Introduction: Embedded Operating Systems and Linux

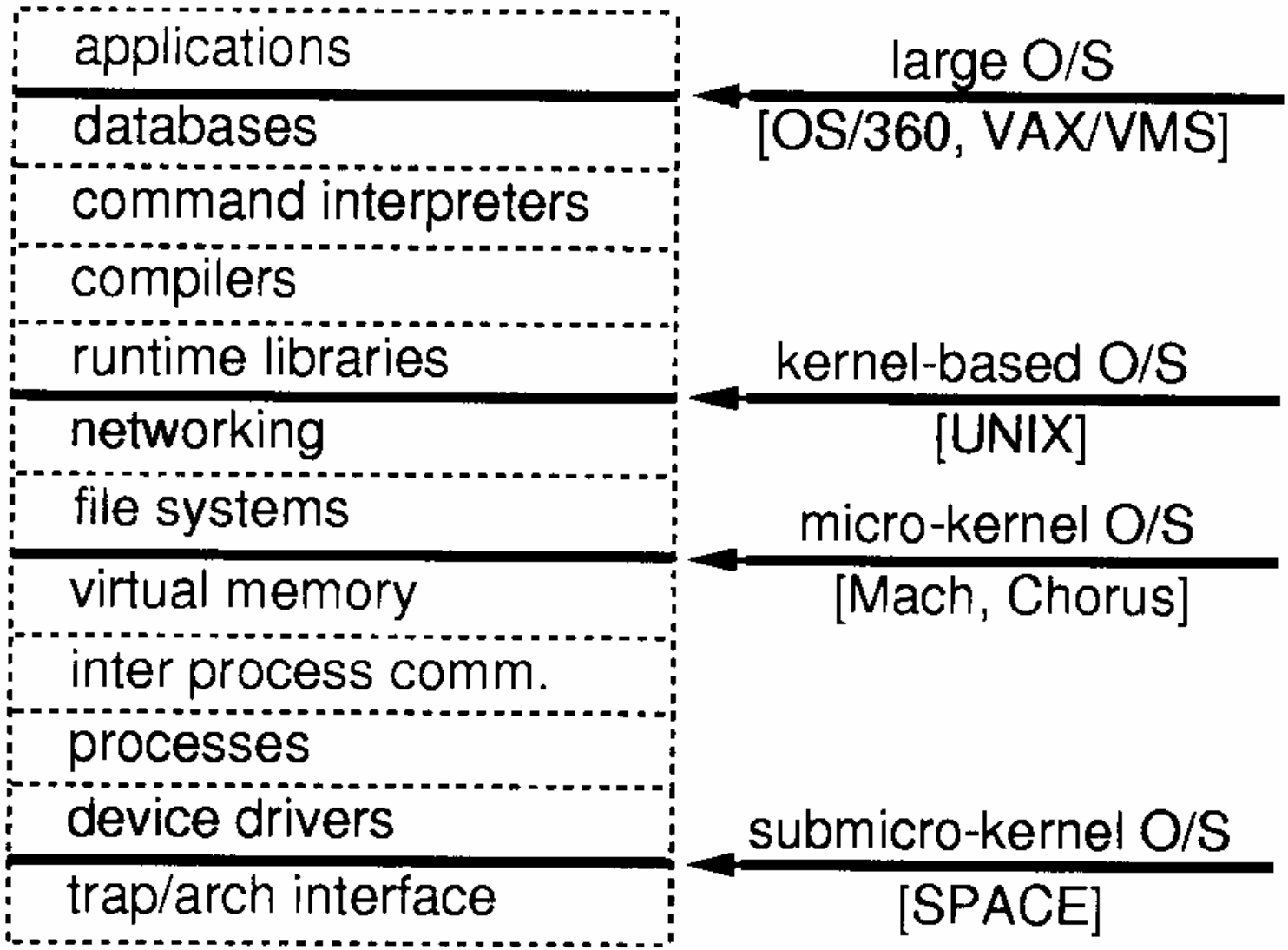
Outline

- What is an embedded Operating System
- Linux as an embedded OS
- Is Linux Real-Time?
  - Can it be and How?
- Embedded Linux Distributions
- What is the Cost of Embedded Linux
- Tools and development
- Embedded Linux Resources

What is an Operating Systems?

- “A Very Special Program” that provide a software platform on top of which other programs, called application *programs*, can run.
- The application programs must be written to run on top of a particular operating system.
- Your choice of operating system, therefore, determines to a great extent the applications you can run.

Various OS Abstractions



OS Varieties

- Desktop
  - Windows (9X, XP Home, XP/2000 Prof)
  - Mac
- Server
  - Windows (XP/2000 Server &Advanced Server)
  - Unix Varieties
- Embedded
  - VxWorks, Windows CE, Embedded Linux, ….

What is an Embedded OS?

- An embedded OS is an operating system which runs on any embedded platform.
- Embedded platforms are generally required to function without human intervention.
- A typical embedded system consists of a single-board microcomputer or SOC with an OS and some software loaded in ROM.
  - It will not usually have any of the normal peripherals such as a keyboard, monitor, serial connections, mass storage, etc. or any kind of user interface software unless these are required by the overall system of which it is a part.
- Often an embedded OS must provide real-time response to perform its requirements.

What makes a good Embedded OS?

- Modular
- Scalable
- Configurable
- Small footprint
- CPU support
- Device drivers
- etc, ...

What is Real Time?

- The ability of the operating system to provide a required level of service in a bounded response time. - POSIX Standard 1003.1.
- Not the CPU speed
- But the Time Constraints.

Hard vs. Soft Real Time

- Hard
  - *guaranteed worst-case* response times
  - absolutely, positively, first time every time
- Soft
  - Kinda, sorta, usually

What makes a good RTOS?

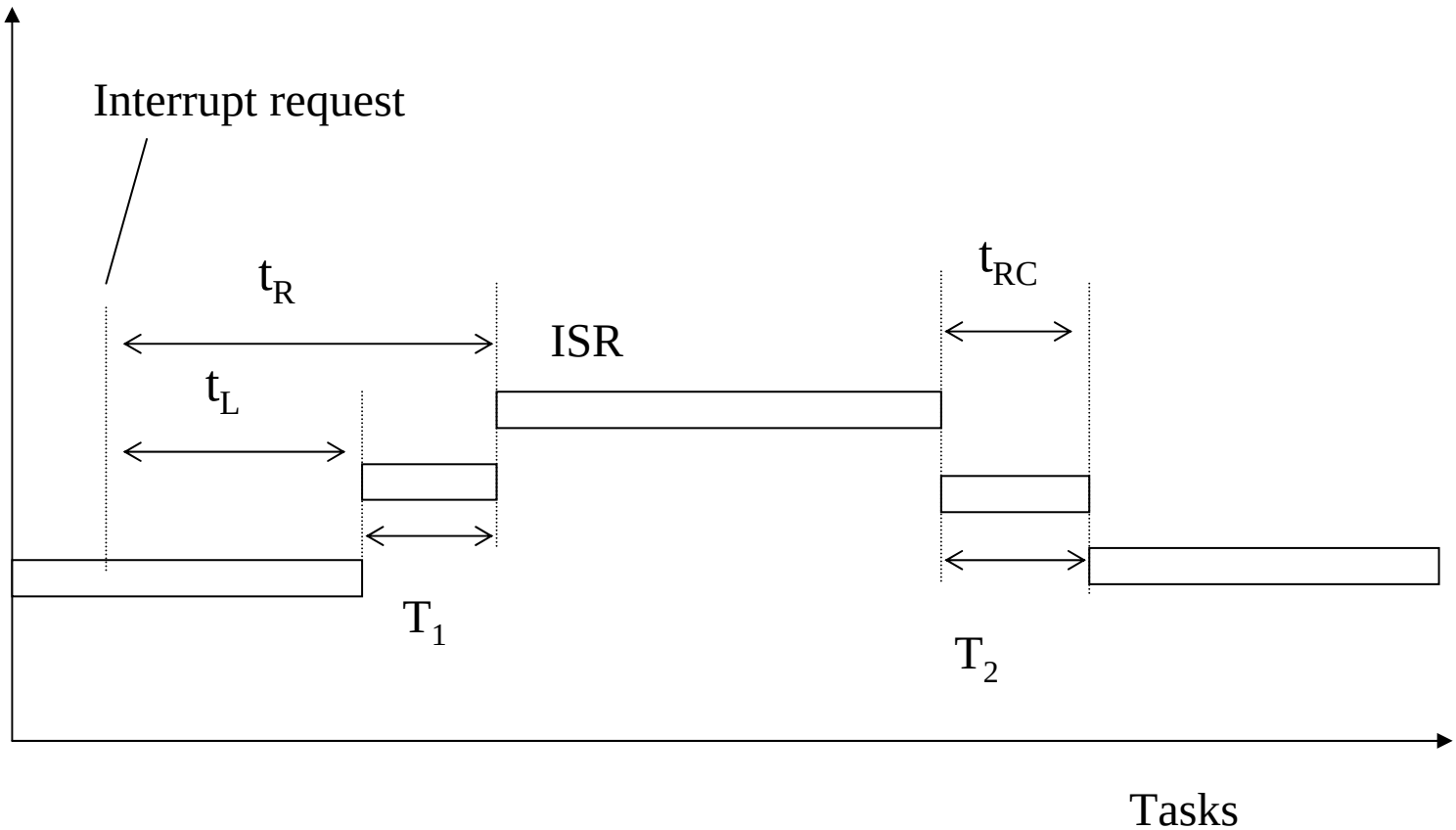
- Multi-threaded and preemptible
- Thread/Task priority-based scheduling
  - Static or Dynamic
- Must support predictable thread synchronization mechanisms
- Should have a system of priority inheritance
  - To solve priority inversion problems

Interrupt latency

- Traditional UNIX Operating systems suffer from large interrupt latency
- How to reduce the interrupt latency?
  - Make kernel highly preemptible by changing its internal structure (minimizing interrupt disabling) or adding a set of preemption points
  - Microkernel approach

Definition of Interrupt Latency

- Interrupt latency(t_L), response(t_R), and recovery (t_{RC}) times, T_1: time for saving CPU contexts, T_2: time for restoring CPU contexts



Linux and Real-Time

- Is Linux Real-Time?
  - In a nut shell : **NO, BUT…**
- Why?
  - (Monolithic Kernel) The Linux kernel uses coarse grained synchronization, which allows a kernel task exclusive access to some data for long periods. This could delay the execution of any POSIX real-time task that needs access to that same data.
  - (NotPreemptible in Kernel Mode) The Linux kernel does not preempt the execution of any task during system calls. If a low priority process is in the middle of a system call and a message is received for a real-time process, the message will unfortunately be held in the queue until the system call completes, despite its low priority.

Linux and Real-Time

- (Resource Lock) Linux makes high priority tasks wait for low priority tasks to release resources. For example, if any process allocates the last network buffer and a higher priority process needs a network buffer to send a message, the higher priority process must wait until some other process releases a network buffer before it can send its message.
- (Priority Scheduling) The Linux scheduling algorithm will sometimes give the most unimportant and nicest process a time slice, even in circumstances when a higher priority process is ready to execute.

Who are the Embedded OS Vendors?

- Wind River Systems
  - VxWorks
  - pSOS
- QNX Software Systems
  - QNX
- Microsoft
  - Windows CE, …

Who are the Embedded OS Vendors? -2

- Mentor Graphics
  - VRTX
- Palm Computing
  - PalmOS
- Symbian
  - SymbianOS

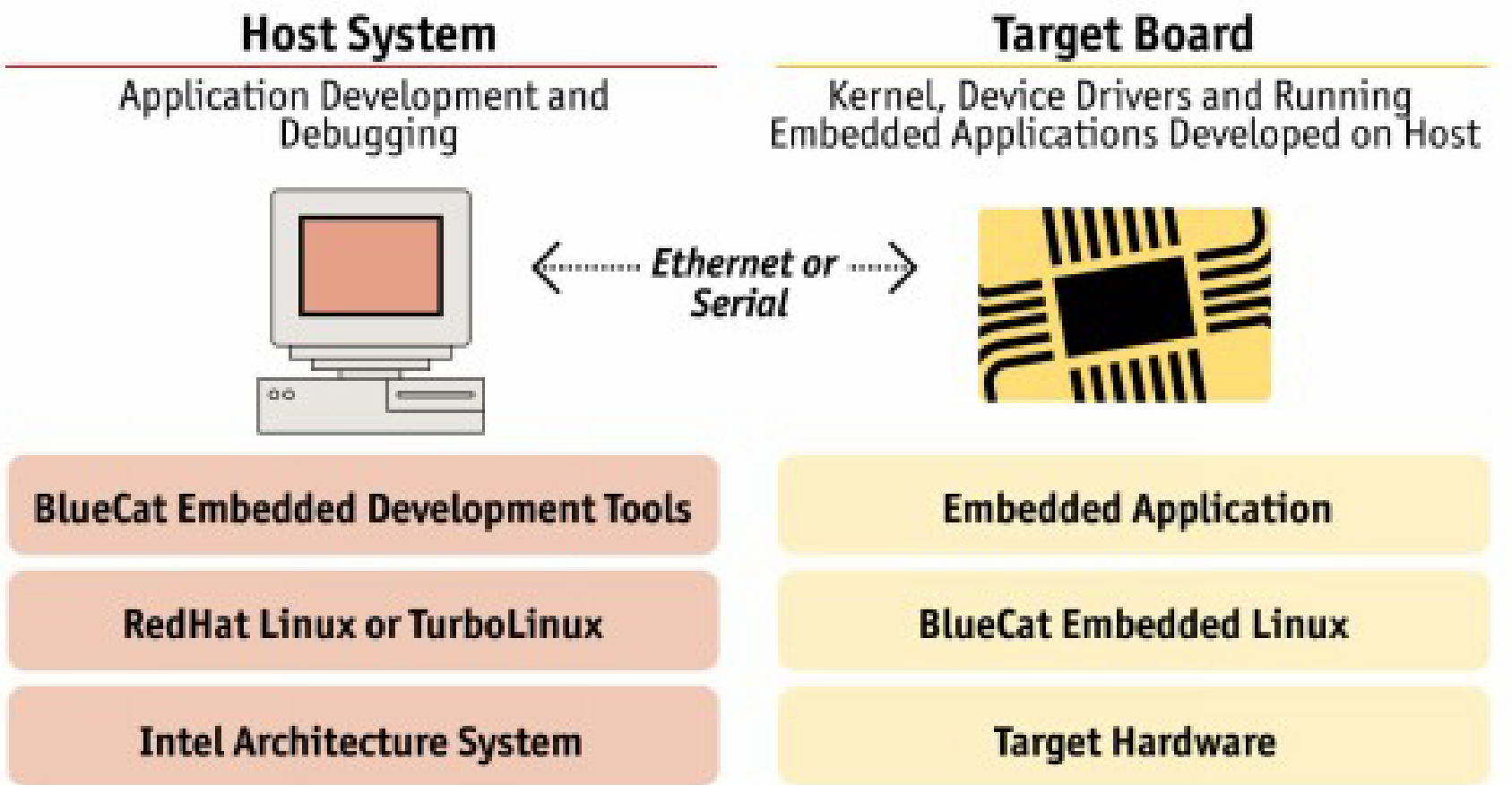
Microsoft

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

Commercial Embedded Linux

- Lineo Embedix
  - supports real time and high availability apps
- LynuxWorks BlueCat
  - general purpose embedded solution
- MontaVista Linux
  - general purpose embedded solution

BlueCat Embedded Linux



Open Source Embedded Linux

- Embedded Debian Project
  - convert Debian to an embedded OS
- uCLinux
  - for microprocessors that don’t have MM

Commercial Linux RTOS

- FSMLabs - Open RT Linux
- Lineo - Embedix Realtime
- LynuxWorks - BlueCat RT
- MontaVista Software - Real Time Extensions
- TimeSys - Linux/Real-Time

Open Source RTOS

- Linux-based RTOS
  - RTLinux
  - RTAI - “hard” Real Time Application Interface
  - KURT - event schedules with 10us resolution
- Other embedded RTOS
  - eCos

RTLinux

- A “hard real-time” mini operating system
- runs Linux as it’s lowest priority execution thread
- Linux thread completely preemptible
- Real time threads and interrupt handlers never delayed by non-realtime operations
- Supports user level programming
- MiniRTL implementation fits on a floppy

KU Real-Time Linux (KURT)

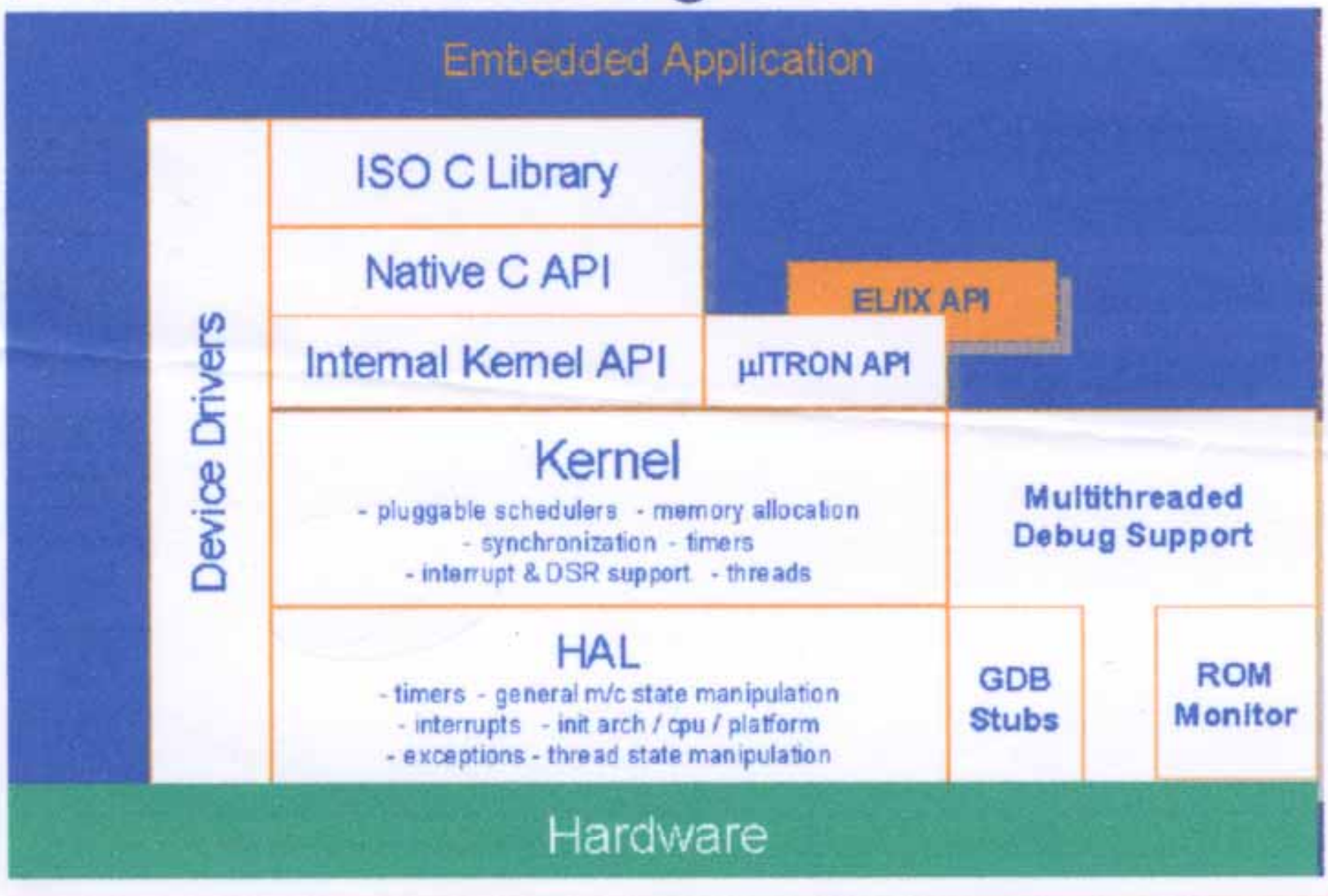
- Kernel modifications in
  - Increasing the resolution of the Linux software clock
  - Scheduling algorithm for firm real-time applications
- KURT scheduler: an explicit plan scheduler, requiring real-time applications to state explicitly the times at which events are to occur.

eCOS: free real-time OS from Red Hat

- eCOS(an embedded configurable operating system)
- Host platforms:
  - Red Hat Linux 5.x, 6.x
  - Window NT 4.0
- Target Architectures: ARM7, 9, PowerPC, MIPS, i386,…

eCos Architecture

Kernel Block Diagram



Advantages of 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

Issues in Linux

- Lack of hardware device drivers
- Competing and/or lacking standards
- No formalized qualification testing
- No single source for marketing
- GPL license issues
- Startup vendors with shaky futures

What CPU’s will it run on?

- Intel X86
- MIPS
- ARM
- StrongARM
- PowerPC
- Hitachi SuperH

Any Development Tools Available?

- QT/Embedded
- Other GUI/Windowing toolkits
- Arcom Control Systems
- GNUPro Tools
- Vendor specific
- Standard Linux toolset

C or C++ for Development?

- In general C is a better choice
  - Advanced OOP features can cause code bloat
  - C++ compilers can generate many routines for a single function
  - Virtual methods and polymorphism slow program launch times significantly
- Size really *does* matter

What is the Cost of Embedded Linux

- Build Embedded Linux OS yourself.

  Advantage:

  - Cost
  - Educational Process
  - Ultimate Control

  Disadvantage:

  - Not very easy
  - Can be a problem to maintain latest changes

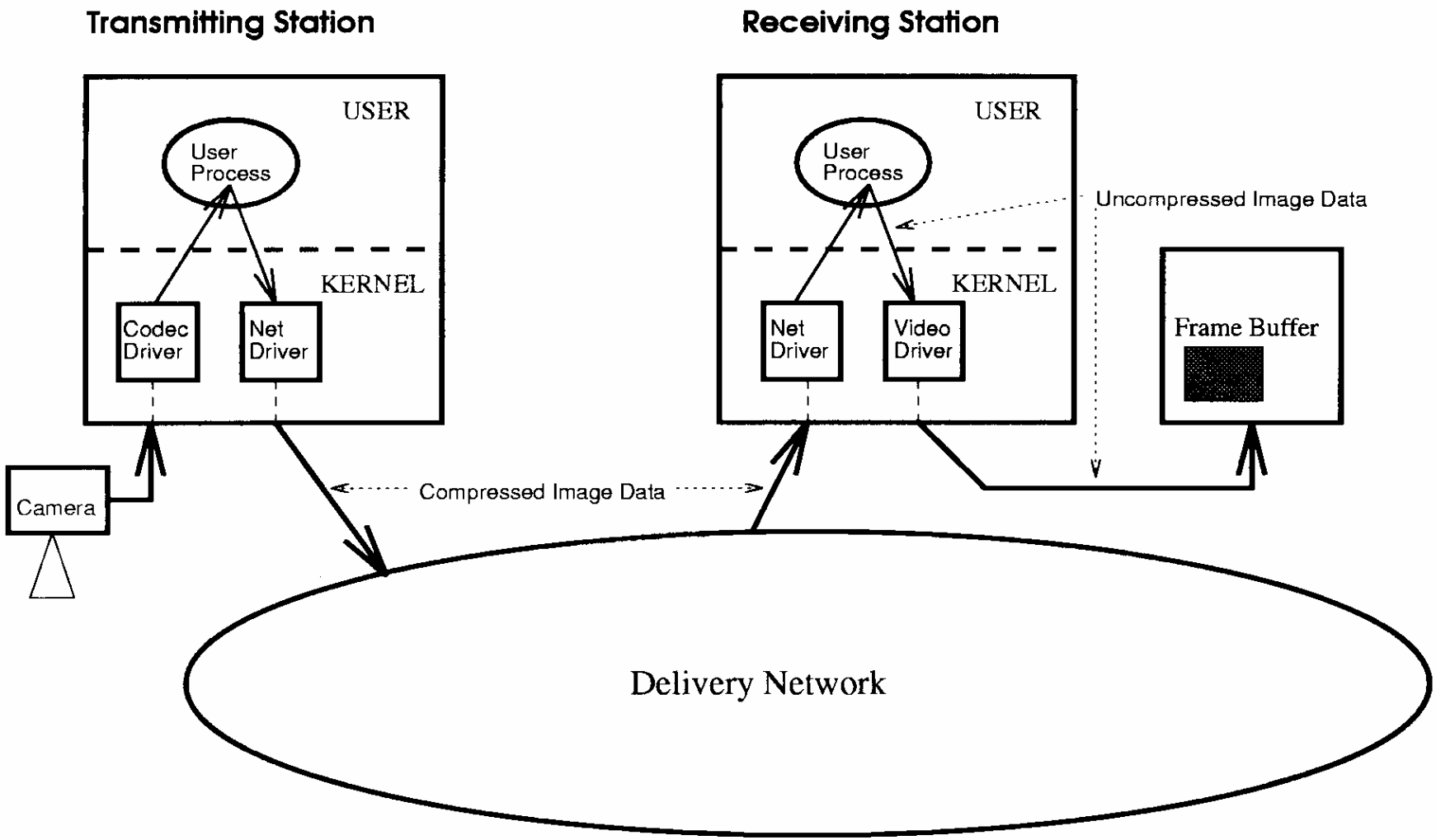
  Recommendation:

  - Getting one of the commercially available embedded Linux OS products.
  - Open source projects hosted by organizations

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
- Myriad and sundry other uses...

An example of networking environment



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

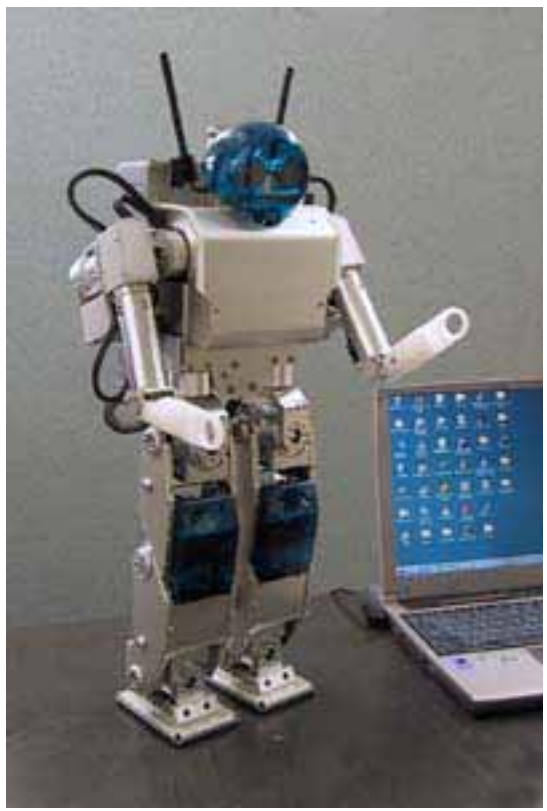
Humanoid Robots

- Isamu

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

Humanoid Robots

- HOAP



- Fujitsu
- RT-Linux
- Height: 48 cm
- Weight: 6 kg
- 100 units/yr

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