IS 651: Distributed Systems
Chapter 2: The Evolution of Distributed Systems

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Notes

• Team building
  ▪ Please introduce yourself again if you still do have not have a team
  ▪ You will be considered as a one-person team until you merge with others

• Piazza
  ▪ You are very welcome to reply others’ questions
  ▪ You can have public/anonymous posts

• Lecture videos will be on blackboard (Course Videos) once they are available

• Submit homework/exercise on Blackboard
  ▪ Look for homework or exercise link on Blackboard for the assignment
  ▪ Multiple submissions are allowed
  ▪ Late submissions are allowed with 10% additional penalty for each additional day delay. For instance, submission by Friday means 20% penalty of the score
Learning Outcomes

• After learning chapter 2, you should be able to
  ▪ Understand the different generations of distributed systems and the reason for the evolution
  ▪ Understand new terms from the chapter: middleware, remote procedure call (RPC), message-oriented, Transaction, etc.
  ▪ Write XML documents and validate them using DTD
## Basic Timeline of Distributed System Evolution

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<th>Era</th>
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Mainframe (1960s)

A typical mainframe architecture
Client/Server (1970s)

- Minicomputers: smaller computers (not Personal Computer yet)
- Ethernet: form local-area networking (LAN)
- X.25: wide-area networking (WAN) service
- Client server architecture
  - A client is a requestor process and server is a responder process
  - One machine could be both client and server
- Beginnings of the Internet
  - ARPANET
  - TCP/IP stack
2 and 3-tier Systems (1980s)

• Personal Computer
• NetWare file servers
• Network file system (NFS)
• Remote procedure call (RPC)
• 3-tier system: with an architectural middle tier, called the application server, and associated middleware
• Middleware

A 2-tier system
Middleware

• Middleware is the software layer that lies between the operating system and the applications on each side of a distributed computer network.

• Middleware offers **general services** that can be used by many applications:
  - Remote procedural call (RPC)
  - Distributed cache
  - Message queue

• Major types of middleware:
  - Remote procedural call middleware
  - Message-oriented middleware
Remote Procedure Call (RPC) Middleware

- The application calls the remote procedure locally at the stub
- The stub intercepts calls that are for remote servers
  - Marshalling: pack the parameters into a message
  - Make a system call to send the message
- The RPC Runtime handles message sending
- The interface definition language (IDL) handles message translation
- RPC hides heterogeneity among the computers and handles the communication across network
Messaging Modes of Communication

• Synchronous (blocking)
  ▪ RPC protocol is synchronous
  ▪ When a client makes a remote call, the calling process blocks or waits until it gets a reply

• Asynchronous
  ▪ The calling process just goes back to processing and is interrupted with a callback message when it does get the response
  ▪ Message-oriented protocol supports it

communication from client to server (for both synchronous and asynchronous)
Distributed File Systems

• A type of RPC middleware
• Allows users to mount directories from remote computers into their own local directory, so they appear as local
• NFS: network file system
• XDR: external data representation

NFS distributed file system protocol stack

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<th>OSI Layer</th>
<th>File System 1</th>
<th>File System 2</th>
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<td>Application</td>
<td>NFS</td>
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<td>Presentation</td>
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<td>RPC</td>
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<tr>
<td>Transport</td>
<td>TCP</td>
<td>TCP</td>
</tr>
</tbody>
</table>
Transaction Middleware

- A database RPC middleware uses an explicit 3-tier architecture
- Transaction processing monitor (TPM) at middleware tier
Transactions

• All the participating operations on (distributed) resources should either succeed or fail and recover together

• 2-Phase Commit
  ▪ commit-request phase: TPM request all the servers to commit and wait responses
  ▪ commit phase: TPM decides either commit or abort based on responses

• A transaction is a unit of work with the following ACID properties
  ▪ ATOMICITY: A transaction should be done or undone completely and unambiguously
  ▪ CONSISTENCY: A transaction should transform the system from one consistent state to another consistent state
  ▪ ISOLATION: Each transaction should appear to execute independently of other transactions that may be executing concurrently in the same environment
  ▪ DURABILITY: The effects of a completed transaction should always be persistent
Object-Oriented RPC Middleware

• RPC-based distributed systems based on object-oriented programming principles

• Two main technologies
  • Common Object Request Broker Architecture (CORBA): a standard designed to facilitate the communication of systems that are deployed on diverse platforms
  • Distributed Component Object Model (DCOM): a proprietary Microsoft technology for software distributed across several networked computers to communicate with each other
CORBA

- **Skeleton**: stub for server object
- **Object request broker (ORB)**
  - Mediates a method call from one object to another local/remote object
- **Internet inter-ORB protocol (IIOP)**
  - Allows ORBs from different vendors to communicate over the Internet
- The client cannot tell whether the target object it communicates with is local or remote
Message-Oriented Middleware (MOM)

• Point-to-point messaging (PTP): 1 to 1
  ▪ Messages are sent to a queue, rather than directly to the intended receiver

• Publish/Subscribe messaging (pub/sub): M to N

• MOM is based on RPC
  • MOM uses queues to give *asynchronous* communication from the viewpoint of the sender and receiver
Point-to-point Messaging (P2P) Example

• MQSeries shows how P2P architecture and asynchronous communication are achieved using RPC protocols

• Message channel agent (MCA): controls message sending and receiving

Example: IBM MQSeries

• General organization of IBM’s MQSeries message-queuing system.
Pub/Sub

• The Pub/Sub model is an excellent message delivery model appropriate for multiple senders and multiple recipients
  ▪ Each publisher can send out messages for multiple topics
  ▪ Each subscriber can decide which topics he/she is interested
Database Access via ODBC

• It shows a client-side type of middleware

• Open Database Connectivity (ODBC)
  ▪ A standard programming language middleware API for accessing database management systems
  ▪ The same client application uses the different ODBC drivers to access different types of databases

• Java Database Connectivity (JDBC): an API for Java
N-tier Systems (1990s)

• N-tier systems are not a different approach than 3-tier systems, they are just an elaboration of the same pattern
• Web server: serves content to the web using http protocol
• Application server: hosts and exposes business logic and processes

![Diagram of N-tier Systems]

- Presentation – Web Browser (client)
- Communication – Web Server
- Logic – Application Server
- Storage – Database Server
LAMP Web Scripting with N-tier Systems

• L – the operating system. L stands for Linux as the most common one, but any operating system can be used such as Windows.

• A – the web server. A stands for Apache HTTP Server, as the most popular open-source web server, but any web server may be used.

• M – the database. M stands for MySql as a popular open-source relational database, but any database may be used.

• P – the scripting language. P originally stood for Perl which is a popular scripting language and oddly enough, many scripting languages begin with P such as Python and PHP.
  ▪ Any scripting language may be used, however, such as Ruby and JavaScript.
  ▪ Scripting languages are characterized as interpreted and dynamically typed.
MEAN Web Scripting with N-tier Systems

• M – MongoDB, a NoSQL database
• E – Express.js, a web application framework that runs on Node.js
• A – Angular, a JavaScript MVC (model, view, control) framework that runs in browser JavaScript engines
• N – Node.js, an execution environment for event-driven server-side and networking applications

• MEAN applications can be written in one language, namely JavaScript, for both server-side and client-side execution environments.
  - An open source project by IS students: https://github.com/rogueriderhood/mean-project/
J2EE (Enterprise Edition) Application Server

- Java naming and directory interface (JNDI): A naming service for containers
- The Java messaging service (JMS): MOM service offered by Java frameworks
- Remote method invocation (RMI): Java framework version of object-oriented RPC
- Servlet Container: a server-side software component for objects to receive requests and generate responses. A servlet is often built as Java Server Pages (JSPs)
- Enterprise JavaBeans (EJB): a server-side software component for business logic
- It is still widely used and can provide Web services
Services (2000s)

• Standard service contracts
  ▪ Participants have agreements
  ▪ They should also be discoverable by using some kind of registry or directory

• Loose coupling
  ▪ The participants have minimal dependencies on each other

• Encapsulation
  ▪ Services should hide their logic from the outside world as a black box
  ▪ This increases flexibility, reusability and increases composability
  ▪ Services should also have location transparency where users do not care where the services are located

• Statelessness
  ▪ Keep track of as little state as possible
  ▪ This is a requirement for loose coupling and encapsulation
Extensible Markup Language (XML)

• Markup language: text document with annotation (normally using tags)
  ▪ HyperText Markup Language (HTML)
  ▪ Extensible Markup Language (XML)
  ▪ Extensible HyperText Markup Language (XHTML)
  ▪ etc.

• XML documents form a tree structure

• Well-formed XML VS. Valid XML

• XML validation
  ▪ Document type definition (DTD)
  ▪ XML Schema
Well-formed XML

• It contains only properly encoded, legal Unicode characters
• None of the special syntax characters (<, &) appear except when performing their markup-delineation roles
• The begin, end, and empty-element tags that delimit the elements are correctly nested, with none missing and none overlapping
• The element tags are case-sensitive - the beginning and end tags must match exactly
• There is a single "root" element that contains all the other elements
• Well-form check command: $>xmllint --noout shiporder.xml
Valid XML

• The declaration in line 1 is contains question mark characters and is called a **processing instruction**. It refers the version and encoding for the XML document.

• Line 2 has a reference to an external DTD file that contains the DTD.
  • It can be replaced by embedding DTD content.

• Line 3 is the root **tag** for the document. Note that it contains an **attribute**. Any XML tag may have an attribute and it must be quoted.

• Note that even though **item** is repeated, it uses the same tag. Never create tags like item1, item2, etc.
Document Type Definition (DTD)

- The declaration of the DTD in the XML document has the syntax where `SYSTEM` refers to that fact that the DTD is a private implementation for this document rather than a standard. It would change to `PUBLIC` if it was a standard.
  - `<DOCTYPE root-element SYSTEM "URI" >`

- DTDs do not have XML syntax. They have their own syntax.

- The `!ELEMENT` declares an element (also called a tag).

- The child elements of a tag are declared as an ordered list in parentheses. If an element can be repeated 1 or more times, it must have a plus sign (+) after it. The character star (*) means 0 or more and so makes elements optional.

- A leaf node of the hierarchy is declared `#PCDATA` which means parsed character data and it is the text of the content.

- The `&lt;` and `&gt;` are XML built-in entities for the less than and greater than (`< >`) characters. XML markup characters cannot be used because they would confuse a parser, so these pre-defined entities must replace them.

- There are no data types in DTDs. Everything is text.

- The `!ATTLIST` declares an attribute for an element and typically declares it as CDATA which means character data. This means that the XML parser does not parse it.

- One can require a document to have an attribute in order to be valid by using `#REQUIRED`. 
DTD Example

```xml
<!ELEMENT shiporder (orderperson, shipto, item+)>
<!ELEMENT orderperson (#PCDATA)>
<!ELEMENT shipto (name, address, city, country)>
<!ELEMENT name (#PCDATA)>
<!ELEMENT address (#PCDATA)>
<!ELEMENT city (#PCDATA)>
<!ELEMENT country (#PCDATA)>
<!ELEMENT item (title, note*, quantity, price)>
<!ELEMENT title (#PCDATA)>
<!ELEMENT note (#PCDATA)>
<!ELEMENT quantity (#PCDATA)>
<!ELEMENT price (#PCDATA)>
<!ATTLIST shiporder orderid CDATA #REQUIRED>
```

• Validation command: `>$>xmllint --noout --valid shiporder.xml`
Demo

• Well-form check command
  - xmllint --noout shiporder.xml
  - xmllint --noout shiporder-not-well-formed.xml
  - xmllint --noout shiporder-well-formed-not-valid.xml

• Validation check command
  - xmllint --noout --valid shiporder.xml
  - xmllint --noout --valid shiporder-well-formed-not-valid.xml