Introduction to Unix

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What is an OS?

- **OS is a resource manager**
  - Sharing
  - Protection
  - Fairness
  - Performance

- **OS provides the program execution environment**
  - Hides the messy details which must be performed.
  - Presents users with a virtual machine, easier to use.
Unix (1)

- Unix is
  - Interactive
  - Time-sharing
  - Multi-tasking
  - Multi-user

- Flavors ofUnix
  - System V (AT&T → USL → Novell → SCO → Caldera → SCO)
  - BSD (UC Berkeley)
  - SunOS, Solaris (Sun)
  - IRIX (SGI), AIX (IBM), HP-UX (HP), Mac OS X (Apple)
  - Linux, FreeBSD, NetBSD, etc.
Unix (2)

**Unix history and motivation**

- Originally developed at AT&T Bell Labs for internal use in the early 1970s.
- Borrowed best ideas from other OS’s.
- Unix was developed by programmers and for programmers.
  - cryptic names
  - special characters and notation
  - around 400 standard utilities
  - documentation is short on examples and tutorials
- Unix is designed so that users can extend the functionality – to build new tools easily and efficiently.
Unix (3)

Why Unix?

- Used in many scientific and industrial settings
- Huge number of free and well-written software programs
- Open-source OS (Linux, FreeBSD, etc.)
- Internet servers and services run on Unix
- Largely hardware-independent
- Based on standards
- Many important OS concepts are developed on Unix.
- Android!
OS Internals (1)

- User Application
- C Library (libc)
- System Call Interface
- Kernel
- Arch-dependent kernel code
- Hardware Platform

User space

Kernel space
OS Internals (2)

- Shell
- ls
- ps

System Call Interface

- File System Management
- Memory Management
- I/O Management (device drivers)
- Process Management
  - scheduler
  - IPC
  - synchronization
- Hardware Control (Interrupt handling, etc.)

User space

Kernel space

Hardware

trap
OS Internals (3)

- OS is a special software between applications and hardware.

- When does the OS take control of the system?
  - Bootstrapping
  - System calls
  - Interrupts

- OS is an event-driven software.
An exception is a transfer of control to the OS in response to some event.

**Diagram**

- **User Process**
  - event
  - current
  - next

- **OS**
  - exception
  - exception processing by exception handler
  - return (optional)
Handling Exceptions

- **Vector table**
  - Each type of event has a unique exception number $k$.
  - Index into jump table (interrupt vector)
  - Jump table entry $k$ points to a function (exception handler)
  - Handler $k$ is called each time exception $k$ occurs.

![Diagram](insert-diagram-here)
Asynchronous Exceptions

- **Interrupts**
  - Caused by events external to the processor
    - Indicated by setting the processor’s interrupt pin
    - Handler returns to “next” instruction.
  - Examples
    - I/O interrupts
      » Hitting a key at the keyboard
      » Arrival of a packet from a network
      » Arrival of a data sector from a disk
    - Hard reset interrupt
      » Hitting the reset button
    - Soft reset interrupt
      » Hitting CTRL-ALT-DELETE on a PC
Synchronous Exceptions

- **Traps**
  - Intentional
  - **System calls**, breakpoint traps, special instructions, etc.
  - Returns control to “next” instruction

- **Faults**
  - Unintentional but possibly recoverable
  - page faults (recoverable), protection faults (unrecoverable), etc.
  - Either re-executes faulting (“current”) instruction or aborts

- **Aborts**
  - Unintentional and unrecoverable
  - Parity error, machine check, etc.
  - Aborts current program
Fault Example (1)

- Memory reference: invalid
  - User writes to memory location
  - Address is not valid
  - Page handler detects invalid address
  - Sends **SIGSEGV** signal to user process
  - User process exits with “segmentation fault”

```c
int a[1000];
main ()
{
    a[5000] = 13;
}
```

User Process

OS

- Detect invalid address
- Signal process

- event
- movl
- page fault

Diagram: User Process flowchart with OS interactions.
Fault Example (2)

- Memory reference: valid but not resident
  - User writes to memory location
  - That portion (page) of user’s memory is currently on disk.
  - Page handler must load page into physical memory
  - Returns to faulting instruction
  - Successful on second try.

```c
int a[1000];
main ()
{
    a[500] = 13;
}
```

User Process

OS

Create page and load into memory
Trap Example

- **Opening a file**
  - User calls open (filename, options)
    - Function open executes system call instruction `int`
      - OS must find or create file, get it ready for reading or writing.
      - Returns integer file descriptor

```assembly
0804d070 <__libc_open>:
  ...  
  804d082:  cd 80     int  $0x80
  804d084:  5b         pop  %ebx
```

User Process

```
int
pop
```

OS

```
exception

return
```
POSIX Standards

- **IEEE Standard 1003.x**
  
  - POSIX is a standard that describes a single interface to a Unix-like operating system.
    - 1003.1 System Application Program Interface (Kernel)
    - 1003.2 Shell and Utilities
    - 1003.4 Real-time Extensions
    - 1003.7 System Administration, etc.
  
  - POSIX is not an implementation – it is a description!
  
  - Most system vendors are now conforming to POSIX standards (specifically IEEE 1003.1)
    - Even Microsoft provides a set of POSIX utilities with the Windows NT 4.0 Resource Kit.
<table>
<thead>
<tr>
<th>POSIX System Calls</th>
<th>Process Management</th>
<th>File Management</th>
<th>File System Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>fork</td>
<td>Create a new process</td>
<td>open</td>
<td>Create a new directory</td>
</tr>
<tr>
<td>waitpid</td>
<td>Wait for a process to exit</td>
<td>close</td>
<td>Remove an empty directory</td>
</tr>
<tr>
<td>execve</td>
<td>Load a new binary image</td>
<td>read</td>
<td>Make a link to a file</td>
</tr>
<tr>
<td>exit</td>
<td>Terminate execution</td>
<td>write</td>
<td>Destroy an existing file</td>
</tr>
<tr>
<td>kill</td>
<td>Send a signal</td>
<td>lseek</td>
<td>Mount a file system</td>
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<tr>
<td></td>
<td></td>
<td>stat</td>
<td>Unmount a file system</td>
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<td></td>
<td></td>
<td>chmod</td>
<td>Change the current working directory</td>
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</tbody>
</table>
Summary

- You need to master Unix/Linux.
- OS is an event-driven software.
- Trap is a pathway to the kernel.
- OS provides various services via system calls.