Presented by : Grégory Clément – Linux / Open Source manager – gclement@adeneo.eu

Embedded Linux Conference Europe 2009

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How we got a 3D application booting in 5 seconds under Linux

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Agenda

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- The Problem
- The context
- The boot process
- Time measurement
- Techniques for optimizations
- Results

Introduction

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- About Adeneo
  - French group
  - Foreign subsiadiaries
    - USA, China, Africa
  - Developping and manufacturing electronics products
  - Developping embedded softwares
    - Application software
    - Drivers development, BSP (Linux, CE)
  - Works with embedded Linux for + 7 years
    - Involved in the community (ex : Xenomai, RTAI)
    - Interested in improving bootup time in our systems

Introduction

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- About us
  - Grégory Clément
  - Simon Polette

The problem

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- People don't want to wait
- Especially with embedded devices

Hardware

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- AT92SAM9261-EK board :
  - ARM9-based µC at 200MHz
  - 64MB SDRAM
  - 256MB NAND Flash
  - DataFlash (SPI)

The boot process

The boot process

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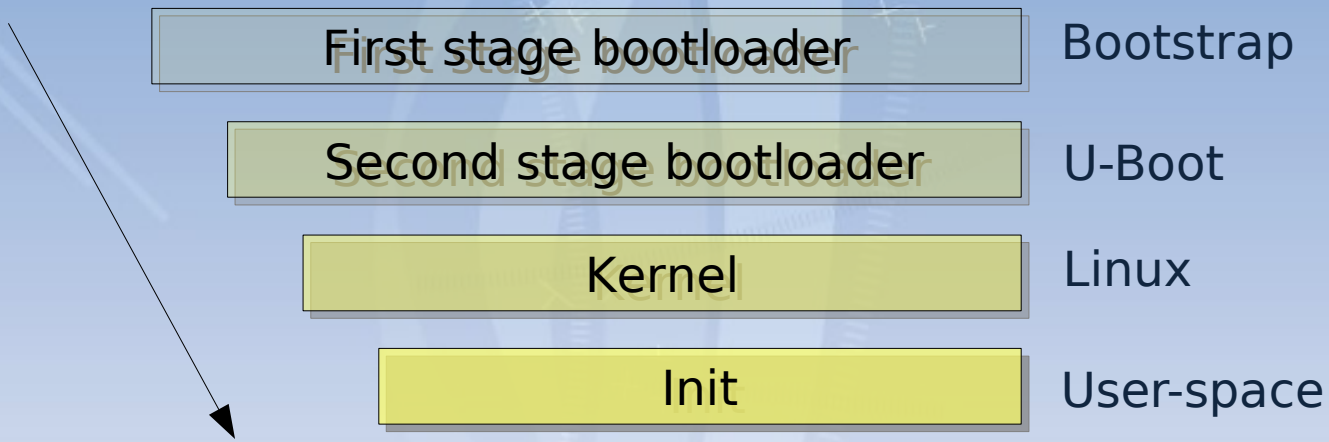

The boot process

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- Bootstrap :
  - Basic hardware init. (GPIO, Clock, SDRAM, etc)
  - Load and start U-Boot
- U-Boot :
  - Hardware initializations
  - Load and start kernel
- Kernel :
  - Drivers initializations
  - Mount root filesystem
- Init :
  - First User-space processus
  - Launch RC scripts
  - Start graphic environment

Time measurement

Time measurement

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- Find where the system loose time
- Be able to trace the boot process
- Identify the worst problem first

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Time measurement

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- Global measurement
  - serialchrono
- Kernel measurement
  - printk-times
  - initcall_debug
- User-space measurement
  - Bootchart-lite

Time measurement

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Global measurement

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Serialchrono

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- Simple script
- Capture serial output, add time stamp at begining of each line, then echo it.
- No need for any other module to run it, just /bin/sh
- Usage :

```
./serialchrono TTYS="/dev/ttyS0"
```

Serialchrono

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- Serialchrono output example :

```
[    1.252419] Area 0:  C0000000 to C00041FF (RO) Bootstrap
[    1.266907] Area 1:  C0004200 to C00083FF      Environment
[    1.274590] Area 2:  C0008400 to C0041FFF (RO) U-Boot
[    1.281892] Area 3:  C0042000 to C0251FFF      Kernel
[    1.289026] Area 4:  C0252000 to C083FFFF      FS
[    1.296206] In:    serial
[    1.303194] Out:   serial
[    1.310185] Err:   serial
[    1.317642] Hit any key to stop autoboot:  0
[    1.984084] ## Booting kernel from Legacy Image at 22000000 ...
[    1.992148]    Image Name:   Linux-2.6.31-rc2
[    1.999412]    Image Type:   ARM Linux Kernel Image (uncompressed)
[    2.007201]    Data Size:    911700 Bytes = 890.3 kB
[    2.013851]    Load Address: 20008000
[    2.021067]    Entry Point:  20008000
[    2.148271]    Verifying Checksum ... OK
[    2.268042]    Loading Kernel Image ... OK
[    2.275552] OK
[    2.282747]
[    2.289796] Starting kernel ...
```

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Serialchrono

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- Advantages :
  - Very simple to use, no need installation
  - "Passive" instrumentation (just read what the target send)
  - Doesn't add any overhead
- Disadvantages :
  - First printks are queued up and printed only once serial console have been initialized
  - Timestamp only what is printed in console

Time measurement

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Kernel measurement

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Kernel measurement

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- Printk-time
  - Add timestamp at the begining of each console output line
  - To activate it, just select the option in kernel configuration, or just add `printk.time=1` in the kernel command line

```
# Kernel hacking
#
CONFIG_PRINTK_TIME=y
```

Kernel measurement

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- Printk-time output example :

```
[    0.000000] NR_IRQS:192
[    0.000000] AT91: 96 gpio irqs in 3 banks
[    0.000000] Console: colour dummy device 80x30
[    0.000000] console [ttyS0] enabled
[    0.120000] Calibrating delay loop (skipped) preset value.. 124.51 BogoMIPS (lpj=622592)
[    0.130000] Mount-cache hash table entries: 512
[    0.130000] CPU: Testing write buffer coherency: ok
[    0.140000] NET: Registered protocol family 16
[    0.180000] bio: create slab <bio-0> at 0
[    0.190000] SCSI subsystem initialized
[    0.200000] usbcore: registered new interface driver usbfs
[    0.200000] usbcore: registered new interface driver hub
[    0.210000] usbcore: registered new device driver usb
[    0.230000] NET: Registered protocol family 2
[    0.230000] IP route cache hash table entries: 1024 (order: 0, 4096 bytes)
[    0.240000] TCP established hash table entries: 2048 (order: 2, 16384 bytes)
```

- Note :
  - Timestamps are available only once clock is initialized

initcall_debug

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- Measure time spend in each 'initcall' during boot
- Usage :
  - Simply add `'initcall_debug'` to kernel command line
- Result will be available in `dmesg`

initcall_debug

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- Exemple of output :
  - `dmesg | egrep 'initcall|calling'`

```
[    1.020000] calling  chr_dev_init+0x0/0xbc @ 1
[    1.030000] initcall chr_dev_init+0x0/0xbc returned 0 after 5047 usecs
[    1.030000] calling  firmware_class_init+0x0/0x78 @ 1
[    1.040000] initcall firmware_class_init+0x0/0x78 returned 0 after 495 usecs
[    1.040000] calling  sysctl_core_init+0x0/0x44 @ 1
[    1.050000] initcall sysctl_core_init+0x0/0x44 returned 0 after 38 usecs
[    1.060000] calling  inet_init+0x0/0x1dc @ 1
[    1.100000] initcall inet_init+0x0/0x1dc returned 0 after 35788 usecs
[    1.100000] calling  af_unix_init+0x0/0x5c @ 1
[    1.110000] initcall af_unix_init+0x0/0x5c returned 0 after 4388 usecs
[    1.120000] calling  populate_rootfs+0x0/0x210 @ 1
[    1.120000] initcall populate_rootfs+0x0/0x210 returned 0 after 495 usecs
[    1.130000] calling  timer_init_sysfs+0x0/0x40 @ 1
[    1.140000] initcall timer_init_sysfs+0x0/0x40 returned 0 after 920 usecs
[    1.140000] calling  fpe_init+0x0/0x84 @ 1
[    1.150000] initcall fpe_init+0x0/0x84 returned 0 after 6369 usecs
```

initcall_debug

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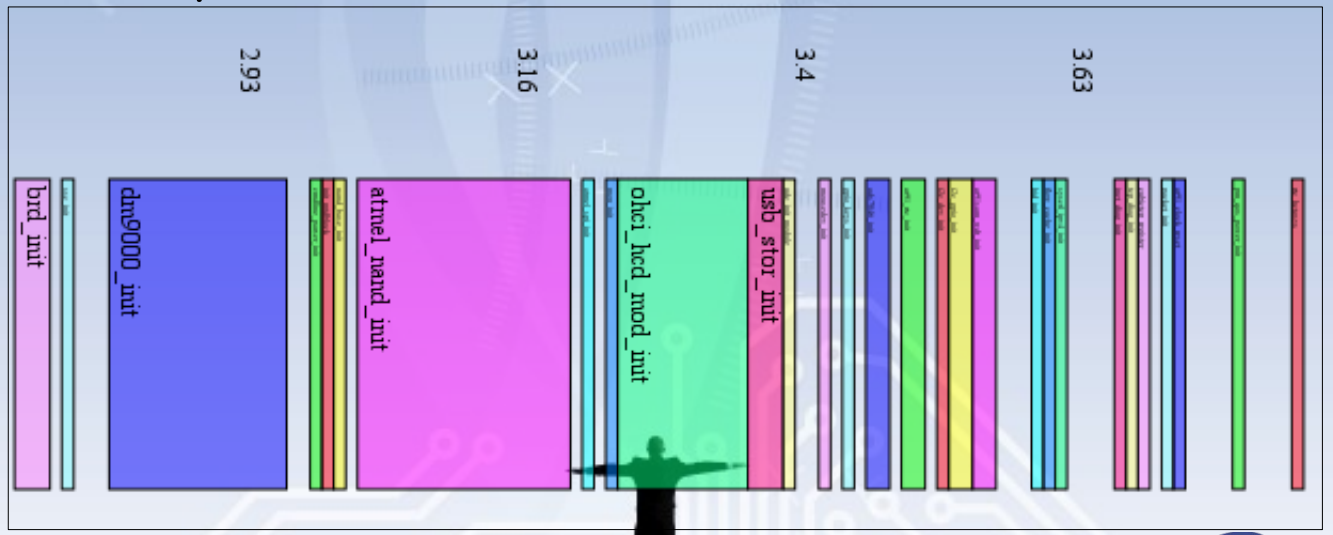
- Possibility to change it into a pretty readable graph thanks to Arjan van de Ven's script :
  - `dmesg | perl scripts/bootgraph.pl > boot.svg`



initcall_debug

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- Notes about initcall_debug :
  - Increase significantly boot time
  - Log buffer could be too small
    - Increase it size by changing `CONFIG_LOG_BUF_SHIFT` value in the `.config`
- Printk-time must be enabled to get the graph

Time measurement

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User-space measurement

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Bootchart-lite

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- http://code.google.com/p/bootchart-lite
- Similar to Bootchart
  - http://www.bootchart.org
- Collects datas from `/proc`
- Written in C
  - Less overhead than a shell script
- Use the same Java parser than Bootchart to change the logs into a nice graph

Bootchart-lite

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- Usage :
  - Launch bootchart-lite instead of traditional `/sbin/init`
  - Make a gzipped tarball of logs
    - `tar -cvzf bootchart.tgz /etc/bootchart-lite/*`
  - Create the graph using bootchart's java parser :
    - `java -jar ./bootchart.jar bootchart.tgz`

Bootchart-lite

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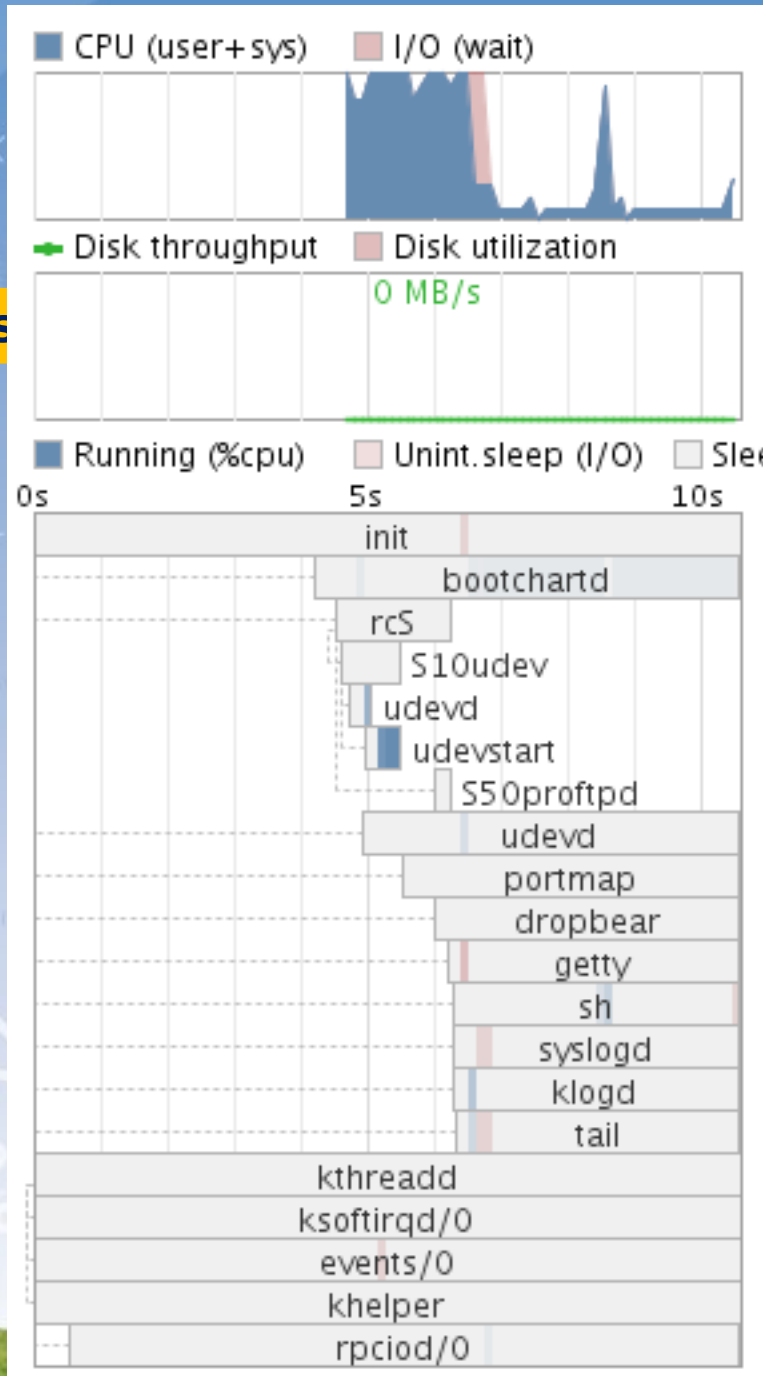
- Bootchart exemple :



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Bootchart-lite

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- Notes about bootchart-lite :
  - The bootchart daemon could be stopped manually :
    - Send `SIGUSR1` to bootchartd
  - Or automatically :
    - `#define EXIT_PROC "proc_name"`
  - Can easily modify the sample time

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Techniques for optimization

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Techniques for optimizations

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- Our environment
  - Atmel AT91SAM9261-EK board
  - 2.6.29 Kernel
  - U-Boot v2009.06
  - at91sam9261ek_defconfig
  - JFFS2 filesystem (on 122MB partition)
  - Qt for embedded Linux graphic application
    - Start **30 seconds** after the board have been powered up

Techniques for optimizations

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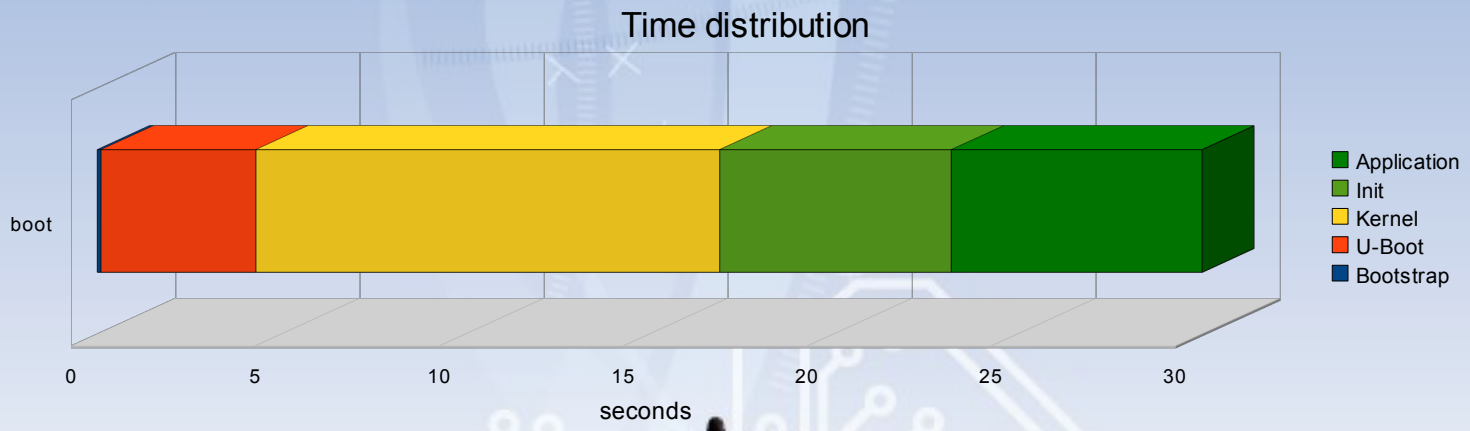
- Initial timing :

Bootstrap	U-Boot	Kernel	User-space	
			Init	application
0.1	4.2	12.6	6.3	6.8



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Techniques for optimizations

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User-Space optimizations

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User-Space optimizations

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- Use UBIFS instead JFFS2
  - Much faster for mounting, writing, reading
  - Will improve both kernel and user-space initialization time
  - User-space applications will be loaded faster

User-Space optimizations

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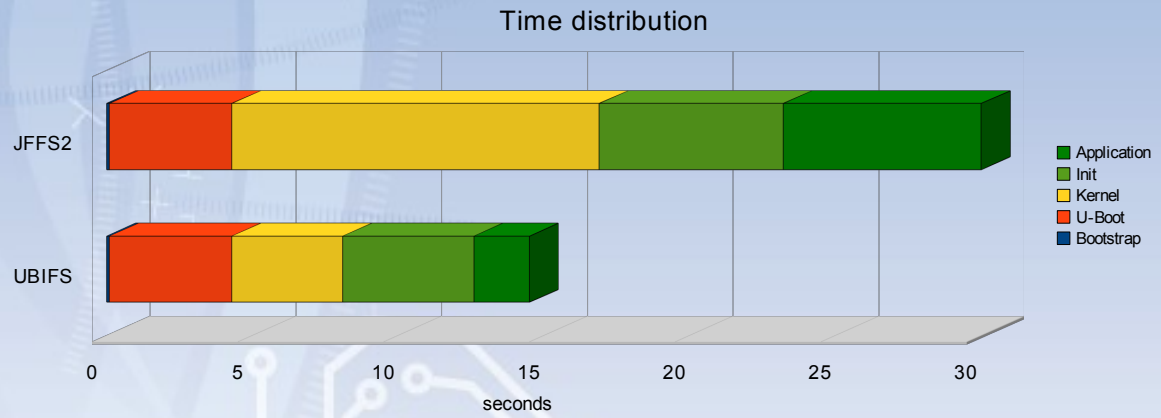
- Results
  - Boot time : **14.5s**
  - Saving : **15.5s**

Bootstrap	U-Boot	Kernel	User-space	
			Init	application
0.1	4.2	3.8	4.5	1.9



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User-Space optimizations

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- Remove unneeded rc scripts
  - For example : No need to start `udev` daemon (hardware configuration in embedded systems is often constant)
  - Keep only the scripts which are essential for your application
  - Still possible to start the other scripts later

User-Space optimizations

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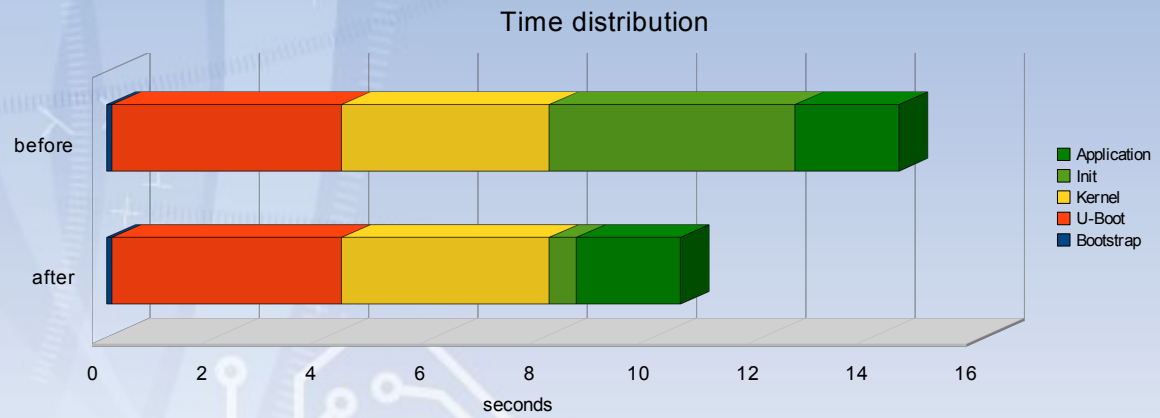
- Results
  - Boot time : **10.5s**
  - Saving : **4s**

Bootstrap	U-Boot	Kernel	User-space	
			Init	application
0.1	4.2	3.8	0.5	1.9



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User-Space optimizations

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- Dynamically linked applications take a long time to get loaded
- Use statically linked application

  Note : The binary size can increase significantly
  - In our example :
    - Dinamically linked : 152KB
    - Statically linked : 12MB

User-Space optimizations

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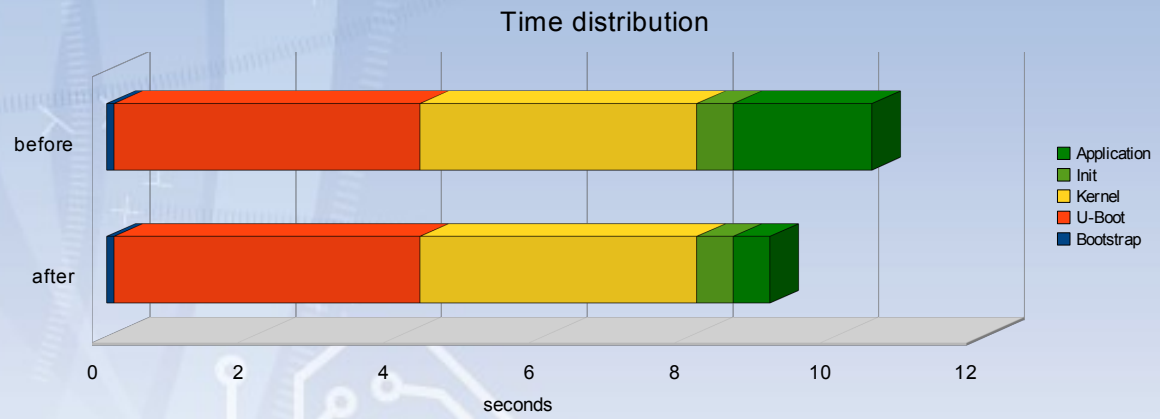
- Results
  - Boot time : **9.1s**
  - Saving : **1.4s**

Bootstrap	U-Boot	Kernel	User-space	
			Init	application
0.1	4.2	3.8	0.5	0.5



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User-Space optimizations

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- Other solutions for optimisation
  - /sbin/init alternatives
    - Initng
    - Upstart
      - Not suitable for small systems
      - Upstart needs additionnal libs such as Dbus
- Better to optimize init process "by hand"

Techniques for optimizations

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Kernel optimizations

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Kernel optimizations

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- Identify what is essential for your system just after boot
- Remove unused features
- Use deferred modules
  - Initialize modules after the system completely booted, by doing

```
echo 1 >/proc/deferred_initcalls
```

Kernel optimizations

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- Best strategy to configure the kernel ?
  - Don't use '`make yourboard_defconfig`'
  - Do '`make allnoconfig`'
  - Then select the minimum required by your system

Kernel optimizations

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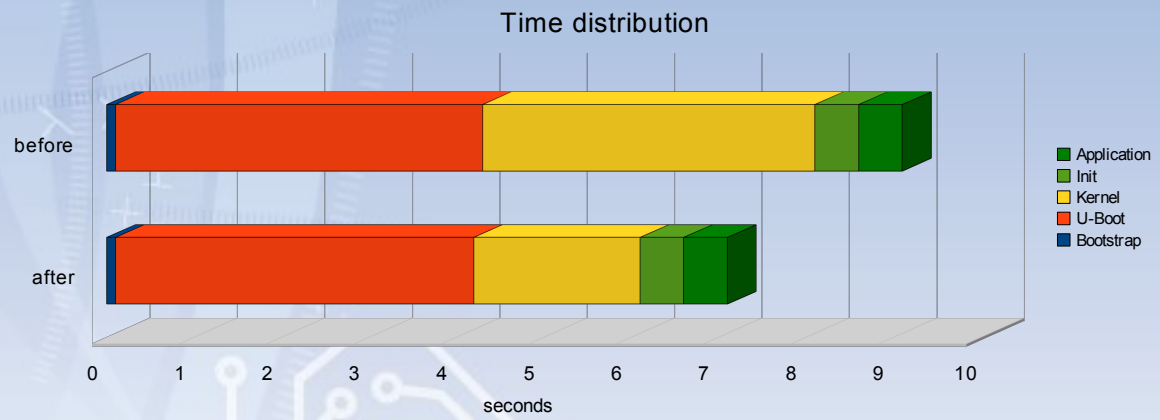
- Results
  - Boot time : **7.1s**
  - Saving : **2s**

Bootstrap	U-Boot	Kernel	User-space	
			Init	application
0.1	4.1	1.9	0.5	0.5



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Kernel optimizations

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- Set 'CONFIG_EMBEDDED=y'
- [*]Configure standard kernel features
  - Allow disabling more (unused) features in the kernel
  - Reduce the kernel size

Kernel optimizations

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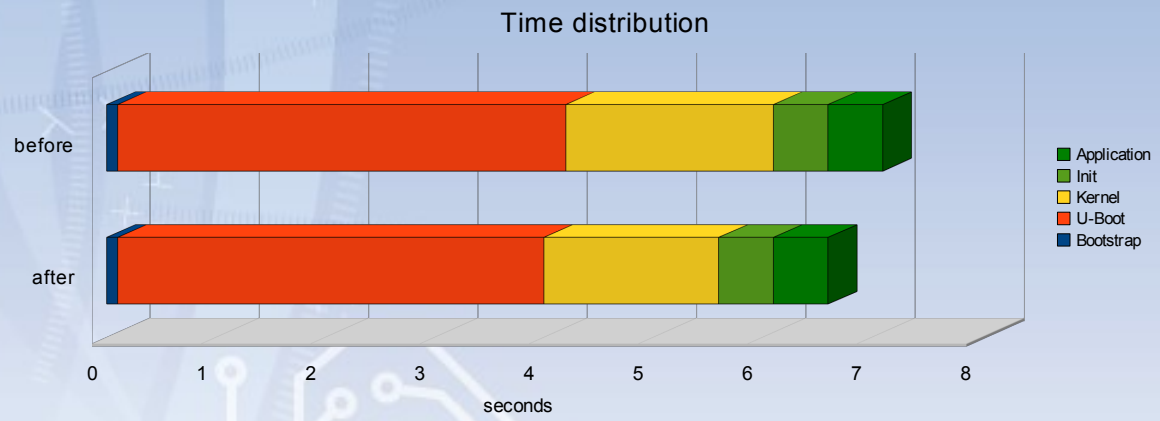
- Results
  - Boot time : **6.6s**
  - Saving : **500ms**

Bootstrap	U-Boot	Kernel	User-space	
			Init	application
0.1	3.9	1.6	0.5	0.5



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Kernel optimizations

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- Make the kernel boot quietly
  - Disable the printk messages on the console during the kernel boot.
- Usage
  - Simply add `'quiet'` in the kernel command line
    - Ex:

```
root=/dev/mtdblock1 console=ttyS0,115200 rootfstype=jffs2 quiet
```

- Time saved will be proportional to number lines printed on the console during boot
- Still possible to consult the boot log in dmesg

Kernel optimizations

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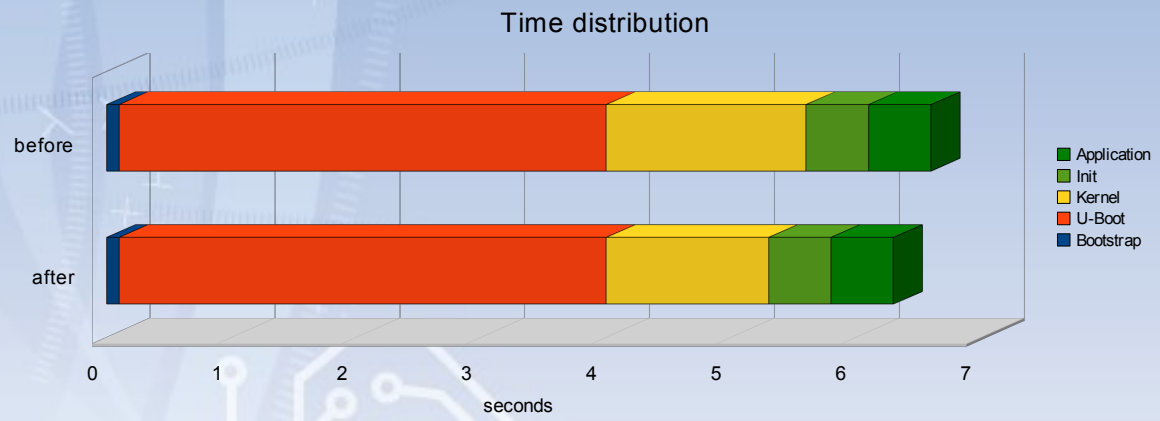
- Results
  - Boot time : **6.3s**
  - Saving : **300ms**

Bootstrap	U-Boot	Kernel	User-space	
			Init	application
0.1	3.9	1.3	0.5	0.5



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Kernel optimizations

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- Preset 'loop per jiffies'
  - Constant value for the architecture, but calculated at each boot
  - Possibility to give this value to the kernel
- Usage :
  - Add `'lpj=<value>'` in the kernel command line

Kernel optimizations

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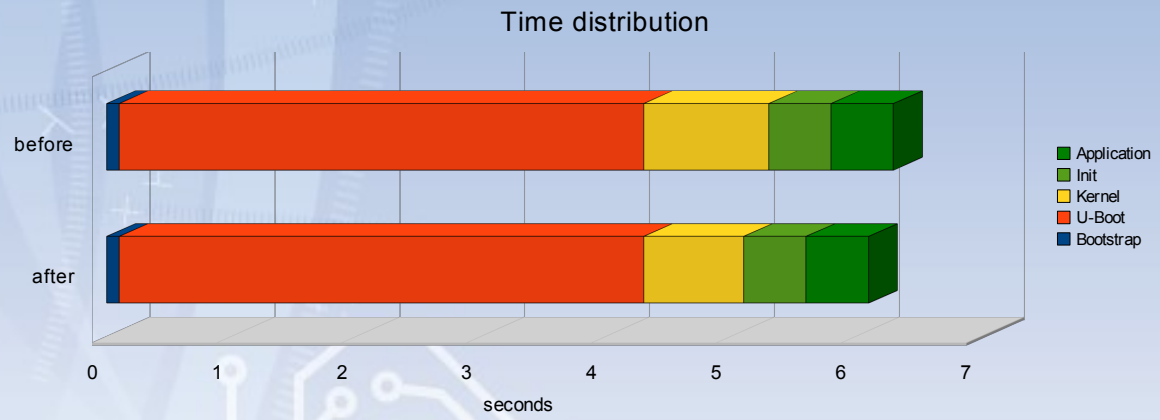
- Results
  - Boot time : **6.1s**
  - Saving : **200ms**

Bootstrap	U-Boot	Kernel	User-space	
			init	application
0.1	3.9	1.1	0.5	0.5



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Kernel optimizations

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- BBT is created at each boot for NAND devices, and stored in RAM
  - Use On Flash BBT
- We made a patch for Atmel nand driver
  - Now merged into the mainline (2.6.30 kernel)
- Usage
  - Add `'atmel_nand.on_flash_bbt=1'` in the kernel command line

Kernel optimizations

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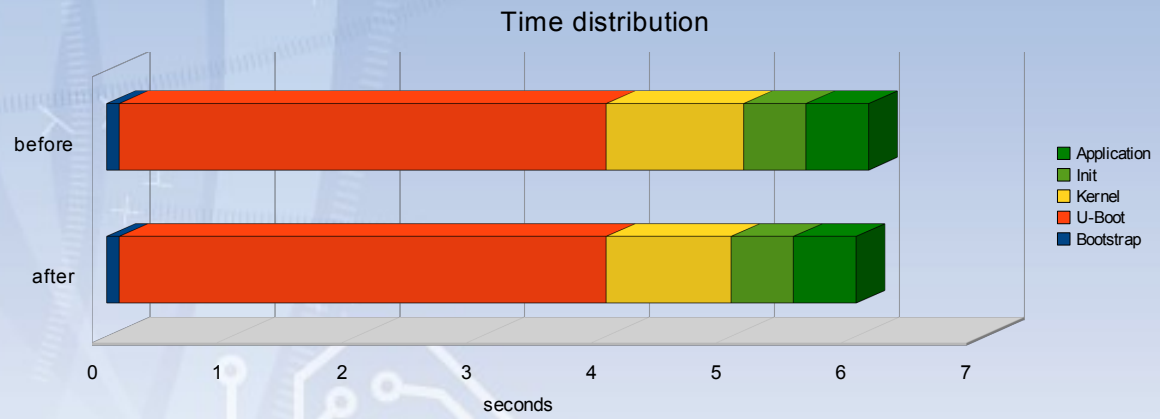
- Results
  - Boot time : **6s**
  - Saving : **100ms**

Bootstrap	U-Boot	Kernel	User-space	
			Init	application
0.1	3.9	1.0	0.5	0.5



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Kernel optimizations

- Other solutions for optimisation
  - Use new 'fastboot' technologie
    - In the mainline since 2.6.30
    - Allow asynchronous initcalls
    - Usefull if there are CPU and/or disk idle during the kernel boot

Techniques for optimizations

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U-Boot optimizations

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U-Boot optimizations

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- Customize U-Boot for doing only what is necessary to launch the kernel
- For example in our system we don't need to use these devices in U-Boot
  - Ethernet device
  - Nand device
- We keep LCD display since it consume a very few time (~20ms)

U-Boot optimizations

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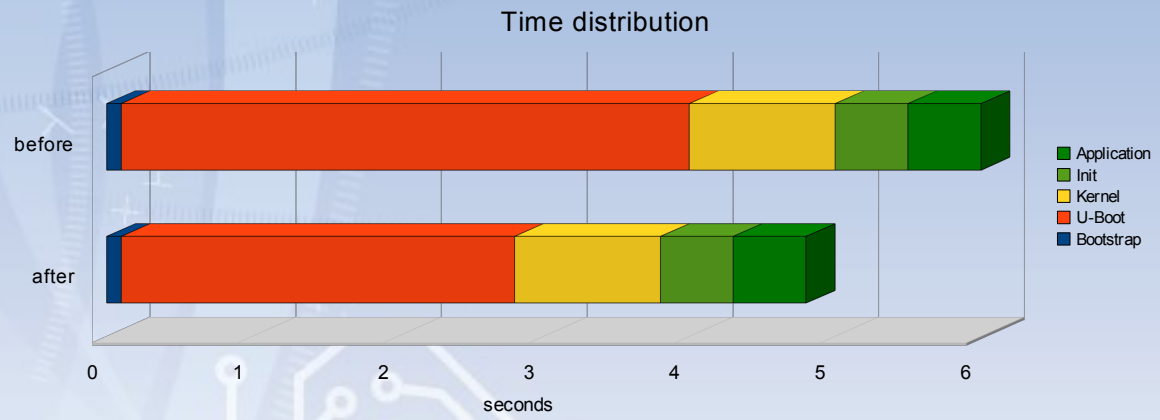
- Results
  - Boot time : **4.8s**
  - Saving : **1.2s**

Bootstrap	U-Boot	Kernel	User-space	
			Init	application
0.1	2.7	1.0	0.5	0.5



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Techniques for optimizations

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Bootstrap optimizations

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Bootstrap optimizations

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- The bootstrap do some hardware initializations, then launch the kernel
- Official Atmel bootstrap offer two choice for initialize master clock : 100MHz and 125MHz
  - Upgrade to 125MHz will cause the CPU to run faster

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U-Boot optimizations

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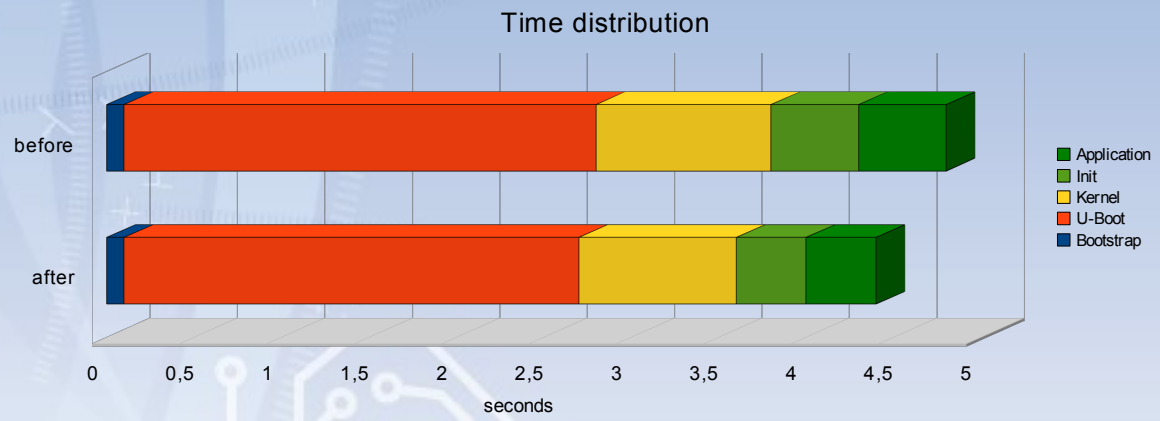
- Results
  - Boot time : **4.4s**
  - Saving : **400ms**

Bootstrap	U-Boot	Kernel	User-space	
			Init	application
0.1	2.6	0.9	0.4	0.4



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Techniques for optimizations

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Now, have a look at how much time we saved

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Techniques for optimizations

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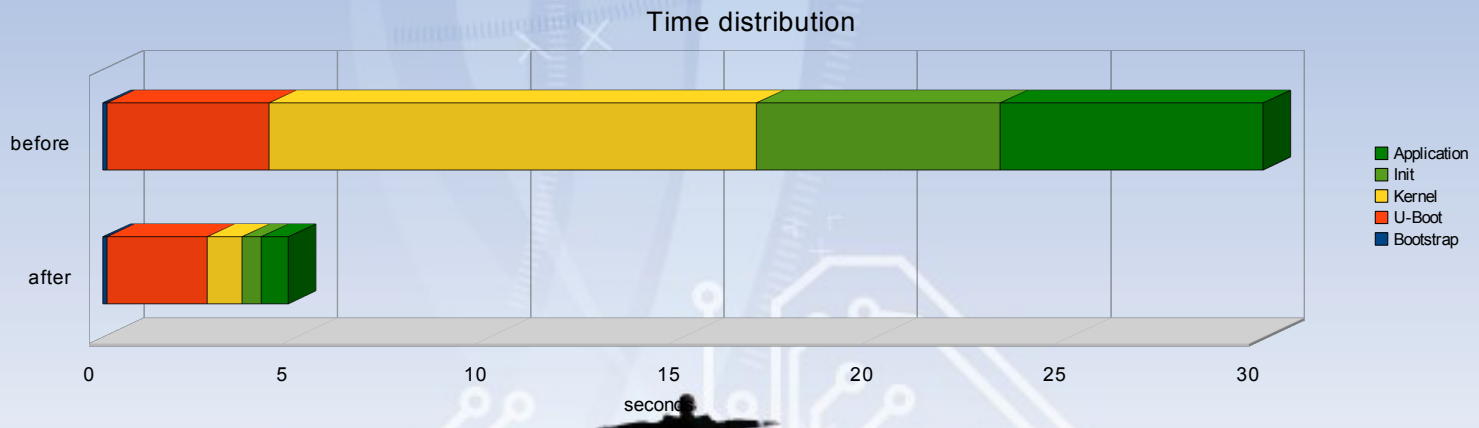
	Bootstrap	U-Boot	Kernel	User-space		Total
				Init	application	
Before optimization	0.1	4.2	12.6	6.3	6.8	30
After optimization	0.1	2.6	0.9	0.4	0.4	4.4



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