ID2212 Network Programming with Java
Lecture 1

Network and Web Basics. Architectures of Distributed Applications. Java Platforms Editions

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Outline

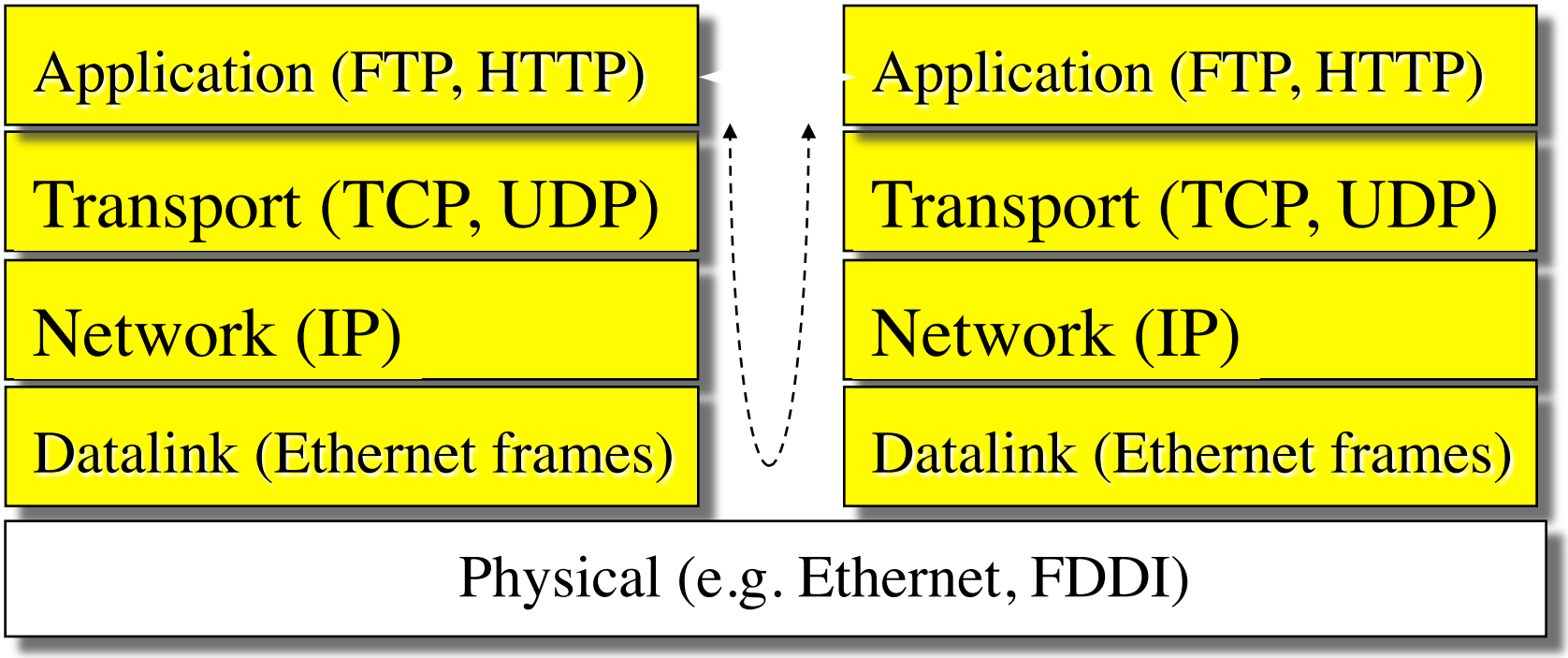
- Basic network concepts
  - IP stack, TCP, UDP, IP address, DNS
  - Sockets, ports, socket connection
- Basic WWW technologies
  - URL, HTTP, HTML
  - Client side: Forms, other client-side technologies
  - Server side: Servlets, Beans, Server side scripting
- Architectures of distributed applications
  - Client-server
  - Three-tier
  - P2P
- Networking technologies in JavaSE
- Java Platform editions: JavaSE, JavaEE, JavaME

Network. Host. Internet

- A ***network*** is a hardware and software data communication system that provides interconnection of computers and other devices.
- A ***node*** (***host***) is an addressable device (computer) attached to a computer network.
- An ***internet*** is a set of networks connected with routers.
- The ***Internet*** is the largest internet that includes commercial, military, university and other networks with different physical links and various protocols including IP (Internet Protocol)

Multi-Layered Network Architecture

- The seven-layer OSI (Open System Interconnect) model
- The IP networking stack includes 5 layers



1. Transport Protocols: TCP

- ***TCP***, Transmission Control Protocol, is a reliable connection-oriented stream-based transport protocol.
  - Allows sending data in a continuous stream.
  - Guarantees delivering in proper order.
- Phases of TCP communication:
  - Establish a connection (open a TCP session)
  - Transfer data over the connection
  - Release the connection
- Applications using TCP: file transfer, email, WWW
- TCP is used on Ethernet and the Internet: TCP/IP
  - See: the standard STD 7, and the Request For Comments RFC 793
    - Standards and RFCs http://www.faqs.org/rfcs/

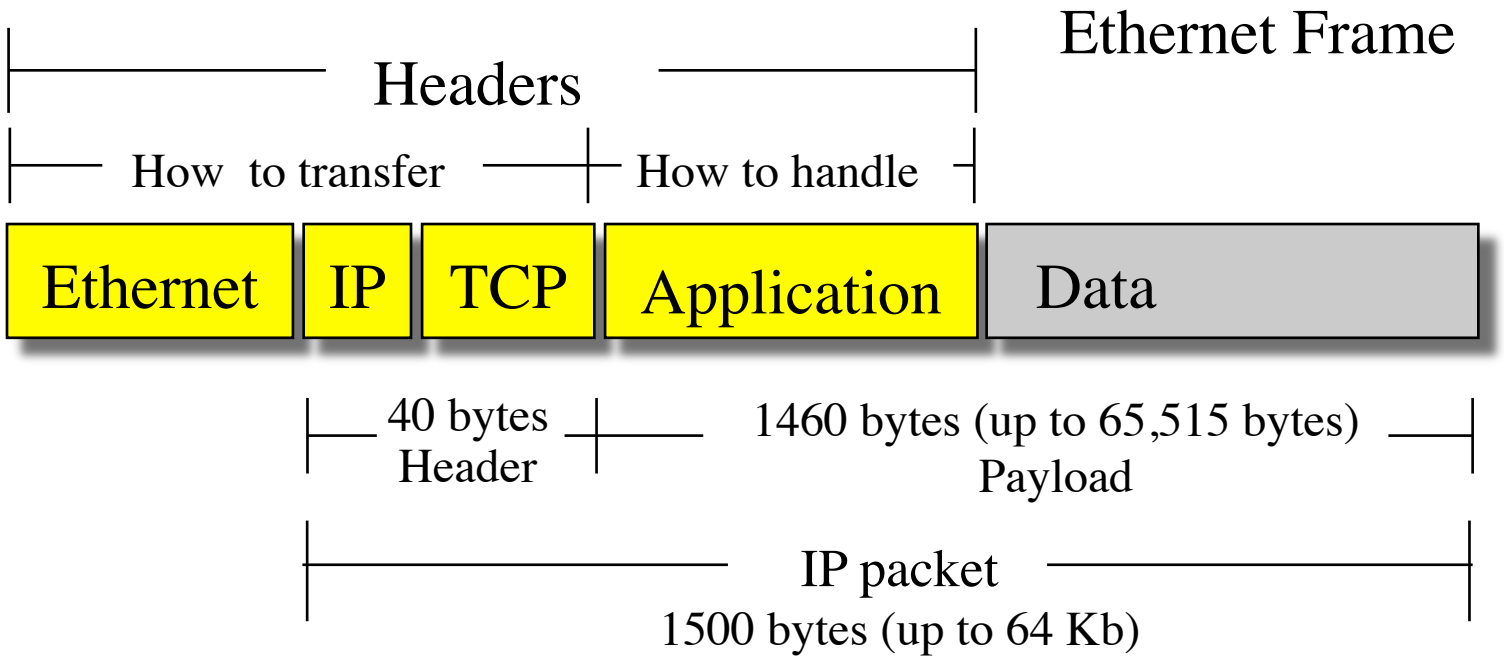
2. Transport Protocols: UDP

- ***UDP***, the User Datagram Protocol
  - For pure message passing (datagram send/receive).
  - Neither guarantees delivery nor requires a connection.
  - Connectionless:
    - UDP datagrams are sent between two hosts with no previous setup.
    - The datagrams contain the destination address, may take different routes.
  - Lightweight and efficient. Low overhead compare to TCP
- Phases of UDP communication:
  - Sending: create a UDP socket; create a datagram with the message and specified destination (IP address & port); send the datagram over the UDP socket.
  - Receiving: receive a datagram from the UDP socket; get data and source from the datagram
- Applications using UDP: DNS, streaming media (IPTV, VoIP, video-conferencing), online games
- UDP is layered on top of IP: UDP/IP; See STD 6, RFC 768

Network Protocol: IP

- ***IP***, Internet Protocol, is a network layer protocol used for routing.
  - IP is connectionless
    - IP datagrams fragmented into IP packets
    - IP header includes destination, source, and time-to-live (TTL)
  - See STD 5, RFC 791

Protocol Encapsulation



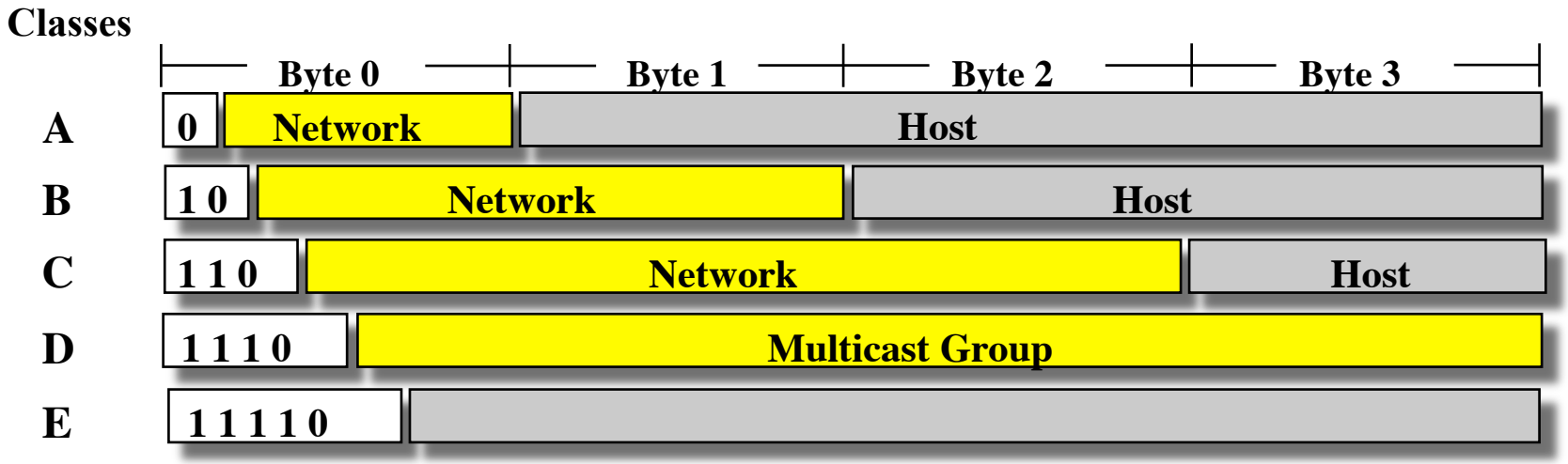
- To get the size of a Maximum Transmission Unit (MTU) on a Linux machine: **`ifconfig -a`**

Addressing a Node on the Internet. IP Address

- An Internet address (***IP address***) of a node on the Internet is a four-byte (32-bit) unsigned integer number (IPv4).
  - Dot decimal notation: four unsigned integers, each ranging from 0 to 255, separated by periods.
  - Example: 130.237.214.84
  - 127.0.0.1 - the local loopback interface, localhost
  - Addresses beginning with 0.0 refer to hosts on the same LAN.
    - 0.0.0.0 is used as a source address of the originating host.
  - Addresses beginning with 10. and 192.168. are non-routable and can be used on internal (private) networks.
  - Addresses beginning with 224. are multicast addresses.
    - 224.0.0.1 - multicast address on the LAN

IP Address Classes

- Internet addresses are assigned by Internet Corporation for Assigned Names and Numbers (ICANN) through Internet Service Providers (ISPs)
- Internet address classes
  - A (1-126.x.x.x) – 126 address blocks, each of 16,000,000 addresses.
  - B (128-191.x.x.x) – one address block contains ~65,000 addresses.
  - C (192-223.x.x.x) – one address block contains 254 addresses.
  - D (224-239.x.x.x) – multicast addresses.
  - E (240-255.x.x.x) –reserved.



Addressing a Node on Ethernet. MAC Address

- ***MAC*** (Media Access Control) address
  - The HW address of a device connected to a shared network medium, e.g. Ethernet.
  - MAC address is used by the link layer.
- ***ARP*** (Address Resolution Protocol) is used for conversion of an IP address into the corresponding MAC address.
  - The sender broadcasts an ARP packet with the Internet destination address and waits for the destination host to send back its Ethernet address.
    - If no reply, the "unreachable host" ICMP message is generated
  - Each host maintains a cache of address translations.
  - `arp -a`
    - Display the Internet-to-Ethernet address translation tables.

Host Names

- A ***hostname*** is a unique name of a computer on the Internet. It consists of a local name and a domain name.
  - For example: oyster.it.kth.se
- A machine may have multiple names, for example:
  - `mail.it.kth.se` - an e-mail server
  - `ftp.it.kth.se` - an FTP server
  - `piraya.it.kth.se` - a host on the Internet.
- One name can be mapped to multiple IP addresses
  - Web site with multiple hosts
- See http://www.iana.org/domain-names.htm

DNS: Domain Name System

- ***DNS*** is a distributed service on the Internet that translates host names into IP addresses.
- Search for a host information:
  - Lookup in the local cache: the `/etc/hosts` file
  - *optional*: NIS (Network Information Service)
  - Lookup in DNS
- **`nslookup`** - lookup IP-address by name (or visa versa)

```
C:\>nslookup www.oracle.com
Server:  res2.ns.kth.se
Address:  130.237.72.200

Non-authoritative answer:
Name:    e7075.x.akamaiedge.net
Address:  23.61.230.140
Aliases:  www.oracle.com
          www.oracle.com.edgekey.net
```

Sockets

- ***Socket*** is an end-point of a virtual network connection between processes – much like a full-duplex channel
  - A socket address: IP address and a port number
  - A socket type: distinguished by the transport protocol used for communication over the socket
    - TCP socket - stream-based, connection-oriented
    - UDP socket - datagram-based, connectionless
- The socket API in C, a.k.a. Berkeley sockets, was introduced in 1981 as the Unix BSD 4.2 generic API for inter-process communication
    - Initially was a part of the kernel (BSD Unix)
    - Today is a library (Solaris, MS-DOS, Windows, OS/2, MacOS)

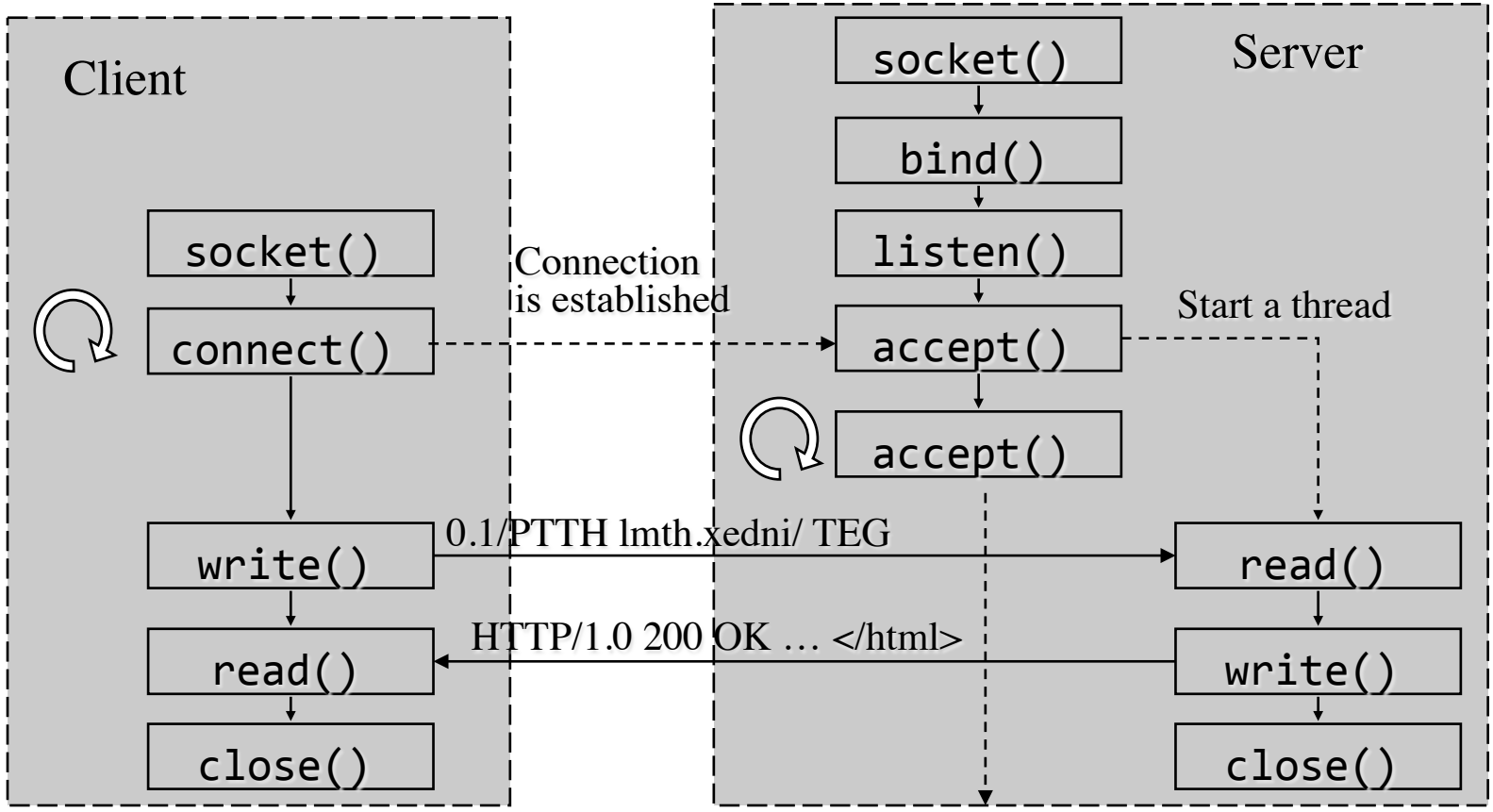
Ports

- ***Port*** is an entry point to a process that resides on a host.
- 65,535 logical ports with integer numbers 1 - 65,535
- A port can be allocated to a particular service:
  - A server listens the port for incoming requests
  - A client connects to the port and requests the service
  - The server replies via the port.
- Ports with numbers 1-1023 are reserved for well-known services.
  - A list of services and allocated ports is stored in
    - /etc/services (Linux)
    - C:\WINDOWS\system32\drivers\etc\services (Windows)

Some Assigned Ports (RFC 1060)

echo	**7**	**tcp/udp**	Echo back the input
discard	**9**	**tcp/udp**	Discard the input
daytime	**13**	**tcp/udp**	Output an ASCII string with the current time
ftp-data	**20**	**tcp**	Data port of ftp: transfer file
ftp	**21**	**tcp**	Command port of ftp: send ftp command
telnet	**23**	**tcp**	Interactive remote command-line sessions
smtp	**25**	**tcp**	"Simple Mail Transfer Protocol": send email
time	**37**	**tcp/udp**	The number of seconds since Jan. 1, 1990
whois	**43**	**tcp**	Directory service for Internet administrators
finger	**79**	**tcp**	Information about a user or users
http	**80**	**tcp**	HyperText Transfer Protocol of WWW
pop3	**110**	**tcp**	Post Office Protocol for server-to-client mail
nntp	**119**	**tcp**	Network News Transfer Protocol
RMI	**1019**	**tcp**	Java RMI registry service

The Berkeley Socket API for the Client-Server Architecture



Some Basic Web Technologies

- URL, HTTP, HTML, XML, SOAP
- Forms, Servlets, Beans, JSF, Sever-side processing

World-Wide Web. URLs

- ***World-Wide Web (WWW, the Web)*** is distributed client-server information system on the Internet
  - allows to locate and to access resources (files, services) on the Internet pointed on by URLs via servers by using Web protocols such as HTTP.
- ***Uniform Resource Locator (URL)*** is the address of a resource on the Internet. See RFC 1738.
  - Common URL syntax:

    <scheme>://<user>:<password>@<host>:<port>/<url-path>
  - For example:

```
ftp://anonymous@ftp.sunet.se/
mailto:jnp-adm@it.kth.se
http://www.it.kth.se/index.html
telnet://vlad@octopus/
http://student:nescafe@vvv.it.kth.se/edu/gru/Java/assignments/
```

Some Web Protocols

- ***HTTP***, Hyper Text Transfer Protocol
  - A client-server TCP/IP protocol. Stateless. RFC 2086 (1.1)
  - The most implemented requests are GET, HEAD and POST
  - URL format: http://user:password@<host>:<port>/<URL-path>
  - Server process: httpd; Default port: 80
- ***FTP***, File Transfer Protocol
  - A session-oriented TCP/IP protocol. See STD 9, RFC 959
  - URL format: ftp://<user>:<password>@<host>:<port>/<URL-path>
  - Ports: 20 (data), 21 (commands)
- ***SMTP***, Simple Mail Transfer Protocol
  - A server-to-server protocol for e-mail transfer. See STD 10, RFC 821
  - SMTP port: 25
- ***SOAP***, Simple Object Access Protocol,
  - A protocol for exchanging structured information in the implementation of Web Services.
  - Relies on XML for message formats, and HTTP (SMTP) as a transport protocol for message transmission.

Telnet

- The ***Telnet protocol*** is the Internet standard protocol for remote login that runs on top of TCP/IP (see: STD 8, RFC 854)
- **`telnet`** is a program that uses the Telnet protocol and acts as a terminal emulator for the remote login session

```
avril:~>telnet www.ict.kth.se 80
Trying 130.237.216.36...
Connected to web.ict.kth.se.
Escape character is '^]'.
GET /index.html HTTP/1.0

HTTP/1.1 302 Found
Date: Mon, 25 Oct 2013 09:34:23 GMT
Server: Apache/2.2.6 (Unix) mod_ssl/2.2.6 ...
...
Connection closed by foreign host.
```

Telnet connection to the web server

GET request to the server

Response from the server

Markup Languages

- ***HTML***: HyperText Markup Language
  - A Hypertext document format used on WWW.
  - "Tags" are use to mark text elements:

  < directive (case insensitive), zero or more parameters > text element </ directive>

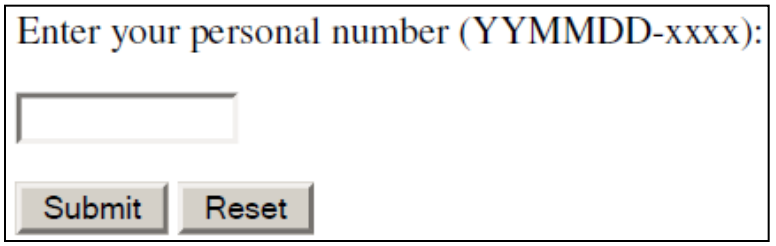
  - Links to other documents:

  ```
  <A HREF="http://machine.edu/subdir/file.html">foo</A>
  ```

- ***XML***: Extensible Markup Language
  - A language for exchange of a wide variety of data on the Web and elsewhere.

HTML Forms

- Allow constructing a simple GUI embedded in an HTML document for a Web client.
  - To input a user request and submit it to a CGI program or a servlet (JSP/JSF).
- Example:




```
<FORM method="POST”
  ACTION="/bin/javacourse/ReportCheck.exe”>
   <P>Enter your personal number (YYMMDD-xxxx):
   <P><INPUT Type="text" Name="personalNumber”
       Value="" Size="11" >
   <P><INPUT Type="submit" value="Submit">
      <INPUT Type="reset" value="Reset"></P>
</FORM>
```

Dynamic Web Content: Server Side Processing

- Provides dynamically generated contents: dynamic web sites, web applications, web services
  - The content is generated when requested (on a HTTP request).
- ***JavaScript*** – a client/server side script language
- ***Java Servlets***
  - Live in server-side JVM, process HTTP requests and generate content
  - Methods `doGet, doPost, doPut, doDelete, init, destroy`
- ***Enterprise JavaBeans***
- ***Sever-Side Scripting***
  - Embedding program code in HTML documents, parsing and executing the code by the Web server; the result is included in the place of the code.
  - Examples:
    - Active Server Pages (ASP.NET) from Microsoft
    - ***Java Server Faces (JSF)*** from Oracle
    - Hypertext Preprocessor (PHP)

GET and POST Requests

Two ways an HTTP request is presented to the server and passed to the target Java servlet, JSP or JSF:

- **GET** method

```
GET /Adder?username=Vladimir+Vlassov&email=vlad%40it%2ekth%2ese HTTP/1.0
```

  - The parameters values are sent as a query string along with the URI.

- **POST** method

```
POST /Adder HTTP/1.0
Content-type: application/x-www-form-urlencoded
Content-length: 65

username=Vladimir+Vlassov&email=vlad%40it%2ekth%2ese
```

  - The parameters values are sent in the request body, in the format that the content type specifies.
  - Can be used for update/upload any content of a specified MIME type.

Java Servlets

- ***Java Servlet*** is a Java object in the server's JVM
  - Provides extra functionality on the server side (extends web-server).
  - Given a name on deployment; addressed by the corresponding URL
  - Accepts and processes user's requests from HTML forms and applets
  - For example, provides access to corporate databases and information services in the third tier of a 3-tier application
- A servlet lives in the server's JVM (application server) much like an applet lives in the client's JVM (in Web browser).
  - Once created, a servlet is alive as long as the server (JVM) is alive
  - The servlet can keep state between requests
    - New state and response is a function of old state and request
  - A servlet can be multithreaded – Scalability
  - A servlet may use EJBs – Extendibility

Some Solutions for Server-Side Scripting

- ASP.NET from Microsoft
  - Languages: C#, VBScript based on Visual Basic
  - Tags <% dynamic code %>
- JavaServer Faces (JSF) from Oracle
  - Language: JSF markup and Java
  - To be studied later in the course
- Hypertext Preprocessor (PHP) – open source software
  - A server-side, cross platform HTML-embedded scripting language

Servlet API and Servlet Enabled Servers

- The Java Servlet API is available as a part of Java Platform, Enterprise Edition (`javax.servlet`)
  - http://www.oracle.com/technetwork/java/index-jsp-135475.html
- The Java Servlet API and JSFs are supported on many web servers (application servers), see
    - http://www.oracle.com/technetwork/java/javaee/overview/compatibility-jsp-136984.html

Architectures of Distributed Applications

- Distributed applications
- Architectures of distributed applications
- Java networking technologies

Distributed Applications

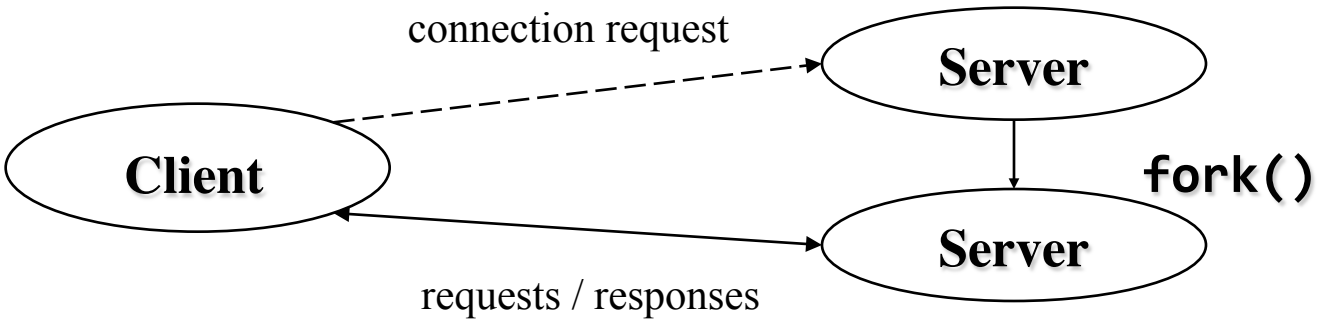
- Motivation:
  - Data, computers and resources, users (clients) are geographically distributed;
  - Improve performance or/and scalability or/and robustness of applications by means of distributed execution.
- Distributed applications on a network of computers (LAN, WAN, the Internet):
  - Print servers, distributed file systems (DFS), DNS, rlogin;
  - WWW: web servers and browsers, ftp and mail servers, ftp and mail clients, instance messaging, on-line games, content delivery networks, streaming media applications, web-services, etc.;
  - Financial and commercial applications: E-commerce, banking (OLTP);
  - Remote control and monitoring of networked devices;
  - Scientific and engineering computing;
  - Cloud computing environments;
  - Content delivery (or distribution) networks (CDN)

Basic Architectures of Distributed Applications

- ***Two-tier architecture*** (a.k.a. ***client-server*** architecture):
  - Clients (with UI, GUI)
  - Servers
- ***Three-tier architecture***
  - Clients (with UI, GUI) – in the 1st tier
  - Business logic – in 2nd tier
  - System services (databases) – in the 3rd tier
- ***Peer-to-peer (P2P) architecture***
  - Formed of peers– processes running on networked nodes
  - On structured or unstructured overlay networks
  - All peers are equal, being both clients and servers
- ***Service-Oriented Architecture (SOA)***
  - Builds on web-services with well defined interfaces, which can be described, deployed, discovered, bound, composed, invoked.
  - Based on WS technologies and standards
  - Studied in ID2208 Programming Web-Services, period 3

2-Tier Client-Server Architecture

- The most commonly used model for distributed applications
  - Can be applied for a particular request-response interaction
- The ***client*** is the entity (process) accessing the remote resource and the ***server*** provides access to the resource.
- Request / response protocols

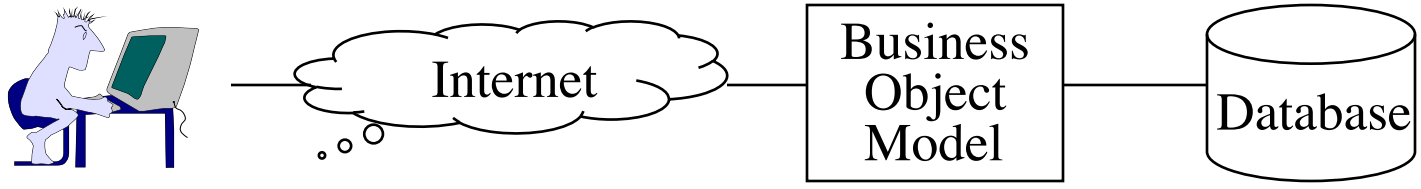


Problems of 2- Tier Client-Server on the Internet

- Portability
  - No control over the client operating system and hardware.
  - Challenging to upload anything to the client if it does not accept.
- Efficiency
  - A “fat” client may require too much resources on a client machine
    - Also slow to download (applets)
  - Direct SQL access can generate lots of network requests
- Security – the most important
  - DBAs do not accept the risks of putting the database on the Internet
  - Internet security should be at the service level, not at the data level

3-Tiered Architecture

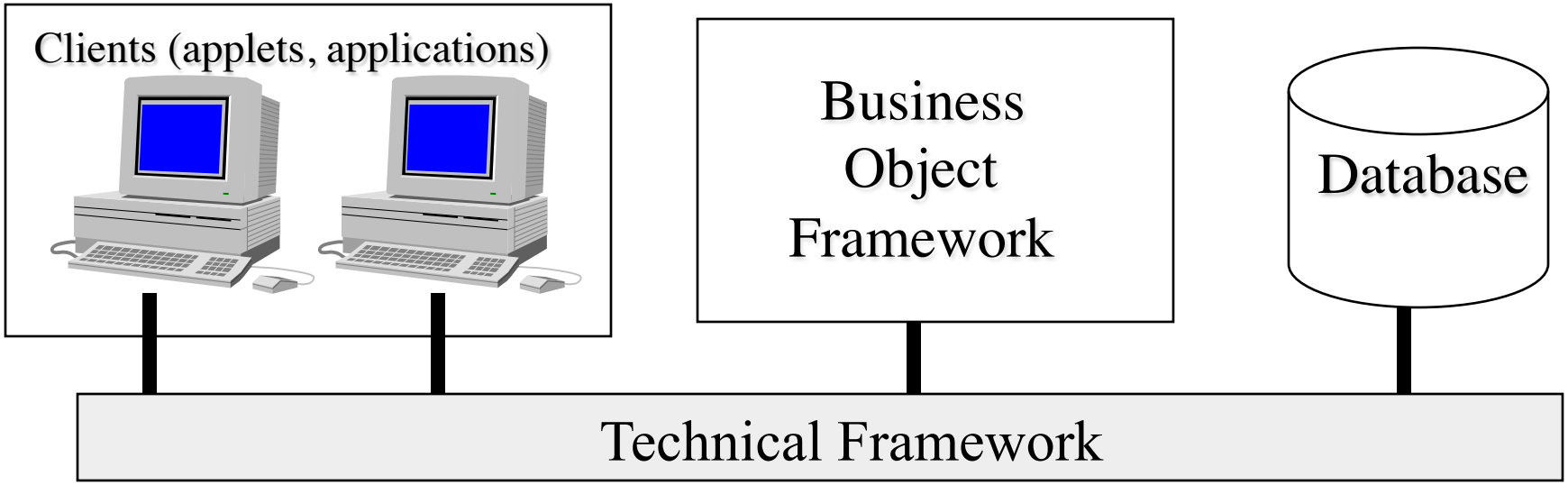
- User-Interface Tier
  - The layer of user interaction.
  - A “thin” client of the business logic servers
- Business Logic Middle-Tier
  - The business logic layer. It is made up of business objects: inventory control, budget, transaction monitors, ORBs, authentication, etc.
- System Service Tier (e.g. persistent storage)
  - Objects that encapsulate database routines and interact with DBMS.



3-Tier Internet Architecture Benefits

- Improved performance
  - Use faster protocols than http or ODBC
  - Download the GUI (thin client), but leave the rest of the logic on the server or in the middle-tier
- Manage security
  - The middle-tier are not restricted by applet security rules
  - The middle-tier can control user authentication, access to resources in the third tier
- Manage user application context
  - The server can remember user data
  - The user can access his context from any Web client

3-Tier and Skills Partitioning



- Application Developers concentrate on the user's needs: GUI, how to present business information, convenient front-ends
- Business Object Modelers work with the domain experts
- Architects manage technology integration
- DBAs focus on data storage, administration and optimization

Peer-to-Peer (P2P) Architecture

- A P2P application runs on an overlay network
  - All peers are equal in terms of responsibility, capabilities and functionality: typically execute the same set of algorithms, participate in distributed algorithms
- An ***overlay network*** is a "virtual" network of nodes created on top of an existing network, e.g. the Internet.
  - Each node has an ID, knows neighbors, does not know the global topology, communicates as a source and a destination, and also ***serves as a router*** in sending data.
  - Can provides a **Distributed Hash-Table (DHT)** functionality
- Structured overlay (P2P) networks
  - E.g. Chord, Pastry, Tapestry, DKS
- Unstructured overlay networks
  - E.g. Gnutella

General Design Issues of Distributed Applications

Quality:

- Functional requirements
  - What functions the application must provide
  - Usage scenarios, use cases – to guide development and to test against
  - API (Application Programming Interfaces) specifications
  - Should be discussed with domain experts and end-users
- Non-functional requirements
  - Given the application fulfills functional requirements, how good is it?
    - "Goodness" has to be defined as measurable metrics;
  - ***Performance***: short response time, low latency, high throughput;
  - ***Complexity***: Message complexity; time complexity;
  - ***Scalability***: ability to handle a growing workload in a capable manner, or ability to be enlarged to accommodate that growth;
  - ***High availability*** and ***dependability*** (trustworthiness)
  - ***Elasticity***: ability to grow (scale out) or shrink depending on workload
  - Other requirements

General Design Issues (cont'd)

- First major problem: Communication latency
  - Affects response time, user experience with the applications
  - Issues at client side:
    - Responsive and informative UI (GUI)
    - Tolerate long communication latency by data caching and prefetching
    - Hide long communication latency by multithreading
  - Issues at server side:
    - Concurrency by multithreading: handle client requests in multiple threads
- Second major problem: Failures
  - Need to build reliable distributed applications and systems
  - Issues at server side:
    - (Transparent) Replication for robustness and/or performance
- Third major problem: Dynamicity
  - Nodes (resources) can un-predicatively join/leave/fail
  - The application/system can be evolving over time

General Design Issues (cont'd)

- How to achieve good quality?
  - Balanced distribution of functionality among distributed components – which component does what; loosely coupled
  - Efficient communication protocols – use as less as possible messages
  - Proper levels of location transparency and location awareness
  - Data replication and caching
    - Consistency and coherence issues
  - Data migration and prefetching
  - Multithreading, caching and prefetching allow to hide and / or to avoid long communication latencies
  - Scalability by concurrent execution – multithreading
    - Servicing of requests in parallel threads
    - Exploit multicore facilities
  - Fault tolerance, failure management

Basic Communication Mechanisms

- Message passing over sockets (TCP or UDP)
  - Application specific request/response protocols
- Remote Procedure Calls (RPC) and rendezvous
  - RPC spawns a new process (thread) to handle a request
  - Rendezvous – request is accepted (selected) and processed by an existing running server process
- Remote Method Invocation (RMI)
  - The object-oriented analog of RPC in a distributed object-oriented environment
  - Distributed object architecture

A Distributed Component Architecture (Platform)

- ***A middleware*** that provides ability to built an application of distributed components (objects, web-services), i.e.
  - To declare, create, name, locate and bind distributed components
  - To (transparently) invoke methods on the components
  - To migrate, replicate and keep consistent distributed copies of a component
  - To manage distributed memory: distributed garbage collection
  - To automate most of systems functions (deployment, runtime reconfiguration and upgrade, failure management, etc.)
- Defines, specifies and provides services (and corresponding APIs) common for most applications, such as naming, deployment, lifetime management, transactions, etc.
- Typically includes:
  - A programming model,
  - A programming environment with APIs,
  - A runtime system (containers, services)

SOA: Service-Oriented Architecture

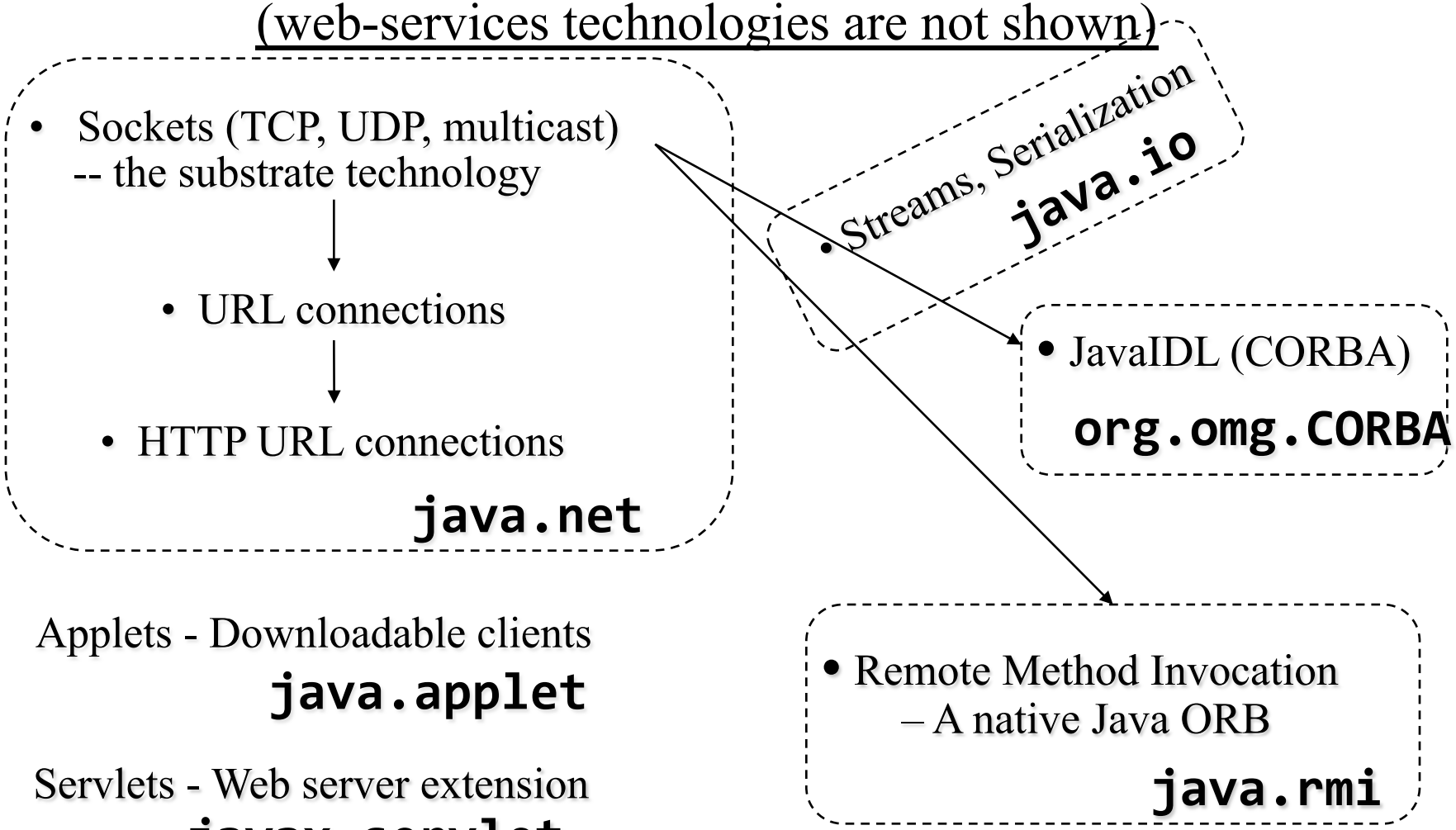
- Applications are built of services
  - Services are built of components
  - Components are bound to each other via client/server interfaces
    - A client interface of a (client) components is bound to a server interface of another (server) component
- Services are loosely-coupled
  - Expose interfaces (port types);
  - Can be described, discovered, bound, and invoked;
  - Service invocation: request-response interaction

Some Existing Approaches

- CORBA
  - Common Object Request Broker Architecture from OMG
  - Heterogeneous
  - Many implementations exist
- .NET (DCOM)
  - Distributed Component Object Model from Microsoft
  - Homogeneous ("MS-only")
- Java RMI
  - Homogeneous
  - Enterprise JavaBeans – A component architecture for building integrated enterprise services based on RMI/IIOP
- Web services
  - SOAP (Simple Object Access Protocol) – a minimal set of conventions and standards for invoking code using XML over HTTP

Essential Networking Technologies in Java

(web-services technologies are not shown)



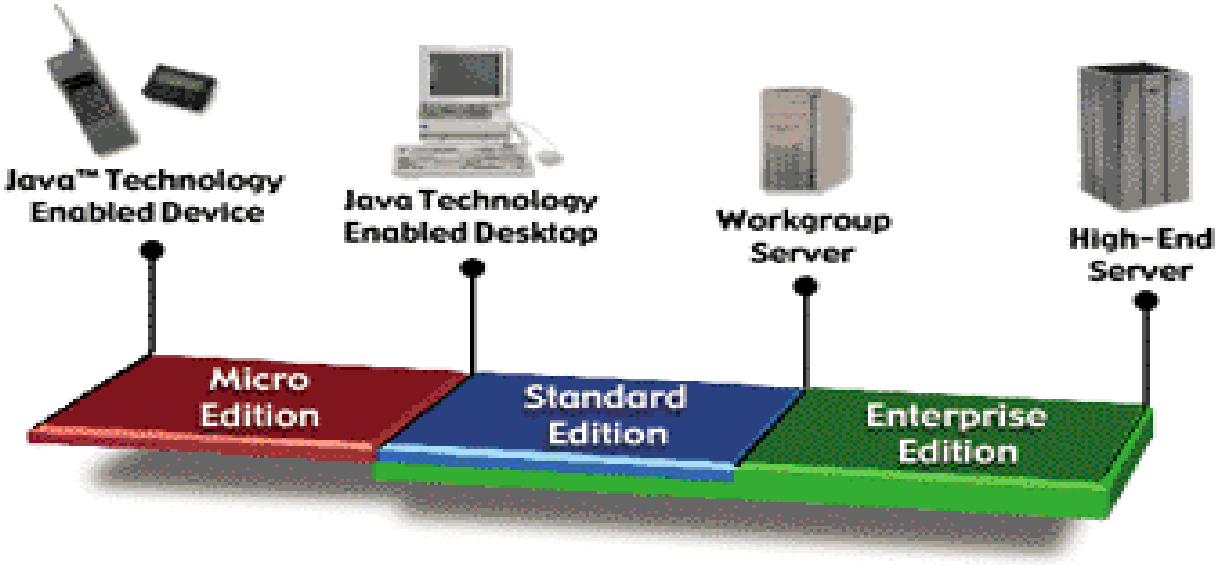
- Applets - Downloadable clients

  java.applet

- Servlets - Web server extension

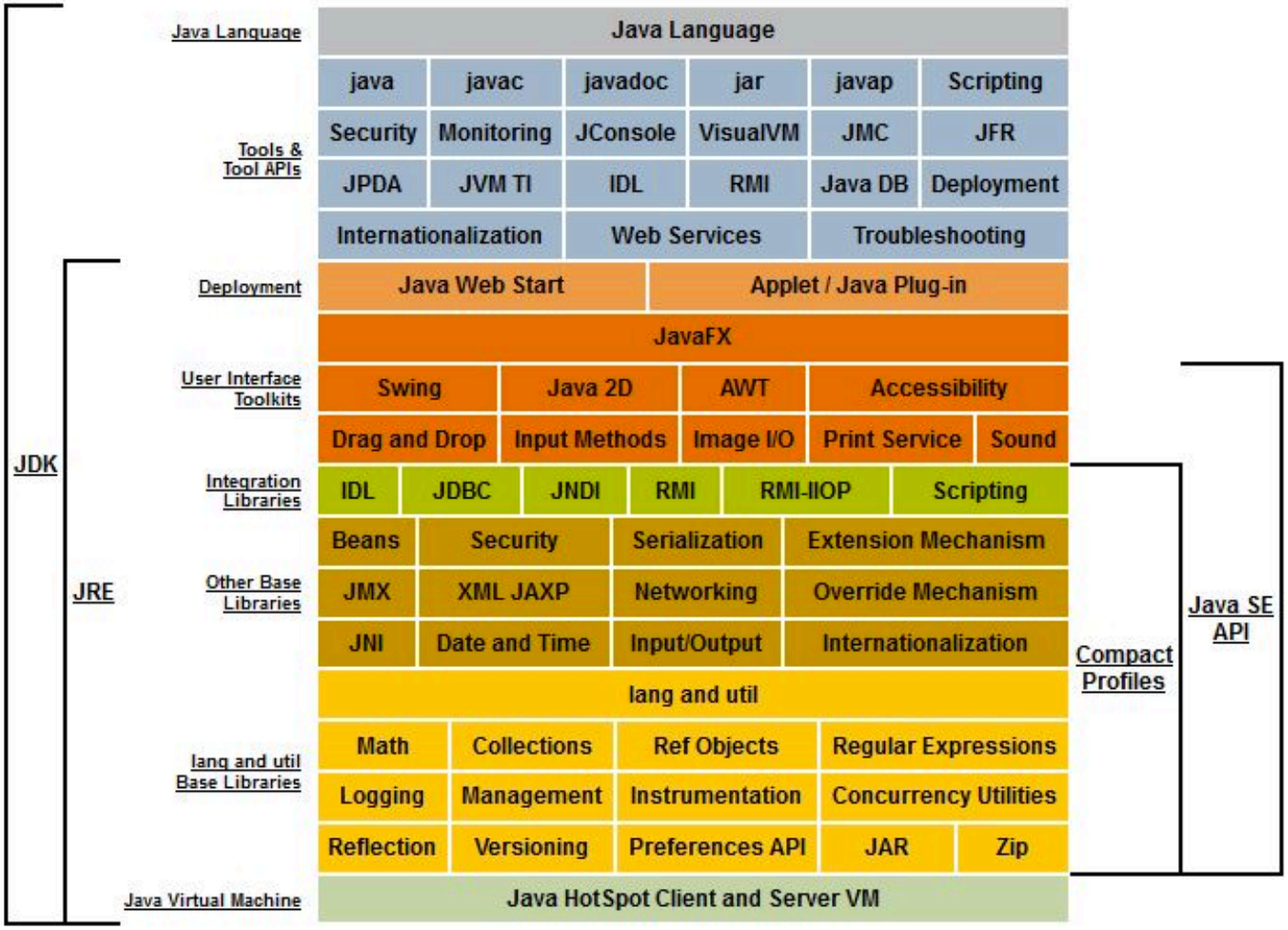
  javax.servlet

Three Java Editions (Platforms)



- Java Platform, Standard Edition (Java SE)
- Java Platform, Enterprise Edition (Java EE)
- Java Platform, Micro Edition (Java ME)

The Java Platform, Standard Edition (Java SE)



http://www.oracle.com/technetwork/java/javase/tech/index.html

Java Platform, Enterprise Edition (Java EE)

- ***Enterprise Application Technologies***
  - Enterprise JavaBeans (EJB)
  - J2EE Connector Architecture
  - Java Message Service (JMS)
  - Java Persistence API (JPA)
    - Provides a persistence model for object-relational mapping. Developed and use for EJB, but can be used directly
  - Java Transaction API (JTA)
  - JavaMail
- ***Web Application Technologies***
  - Java API for WebSocket
  - Java Servlet
  - JavaServer Pages (JSP)
  - JavaServer Faces (JSF)
- ***Management and Security Technologies***
  - J2EE Application Deployment
  - J2EE Management
  - Java Authorization Contract for Containers

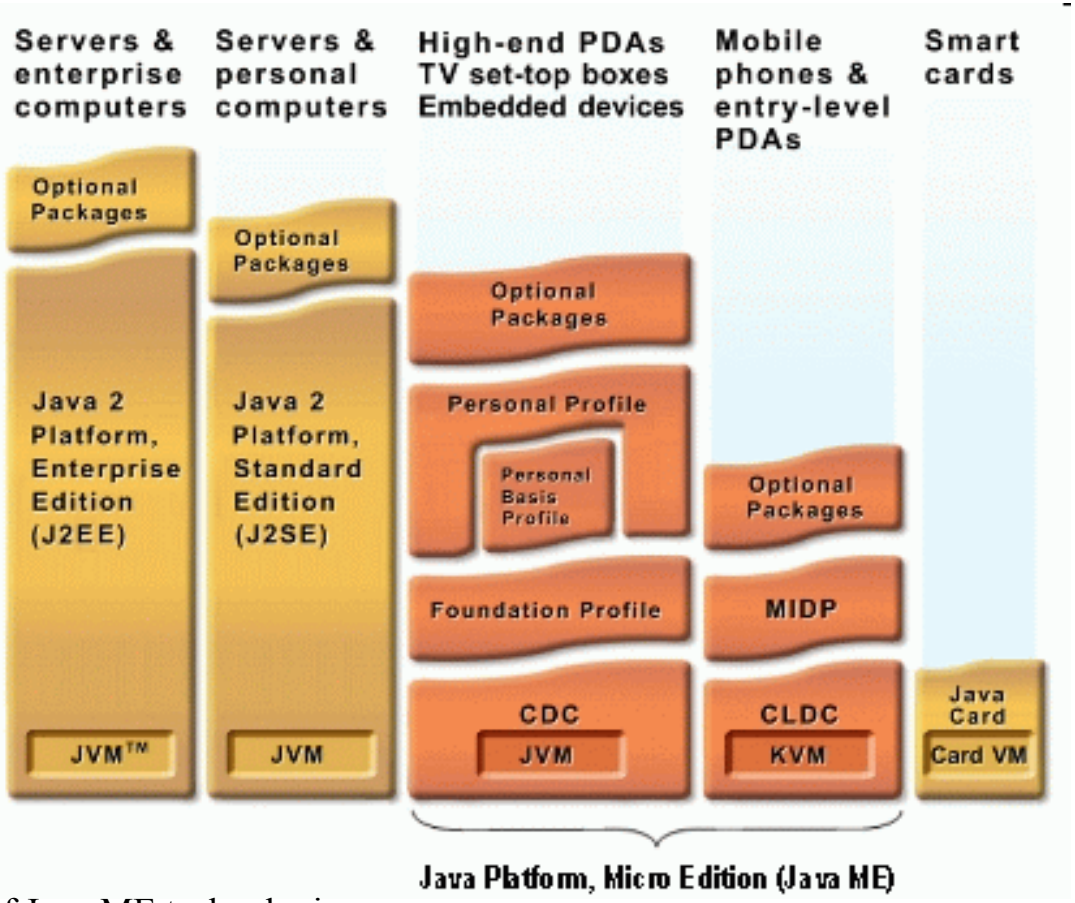
See the complete list of Java EE technologies at http://www.oracle.com/technetwork/java/javaee/tech/index.html

Java EE (cont'd)

- ***Java EE Web Services Technologies***
  - Java API for RESTful Web Services (JAX-RS)
  - Java API for XML-Based Web Services (JAX-WS)
    - Replaces JAX-RPC
  - Java API for XML-Based RPC (JAX-RPC)
  - Java Architecture for XML Binding (JAXB)
    - Provides a convenient way to bind an XML schema to a representation in Java code.
  - SOAP with Attachments API for Java (SAAJ)
    - Provides a standard way to send XML documents over the Internet from the Java platform.
  - Streaming API for XML
    - Streaming Java-based, event-driven, pull-parsing API for reading and writing XML documents.
  - Web Service Metadata for the Java Platform

See the complete list of Java EE technologies at http://www.oracle.com/technetwork/java/javaee/tech/index.html

Java Platform Micro Edition (Java ME)



Components of Java ME technologies.
Retrieved from http://www.oracle.com/technetwork/java/javame/tech/index.html

Java ME (cont'd)

- ***Configurations***
  - functionalities (runtime, APIs) for a particular range of devices with similar characteristics
  - ***CLDC***: The Connected Limited Device Configuration;
  - ***CDC***: The Connected Device Configuration.
- ***KVM***: Kilobyte Virtual Machine

- ***Profiles***
  - complete runtime environments and APIs for a specific device category
  - ***MIDP***: Mobile Information Device Profile;
  - ***FP***: Foundation Profile;
  - ***PDAP***: Personal Digital Assistant Profile