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Operating Systems

I. Introduction

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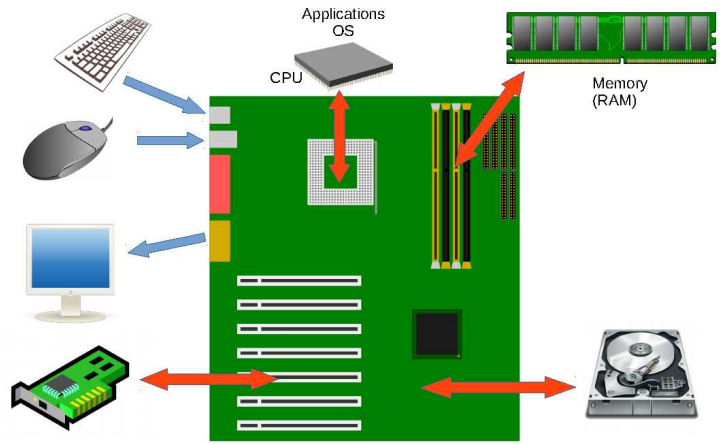
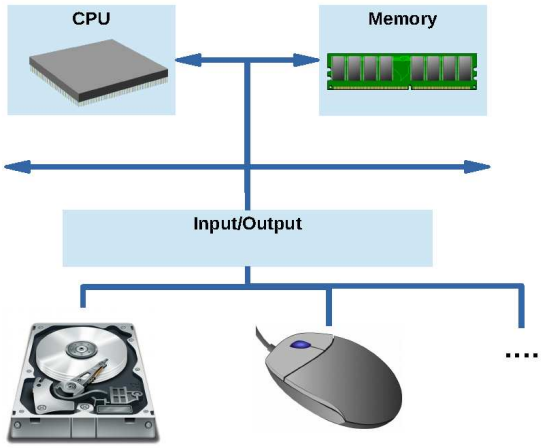
What is a Computer System?

In other words: what are the main components of a PC?



Computer System: Simplified View



This is Also a Computer!

What's inside? Let's see together!

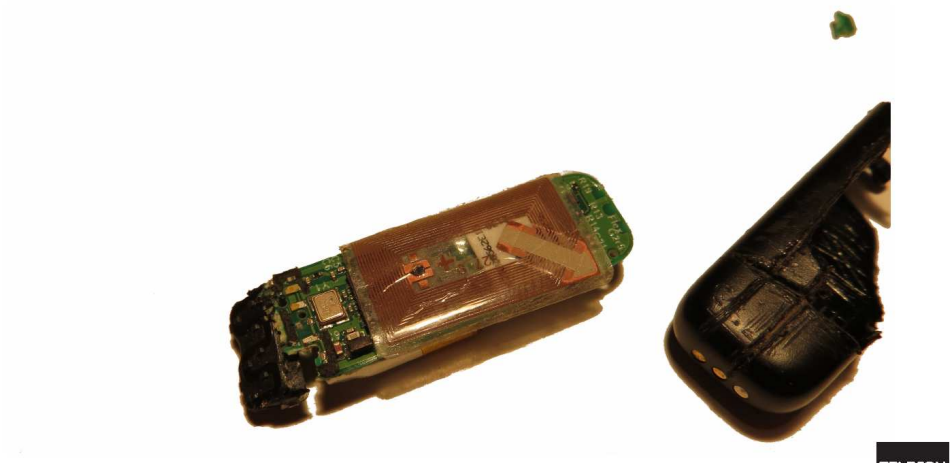
Inside a Fitbit

Don't try this at home!

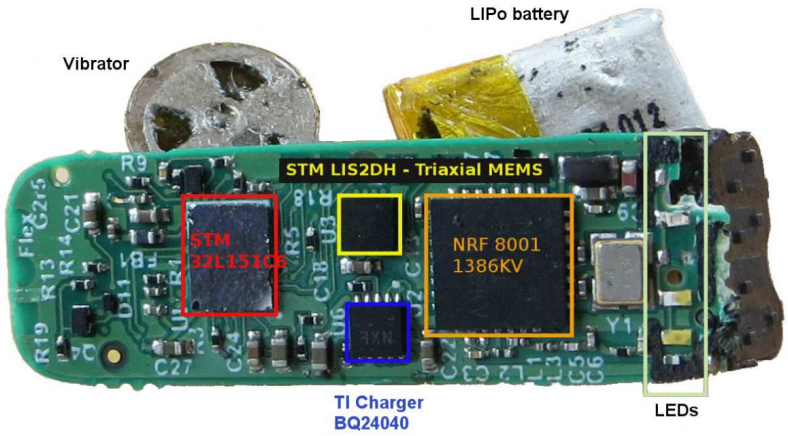
Inside a Fitbit (Cont.)

Again: don't try this at home!

Inside a Fitbit (Cont.)



Fitbit: Hardware Components



What is an Operating System?

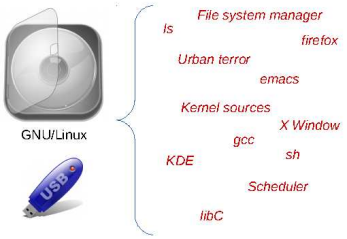
Definition

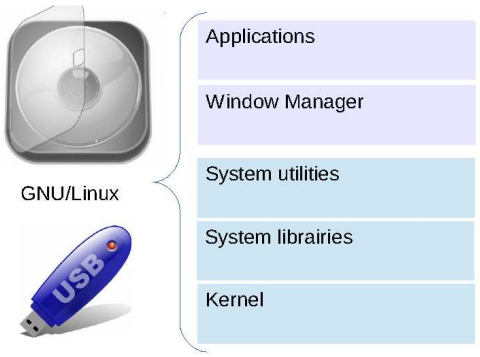
The most fundamental program of a computer system

Objectives

- **Make computers convenient to use** i.e. simplify programmers' tasks
  - Abstract hardware concerns
    - e.g., simplify memory allocations
- **Use hardware in an efficient manner**
- **Security**
  - Protect systems from wrong and malicious utilizations

Layered View of Packaging





1930 → 1965: First Computers

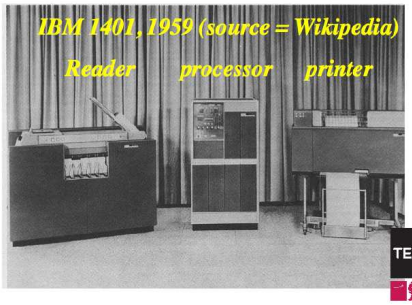
1930 → 1955: Vacuum tubes

Use of plugboards for programming

1955 → 1965: Transistors

- Batch jobs directly written on cards / tapes
  - Assembly language
  - Fortran
- OS
  - FMS - Fortran Monitor System
  - IBSYS - IBM's Operating System

IBM 402, 1933 (source = Wikipedia)



1965 → 1980: Integrated Circuits

- Multiprogramming
  - Can start loading a program while another one is being executed
  - Memory partitioning
- Timesharing
  - CPU partitioning
- Examples
  - IBM OS/360
    - Millions of lines of assembly code
  - MIT CTSS: time sharing system (62) → MULTICS (65) → UNIX
  - Minicomputer: DEC PDP-1 (61)

Xerox Alto, 1973 (source = Wikipedia)

Apple II, 1977-1988
(source = Wikipedia)

1980 → . . . : Large-Scale Integrated Circuits

- Personal Computers, workstations, smartphones
- Graphical user interfaces
- Cloud computing
  - Unawareness of data and jobs execution location
- Real-Time
  - Specialized functionalities for jobs to meet their timing requirements e.g., deadlines
- Examples of OS
  - Solaris, GNU/Linux, macOS, Android, iOS
  - MS-DOS, 3.11, 95, 98, 98SE, ME, NT (NT4, XP, Server 2003, Vista, 7, 8, 10, 11)

Main Services

- Program execution
- Resource allocation and release
- I/O operations
- Files handling
- Communication
  - Between programs running on the same computer
  - Between programs running on different computers
- Error detection and handling
  - Hardware failure, illegal memory access, illegal instruction, exception (divide by zero)
- Accounting
- Security (not addressed in this course)

While ensuring . . .

- Ease of use
- Efficiency
- System protection

Protection

Protection of what?

- Hardware
  - Prevent illegal instructions
  - Devices
    - Prevent illegal use of devices
  - Memory
    - Prevent a process from addressing the memory space of other processes and OS
  - CPU
    - Prevent a process from jeopardizing processing resources

Dual Mode

Protections are based on hardware techniques .... including **Dual Mode**

Dual Mode of Processors

User mode

Privileged assembly instructions cannot be executed

- → If so, the system "traps"

Monitor mode

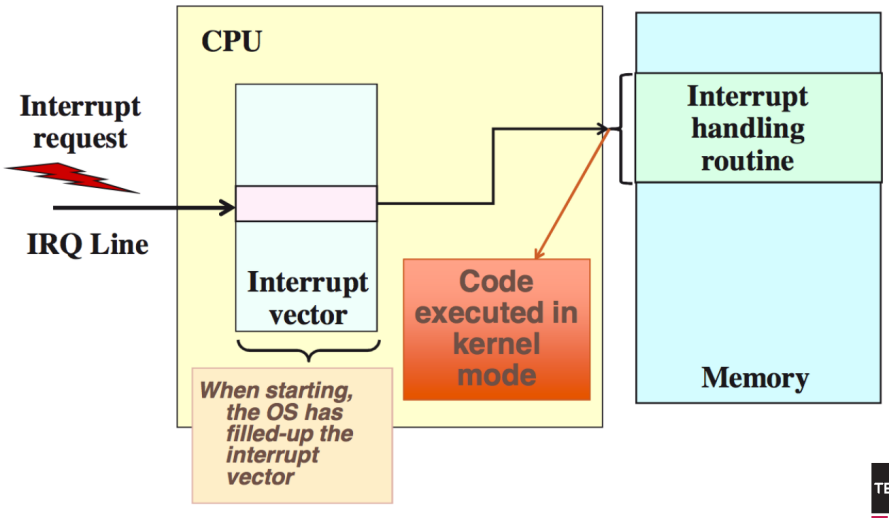
= Supervisor mode, system mode, privileged mode, kernel mode, etc.

- In this mode, privileged assembly instructions can be executed
- **Not** related at all to the *administrator* or *root* of a machine

Mode switching

- Monitor mode → user mode: a given assembly instruction
- User mode → monitor mode: interrupt (or trap)

Interrupts



Protection: Use of Dual Mode

1. Hardware starts in monitor mode
2. OS boots in monitor mode
3. OS starts user processes in user mode
   - So, user processes cannot execute privileged instructions
4. When a trap or an interrupt occurs:
   - Hardware switches to monitor mode
   - Routine pointed to by interrupt vector is called
     - Vector was setup by the OS at boot time

So, the Operating System is in monitor mode whenever it gains control i.e., when its code is executed in the CPU

Hardware Protection

Goals

Prevent instructions that shall not be executed

- Divide by zero, privileged instruction in user mode, etc.

Mechanisms

- Hardware detects illegal instructions and accordingly generates interrupts
- The control is transferred to the OS
  - Faulty program is aborted
  - Error message (popup window, message in console or terminal)
  - Program's memory may be dumped for debug purpose
    - Under Unix, it is dumped to a file named *core*
- If faulty element = OS: blue screen, kernel panic, ...

System Calls (a.k.a. Syscalls)

Definition

Interface between user processes and the Operating System

- Windows: systems calls are included in the Win32/Win64 API
- Solaris

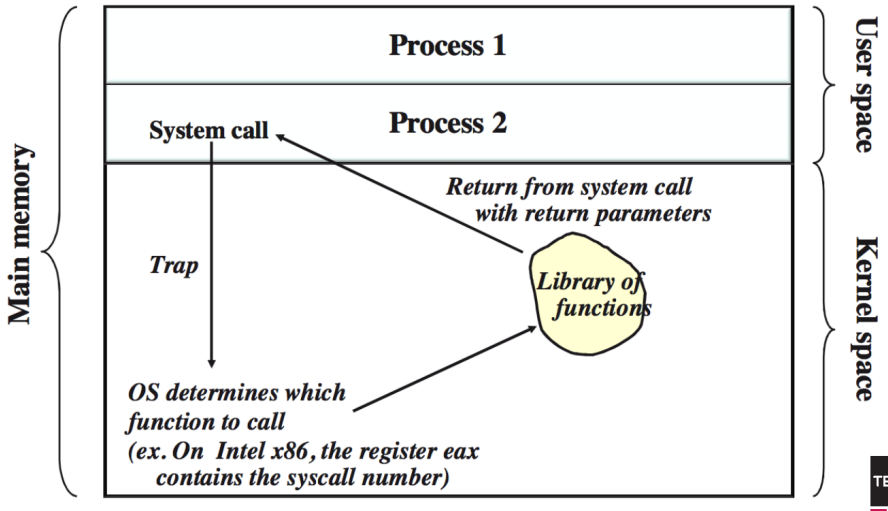
```
$man -s2 read
System Calls
NAME
        read, readv, pread - read from file
SYNOPSIS
#include <unistd.h>
ssize_t read(int fildes, void *buf, size_t nbyte);
...
```

- macOS (Similar result in GNU/Linux)

```
$ man -s2 read
READ(2)  BSD System Calls Manual  READ(2)

NAME
     pread, read, readv -- read input
...
```

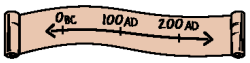
System Calls: Implementation



Categories of System Calls

- Process control
  - Create, load, wait event, allocate and free memory, ...
- File manipulation
  - Create, open, close, read, write, attributes management, ...
- Device manipulation
  - Request, read, write, attributes management, ...
- Getting and setting system related information
  - Time management, process management, ...
- Communications
  - Send, receive messages / signals, create communication links, ...

UNIX: History



Idea originated in 1965

- Research lab of AT&T (Bell Labs)
- Idea of Ken Thompson: develop what no computer company was ready to provide i.e. a multi-user and multiprocessing OS
- Multics created in cooperation with MIT and General Electric
- Less complex version of Multics: UNIX, operational at Bell Labs in 1971
  - Fully written in assembly language

Diffusion in the academic world: 1970 → 1972

Code is modified by graduate students to make UNIX more robust

UNIX: History (Cont.)

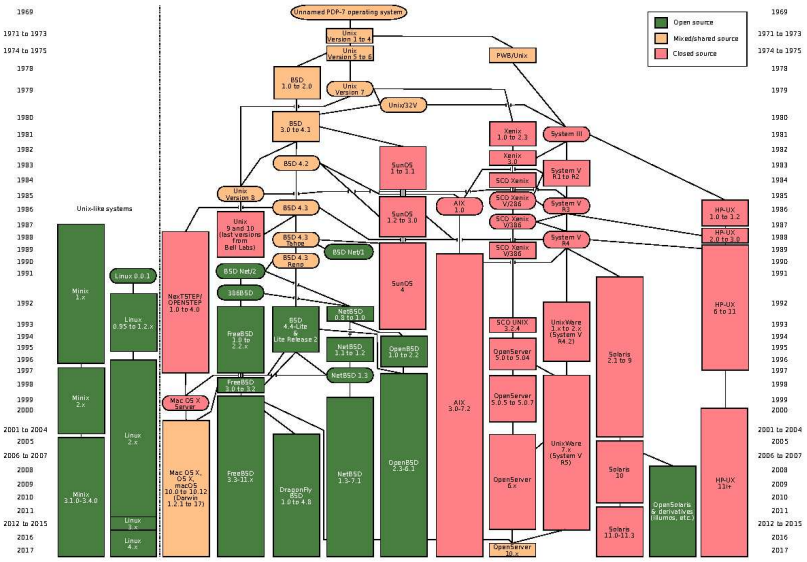
Improvements: 1973 → 1979

- UNIX rewritten in C
  - C developed by Denn
- BSD Unix (1975): C-shell, virtual memory
- Performance improvements (file systems, etc.)
- Support of more hardware platforms

Commercial versions: 1979 → now

- First commercial UNIX: System III, and then System V
- SunOS/Solaris added networking tools (e.g., NFS)
- Domination of two UNIX: BSD and System V (AT&T)
- Runs on a large majority number of smartphones, tablets, objects, embedded systems

UNIX: Versions



source = *Wikipedia*

GNU/Linux (Free Software)

GNU/Linux (a.k.a. Linux) = GNU Operating System + the Linux kernel

The GNU Operating System

- *GNU's Not Unix!*
- Applications, libraries, and developer tools
- Started in 1984

The Linux Kernel

- Created in 1991 by Linus Torvalds
- *see next slide*

First Post by Linus Torvald

comp.os.minix ›

What would you like to see most in minix?

285 posts by 262 authors G+1

Linus Benedict Torvalds

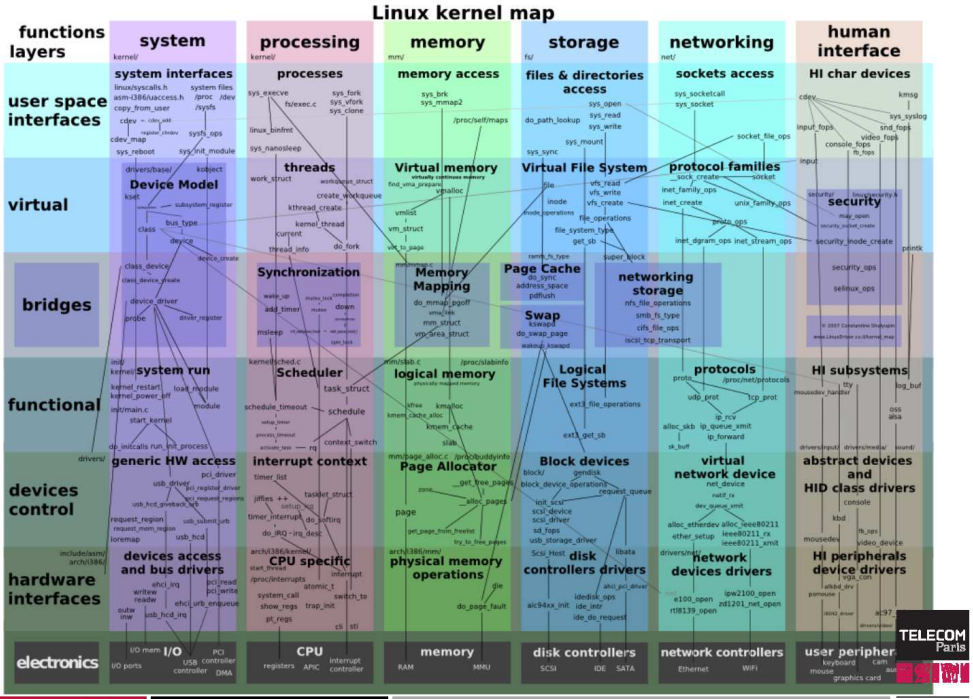
Hello everybody out there using minix -

I'm doing a (free) operating system (just a hobby, won't be big and professional like gnu) for 386(486) AT clones. This has been brewing since april, and is starting to get ready. I'd like any feedback on things people like/dislike in minix, as my OS resembles it somewhat (same physical layout of the file-system (due to practical reasons) among other things).

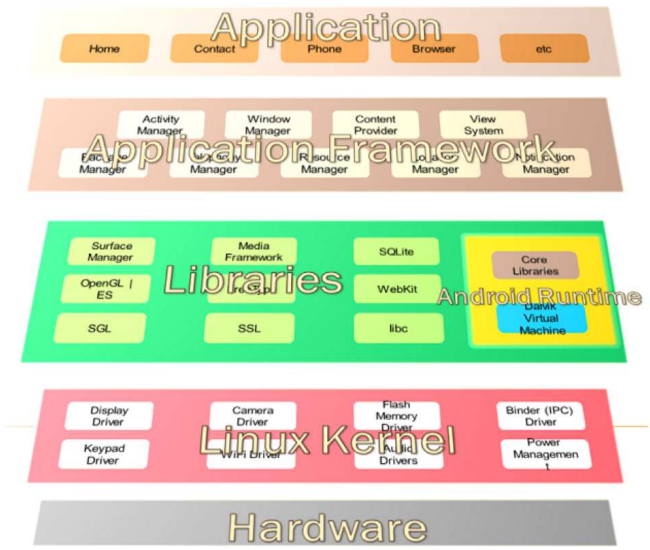
I've currently ported bash(1.08) and gcc(1.40), and things seem to work. This implies that I'll get something practical within a few months, and I'd like to know what features most people would want. Any suggestions are welcome, but I won't promise I'll implement them :-)

Linus (torv...@kruuna.helsinki.fi)

PS. Yes - it's free of any minix code, and it has a multi-threaded fs. It is NOT protable (uses 386 task switching etc), and it probably never will support anything other than AT-harddisks, as that's all I have :-(.



Android



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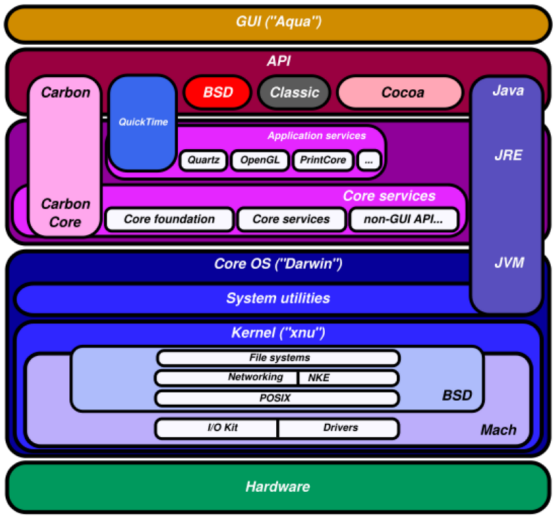
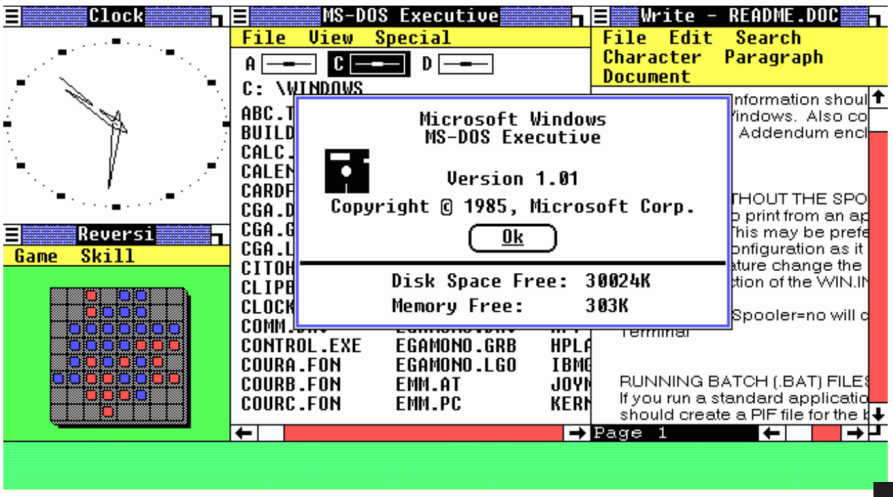
macOS



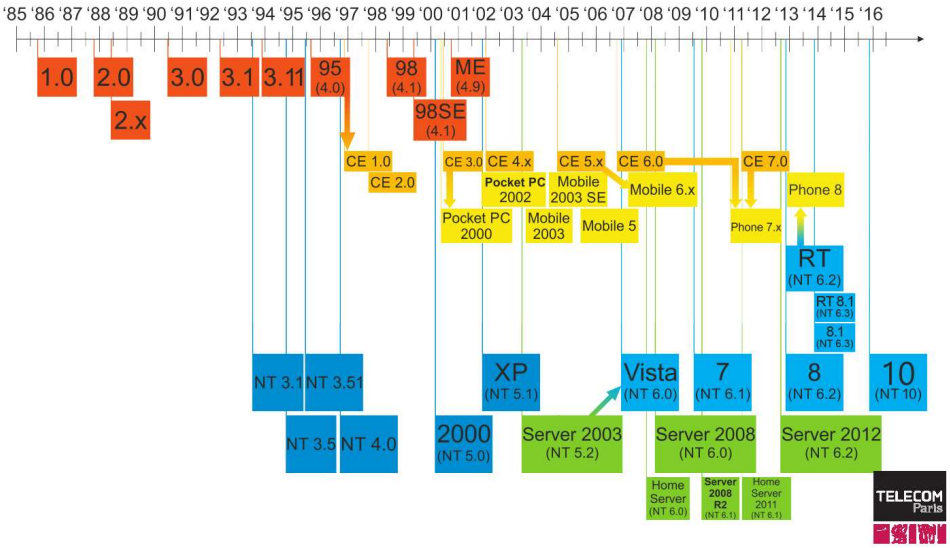
source = *Android sources*

Windows 1!

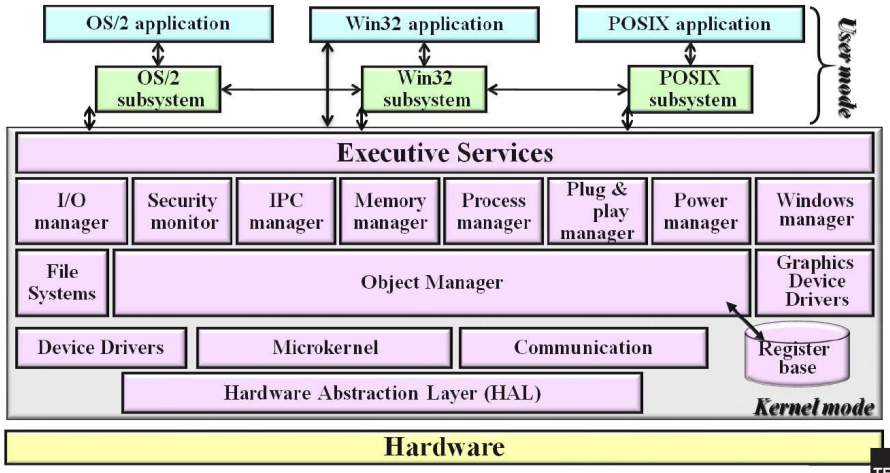


source = *Wikipedia*

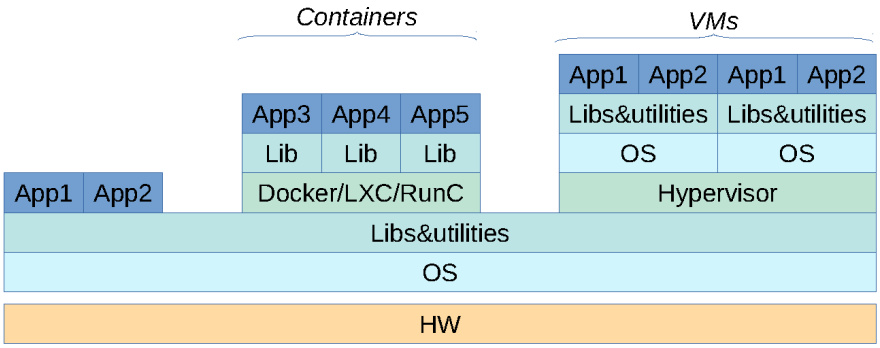
Windows: Chronology



Windows NT Architecture (2000/XP/Vista/7/8/10)



Containers and Virtual Machine Approach



Containers and Virtual Machines

VM

Completely isolated guest operating system installation within a normal host operating system (source: *Wikipedia*)

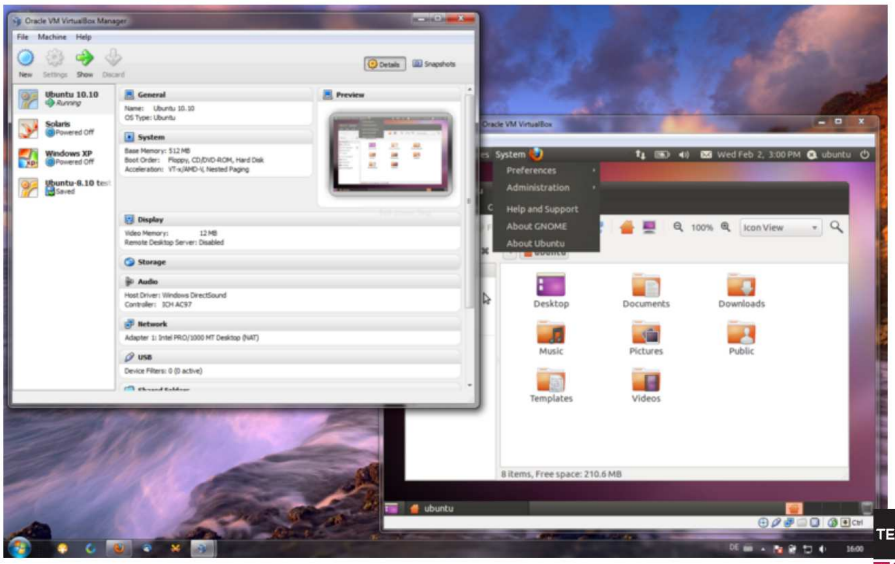
- The underlying layers of a virtual machine are considered as bare hardware
  - i.e., a guest OS thinks it is running alone on the machine
- The interface offered by a virtual machine is identical, whatever the underlying layers

Container

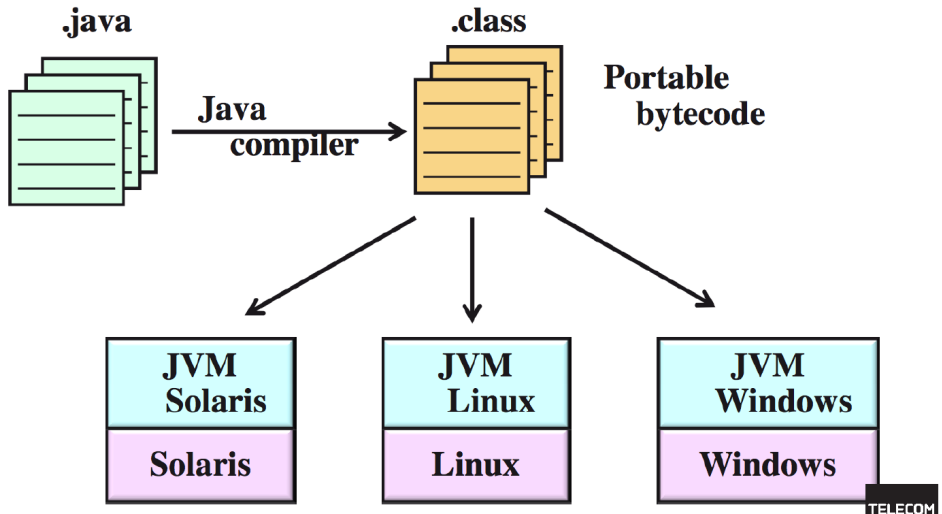
Package of an application and all its dependencies so as to seamlessly exexute this application in any (Linux) environment and isolate this application from others

- Reuses as much as possible resources of the OS

Example #1: *VirtualBox*



Example #2: *Java Virtual Machine*



Inside the Java Virtual Machine