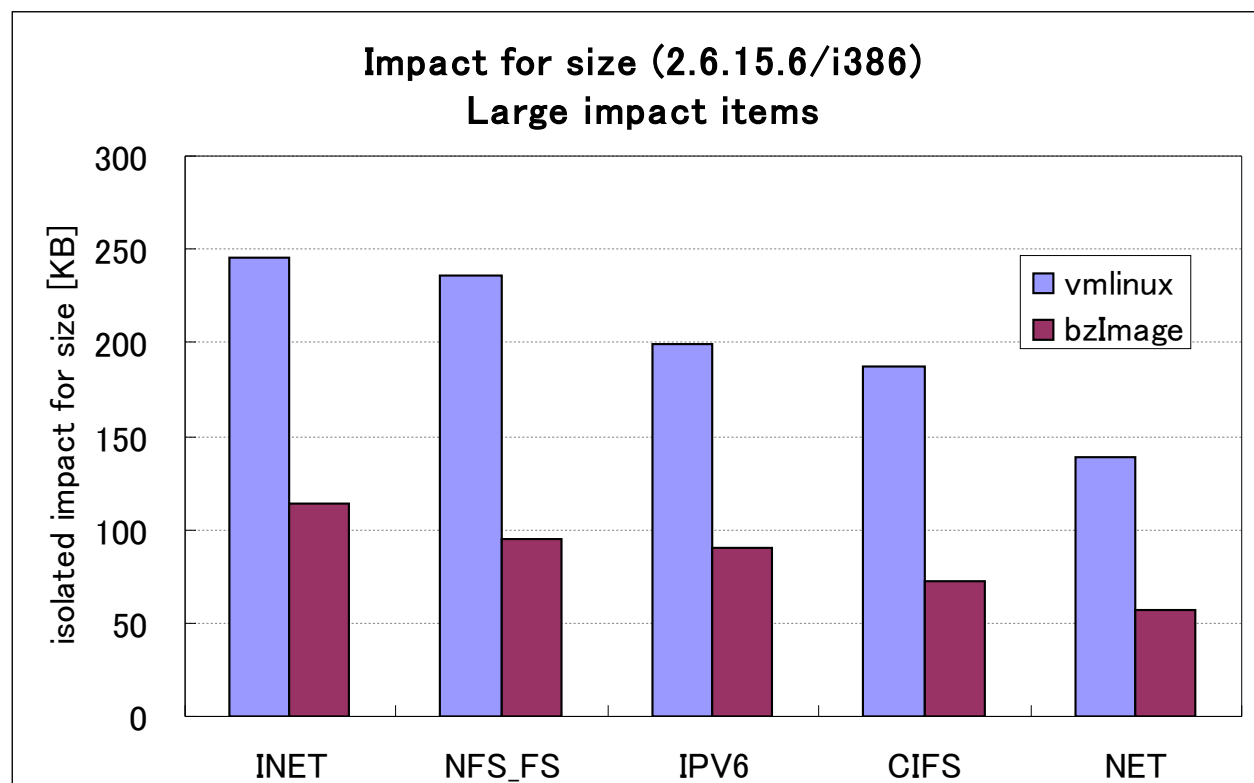   - bzImage : 50[KB]

Trend of base Kernel size (i386)

Note(1) : gcc 3.3.5, binutils 2.15

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4. Current examination result (3)

- **Result about size : Isolated impact of each config item**
  - Top 5 items
    - Network features have larger impact.

Impact for size (2.6.15.6/i386)
Large impact items

isolated impact for size [KB]

Legend:
- vmlinux
- bzImage

Categories (x-axis): INET, NFS_FS, IPV6, CIFS, NET

y-axis: 0, 50, 100, 150, 200, 250, 300

Note(1) : gcc 3.3.5, binutils 2.15

Note(2) : Some config items are not completely isolated.
NFS_FS += LOCKD + SUNRPC
IPV6   += CRYPTO + CRYPTO_MD5

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4. Current examination result (4)

- **Result about size : Trend of impacts**
  - Bloating trend of NFS and DVB_BUDGET are found.

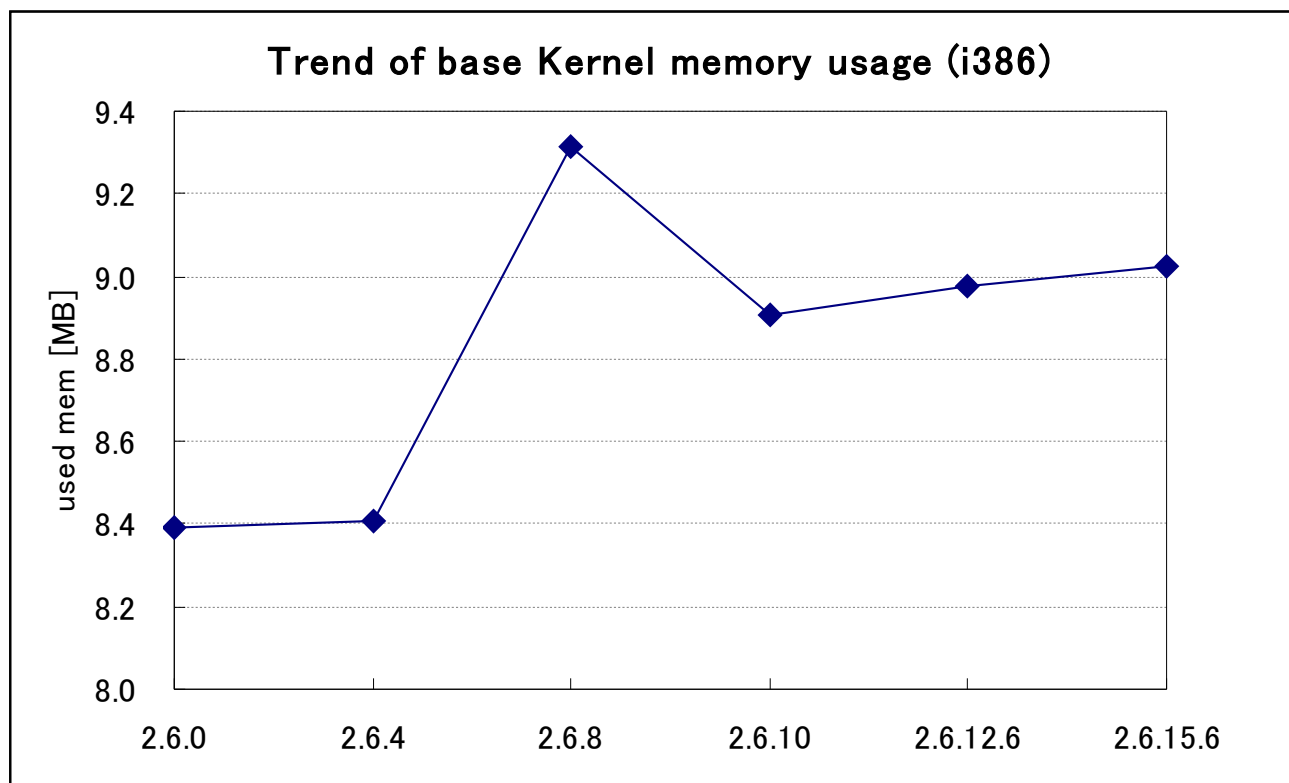Size bloating items (i386)
Impact for vmlinux size

Note : gcc 3.3.5, binutils 2.15

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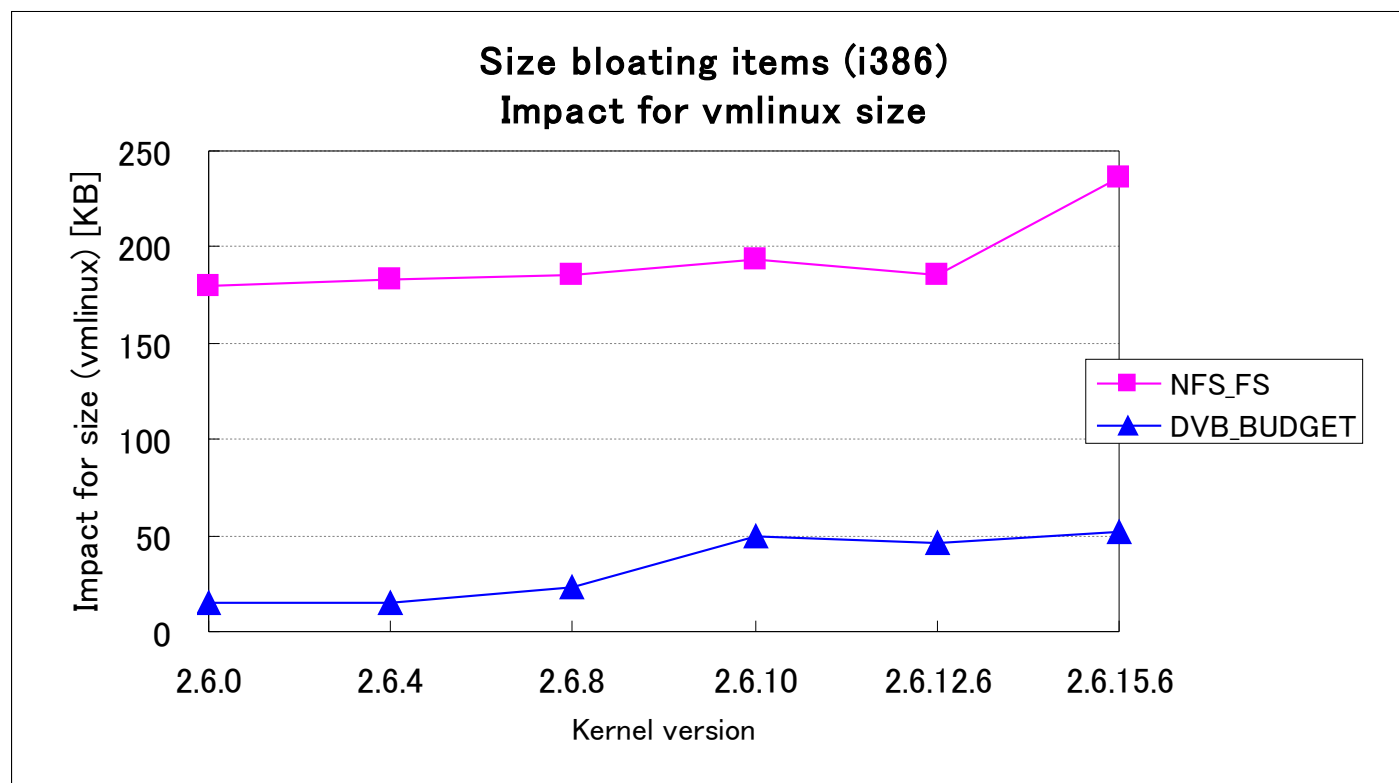
4. Current examination result (5)

- **Result about memory usage : Base Kernel**
  - Memory usage increased by about 7% from 2.6.0 to 2.6.15.
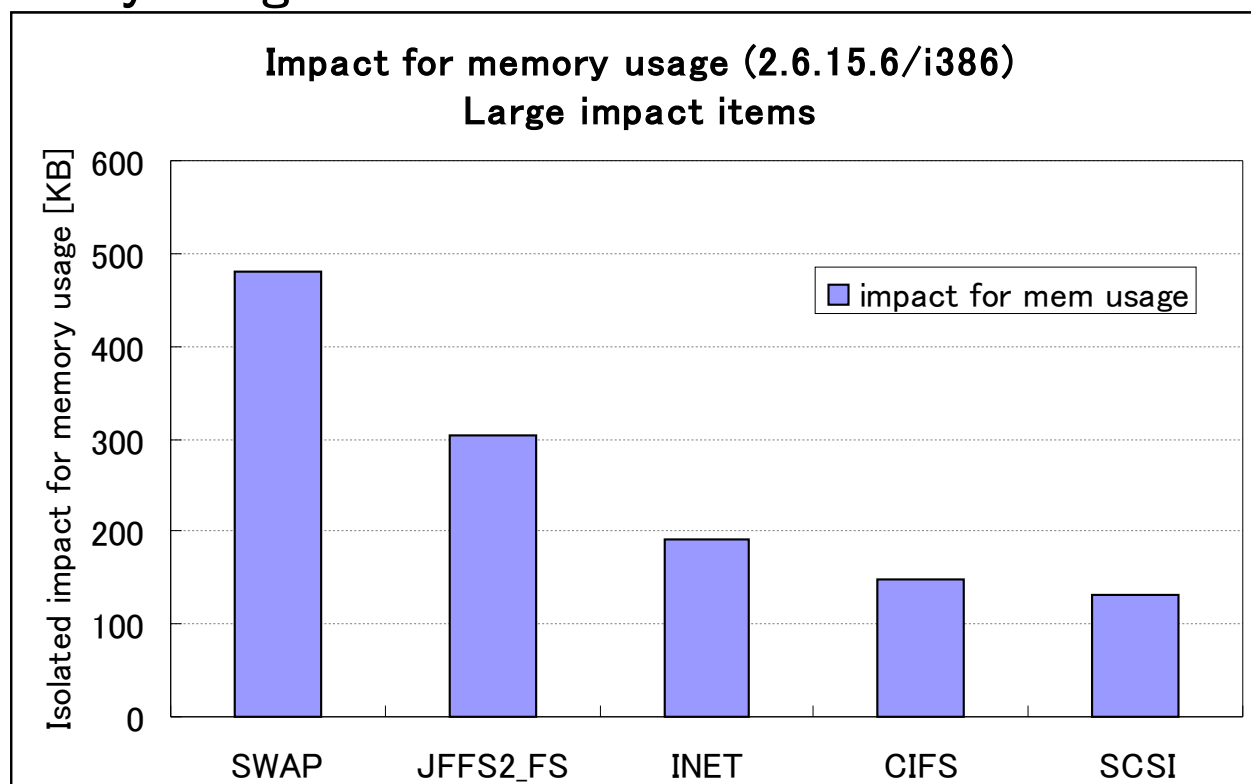 - Peak at 2.6.8 is observed. (needs analysis)

Trend of base Kernel memory usage (i386)

Note(1) : gcc 3.3.5, binutils 2.15

Note(2) : Target machine ... Pentium IV 2.2GHz/RAM 256MB/HD 40GB

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4. Current examination result (6)

- **Result about memory usage :**
  Isolated impact of each config item
  - Top 5 items
    - SWAP, JFFS2, and network features have large impact for memory usage.

Impact for memory usage (2.6.15.6/i386)
Large impact items

Note(1) : gcc 3.3.5, binutils 2.15

Note(2) : Target machine ... Pentium IV 2.2GHz/RAM 256MB/HD 40GB

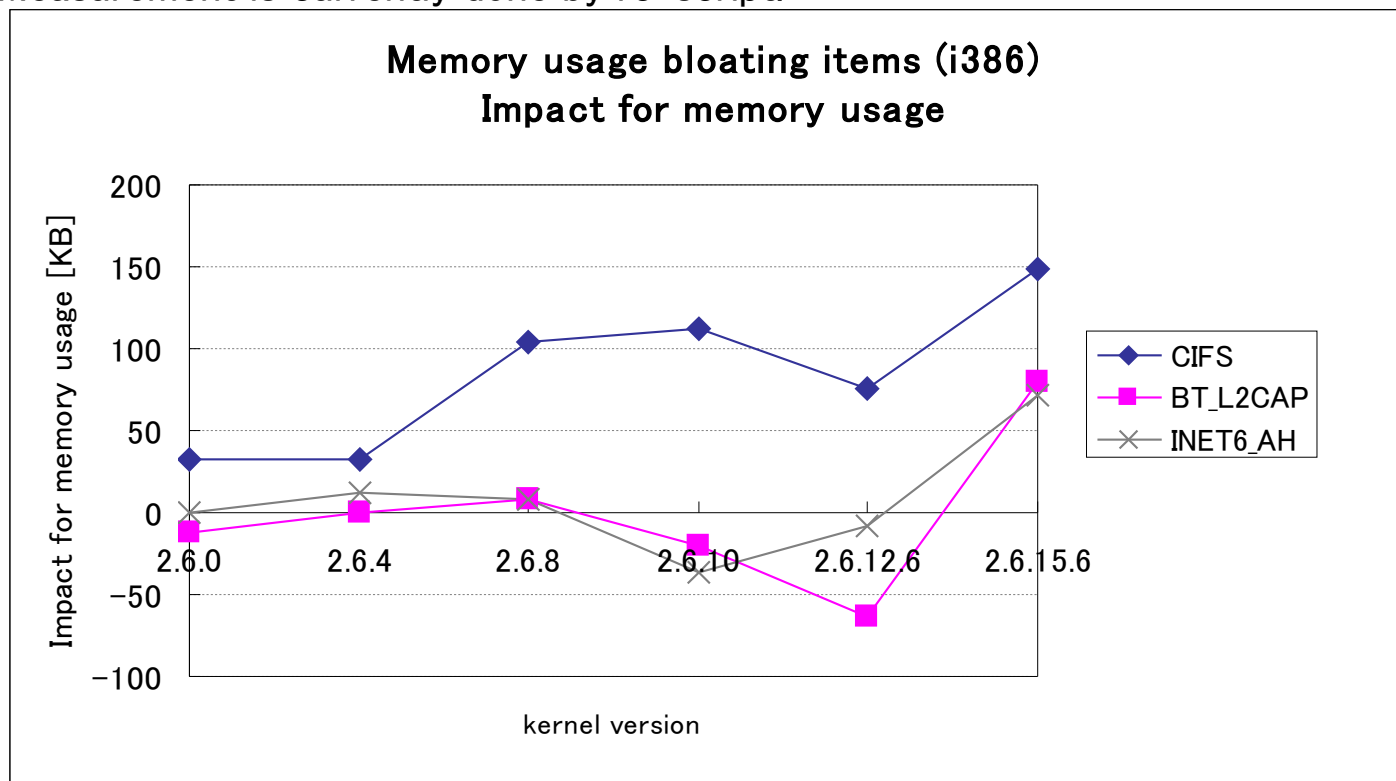Empowered by Innovation NEC

4. Current examination result (7)

- ## Result about memory usage : Trend of impacts
  - Memory impact of most of items increased from 2.6.10/2.6.12 to 2.6.15.
  - There are some impacts less than 0.
    More precision measurement is needed.
    - Current measurement method is using sysinfo(2).
    - Measurement is currently done by rc-script.

Memory usage bloating items (i386)
Impact for memory usage

Legend: CIFS, BT_L2CAP, INET6_AH

Y-axis: Impact for memory usage [KB] (−100 to 200)
X-axis: kernel version (2.6.0, 2.6.4, 2.6.8, 2.6.10, 2.6.12.6, 2.6.15.6)

Note(1) : gcc 3.3.5, binutils 2.15
Note(2) : Target machine ... Pentium IV 2.2GHz/RAM 256MB/HD 40GB

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4. Current examination result (8)

- **Result summary about Size**
  - Base kernel size has increased by about 10% within 2.6 series.
  - Network features have the largest impact for size.
  - NFS's bloating trend has been shown along recent versions.

- **Result summary about Memory usage**
  - Memory usage of base kernel fluctuates about 1MB within 2.6 series. Increase is about 7%.
  - Swap and JFFS2 have the largest impact for memory usage.

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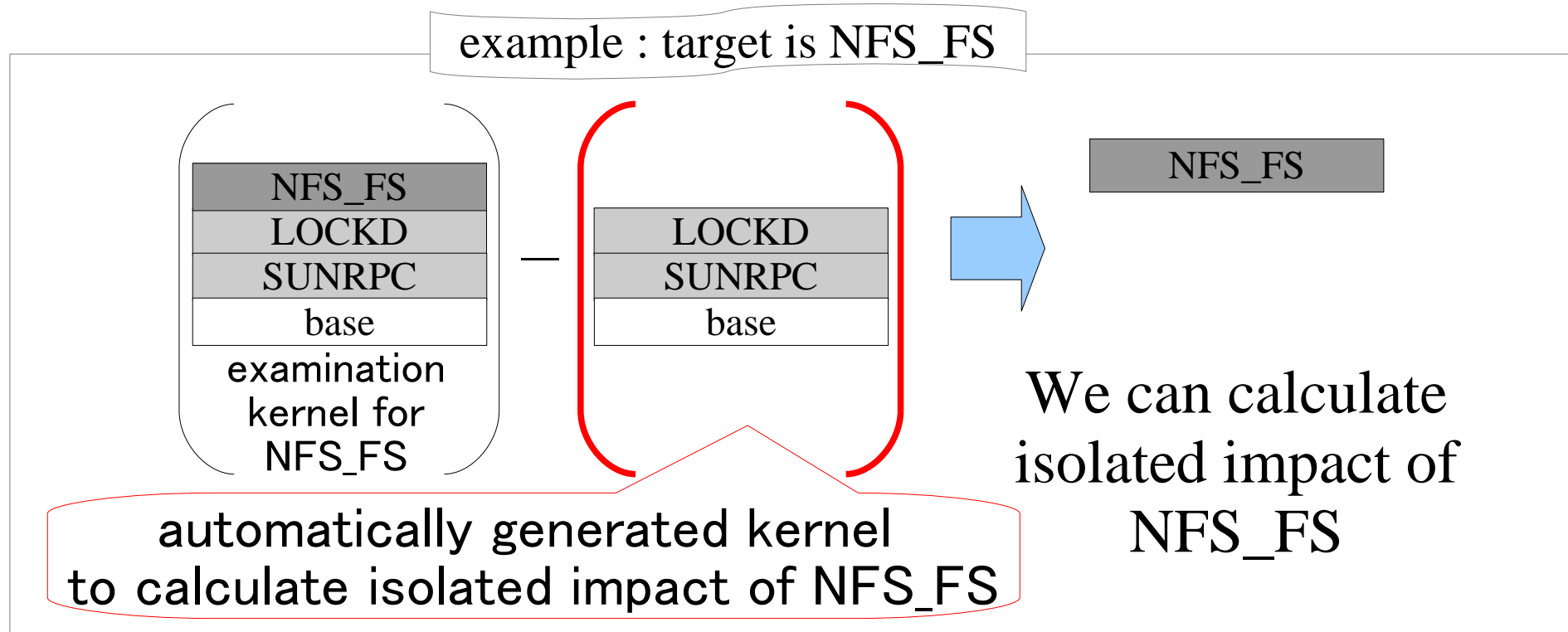
5. Issue

- **Semantic change of config item breaks version comparison.**
  - ex1 : Dependency change : DVB_BUDGET
    - 2.6.9   : select VIDEO_SAA7146
    - 2.6.10 : select DVB_STV0299
      - select DVB_VES1X93
      - select DVB_VES1820
      - select DVB_L64781
      - select DVB_TDA8083
      - select DVB_TDA10021

  - ex2 : Name change :
    JFFS2_FS_NAND -> JFFS2_FS_WRITEBUFFER
    - 2.6.12 : jffs2-$(CONFIG_JFFS2_FS_NAND) += wbuf.o
    - 2.6.13 : jffs2-$(CONFIG_JFFS_FS_WRITEBUFFER)+= wbuf.o

    - This is fundamental issue for our approach based on config items.
    - Human check is needed for cases like this.

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6. Future works (1)

- **Improvement of our tool**
  - Currently we have to list item(s) other than target to calculate isolated impact of the target.
  - We have a plan to improve .config generator to generate .config file(s) which are enough to calculate isolated impact of the target item automatically.

example : target is NFS_FS

| NFS_FS |
| LOCKD |
| SUNRPC |
| base |

examination kernel for NFS_FS

—

| LOCKD |
| SUNRPC |
| base |

| NFS_FS |

We can calculate isolated impact of NFS_FS

automatically generated kernel
to calculate isolated impact of NFS_FS

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6. Future works (2)

- **Investigation for better memory measurement approach**
  - Approach other than sysinfo(2).
  - Approach which can measure memory usage before rc-script to prevent measurement error caused by process environment.

- **Examining more architectures**
  - Examining popular architectures for embedded use. (mips, ppc, sh etc.)
  - Utilization of CELF Test Lab.

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7. Getting involved !

- **Please get involved in this project !**
- **Any suggestions are welcome !**
  - Configuration set for base-kernel
  - Configuration profile to decide target items
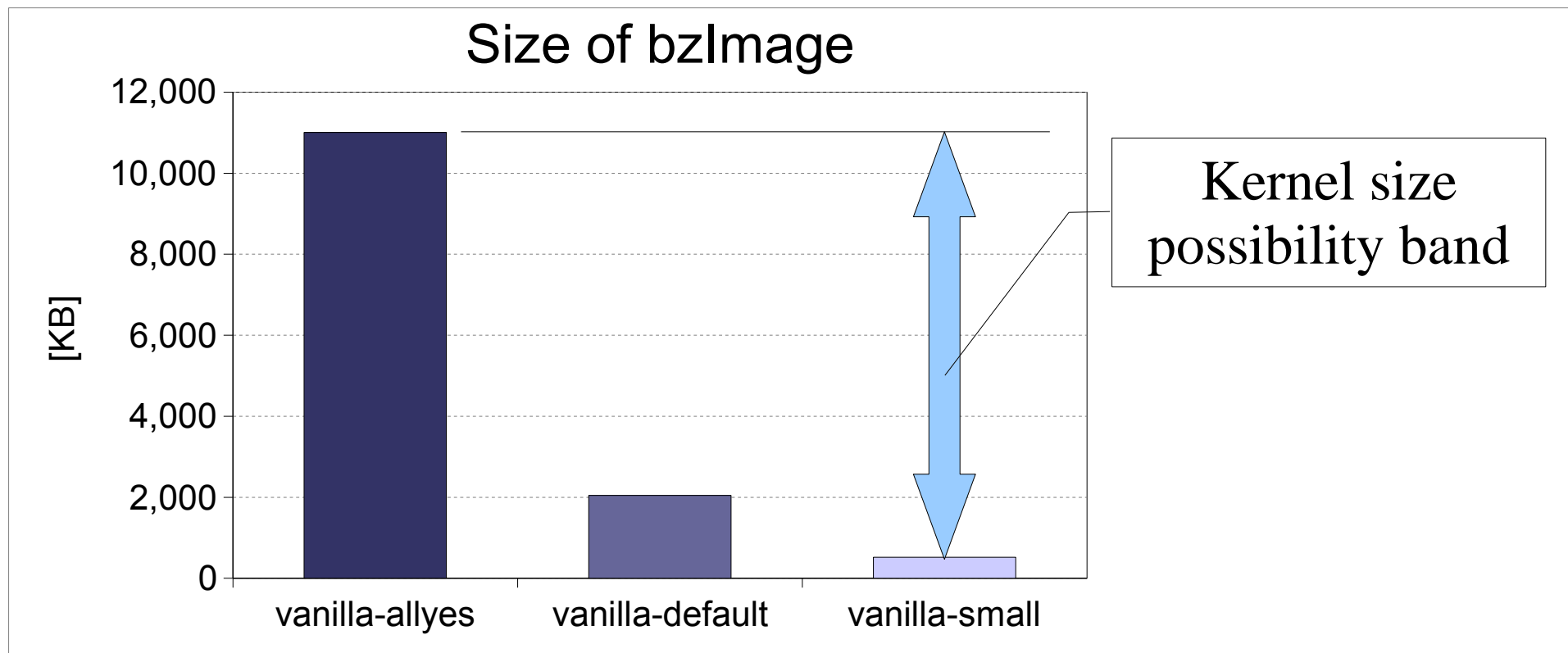 - How to provide the result
  - etc...

CELF Public WiKi

http://tree.celinuxforum.org/CelfPubWiki/KernelConfigWeight

celinux-dev ML

celinux-dev@tree.celinuxforum.org

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Thank you !

Appendix : reference data

Kernel size possibility

Size of bzImage

Kernel size possibility band

- **Sort of Kernels**
  - vanilla-allyes
    almost "make allyesconfig"
    disable debug-info and size optimization
  - vanilla-default :
    almost "make deconfig"
  - vanilla-small :
    Enabling least drivers, fs to boot.

- **Measurement conditions**
  - Kernel 2.6.10
  - i386
  - gcc 3.3.5

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