

Software Testing and Maintenance Designing for Change

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Based on *Enterprise Integration Patterns*, Hohpe and Woolf, Addison-
Wesley, Introduction and Chapter 1
Thanks to Hyanghee Lim

Designing for Maintainability

- 1. Integrating Software Components**
- 2. Sharing Data and Message Passing**
- 3. Advantages and Disadvantages of Message Passing**
- 4. Application Integration**
- 5. Using Design Patterns to Integrate**

Modern Software is Connected

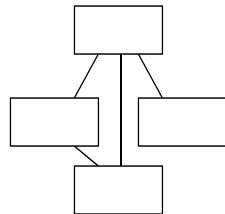
- **In 1980, we built single stand-alone systems**
- **Now we build collections of integrated software systems**
- **Modern programs rarely live in isolation**
 - They interact with other applications on the same computing device
 - They use shared library modules
 - They communicate with related applications on different computers
 - Data is shared among multiple computing devices
- **Web applications communicate across a network**
- **Web services make connections dynamically during execution**
- **This increase in couplings among software systems has major impacts on the software is designed**
- **Distributed computing has become the norm, not the exception**

Fundamental Challenges of Integration

- **Networks are unreliable**
 - Distributed software has to deal with more potential problems
 - Phone lines, LAN segments, routers, switches, satellites, ...
- **Networks are slow**
 - Multiple orders of magnitude slower than a function call
- **Applications on different computers are diverse**
 - Different languages, operating systems, data formats, ...
 - Connected through diverse hardware and software applications
- **Change is inevitable and continuous**
 - Applications we connect with changes
 - Host hardware and software changes

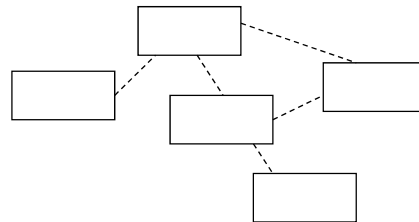
Distributed software must use extremely low coupling

Coupling in Distributed Software



Traditional software

Connected by calls and message passing
High and moderate coupling



Distributed software

Connected with Networks
Loose, *extremely* loose, and dynamic coupling

Extremely Loose Coupling

- **Tight Coupling** : Dependencies among the methods are encoded in their logic
 - Changes in A may require changing logic in B
 - This was common in the 1970s
 - Often a characteristic of functional design of software
- **Loose Coupling** : Dependencies among the methods are encoded in the structure and data flows
 - Changes in A may require changing data uses in B
 - Goal of data abstraction and object-oriented concepts
- **Extremely Loose Coupling (ELC)**: Dependencies are encoded only in the data contents
 - Changes in A only affects the contents of B's data
 - Goal of distributed software and web applications

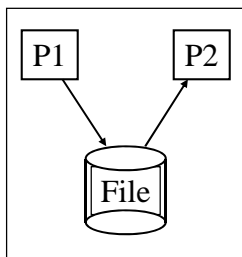
The issues come down to how we share data ...

ELC Leads Directly to XML

- Passing data from one software component to another has always been difficult
- The two components must agree on format, types, and organization
- Distributed applications have unique requirements for data passing:
 - Very loose coupling
 - Dynamic integration
 - Frequent change

Passing Data - 1978

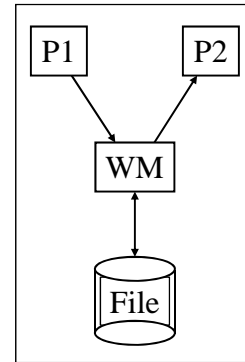
- Program P2 needs to use data produced by program P1
 - Data saved to a file as records (COBOL, Fortran, ...)
 - The file format often not documented
 - Source for P1 may not be available
 - Data saved in binary mode – not readable by hand



- Format of file deduced from executing P1 and from trial and error
- MSU Computing Services, 1979: Two weeks of trial and error executions of P1 to understand format of file

Passing Data - 1985

- **Program P2 needs to use data produced by program P1**
 - Data saved to a file as records (C, Ada, ...)
 - The file format often not documented
 - Data saved as plain text
- Both P1 and P2 access the file through a “wrapper module”
- Module needs to repeatedly updated
- Module written by development team
- Data hard to validate
- Mothra, 1985: ~12 data files shared among 15 to 20 separate programs



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Wrapper Method Problems

- **Slow – Everything is a file in plain text**
- **Sharing – Developers of P1 and P2 must agree to share source of WM**
- **Maintenance – Who has “control” of WM?**
- **Solution – data sharing that is:**
 - Independent of type
 - Self documenting
 - Easy to understand format
 - Especially important for distributed software – XML

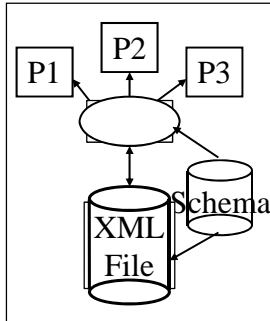
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Passing Data - 21st Century

- Data is passed directly between components
- XML allows for self-documenting data



- P1, P2 and P3 can see the format, contents, and structure of the data
- Free parsers are available to put XML messages into a standard format
- Information about type and format is readily available

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General Approaches to Sharing Data

- **File Transfer**
 - One application writes to a file that another later reads
 - The “1978” and “1985” strategies are variants of file transfer
 - Both applications need to agree on:
 - File name, location
 - Format of the file
 - Timing for when to read and write it
 - Who will delete the file
- **Shared Database**
 - Replace a file with a database
 - Most decisions are encapsulated in the table design
- **Remote Procedure Invocation**
 - One application calls a method in another application
 - Communication is real-time and synchronous
- **Message Passing**
 - One application sends a message to a common message channel
 - Other applications read the messages at a later time
 - Applications must agree on the channel and message format
 - Communication is asynchronous
 - XML is often used to implement message passing

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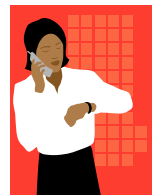
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Message Passing

Message passing is asynchronous and very loosely coupled



- Telephone calls are *synchronous*
- This introduces restrictions :
 - Other person must be there
 - Communication must be in real-time



- Voice mail is *Asynchronous*
- Messages are left for later retrieval
- Real-time aspects are less important



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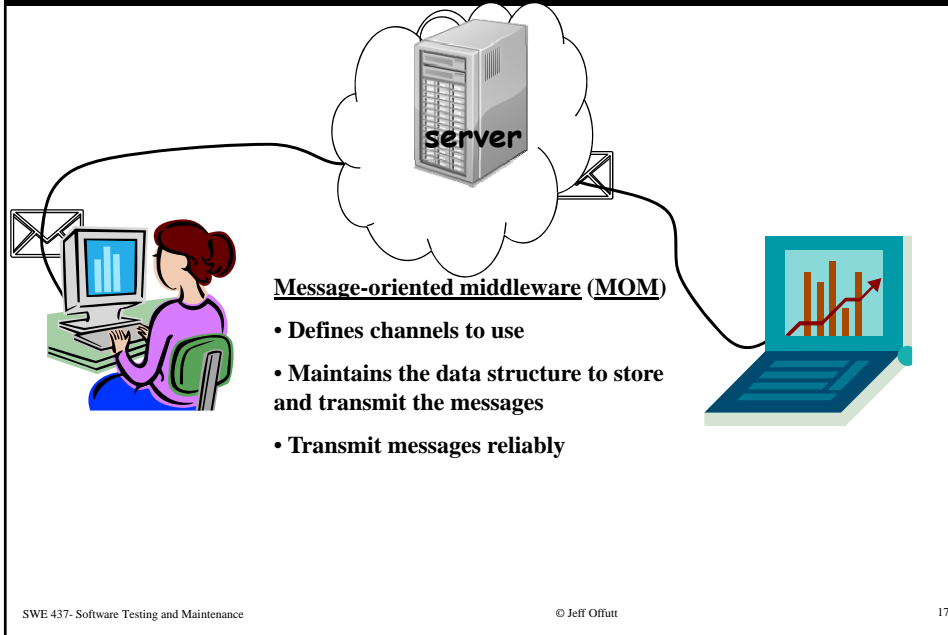
Message Terminology

- A *message* is a packet of data
- *Channels* (or *queues*) are logical pathways that transmit messages from one program to another
- A *sender* (or *producer*) writes a message to a channel
- A *receiver* (or *consumer*) reads a message from a channel
- A message has two parts :
 - *Header* contains *meta*-information : who, where, when
 - **Body** contains the data
 - Message system ignores the body

Messaging Impacts Software Engineering

- Asynchronous messaging architectures are very powerful
- But the way we develop software needs to change !
- We have much more knowledge for file transfer, shared database, and remote procedure calls
 - Colleges have been teaching them for 20+ years
 - Companies have been using them for 15 years or more
- The world wide web made message-based software systems easy to build
- E-commerce has made message-based software systems essential and ubiquitous !

How Does Messaging Work ?



Message-Oriented Middleware

- **Must move messages from the sender's computer to the receiver's computer in a reliable way**
- **Networks are inherently unreliable**
- **Either computer, or the network, or the middleware server may be unavailable**
- **Messaging systems repeat sending until successful**
- **Message transmission has 5 steps :**
 1. **Create – Sender creates the message header and body**
 2. **Send – Sender write the message to a channel**
 3. **Deliver – Messaging system moves the message from the sender to the receiver**
 4. **Receive – Receiver reads the message from the channel**
 5. **Process – Receiver extracts data from the body of the message**

Forgetting and Forwarding

- **Send and forget**
 - In step 2, the sender writes the message to the channel, then forgets about it
 - The sender can do something else while the message is being delivered
- **Store and forward**
 - In step 2, the messaging system stores the message on the sender's computer
 - In step 3, the messaging system forwards the message to the receiver
 - In step 3, the messaging system stores the message on the receiver
- **The “store and forward” process may be repeated along several computers between the sender and the receiver**
 - Think about how many copies of your “private” email messages exist ...

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Benefits of Messaging

- **Number one reason : Message-based software is easier to change and reuse**
 - Better encapsulated than shared database
 - More immediate than file transfer
 - More reliable than remote procedure invocation
- **Software components depend less on each other**
 - Less coupling
- **Several engineering advantages:**
 - Reliability
 - Maintainability / Changeability
 - Security
 - Scalability
- **The disadvantage of speed is offset by these advantages and ameliorated by good quality middleware**

Specific Benefits

- 1. Remove Communication : Separate applications can share data**
 - Programs on the same computer share memory
 - Sending data to another computer is more complicated – objects must be *serialized* – converted into a byte stream
 - Messaging handles this so that applications do not
- 2. Platform / Language Integration : Separate applications are in different languages and run on different operating systems**
 - Middleware makes the data independent of language
 - The middleware serves as a *universal translator*
- 3. Asynchronous Communication : Allows *send-and-forget***
 - Sender does not have to wait for receiver
 - Once a message is sent, the sender can do other work while the message is transmitted in the background

Specific Benefits (2)

4. **Variable Timing : Send and receiver can run at different speeds**
 - Synchronous communication means caller must wait for receiver
 - Asynchronous communication means no waiting
5. **Throttling : Receiver is not overwhelmed with messages**
 - RPCs can overload the receiver, degrading performance or crashing
 - Messaging system holds messages until the receiver is ready
6. **Reliable Communication : Undelivered messages can be re-sent**
 - Data is packaged as atomic, independent messages
 - Messaging system stores messages and can re-transmit if the transmission fails
 - Network problems don't create transmission failures

Specific Benefits (3)

7. **Disconnected Operations : Application can run independent of the network**
 - PDAs and phones can run offline, and synchronize through messaging system when needed
 - My calendar is duplicated on my home computer, my office computer, and my PDA
8. **Mediation : Applications deal with middleware, not other apps**
 - Some applications interact with several other applications
 - Instead of integrating directly with all other applications, an application can integrate with the messaging system, which keeps a directory of all applications
9. **Thread Management : Blocking is not necessary**
 - One application does not need to block while waiting for another to perform a task
 - A *callback* can be used to tell the caller when a reply arrives
 - The sender not use threads for communication, so has more available

Disadvantages of Messaging

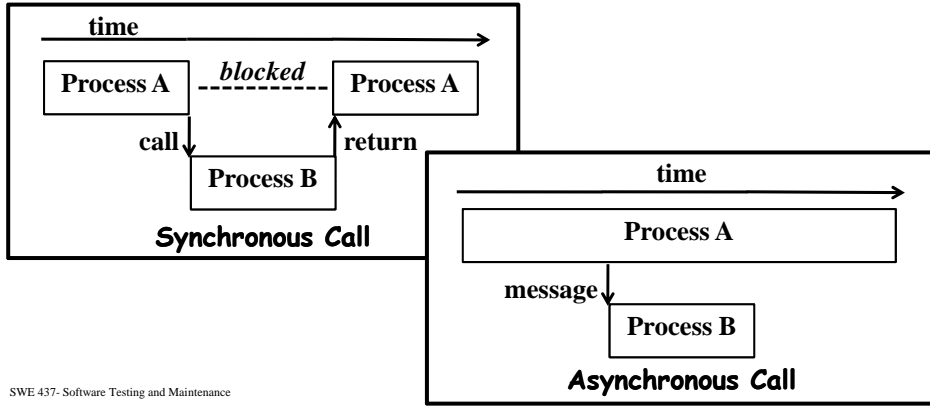
- 1. Programming model is different – and complex**
 - Programmers are not used to event-driven software
 - Universities do not teach event-driven software
 - Logic is distributed across several software components
 - Harder to develop and debug
- 2. Sequencing is harder**
 - Message systems do not guarantee when the message will arrive
 - Messages sent in a particular sequence may arrive out of sequence
 - Including sequence numbers with message data is painful
- 3. Some programs require applications to be synchronized**
 - If I am looking for an airline ticket, I need to wait for a response
 - Most web applications are synchronized ... Ajax allows asynchronous communication within web applications

Disadvantages of Messaging (2)

- 4. Messaging introduces some overhead – reducing performance**
 - The message system needs time to pack, send and unpack the data
 - If a large amount of data needs to be sent, “*extract, transform, and load*” (*ETL*) tools are more efficient
- 5. Not available on all platforms**
 - Sometimes FTP is the only option available
- 6. Some messaging systems rely on proprietary protocols**
 - Different messaging systems do not always connect with each other
 - Sometimes we must integrate different integration solutions !

Thinking Asynchronously

- From CS 1, we have learned to program with function calls
 - Call a method and don't do anything else until it returns
- **Asynchronous programming allows a program to give a task to another program, and keep on working without waiting**
 - This should be comfortable – it is how real life works ...



Implications of Asynchronous Communication

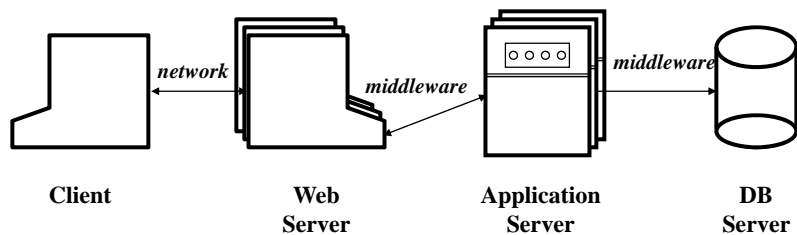
- **No longer have a single thread of execution**
 - Multiple threads allow methods to run concurrently
 - Improves performance
 - Makes testing and debugging harder
- **Results arrive via callback**
 - The receiver sends a "call" "back" to the sender
 - Sender has to have a way to process the results
- **Asynchronous processes can execute in any order**
 - More efficient
 - The overall algorithm must not depend on order
 - Sender must know who a result comes from

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Distributed Integration

- Writing distributed programs is a major challenge
- Integrating separate distributed programs is easier
- An n-tier architecture is application distribution



Typical n-tier application - web application
Each tier only communicates with the next tier

Why is N-Tier *Application Distribution*

- **The communicating parts are coupled**
 - The depend directly on each other
 - One tier cannot function without the other
- **Communication between tiers is usually synchronous**
- **Most n-tier applications have a human user**
 - Expect rapid system response times

Application Integration

- **Each application is independent**
 - Can run by themselves
- **Applications *coordinate* in a loosely coupled way**
- **Each application focuses on one comprehensive set of functions**
 - Delegate other functions to other applications
- **Applications run asynchronously**
 - Usually don't wait for responses from other applications
 - Usually have broad time constraints

Commercial Messaging Systems

- Messaging middleware available from several software vendors
- Operating systems
 - MS Windows includes Microsoft Message Queuing (MSMQ) software
 - Available through several APIs, COM components, System.Messaging, and .NET
 - Oracle offers Oracle AQ with its database platform
- Application servers
 - Java Messaging Service (JMS) is specified in the J2EE platform
 - IBM WebSphere, BEA WebLogic, J2EE JDK
- EAI suites
 - Proprietary suites with lots of functionalities – messaging, business process automation, workflow, portals, etc
 - IBM WebSphere MQ, MS BizTalk, TIBCO, WebMethods, ...
- Web service toolkits
 - Still in development but industry and researchers are very excited

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Enterprise Applications

- Enterprise systems contain hundreds, even thousands, of separate applications
 - Custom-built, third party vendors, legacy systems, ...
 - Multiple tiers with different operating systems
- Until recently, nobody built a single big application to run a complete business
 - Nobody has yet done it particularly well
- Enterprise systems have *grown* from multiple smaller pieces
- Companies want to buy the best package for each task
 - Then integrate them !

Thus - integrating diverse applications into a coherent enterprise application will be an exciting task for years to come

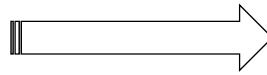
Types of Application Integration

1. Information portals
2. Data replication
3. Shared business functions
4. Service-oriented architectures
5. Distributed business processes
6. Business-to-business integration

This is not a complete list of all types of integration, but represents some of the more common types

Information Portals

Information portals aggregate information from multiple sources into a single display to avoid making the user access multiple systems



- Answers are accessed from more than one system
- Gradesheet, syllabus, transcript ...
- Information portals divide the screen into different zones
- They should ease moving data from one zone to another

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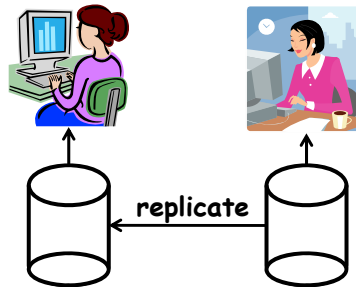
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Data Replication

Making data that is needed by multiple applications available to all hardware platforms

- Multiple business systems often need the same data
- Student email address is needed by professors, registrar, department, IT, ...
- When email is changed in one place, all copies must change
- Data replication can be implemented in many ways
 - Built into the database
 - Export data to files, re-import them to other systems
 - Use message-oriented middleware



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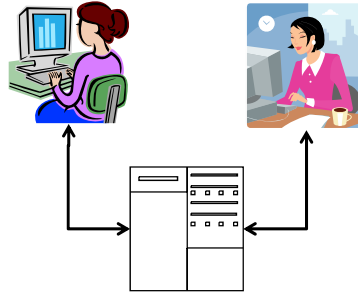
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Shared Business Functions

The same function is used by several different applications

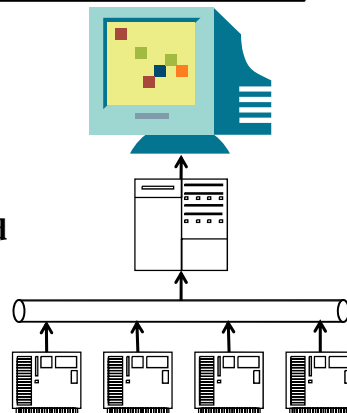
- Multiple users need the same function
- Whether a particular course is taught this semester
 - Student, instructor, admins
- Function should only be implemented once
- If the function only accesses data to return result, duplication is fairly simple
- If the function modifies data, race conditions can occur



Service-Oriented Architectures (SOA)

A service is a well-defined function that is universally available and responds to requests from "service consumers"

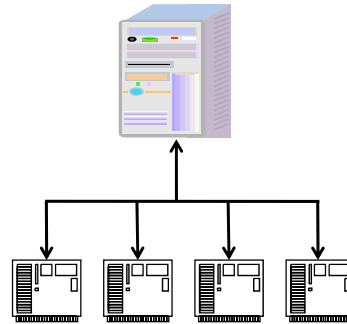
- Managing a collection of useful services is a critical function
 - A service directory
 - Each service needs to describe its interface in a generic way
- A mixture of integration and distributed application



Distributed Business Processes

A business process management component manages the execution of a single business process across multiple systems

- A single business transaction is often spread across many different systems
- A separate software component must coordinate between these applications
- A distributed business process is very similar to an SOA
 - If the business functions are not exposed in a “service directory”, then it is not used in an SOA



Business-to-Business Integration

Integration between two separate businesses



- Business functions may be available from outside suppliers or business partners
- Online travel agent may use a credit card service
- Integration may occur “on-the-fly”
 - A customer may seek the cheapest price on a given day
- Standardized data formats are critical

Summary : Coupling, Coupling, Coupling

- **Coupling has been considered to be an important design element since the 1960s**
- **Goal of coupling is to reduce the assumptions that two components have to make when exchanging data**
 - Loose coupling means fewer assumptions
- **A local method call is very tight couplings**
 - Same language, same process, typed parameters checked, return value
- **Remote procedure call has tight coupling, but with the complexity of distributed processing**
 - The worst of both worlds
 - Results in systems that are very hard to maintain
- **Message passing has very loose coupling**
 - Results in systems that are very easy to maintain