Reprise: what an operating system does

- **manages CPUs, schedules and coordinates running programs**
  - switches CPU among programs that are actually computing
  - suspends programs that are waiting for something (e.g., disk, network)
  - keeps individual programs from hogging resources
- **manages memory (RAM)**
  - loads programs in memory so they can run
  - swaps them to disk and back if there isn't enough RAM (virtual memory)
  - keeps separate programs from interfering with each other
  - and with the operating system itself (protection)
- **manages and coordinates input/output to devices**
  - disks, display, keyboard, mouse, network, ...
  - provides fairly uniform interface to disparate devices
- **manages files on disk (file system)**
  - provides hierarchy of folders/directories and files for storing information

How applications use the operating system

- **operating system provides services to be accessed by application programs**
  - Unix "system calls", Windows Application Programming Interface ("API")
    "what is the exact time?"
    "allocate more memory to me"
    "read N bytes from file F into memory location M"
    "write N bytes from memory location M into file F"
    "establish a network connection to www.princeton.edu"
    "write N bytes to the network connection"
    “I’m all done; get rid of me”
- **operating system provides an interface for applications to use**
  - programs access machine capabilities only through this interface
  - different physical hardware can provide the same interface
  - programs can be moved to any system that provides the same interface
  - different operating systems can provide the same interface
  - one operating system can simulate the interface provided by another
- **operating system hides details of specific hardware**

Example of system-call level coding

- **C program to copy input to output ("copy" command)**
- **read, write, exit are system calls**

```
main() {
  char buf[8192];
  int n;
  while ((n = read(0, buf, sizeof(buf))) > 0)
    write(1, buf, n);
  exit(0);
}
```

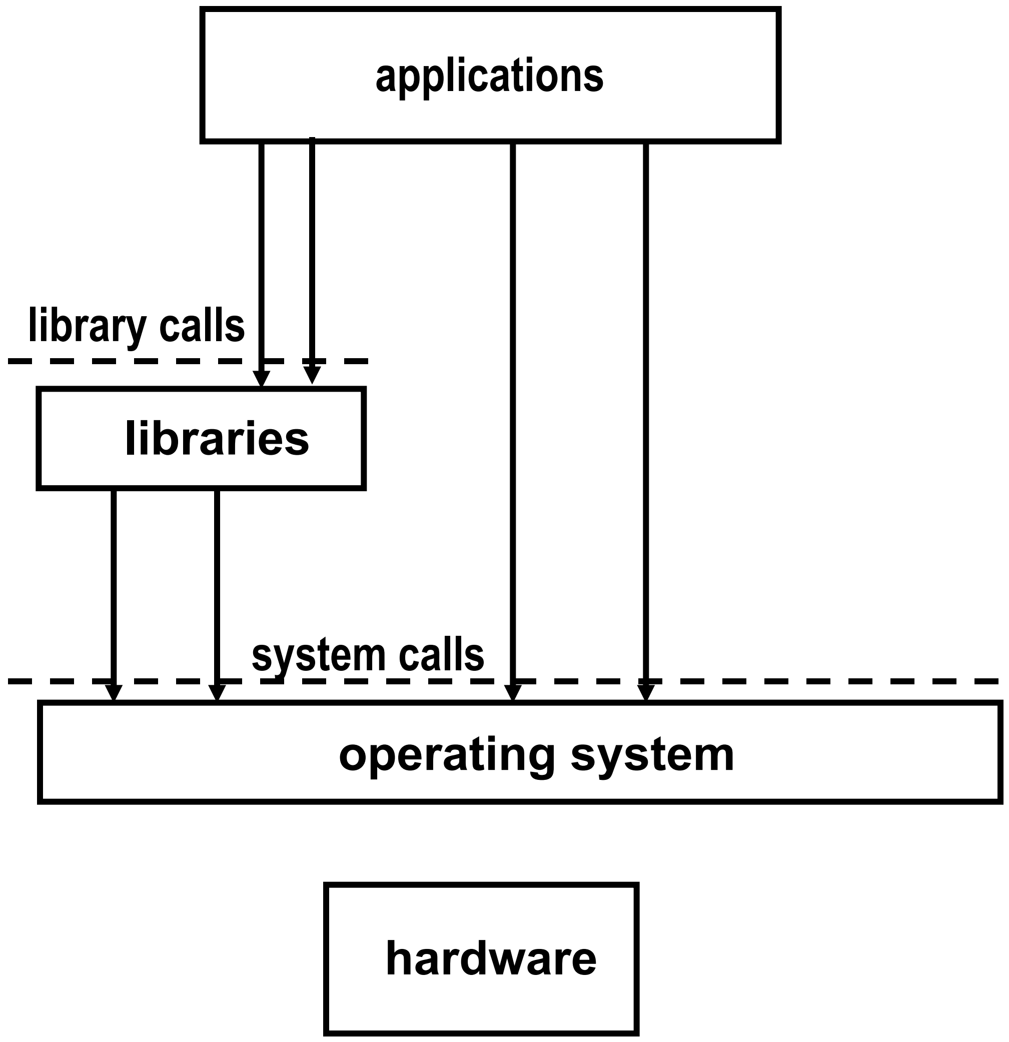
Software is organized into "layers"

- **each layer presents an interface that higher layers can use**
  - defines a "platform" for putting more on top
  - insulates the higher layer from how the lower layer is implemented
  - often called "Application Programming Interface" or API
- **operating system ("kernel")**
  - lowest software layer, on top of hardware

    (usually: virtual machine is on top of another program, e.g., an operating system)
  - presents its capabilities as system calls
- **libraries**
  - code to be used as building blocks in programs
  - present their capabilities as APIs
- **applications**
  - e.g., browser, word processor, mailer, compiler, directory lister, ...
  - use libraries and system calls through APIs

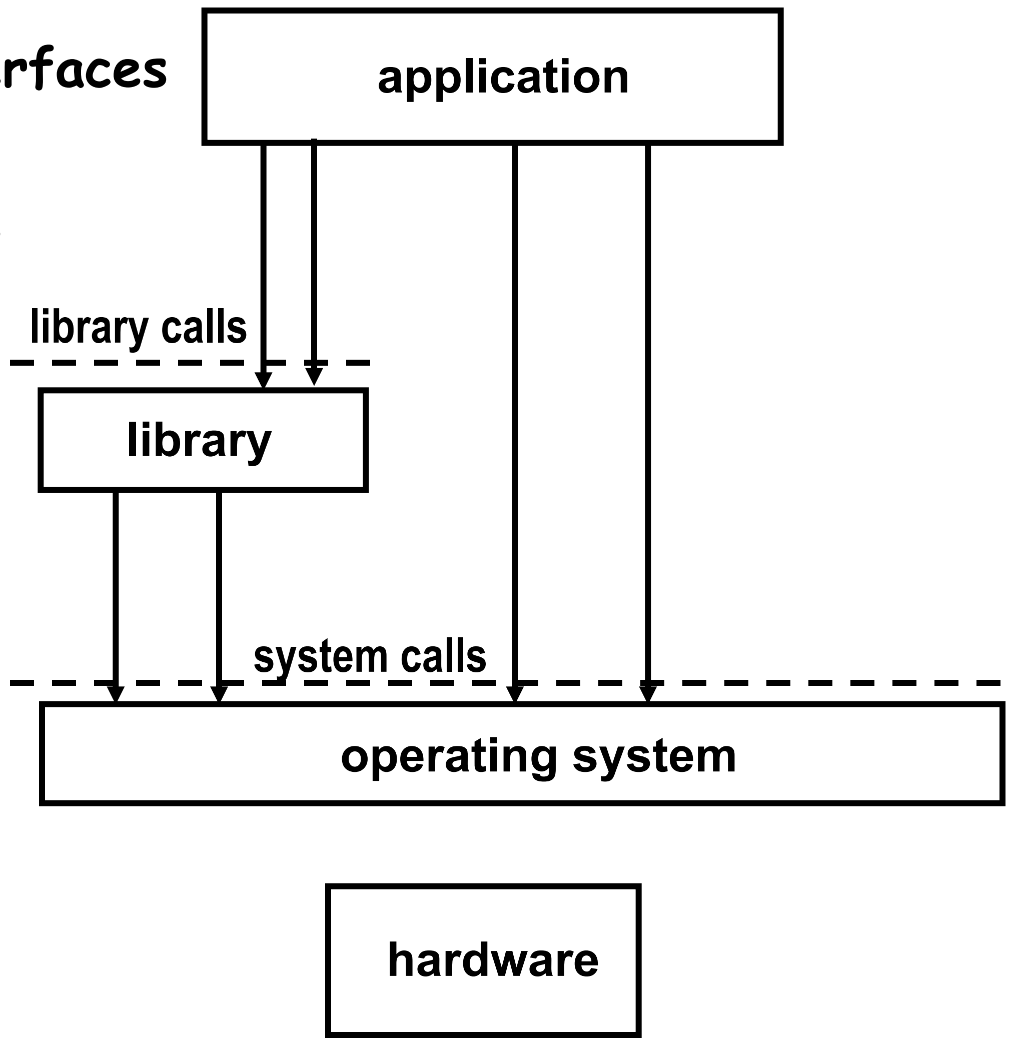
Layering

- **an application generally calls multiple libraries**
  - might not make direct system calls
- **a library generally calls other libraries**
- **library and system call levels define interfaces (APIs)**
- **programmers may not know what is "library" and what is "system call"**



Interface issues

- application/kernel boundary
- application programming interfaces
- interface ownership
- independent implementations
- platforms
- middleware
- virtual machines



Where's the line between OS and applications?

- **there are lots of ways to create layers and glue them together**
- **many choices of what to include in kernel or put in library**

- **“operating system” and “kernel” are not well defined**
  - “Windows” might mean everything (OS, applications, etc)
  - “Windows OS” usually means the part that controls the rest
  - "Linux" may mean "kernel" or may mean "kernel + applications"
  - dividing line is not always clear

- **"kernel"**
  - minimal part that runs regardless of what else the system is being used for or is doing
  - provides essential, central services
  - controls shared resources
  - protects information, enforces privacy and security
  - user programs can only use it through its defined interfaces
  - usually runs in hardware-supported protected mode

Microsoft antitrust case (1994-2011)

- **"operating system" and "kernel" are not well defined**
  - "Windows" might mean everything (OS, applications, etc)
  - "Windows OS" usually means the part that controls the rest
- **what is operating system and what is application?**
- **Dept of Justice v Microsoft was partly about this question**
  - is Internet Explorer part of the operating system?
  - will the system be damaged or restricted if IE is removed or replaced?
- **Microsoft said Yes, DoJ said No**
  - http://www.usdoj.gov/atr/cases/ms_index.htm

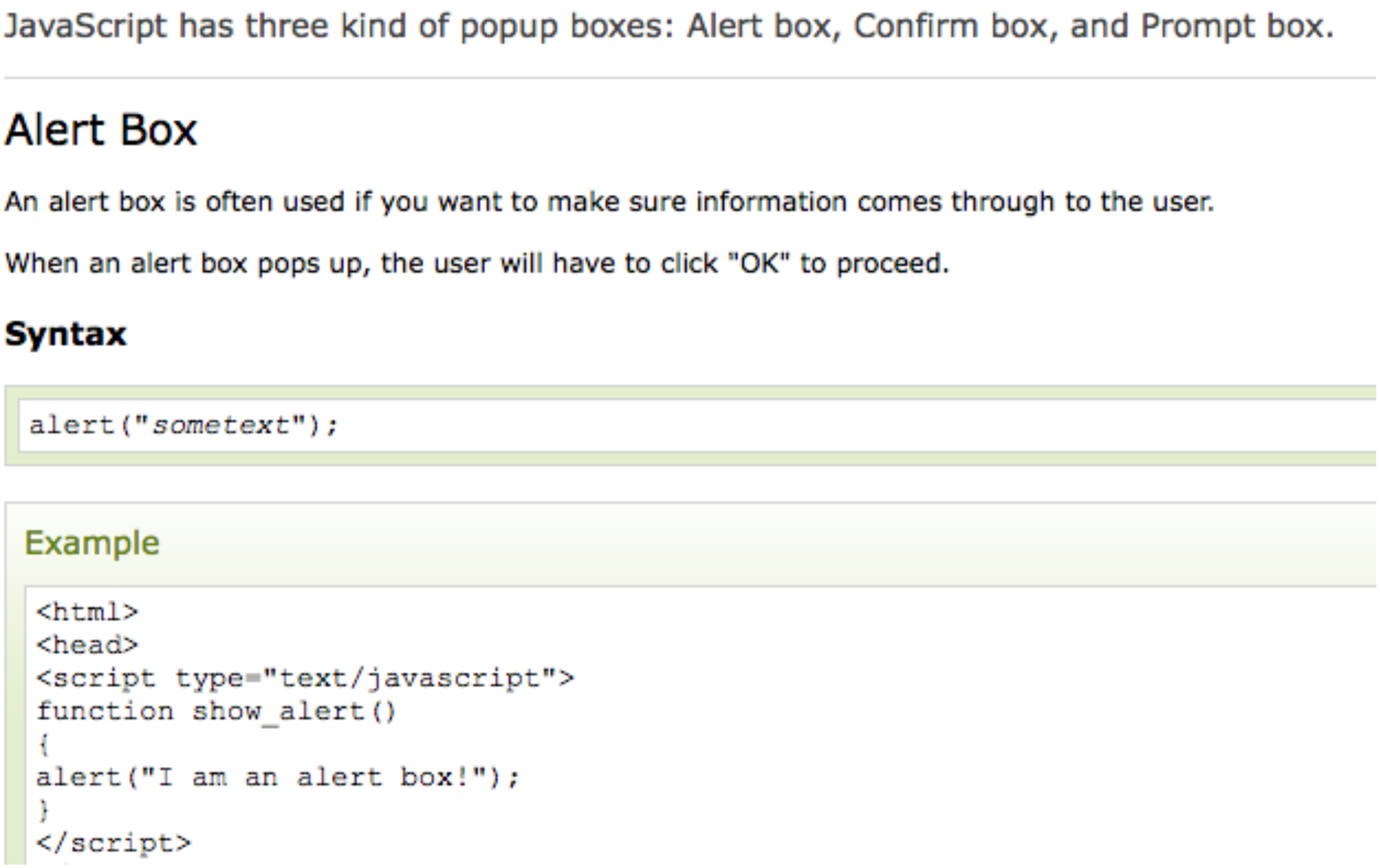
USA v. Microsoft Chronology (you are not expected to remember this)

- **7/94: Microsoft sued for Sherman Antitrust Act violations; judgment against MS**
- **10/97: Dept of Justice says MS is still doing it**
- **5/98: DoJ & 18 states sue MS**
- **10/98-2/99: trial with judge Thomas Jackson**
  - Prof Ed Felten one of government expert witnesses
  - showed it was quite possible to remove IE from Win95 without harm

- **11/99: "findings of fact": MS is a monopoly, used its power to stifle competition**
- **4/00: "findings of law": MS violated Sherman act**
- **6/00: Judge Jackson approves proposal to split MS into an "operating system company" and an "applications company"**
- **6/01: appeals court affirms conclusions, but overturns breakup remedy**
- **8/01: new judge Colleen Kollar-Kotelly to decide penalties, remedies**
- **9/01: DoJ backs off on major issues**
- **11/01: proposed settlement:**
  - MS can add anything to OS, can't keep OEMs from installing other software, can't retaliate, must charge uniform prices, must disclose technical information

- **2/02: 11 states pursue suit anyway**
  - Prof Andrew Appel an expert witness for states
- **11/02: Kollar-Kotelly's decision basically leaves settlement alone**
- **10/05: Kollar-Kotelly scolds Microsoft for delay, violations of settlement**
- **10/07: 7 states want agreement extended for 5 more years!**
- **8/11: I think it's settled and Microsoft is no longer under supervision**

API fragment


JavaScript has three kind of popup boxes: Alert box, Confirm box, and Prompt box.

Alert Box

An alert box is often used if you want to make sure information comes through to the user.

When an alert box pops up, the user will have to click "OK" to proceed.

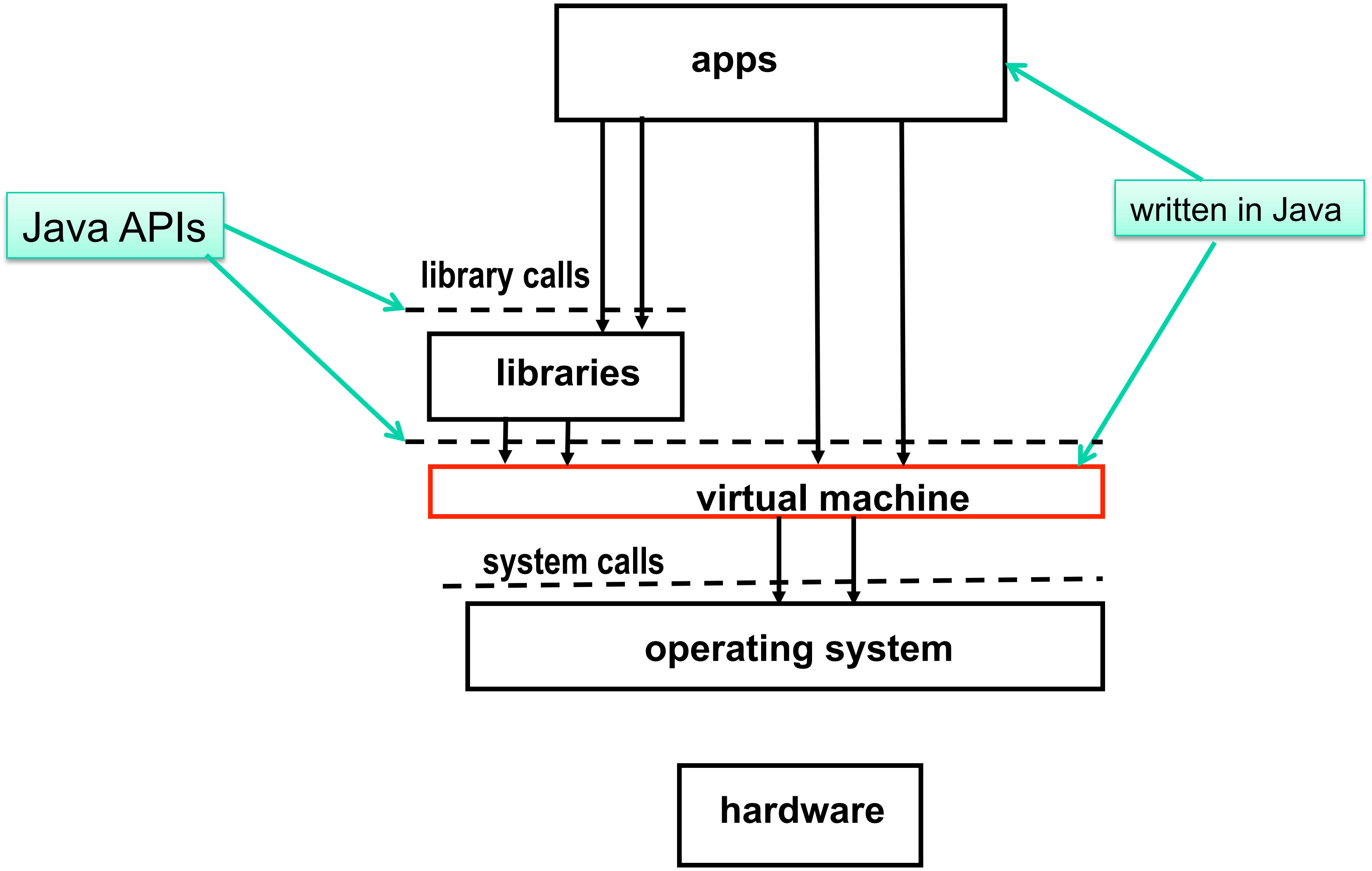
Syntax

```
alert("sometext");
```

Example

```
<html>
<head>
<script type="text/javascript">
function show_alert()
{
alert("I am an alert box!");
}
</script>
```

Android phone organization

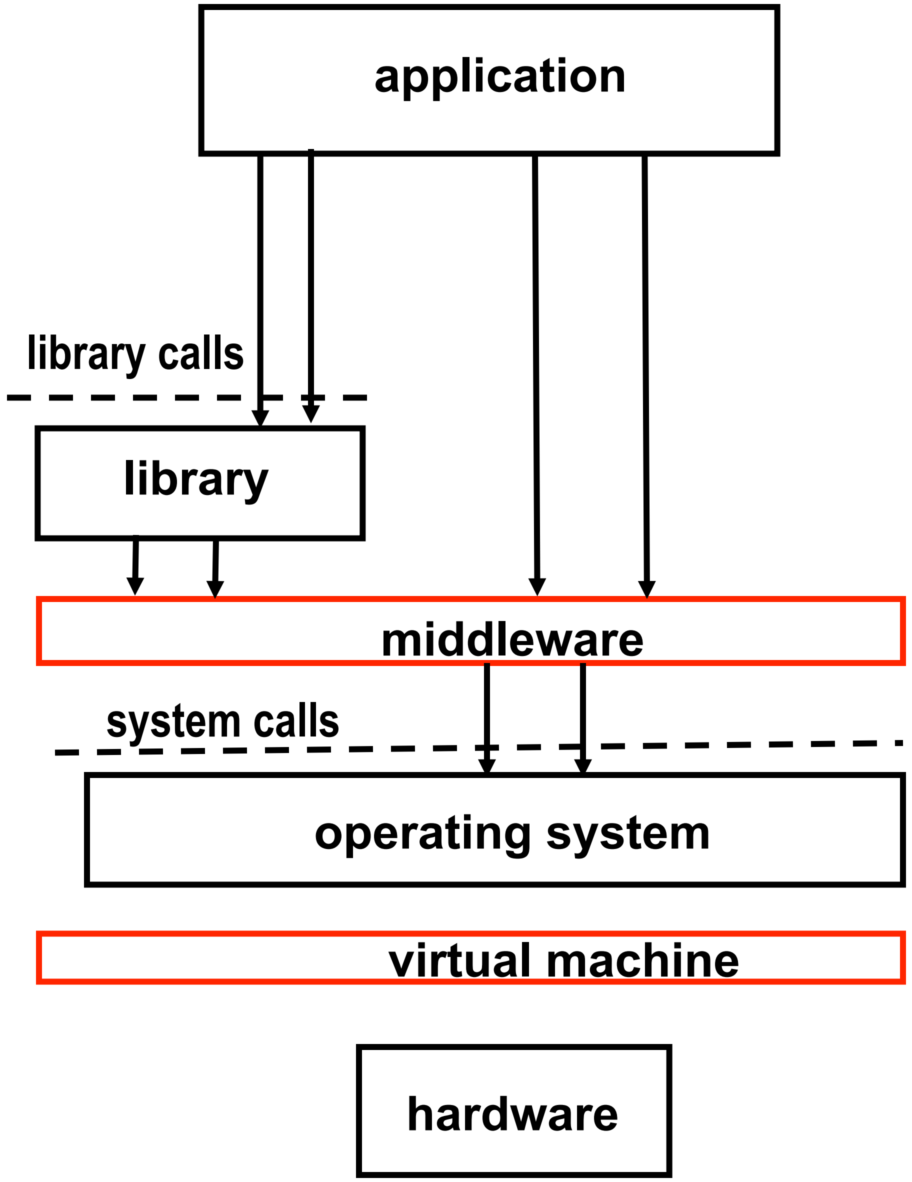


Platforms, middleware, virtual machines

- **platform: hardware or software on which applications can run**
- **middleware: uses OS interface but exposes its own APIs to developers, so applications using it can move to any OS where the middleware has been moved**

  (e.g., browser-based software)
- **virtual machine: software that mimics behavior of hardware so other software can run on it**

  (can be above the operating system too, as in VMWare)



Virtualization Use Rights for Windows 7 Enterprise

For each device licensed for Windows 7 Professional Upgrade with active Software Assurance:

Installation rights: Customers may install unlimited copies of the software on the licensed device. However, at any one time, they may run no more than one instance directly on the physical hardware and no more than four instances in virtual machines. Despite the allowance of more than one copy, use of the software is limited to one user at a time.

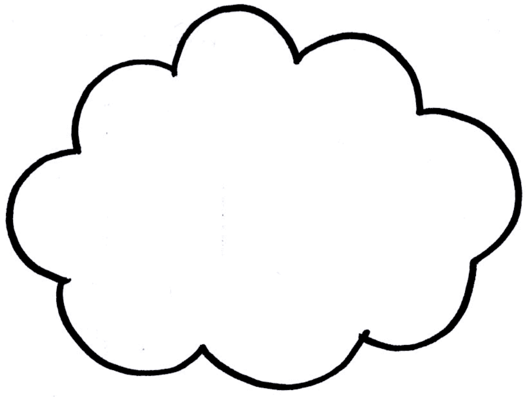
Host operating system: If customers use all five permitted instances, the instances running directly on the physical hardware may be used solely to:

- Run the hardware virtualization product.
- Manage and service the virtual (or otherwise emulated) hardware systems on that device.
- Alternative installations: Customers may install and use a second instance on the licensed device in a separate hard-drive partition. Choosing this option forfeits the right to run four virtualized instances.

Cloud computing

- **'Cloud' has been a go-to metaphor for almost as long as the Internet has existed, conveying a sense that the Internet was intangible and bigger than the sum of its parts."**
  (Wall Street Journal, 9/23/08)

- **software services delivered via the Internet**
  - Gmail, Yahoo mail, ...
  - Facebook, Twitter, Flickr, ...
  - Google Docs
  - Windows Live, Office 360
  - Amazon Web Services (AWS)



- **most cloud services have an API for access by programs**

Who provides the servers for cloud computing?

- **many companies provide their own**
  - Google, Amazon, Microsoft, Yahoo, Facebook, Twitter, …
- **some companies offer cloud services for others**
  - Rackspace, … (Wikipedia lists 140)
- **some do both**
  - especially Amazon
  - Amazon Web Services is bigger than most of the others combined
- **advantages:**
  - professional administration, reliability, backup, security, …
  - scalability