
Embedded Operating Systems and Linux

Amir Hossein Payberah
payberah@gmail.com



Agenda

- ⇒ Embedded Systems
- ⇒ Real Time Systems
- ⇒ Who Are The Players?
- ⇒ Linux As An Embedded OS
- ⇒ Kernel 2.4 vs. 2.6
- ⇒ Applications And Products
- ⇒ The Embedded OS Market



Embedded Systems



What is an Embedded OS?

- ➔ An "embedded system" is any computer system or computing device that performs a dedicated function or is designed for use with a specific embedded software application.
- ➔ Embedded systems may use a ROM-based operating system or they may use a disk-based system, like a PC. But an embedded system is not usable as a general purpose computers or devices.



What makes a good Embedded OS?

- ⇒ Modular
- ⇒ Scalable
- ⇒ Configurable
- ⇒ Small footprint
- ⇒ Device drivers
- ⇒ etc, etc, etc...



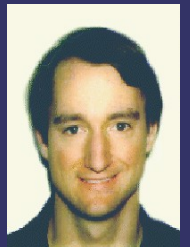
Real Time Systems



What is Real Time?

“A real time system is one in which the correctness of the computations not only depends upon the logical correctness of the computation but also upon the time at which the result is produced. If the timing constraints of the system are not met, system failure is said to have occurred.”

Donald Gillies



What is Real Time?

“Real time in operating systems:

The ability of the operating system to provide a required level of service in a bounded response time.”

POSIX Standard 1003.1



Hard vs. Soft Real Time

⇒ Hard

- Absolute deadlines that must be met
- Example: Braking system controller

⇒ Soft

- Time tolerance within which an event can occur
- Example: Multimedia streaming



What makes a good Real Time OS?

- ⇒ Multi-threaded and pre-emptible
- ⇒ Thread priority has to exist
- ⇒ Must support predictable thread synchronization mechanisms
- ⇒ A system of priority inheritance must exist



Who are the players



Who are the Embedded OS players?

- ⇒ Wind River Systems
 - VxWorks
 - pSOS

- ⇒ QNX Software Systems
 - QNX

- ⇒ Green Hills Software
 - Integrity



Who are the Embedded OS players?

⇒ Mentor Graphics

- VRTX

⇒ Palm Computing

- PalmOS

⇒ Symbian

- SymbianOS



Who are the Embedded OS players?

- ⇒ Windows
 - Embedded NT/XP
 - “Real-time” control
 - Windows CE (CE.NET)
 - Internet devices
 - Pocket PC 2002
 - Handheld PC's and PDA's

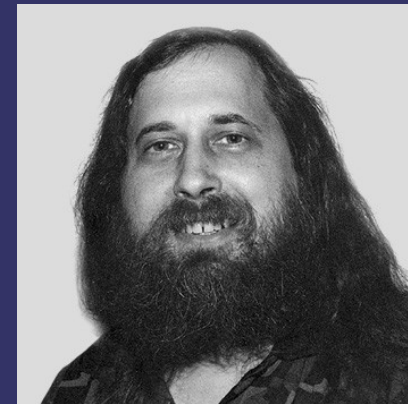


Linux as an Embedded and Real Time system



GNU History

- ⇒ In 1983
- ⇒ Richard Stallman
- ⇒ It is free
 - free means freedom
- ⇒ GNU's Not Unix



Linux History

- ⇒ In 1991
- ⇒ Linus Torvalds
- ⇒ Based on Minix
- ⇒ GNU/Linux



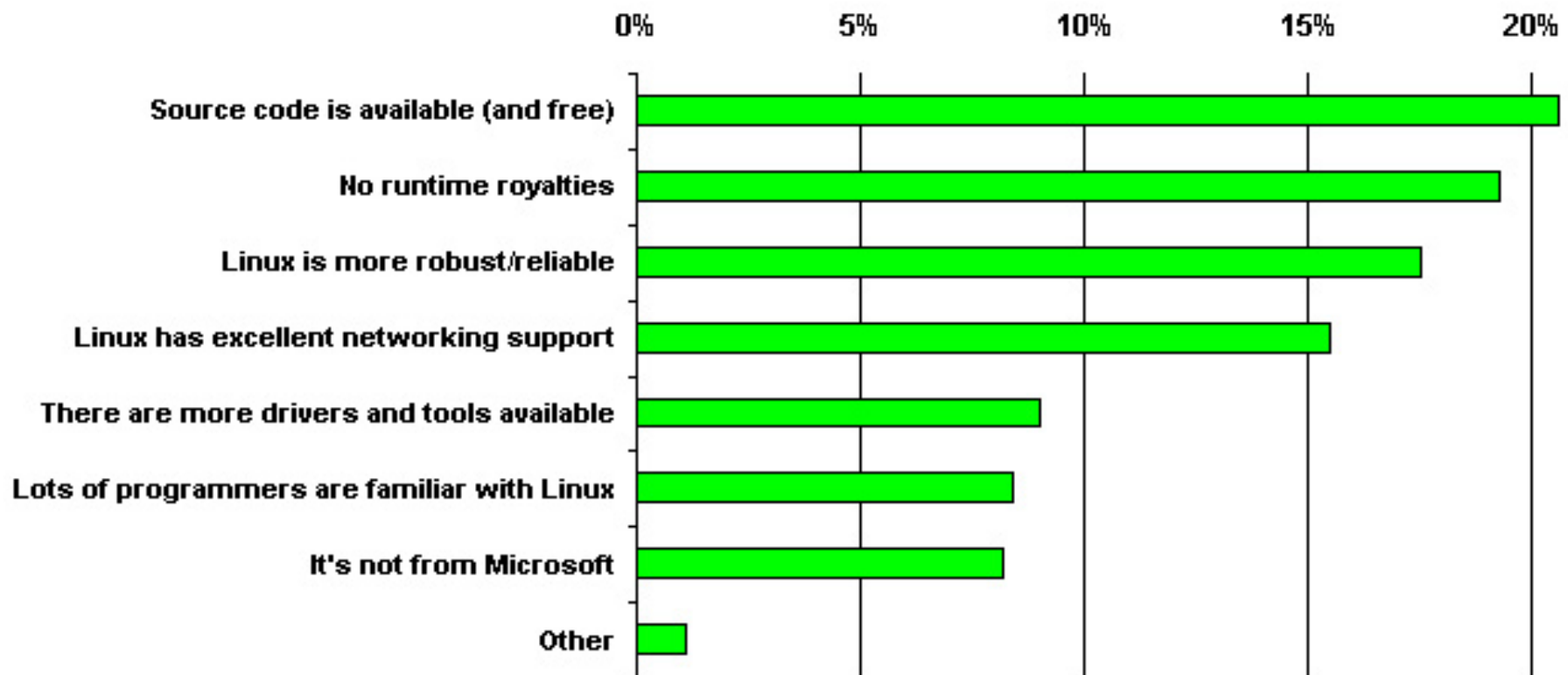
What's so special about Linux?

- ⇒ Multiple choices vs. sole source
- ⇒ Source code freely available
- ⇒ Robust and reliable
- ⇒ Modular, configurable, scalable
- ⇒ Superb support for networking and Internet
- ⇒ No runtime licenses
- ⇒ Large pool of skilled developers



What's so special about Linux?

What are your main reasons for wanting to use Linux in embedded applications?

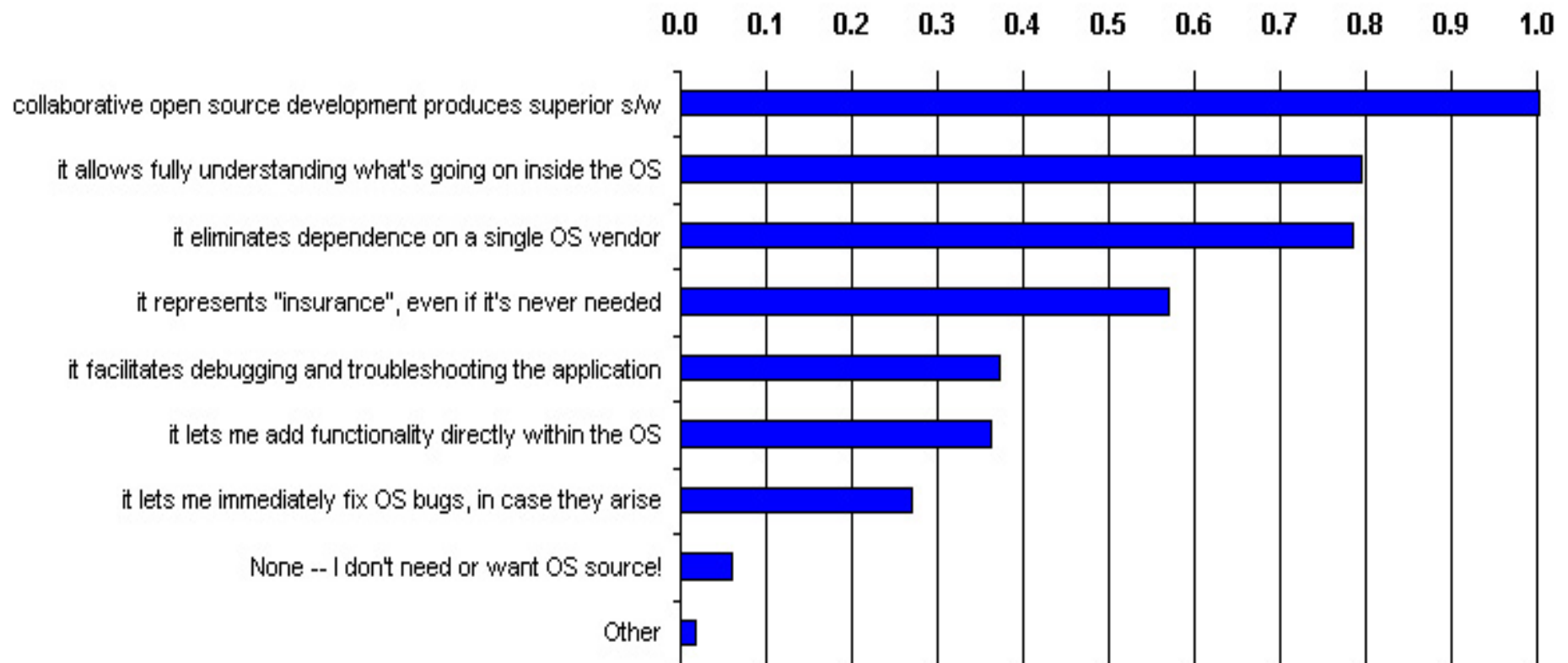


Source: LinuxDevices.com survey, December 2000 -- <http://www.linuxdevices.com/polls/>



What's special about Open Source?

What do you value most about using open source software in embedded applications?



Source: LinuxDevices.com survey, December 2000 -- <http://www.linuxdevices.com/polls/>



Commercial Embedded Linux

⇒ AMIRIX Embedded Linux

- Derived from Debian

⇒ Coollogic Coollinux

- Combines Linux and Java for Internet apps

⇒ Coventive Xlinux

- Kernel can be as small as 143KB

⇒ Esfia RedBlue Linux

- 400K, designed for wireless apps
-



Commercial Embedded Linux

- ⇒ KYZO Pizza Box Linux
 - SAMBA based file, print, CD server
 - ⇒ Lineo Embedix
 - Supports real time and high availability apps
 - ⇒ LynuxWorks BlueCat
 - General purpose embedded solution
 - ⇒ MontaVista Linux
 - General purpose embedded solution
-



Commercial Embedded Linux

- ⇒ Neoware NeoLinux
 - Red Hat derived for information appliances
 - ⇒ PalmPalm Tynux
 - Internet appliance and multimedia
 - ⇒ Red Hat Embedded Linux
 - General purpose embedded solution
 - ⇒ RedSonic Red-Ice Linux
 - Runs from DiskonChip or CompactFlash
-



Commercial Embedded Linux

- ⇒ RidgeRun DSP Linux
 - For multimedia, wireless, RT on DSP
 - ⇒ TimeSys Linux GPL
 - Low latency enhanced kernel
 - ⇒ Tuxia TASTE
 - Distro targets Internet appliances
 - ⇒ Vital Systems vLinux
 - For ARM based embedded apps
-



Open Source Embedded Linux

- ⇒ Embedded Debian Project
 - Convert Debian to an embedded OS
 - ⇒ ETLinux
 - It is small, modular, flexible and complete
 - ⇒ uCLinux
 - For microprocessors that don't have MM
 - ⇒ uLinux (muLinux)
 - Distro fits on a single floppy
-



Commercial Real Time Linux

- ⇒ FSMLabs
 - Open RT Linux
- ⇒ Lineo
 - Embedix Realtime
- ⇒ LynuxWorks
 - BlueCat RT



Commercial Real Time Linux

⇒ MontaVista Software

- Real Time Extensions

⇒ REDSonic

- REDICE Linux

⇒ TimeSys

- Linux/Real-Time

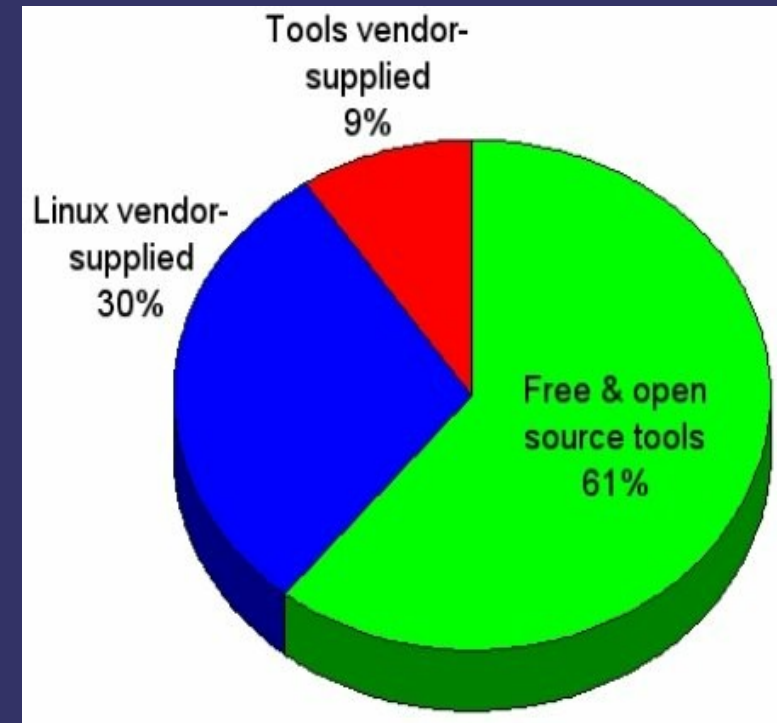
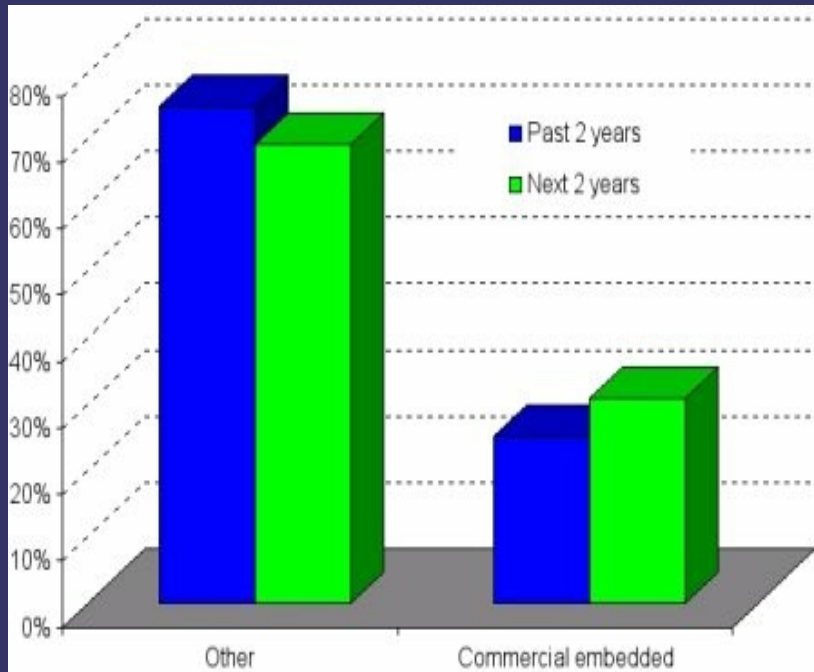


Open Source Real Time Linux

- ⇒ RT Linux
 - “Hard” Real Time Application Interface
 - ⇒ RTAI
 - “Hard” Real Time Application Interface
 - ⇒ KURT
 - Event schedules with 10us resolution
 - ⇒ Linux-SRT
 - For soft real time apps like multimedia
 - ⇒ Qlinux
 - Provides Quality of Service guarantees
-



Commercial or Open Source Linux



What makes them different?

- ⇒ Which of Linux utilities are included
- ⇒ What modules or utilities added
- ⇒ What kernel patches and modifications are provided
- ⇒ How the installation, configuration, maintenance, and upgrade process is managed.



How to create Embedded Linux?

- ⇒ Leaving out modules you don't need
- ⇒ Changing configuration

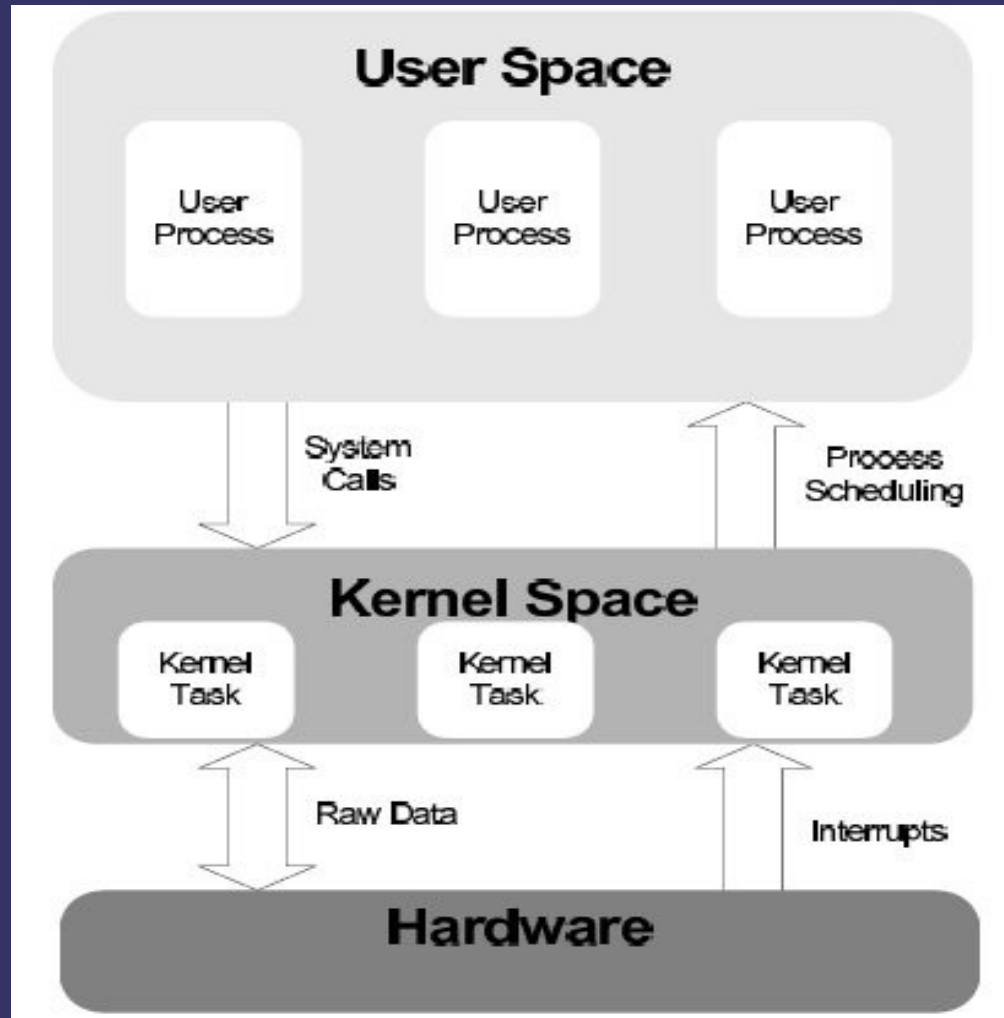


How to create Embedded Linux?

- ⇒ Linux is not a real-time operating system
 - The kernel disables interrupts
 - The kernel is not suitably preemptible
 - ⇒ Using the dual-kernel system
 - A general purpose (non-real-time) OS runs as a task under a real-time kernel.
 - The general purpose OS provides functions such as disk read/write, LAN/communications, serial/parallel I/O, system initialization, memory management, etc.
 - The real-time kernel handles real-world event processing.
 - ⇒ Modifying the Linux kernel
-



Linux kernel architecture



Providing Real Time Service within Linux

- ⇒ Preemption improvement
- ⇒ Interrupt abstraction

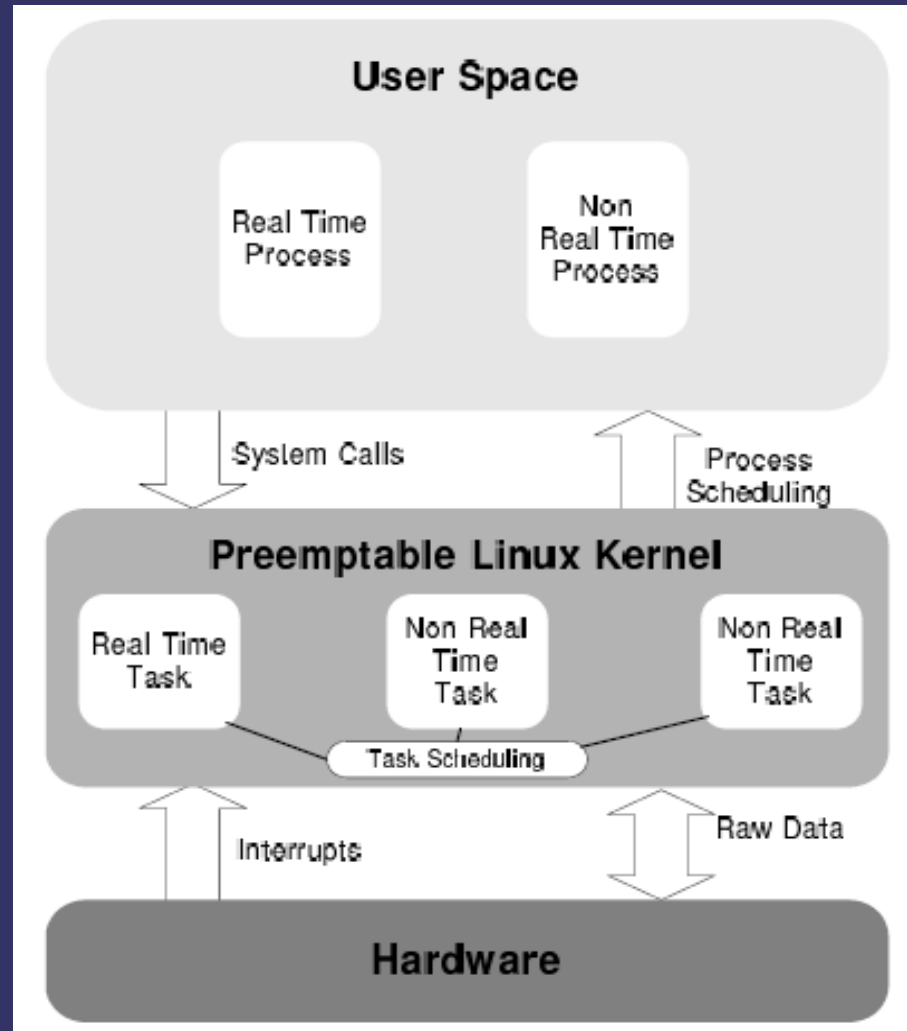


Preemption improvement

- ➔ Modifying the Linux kernel code to reduce the amount of time that the kernel spends in non-preemptible sections of code.
- ➔ It is used to implement **soft real time systems**.



Preemption improvement

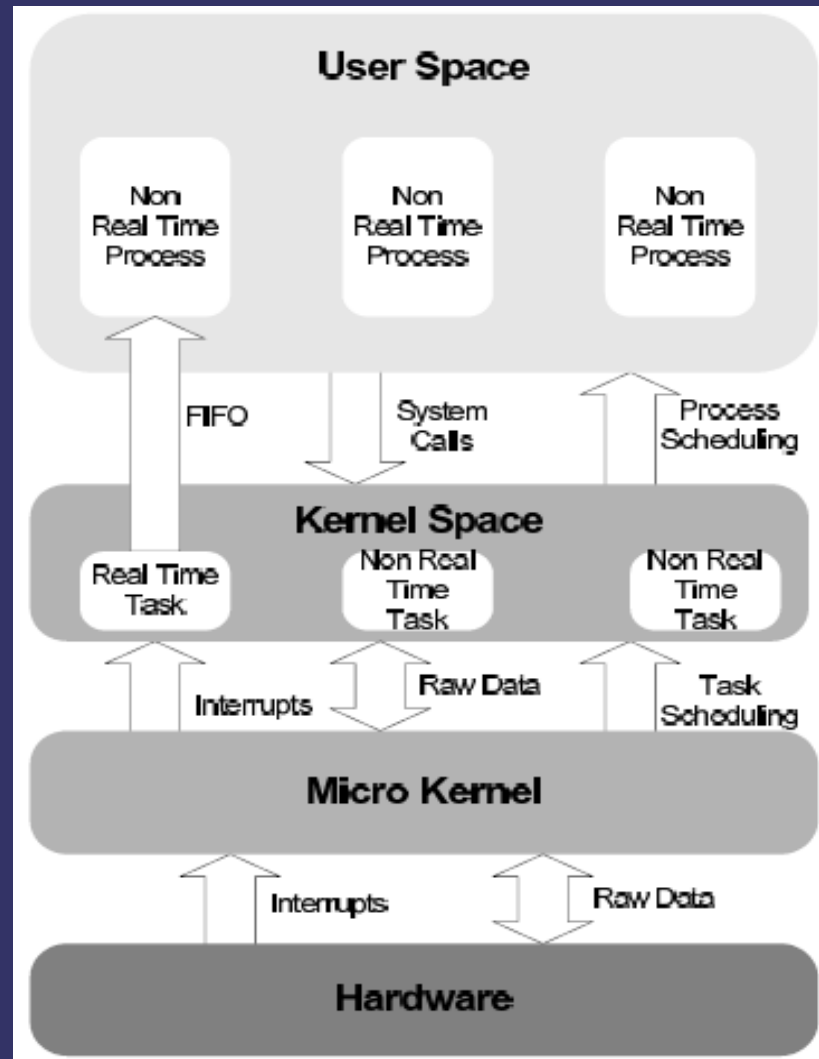


Interrupt abstraction

- ➔ The entire kernel is made preemptible by having a **separate hardware-handling layer**.
- ➔ This hardware abstraction layer has complete control over the hardware interrupts, and **simulates the interrupts** up to the Linux kernel in a way that allows the kernel to run unmodified on the real-time scheduler.
- ➔ This system is often described as a **micro-kernel system**.
 - where the full Linux kernel runs as the lowest priority task alongside real-time tasks in the system on top of the real-time scheduler.
- ➔ It is used to implement **hard real time systems**.



Interrupt abstraction



RTLinux and RTAI

- ➔ Interrupt abstraction
- ➔ Hard real time
- ➔ Real time tasks are operating in kernel space
- ➔ Real-time tasks are written to the API of RTLinux or RTAI, not to the Linux API.
- ➔ RTAI offers an alternative to kernel-space operation, in the form of LXRT.
 - LXRT supports the same API as RTAI, but via tasks that run in user-space.
- ➔ The recent announcement of RTLinux V3.0 pre-7 also introduces user-space real-time in RTLinux.
 - In this model, a function in user address space may be activated by an interrupt or timer.



MontaVista and TimeSys

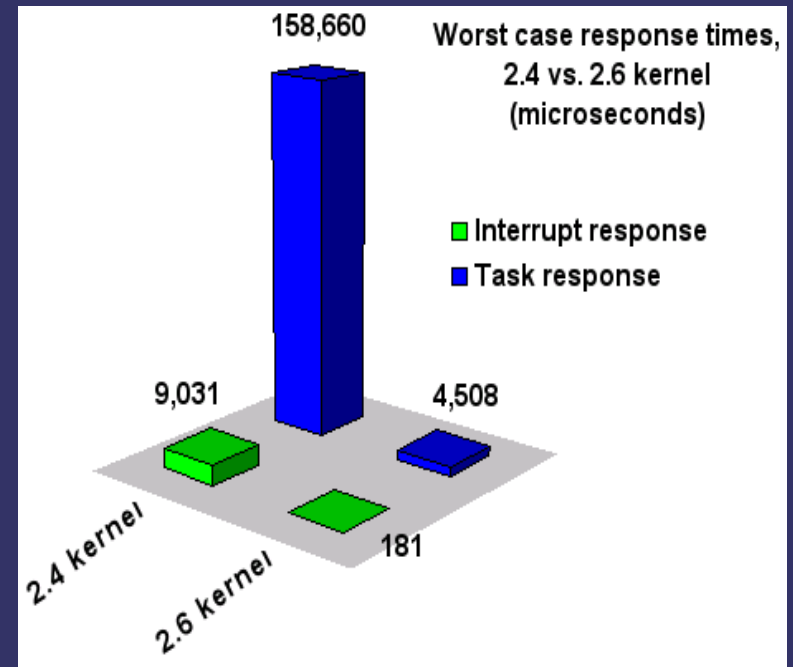
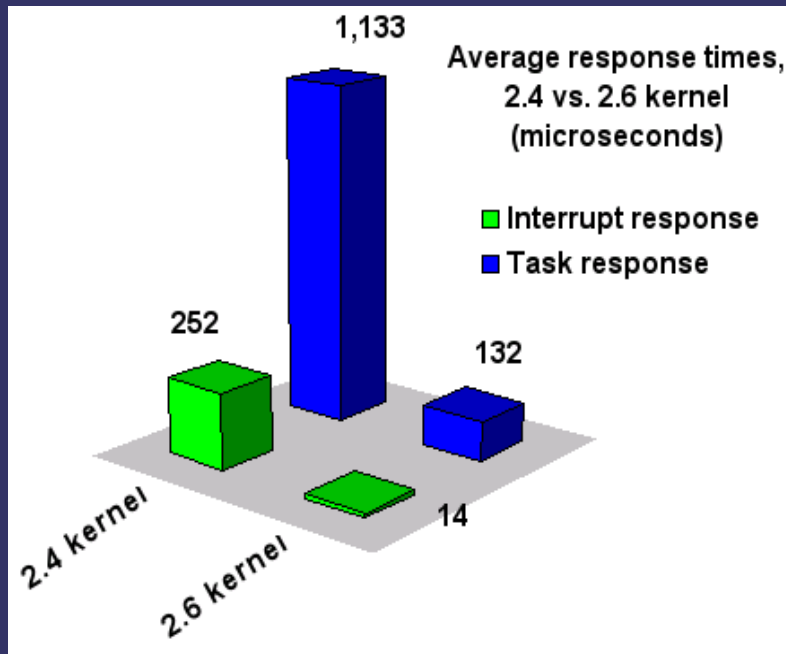
- ⇒ Preemption improvement
- ⇒ Hard real time
- ⇒ They use preemptible kernel
 - This preemption cannot be done safely at arbitrary places in the kernel code (critical sections).
- ⇒ They alter the spin-lock calls to additionally prevent preemption.
- ⇒ They use separate real time kernels.
 - Interrupt abstraction
 - MontaVista uses RTLinux
 - TimeSys uses RTAI



Kernel 2.4 vs. 2.6



Linux Kernel 2.4 vs. 2.6



Device Drivers and Loadable Kernel Modules

- ➔ The Linux 2.6 kernel introduces a new, unified framework for device drivers.
 - ➔ The new driver model provides a framework for full and complete support for device Plug and Play and power management by defining the interfaces that these subsystems can use when communicating with individual drivers.
 - ➔ The new driver framework provides a much cleaner separation of responsibilities between buses and drivers.
 - ➔ The 2.6 Linux kernel also introduces the sysfs filesystem to provide a hierarchical view of each system's device tree.
 - ➔ The 2.6 Linux kernel also introduces a new naming convention for loadable kernel modules, using the .ko extension (kernel object) rather than the standard .o (object) extension used for loadable kernel modules in all previous stable releases of the Linux kernel.
-



Verifying and updating critical packages

Software Package	Minimum Version	Command to Show Version
binutils	2.12	<code>ld -v</code>
e2fsprogs	1.29	<code>tune2fs</code>
gcc (GNU C Compiler)	2.95.3	<code>gcc --version</code>
make (GNU make)	3.78	<code>make --version</code>
module-init-tools	0.9.10	<code>depmod -V</code>
procps	3.1.13	<code>ps --version</code>
util-linux	2.10o	<code>fdformat --version</code>



Real Time Linux Alternatives

	Commercial Real-time Distributions				Open Source Real-time Projects						
	MontaVista Hard Hat Linux	TimeSys Linux/RT	Lineo Embedix RealTime	REDSonix RED-ICE Linux	RTLinux	RTAI	RTAI + LXRT	RED-Linux	KURT	Linux-SRT	Molnar patch
Separate real-time kernel	with RTLinux	with RTAI	with RTAI	with RTAI	✓	✓	✓				
User space programming	✓	✓	✓	✓	(2)		(1)	✓	✓	✓	✓
Improved Linux kernel preemption	✓	within RK		✓				✓			✓
"Fully preemptible" Linux kernel	announced	announced									
Precise scheduling, within Linux	✓	with RK, without RTAI		✓				✓	✓	✓	
Includes solution for priority inversion, within Linux		with RK, without RTAI									
"Fast" Interrupt response, < 1 mS	with RTLinux	with RTAI	with RTAI	with RTAI	✓	✓	✓				
"Moderate" interrupt response, < 5 mS, within Linux	✓	within RK		✓				✓			✓
Improved precision for time/timers, within Linux		with RK, without RTAI		✓				✓	✓		

NOTES: (1) = Limited (2) = Very limited



Applications and Products



What's It Being Used For?

- ⇒ Control and Monitoring Applications
- ⇒ Industrial Controllers
- ⇒ TV Set Top Boxes (TiVO)
- ⇒ Handheld PDA's
- ⇒ Automobile Computers
- ⇒ Telecomm and Networking Hardware
- ⇒ Other uses...



Cyclades TS-100 (Console Server)



- ⇒ Netlinos OS
- ⇒ Dual 50MHz PowerPC
- ⇒ 16MB SDRAM 4MB Flash
- ⇒ Ethernet/Serial/RS485



Sixnet VersaTRAK IPm (Remote Terminal Unit)



- ⇒ Embedded Linux
- ⇒ PowerPC CPU
- ⇒ 16MB DRAM 16MB Flash
- ⇒ Serial & Ethernet Ports



Sharp Zaurus

- ➔ Lineo Embedix
- ➔ 206 MHz StrongARM
- ➔ 64 MB DRAM 16MB Flash
- ➔ 3.5" display (320x240) 64K colors
- ➔ Opera browser & Qtopia
- ➔ QT/Embedded GUI



Cell and Web Phones



Telepong
Mobile Phone



GITWiT
Mobile Phone



Aplio/PRO
IP Phone



TIVO Set Top Box



- ⇒ Home grown port of Embedded Linux
- ⇒ 54MHz PowerPC
- ⇒ Multi GB hard disk



Axis 2120 Network Camera



- ⇒ uCLinux
- ⇒ Built-in Ethernet port
- ⇒ 100 MHz ETRAX CPU
- ⇒ 16 MB RAM



Humanoid Robots

- ⇒ Univ. of Tokyo
- ⇒ Dual Pentium CPU
- ⇒ RT-Linux
- ⇒ Height: 53 inches
- ⇒ Weight: 121 lbs



Humanoid Robots

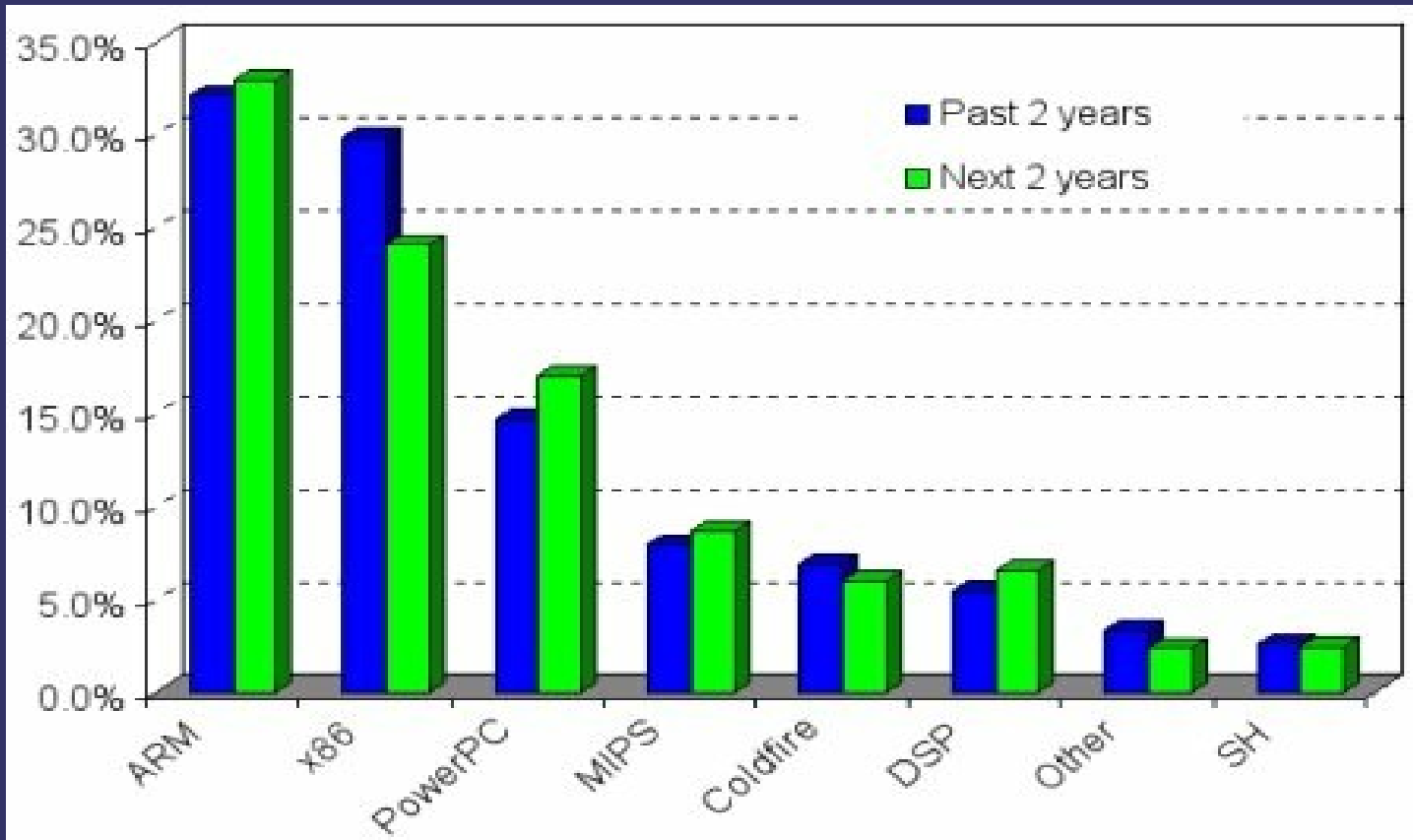
- ⇒ Fujitsu
- ⇒ RT-Linux
- ⇒ Height: 48 cm
- ⇒ Weight: 6 kg



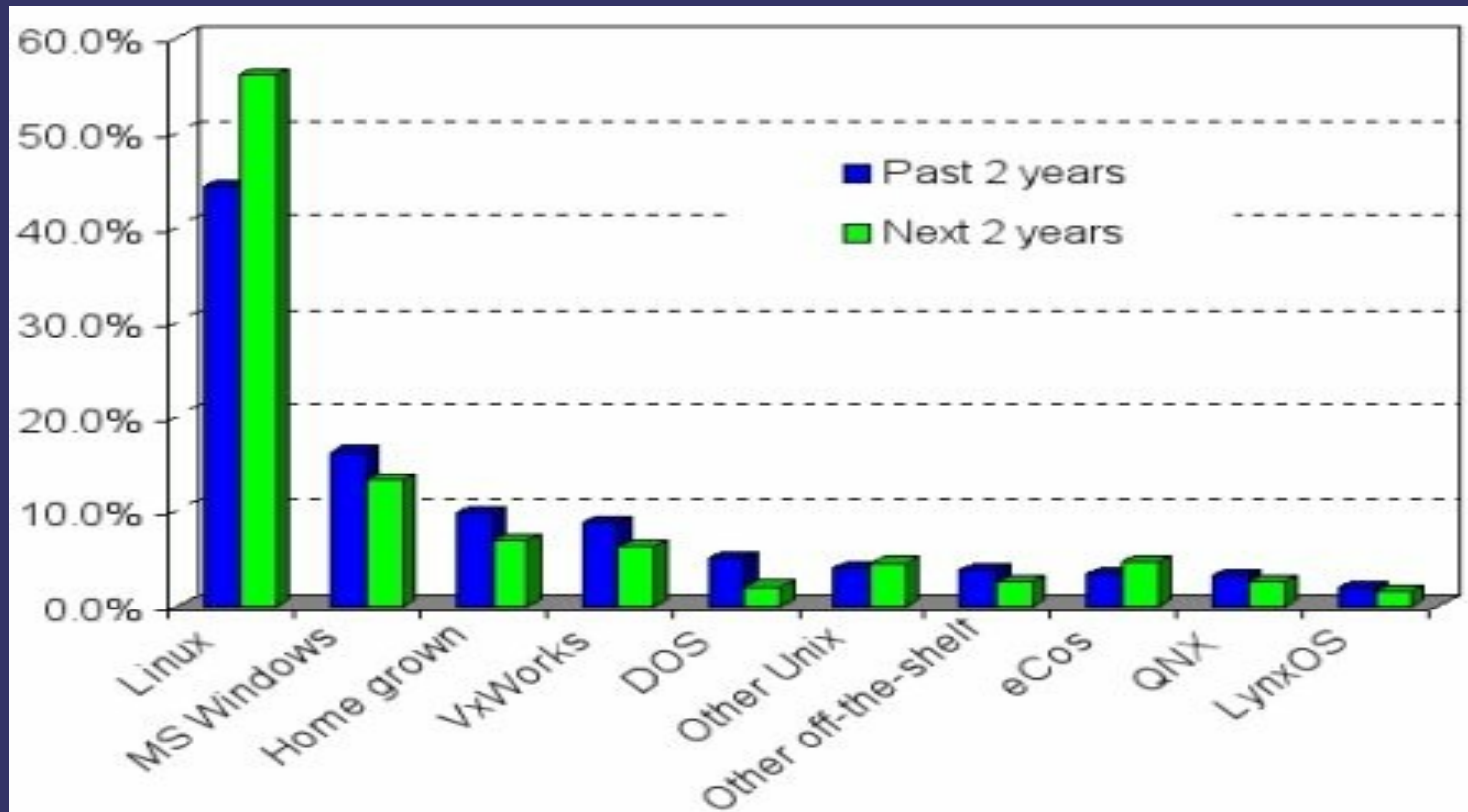
The Embedded OS Market



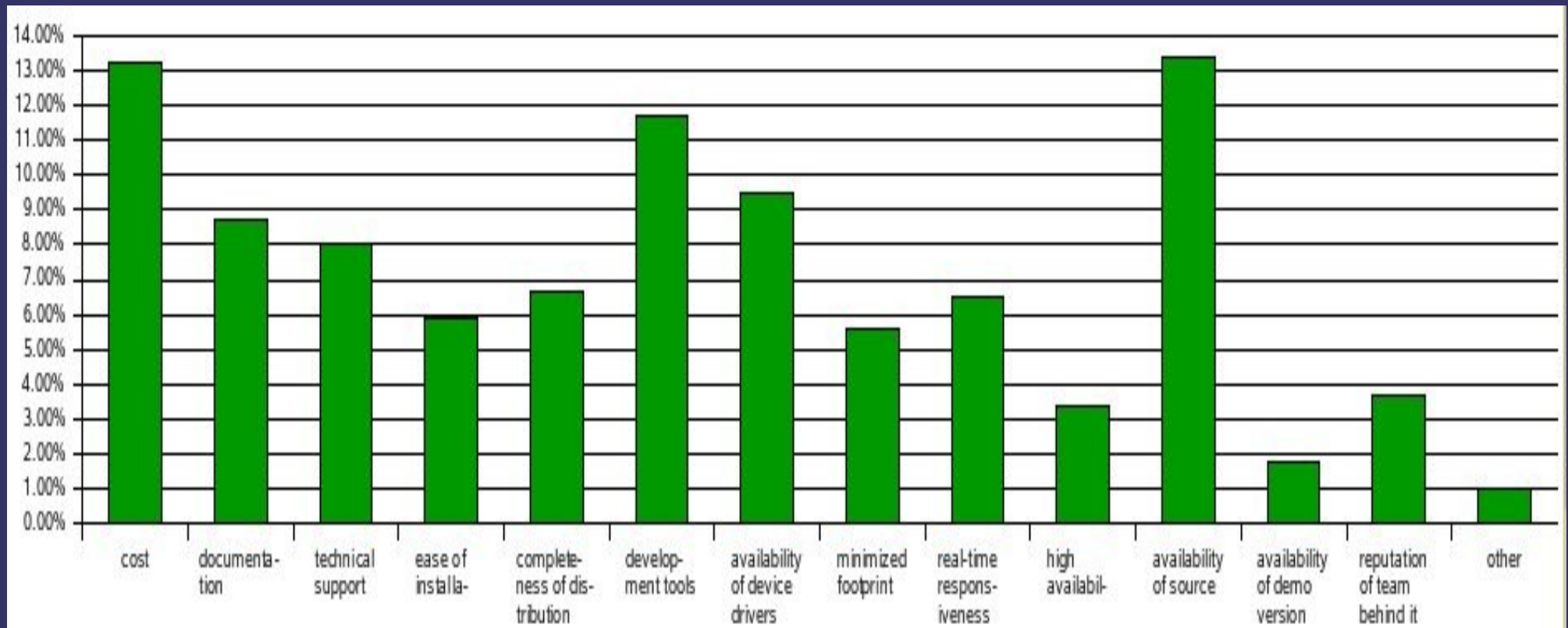
What CPU's will it run on?



Which OS for Embedded System (2005)

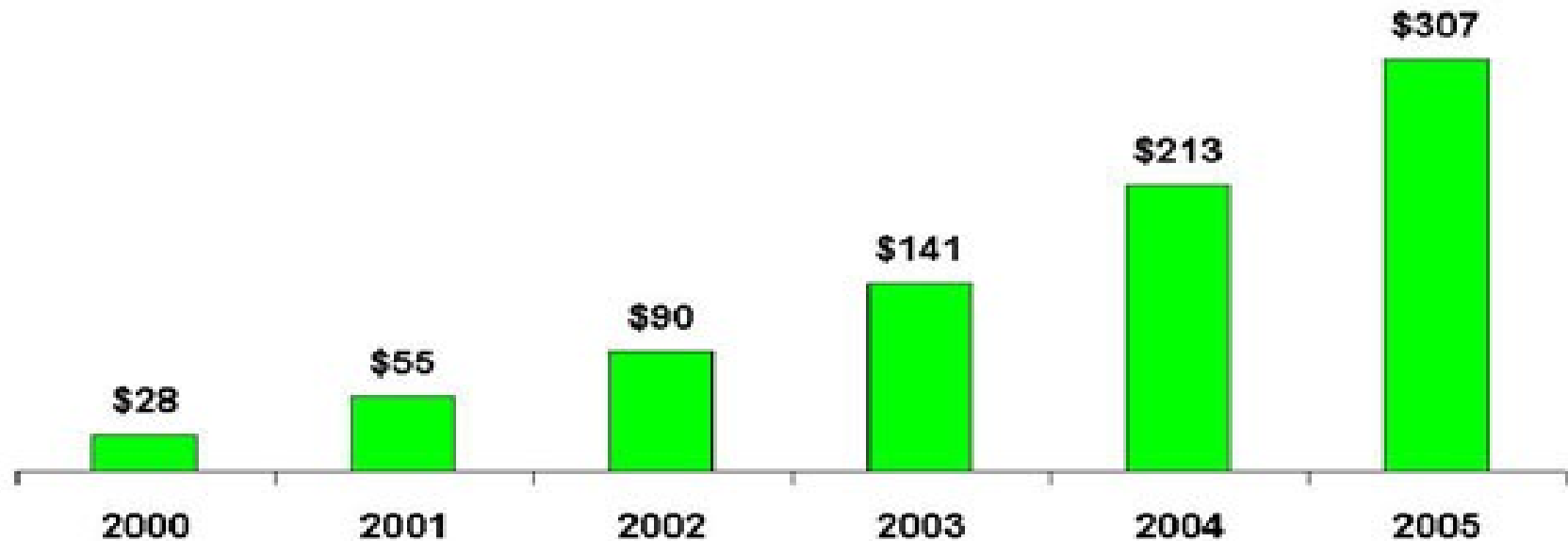


The Choice Factor (2005)



Growth of Embedded Linux

Worldwide Shipments of Embedded Linux OSes, Software Development Tools, and Related Services
(in millions of dollars)



Source: Venture Development Corporation (VDC) 2000 Embedded Linux Market Study

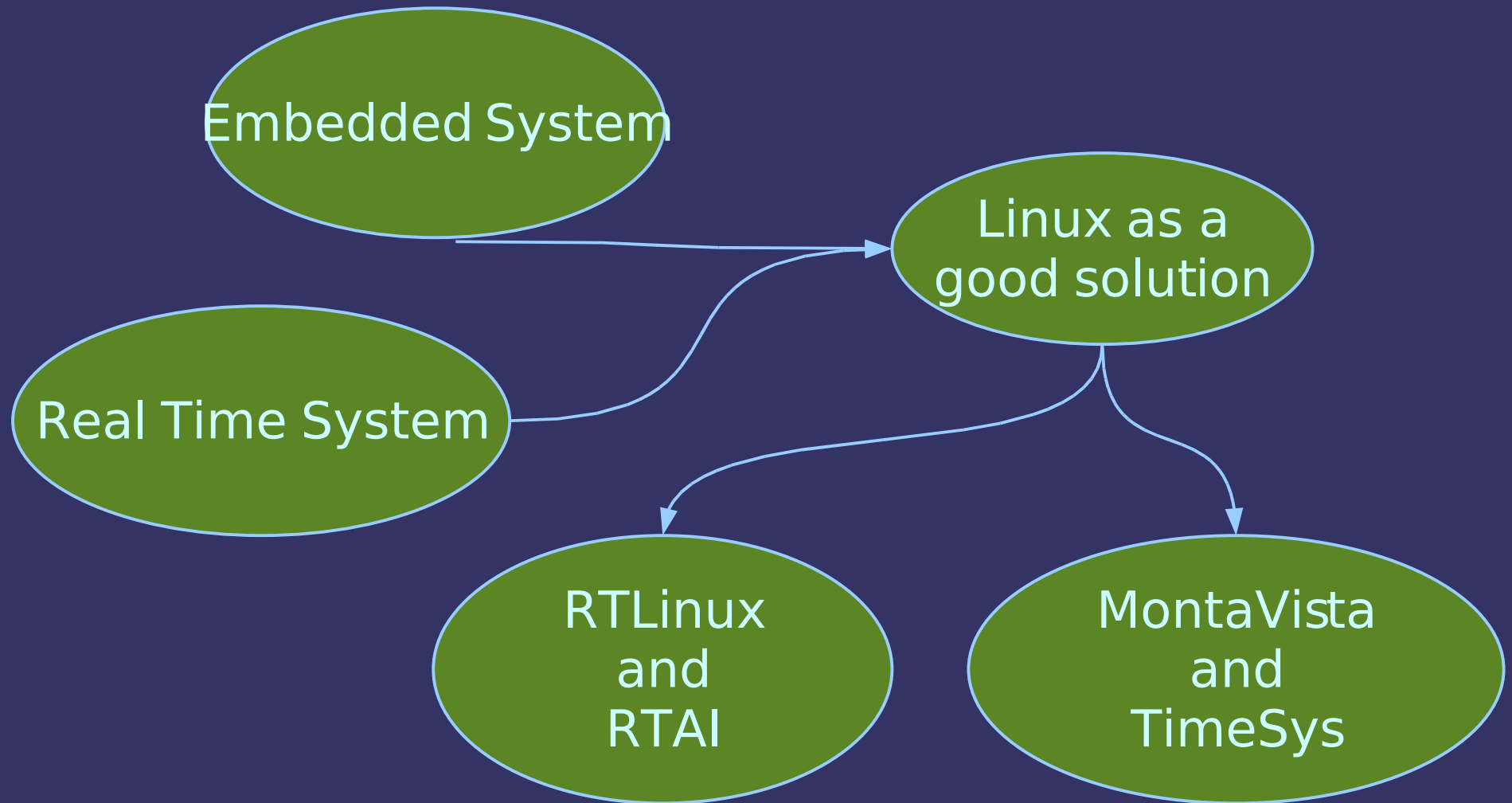
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Conclusion



Conclusion



Resources

- ➔ LinuxDevices.com
<http://www.linuxdevices.com/>
- ➔ Embedded Linux Consortium
<http://www.embedded-linux.org>
- ➔ All Linux Devices
<http://alllinuxdevices.com/>
- ➔ Embedded Linux StarGate
<http://linux-embedded.com/>



Questions



Comments

