The OS Wars

Selecting the Right Operating System for your CE Device

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Success

- It works!
- On time
- Under budget

Conclusion

Success of a CE software project depends on:

- Experience of software team
- Core OS technology
- Tools
- Off-the-shelf components / Code re-use

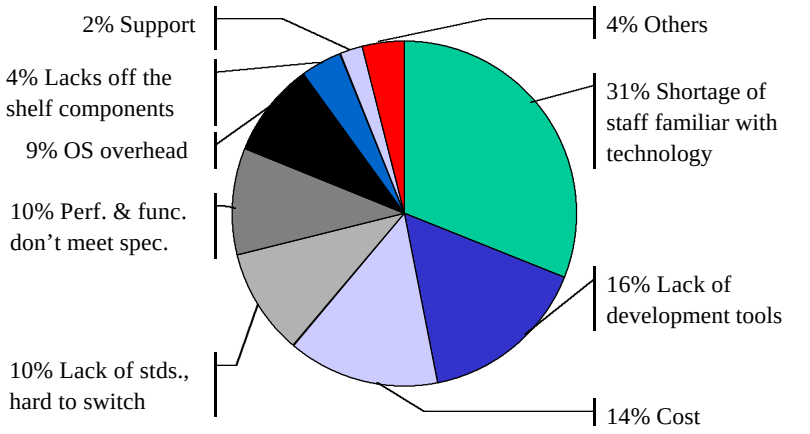
Evaluation Criteria

Qualitative comparison of

- OS Architectures
- Tools
- Off the shelf components
- Licensing models

Problems with RTOS's

Source: TRON Association Survey in Japan



CE may not be Real-Time

Real-Time
- Set-top box
- Mobile phone
- Modems
- GPS receivers

unReal-Time
- PDA
- Web receivers

Low user interaction

High user interaction

Tutorial Outline

- OS Architecture
  - Execution model, Memory model, Processor mode, Interrupt model, Preemption model, Scheduling policy, Inter-process communication, Dynamic component support
- Tools - hardware, software
- Processor support, off the shelf components
- Licensing models
- Java

OS Architecture

- Execution model
- Memory model
- Processor mode
- Interrupt model
- Preemption model
- Scheduling policy
- Inter-process communication
- Dynamic component support

OS Architecture

- Execution model
- Memory model
- Processor mode
- Interrupt model
- Preemption model
- Scheduling policy

- Inter-process communication
- Dynamic component support

Impact security/reliability

Execution Model

- Threads
- Processes / Tasks
  - traditional kernel like Lynx, OS-9, WinCE
  - micro kernel like QNX

Threads

- Share all memory
- All threads share all global variables
- Typically all threads run in privileged mode

Thread Based Kernels

Advantages

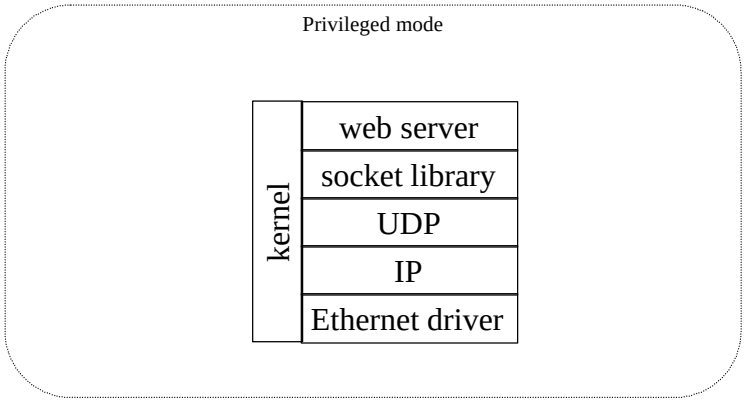
- Fast context switch
- Simple
  - direct calls into kernel
- Easier preemption
- Shared globals

Disadvantages

- Lack of security
- Shared globals
- One rouge application damages entire system
- Cannot support processes

Examples: Nucleus, VxWorks

Thread Example



Processes

Each process has its own:

- Memory space
- Global variables
- Default processor state

Process Based Kernels

Advantages

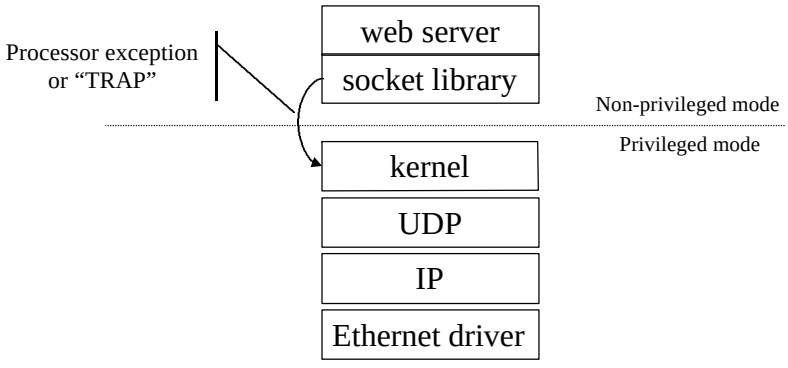
- Secure
  - inter process
  - globals
- Can support threads

Disadvantages

- Slower context switch
- Complex
  - exception into kernel
- Complex variable sharing
- Insecure system s/w

Examples: Lynx, OS-9, WinCE

Process Example



Microkernels

- Don’t trust anyone
- Only kernel in privileged mode
- Everything else is a process in non-privileged mode

Process Based Microkernels

Advantages

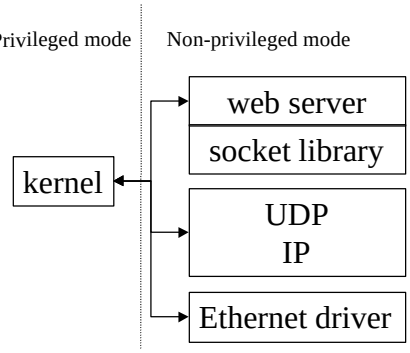
- Very secure
  - inter process
  - variables
  - system software
- Can support threads

Examples: QNX

Disadvantages

- Slowest
  - context switch
  - message passing
- Complex
  - exception into kernel
- Complex variable sharing

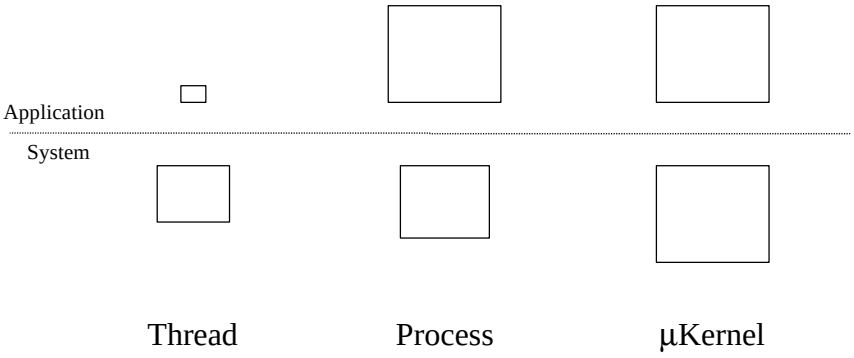
Microkernel Example



Execution Model Review

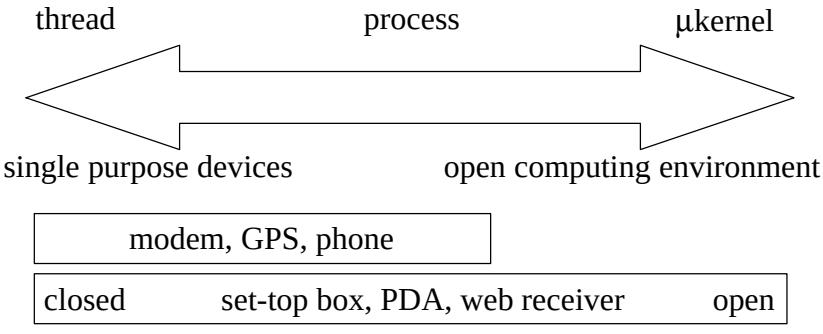
- Itron — Thread or Process
- Linux — Process + Thread
- Lynx — Process + Thread
- Nucleus — Thread
- OS-9 — Process
- pSOS+ — Process + Thread
- QNX — Microkernel
- VxWorks — Thread
- WinCE — Process + Thread

Suitability Based on Complexity



Area of box represents amount & complexity of software

Suitability to Device Type



Memory Model

- Flat/real/absolute memory space
  - each execution unit sees same address space
  - MMU optional
  - subject to memory fragmentation
- Virtual memory space
  - each EU's address space starts at zero
  - requires MMU
  - not subject to fragmentation

Memory Model

• Itron	Absolute
• Nucleus	
• OS-9	
• pSOS+	
• VxWorks	
• Linux	Virtual+disk(required)
• Lynx	Virtual+disk
• WinCE	Virtual+disk
• QNX	Virtual+disk

Processor Mode

- Privileged
  - can execute all privileged instructions
  - can access all memory
- Non-privileged
  - restricted to “safe” instructions
  - only memory allowed by MMU

Processor mode

- Itron privileged+non-privileged
- Linux privileged+non-privileged
- Lynx privileged+non-privileged
- Nucleus privileged
- OS-9 privileged+non-privileged
- pSOS+ privileged+non-privileged
- QNX privileged+non-privileged
- VxWorks privileged
- WinCE privileged+non-privileged

Interrupt Model

- Nested interrupts (NI)
- Multiple interrupts per vector (MIPV)
- Partial masking at all levels (PM)

Interrupt Model

- Itron NI, MIPV?, PM
- Linux NI, MIPV
- Lynx MIPV
- Nucleus NI, MIPV
- OS-9 NI, MIPV, PM
- pSOS+ NI, MIPV?, PM?
- QNX NI, MIPV, PM
- VxWorks NI, MIPV, PM
- WinCE

Preemption Model

- Kernel preemption by interrupts
- Worst case interrupt response
- Kernel preemption by alarms, signals, etc.
- Preemption in privileged mode for dual mode operating systems

Preemption Model

- Itron
- Linux
- Lynx
- Nucleus
- OS-9
- pSOS+
- QNX
- VxWorks
- WinCE

} Kernel preemption by interrupts

Scheduling Policy

- Round Robin
- Priority
- Priority aging

- Priority inversion prevention (PIP)

Scheduling Policies

• Itron	Priority
• Linux	non real-time/complex
• Lynx	Priority
• Nucleus	Priority
• OS-9	Priority aging
• pSOS+	Priority
• QNX	Priority
• VxWorks	Priority, Round robin, PIP
• WinCE	Priority, PIP (8 priorities)

Inter-Process communication

- Signals
- Semaphores
- Multi-valued semaphores
- Mail boxes
- message pipes
- Sockets

Dynamic Component Support

- Without rebooting does the OS allow loading:
  - new application (NA)
  - already running application (RA)
  - OS component (OC)

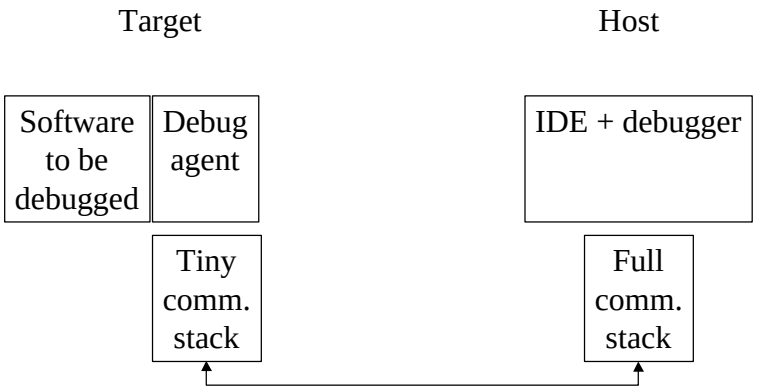
Dynamic Component Support

• Itron	NA
• Linux	NA, OC
• Lynx	NA
• Nucleus	In future release
• OS-9	NA, RA, OC
• pSOS+	NA, OC
• QNX	NA, OC
• VxWorks	NA*, OC
• WinCE	NA, OC

Tools

- Hardware based
- Software based
  - more prone to lockup
  - you have to port the debug agent
  - slow (Ethernet, serial, parallel)

Software based debuggers



Tools

- Proprietary
- Third Party
- Proprietary IDE + Third Party

Hard/Soft Tools

- Hardware based (must, must, must!)
  - BDM
  - JTAG
  - ICE
  - Logic Analyzer
- Software Based
  - Debug agent on target, tool on workstation

Tool features

- Source level debugging
  - in privileged mode also, for dual mode OS
- Breakpoints, watchpoints, etc.
- Hardware based breakpoints
- Edit while debug
- Post-mortem
- OS build wizard

Compilers

- Diab-data
- Metaware
- GNU (public domain)
- Ultra-C/C++ for OS-9
- Compilers support CPUs not OS, except OS-9. Proprietary executable format for virus protection. Includes CRC in header.

Third Party Tools

- Software Development Systems (SDS)
- Embedded Support Tools (EST)
- Greenhills - Multi
- Applied Microsystems
- Metrowerks

Original Vendor Tools

- Tornado from WindRiver Systems
- pRISM+ for Integrated Systems
- Visual Studio from Microsoft
- Hawk from Microware

OS & Tool Choices

• Itron	Third party (TP)
• Linux	GNU, TP
• Lynx	Third Party
• Nucleus	Visual Studio +, TP
• OS-9	Hawk
• pSOS+	pRISM+, TP
• QNX	CodeWarrior, TP
• VxWorks	Tornado, TP
• WinCE	Visual Studio

Experience of Software Team

- Retaining the best engineers
- Not changing OS for every new project
  - Processors supported
  - Off the shelf components
  - Driver support

Processor Support

- Itron 8
- Linux >4
- Lynx 3
- Nucleus 17
- OS-9 7
- pSOS+ 14
- QNX 3
- VxWorks 16
- WinCE 5

Off The Shelf Components

- Networking
  - TCP/IP, Ethernet, WAN, USB, IEEE 1394
- Graphics
- MPEG
- Java
- Embedded web server
- Browser

Licensing Models

• Itron	per individual supplier
• Linux	GNU Public License
• Lynx	license+royalty
• Nucleus	Full source, per-project, no royalty
• OS-9	license+royalty
• pSOS+	license+royalty
• QNX	license+royalty
• VxWorks	license+royalty
• WinCE	license+royalty

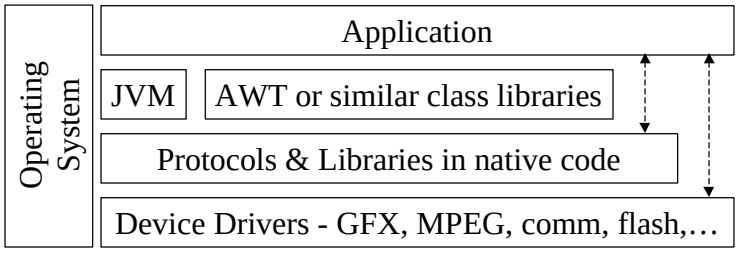
Java

- Processor independence
- Large size
  - JVM 80-500k
  - AWT 1500k
- For very large projects code size starts falling

Java/AWT Alternatives

- HP's Chai VM
- HAVi
- Newmonics - PERC
- NSI Com - JSCP

Java - The OS Still Matters



Postscript

- POSIX
- Quantitative measures
- Power management support

POSIX

- UNIX like
- Real-time signals with data
- Message Queues
- Async I/O
- Timeouts for blocking
- Binary semaphores
- Lock pages into memory

POSIX

- pthreads - priority inversion
- Control over scheduling
- At least 32 priorities

- Support can be at superficial library layer…
- Or, core capabilities can be supported
- Can it be all things to all people?

Quantitative Measures

- Interrupt response
- “Hookable” Interrupt points
- Context switch time (2 busy loops + LA)

- Caching changes everything
- Best, average & worst case
- Purchase from Real-Time Magazine

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