BITS Pilani

Pilani|Dubai|Goa|Hyderabad

Software Architectures

SECLZG651/SSCLZG653

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SECLZG651/SSCLZG653 – CS#5

Quality Attributes

Agenda for CS #5

1) Recap of CS#4
2) Security and its tactics
3) Testability and its tactics
4) Interoperability and its tactics
5) Other Quality Attributes
5) Q&A!

Security and its Tactics

What is Security

A measure of the system's ability to resist unauthorized usage while still providing its services to legitimate users

- Ability to protect data and information from unauthorized access

An attempt to breach this is an "Attack"

- Unauthorized attempt to access, modify, delete data
  - Theft of money by e-transfer, modification records and files, reading and copying sensitive data like credit card number
- Deny service to legitimate users

Important aspects of Security

Security comprises of

Confidentiality

- prevention of the unauthorized disclosure of information. E.g. Nobody except you should be able to access your income tax returns on an online tax-filing site

Integrity

- prevention of the unauthorized modification or deletion of information. E.g. your grade has not been changed since your instructor assigned it

Availability

- prevention of the unauthorized withholding of information – e.g. DoS attack should not prevent you from booking railway ticket

Important aspects of Security

Non repudiation: An activity (say a transaction) can't be denied by any of the parties involved. E.g. you cannot deny ordering something from the Internet, or the merchant cannot disclaim getting your order.

Assurance: Parties in an activity are assured to be who they purport to be. Typically done through authentication. E.g. if you get an email purporting to come from a bank, it is indeed from a bank.

Auditing: System tracks activities so that it can be reconstructed later

Authorization grants a user the privileges to perform a task. For example, an online banking system authorizes a legitimate user to access his account.

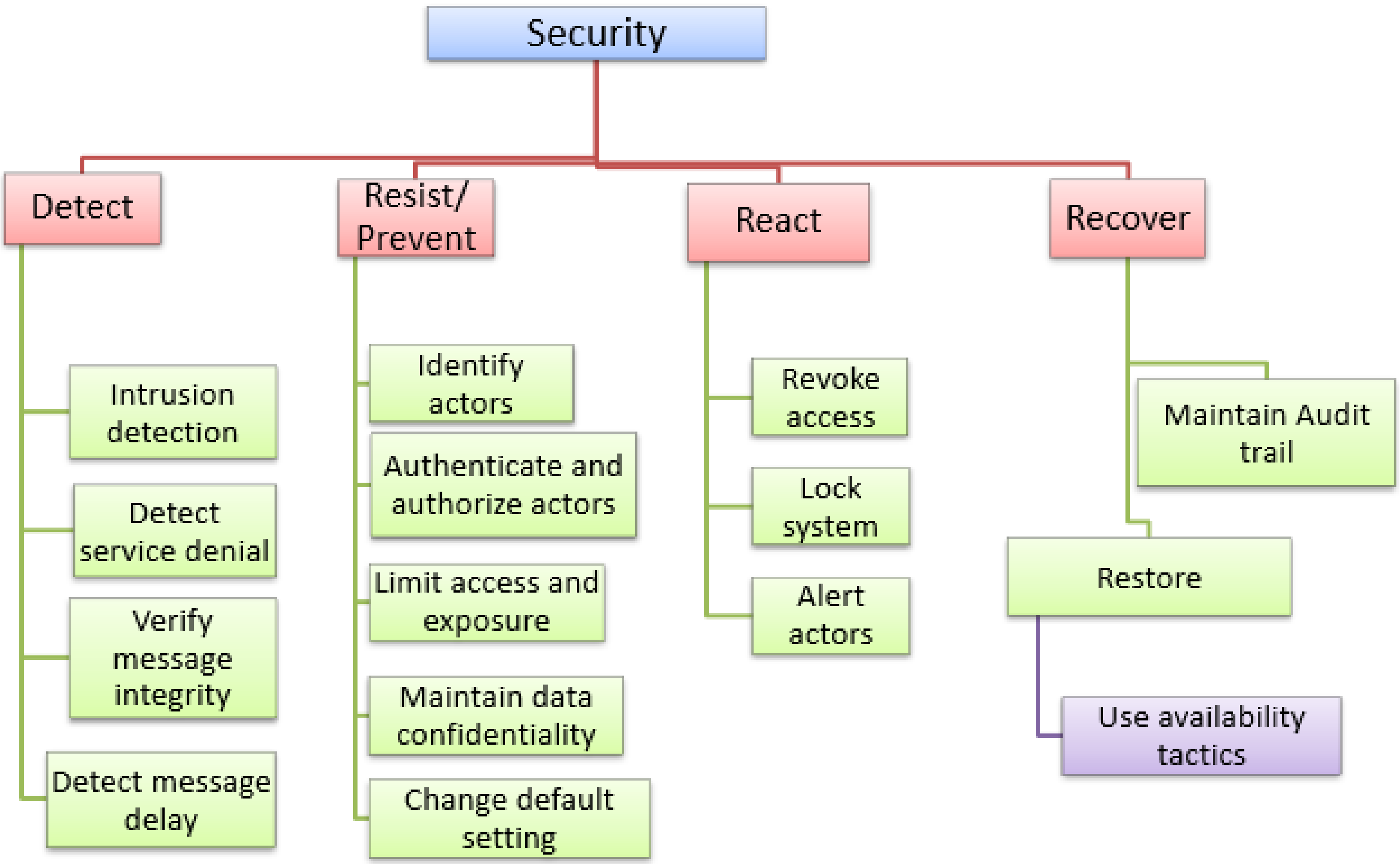
Security Scenario

WHO	STIMULUS	IMPACTED PART	MITIGATING ACTION	MEASURABLE RESPONSE
• **Individual or a system** ✓Correctly identified OR ✓Incorrectly identified ✓OR unknown • **Who is** ✓Internal or external ✓Authorized or unauthrized • **Has access to** ✓Limited resource ✓Vast resource	•**Tries to** ✓Read data ✓Change/delete data ✓Access system services ✓Reduce availability of services	System services, data •Online/offline •Within firewall or Open	• **Authentication** ✓Authenticates ✓Hides identity • **Access control to data or services** ✓Blocks access ✓Grants/withdraws permission to access ✓Audits access/ modification attempts • **Corrective Actions** ✓Encrypts data ✓Detect anomalous situation (high access req.) and informs people/another system ✓Restricts availability	• Time required to circumvent security measure with Probability of success • Probability of detecting attack • Probability of detecting the individual responsible • %of services available during attack • Time to restore data/services • Extent of damage- how much data is vulnerable • No of access denials
An insider	Updates payment details	Pay database table	Anomaly detected Audit trail maintained	Corrective action taken in 1 day

Security Tactics- Close to Physical Security

- Detection:
  - Limit the access through security checkpoints
  - Enforces everyone to wear badges or checks legitimate visitors
- Resist
  - Armed guards
- React
  - Lock the door automatically
- Recover
  - Keep backup of the data in a different place

Security Tactics



Detect Attacks

- Detect Intrusion: compare network traffic or service request patterns *within* a system to
  - a set of signatures or
  - known patterns of malicious behavior stored in a database.
- Detect Service Denial
  - Compare the pattern or signature of network traffic *cominginto* a system to historic profiles of known Denial of Service (DoS) attacks.
- Verify Message Integrity
  - Use checksums or hash values to verify the integrity of messages, resource files, deployment files, and configuration files.
- Detect Message Delay:
  - checking the time that it takes to deliver a message, it is possible to detect suspicious timing behavior.

Resist Attacks

- Identify Actors: identify the source of any external input to the system.
- Authenticate & Authorize Actors:
  - Use strong passwords, OTP, digital certificates, biometric identity
  - Use access control pattern, define proper user class, user group, role based access
- Limit Access
  - Restrict access based on message source or destination ports
  - Use of DMZ

Resist Attacks

- Limit Exposure: minimize the attack surface of a system by allocating limited number of services to each hosts
- Data confidentiality:
  - Use encryption to encrypt data in database
  - User encryption based communication such as SSL for web based transaction
  - Use Virtual private network to communicate between two trusted machines
- Separate Entities: can be done through physical separation on different servers attached to different networks, the use of virtual machines, or an "air gap".
- Change Default Settings: Force the user to change settings assigned by default.

React to Attacks

- Revoke Access: limit access to sensitive resources, even for normally legitimate users and uses, if an attack is suspected.
- Lock Computer: limit access to a resource if there are repeated failed attempts to access it.
- Inform Actors: notify operators, other personnel, or cooperating systems when an attack is suspected or detected.

Recover From Attacks

- In addition to the Availability tactics for recovery of failed resources there is Audit.

- Audit: keep a record of user and system actions and their effects, to help trace the actions of, and to identify, an attacker.

Design Checklist- Allocation of Responsibilities

- Identify the services that needs to be secured
  - Identify the modules, subsystems offering these services
- For each such service
  - Identify actors which can access this service, and implement authentication and level of authorization for those
  - verify checksums and hash values
  - Allow/deny data associated with this service for these actors
  - record attempts to access or modify data or services
  - Encrypt data that are sensitive
  - Implement a mechanism to recognize reduced availability for this services
  - Implement notification and alert mechanism
  - Implement recover from an attack mechanism

Design Checklist- Manage Data

- Determine the sensitivity of different data fields
- Ensure that data of different sensitivity is separated
- Ensure that data of different sensitivity has different access rights and that access rights are checked prior to access.
- Ensure that access to sensitive data is logged and that the log file is suitably protected.
- Ensure that data is suitably encrypted and that keys are separated from the encrypted data.
- Ensure that data can be restored if it is inappropriately modified.

Design Checklist- Manage Coordination

- For inter-system communication (applied for people also)
  - Ensure that mechanisms for authenticating and authorizing the actor or system, and encrypting data for transmission across the connection are in place.
- Monitor communication
  - Monitor anomalous communication such as
    - unexpectedly high demands for resources or services
    - Unusual access pattern
  - Mechanisms for restricting or terminating the connection.

Design Checklist- Manage Resource

- Define appropriate grant or denial of resources
- Record access attempts to resources
- Encrypt data
- Monitor resource utilization
  - Log
  - Identify suddenly high demand to a particular resource- for instance high CPU utilization at an unusual time
- Ensure that a contaminated element can be prevented from contaminating other elements.
- Ensure that shared resources are not used for passing sensitive data from an actor with access rights to that data to an actor without access rights.

Design checklist- Binding

- Runtime binding of components can be untrusted. Determine the following
  - Based on situation implement certificate based authentication for a component
    - Implement certification management, validation
  - Define access rules for components that are dynamically bound
  - Implement audit trail for whenever a late bound component tries to access records
  - System data should be encrypted where the keys are intentionally withheld for late bound components

Design Checklist- Technology choice

- Choice of technology is often governed by the organization mandate (enterprise architecture)

- Decide tactics first. Based on the tactics, ensure that your chosen technologies support the tactics

- Determine what technology are available to help user authentication, data access rights, resource protection, data encryption
- Identify technology and tools for monitoring and alert

Testability and its Tactics

What is Testability

The ease with which software can be made to demonstrate its faults through testing

If a fault is present in a system, then we want it to fail during testing as quickly as possible.

At least 40% effort goes for testing

- Done by developers, testers, and verifiers (tools)

Specialized software for testing

- Test harness
- Simple playback capability
- Specialized testing chamber

Testable Software

- Dijkstra’s Thesis
- Test can’t guarantee the absence of errors, but it can only show their presence.
- Fault discovery is a probability
  - That the next test execution will fail and exhibit the fault
- A perfectly testable code – each component’s internal state must be controllable through inputs and output must be observable
- Error-free software does not exist.

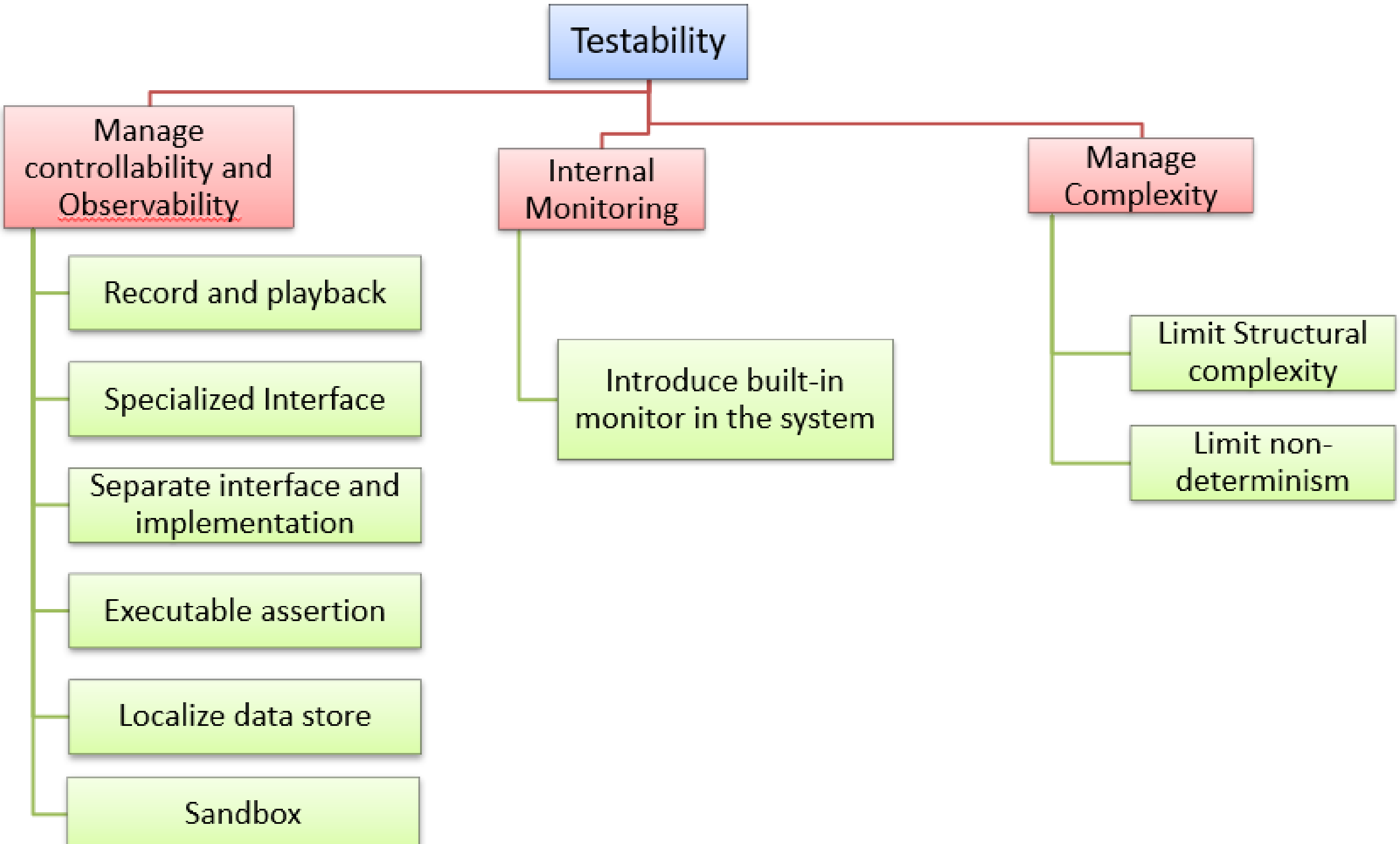
Testability Scenario

WHO	STIMULUS	IMPACTED PART	RESPONSE ACTION	MEASURABLE RESPONSE
• **Unit tester (typically unit developers)** • **Integration tester** • **System tester or client acceptance team** • **System user**	•**Milestone in the development process is met** ✓Completion of design ✓Completion of coding ✓Completion of integration	Component or whole system •Design time •Development time •Compile time •Integration time	• Prepare test environment • Access state values • Access computed values	• %executable statements executed (code coverage) • Time to test • Time to prepare test environment • Length of longest dependency chain in test • Probability of failure if fault exists
A unit tester	Performs unit test	Component that has controllable interface After component is complete	Observe the output for inputs provided	Coverage of 85% is achieved in 2 hours

Goal of Testability Tactics

- Using testability tactics the architect should aim to reduce the high cost of testing when the software is modified
- Two categories of tactics
  - Introducing controllability and observability to the system during design
  - The second deals with limiting complexity in the system's design

Testability Tactics



Control and Observe System State

- Specialized Interfaces for testing:
  - to control or capture variable values for a component either through a test harness or through normal execution.
  - Use a special interface that a test harness can use
  - Make use of some metadata through this special interface
- Record/Playback: capturing information crossing an interface and using it as input for further testing.
- Localize State Storage: To start a system, subsystem, or module in an arbitrary state for a test, it is most convenient if that state is stored in a single place.

Control and Observe System State

- Interface and implementation
  - If they are separated, implementation can be replaced by a stub for testing rest of the system
- Sandbox: isolate the system from the real world to enable experimentation that is unconstrained by the worry about having to undo the consequences of the experiment.
- Executable Assertions: assertions are (usually) hand coded and placed at desired locations to indicate when and where a program is in a faulty state.

Manage Complexity

- Limit Structural Complexity:
  - avoiding or resolving cyclic dependencies between components,
  - isolating and encapsulating dependencies on the external environment
  - reducing dependencies between components in general.
- Limit Non-determinism: finding all the sources of non-determinism, such as unconstrained parallelism, and remove them out as far as possible.

Internal Monitoring

- Implement a built-in monitoring mechanism
  - One should be able to turn on or off
    - one example is logging
  - Performed typically by instrumentation- AOP, Preprocessor macro. Instrument the code to introduce recorder at some point

Design Checklist- Allocation of Responsibility

- Identify the services are most critical and hence need to be most thoroughly tested.
  - Identify the modules, subsystems offering these services
- For each such service
  - Ensure that internal monitoring mechanism like logging is well designed
  - Make sure that the allocation of functionality provides
    - low coupling,
    - strong separation of concerns, and
    - low structural complexity.

Design Checklist- Testing Data

- Identify the data entities that are related to the critical services need to be most thoroughly tested.
- Ensure that creation, initialization, persistence, manipulation, translation, and destruction of these data entities are possible--
  - State Snapshot: Ensure that the values of these data entities can be captured if required, while the system is in execution or at fault
  - Replay: Ensure that the desired values of these data entities can be set (state injection) during testing so that it is possible to recreate the faulty behavior

Design Checklist- Testing Infrastructure

- Is it possible to inject faults into the communication channel and monitoring the state of the communication
- Is it possible to execute test suites and capture results for a distributed set of systems?
- Testing for potential race condition- check if it is possible to explicitly map
  - processes to processors
  - threads to processes
- So that the desired test response is achieved and potential race conditions identified

Design Checklist- Testing resource binding

- Ensure that components that are bound later than compile time can be tested in the late bound context
  - E.g. loading a driver on-demand
- Ensure that late bindings can be captured in the event of a failure, so that you can re-create the system's state leading to the failure.
- Ensure that the full range of binding possibilities can be tested.

Design Checklist- Resource Management

- Ensure there are sufficient resources available to execute a test suite and capture the results
- Ensure that your test environment is representative of the environment in which the system will run
- Ensure that the system provides the means to:
  - test resource limits
  - capture detailed resource usage for analysis in the event of a failure
  - inject new resources limits into the system for the purposes of testing
  - provide virtualized resources for testing

Choice of Tools

- Determine what tools are available to help achieve the testability scenarios
  - Do you have regression testing, fault injection, recording and playback supports from the testing tools?
- Does your choice of tools support the type of testing you intend to carry on?
  - You may want a fault-injection but you need to have a tool that can support the level of fault-injection you want
  - Does it support capturing and injecting the data-state

Interoperability and its Tactics

Interoperability

- Ability that two systems can usefully exchange information through an interface
  - Ability to transfer data (syntactic) and interpret data (semantic)
- Information exchange can be direct or indirect
- Interface
  - Beyond API
  - Need to have a set of assumptions you can safely make about the entity exposing the API
- Example- you want to integrate with Google Maps

Why Interoperate?

- The service provided by Google Maps are used by unknown systems
  - They must be able to use Google Maps w/o Google knowing who they can be
- You may want to construct capability from variety of systems
  - A traffic sensing system can receive stream of data from individual vehicles
  - Raw data needs to be processed
  - Need to be fused with other data from different sources
  - Need to decide the traffic congestion
  - Overlay with Google Maps

Interoperability Scenario

innovate achieve lead

WHO	STIMULUS	IMPACTED PART	RESPONSE ACTION	MEASURABLE RESPONSE
• **A system** **initiating request**	•**Request to exchange information**	Component or whole system •It has been already discovered •at runtime •Prior to runtime	• The request is ACCEPTED and information is exchanged • The request is REJECTED and appropriate entities are notified • The request is logged by one or more systems	• %information that has been exchanged successfully • %information that has been REJECTED successfully
Avehicle information system	Sends current location	Traffic monitoring system -- discovered prior to runtime	Combines the location information with other details, overlays with Google Maps, and broadcasts	The vehicle information is included correctly 99.9% of the time

Notion of Interface

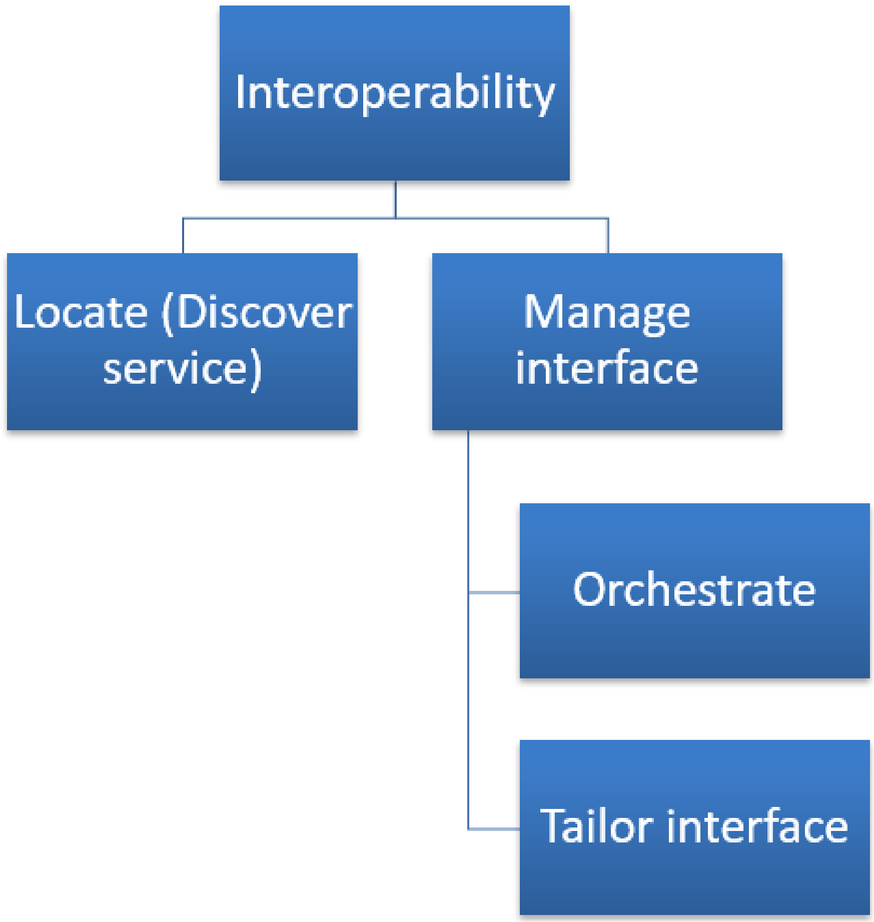
Information exchange

- Can be as simple as A calling B
- A and B can exchange implicitly w/o direct communication
- Operation Dessert Storm 1991: Anti-missile system failed to exchange information (intercept) an incoming ballistic rocket
  - The system required periodic restart in order to recalibrate its position. Since it wasn't restarted, the information wasn't correctly captured due to error accumulation

Interface

- Here it also means that a set of assumptions that can be made safely about this entity
- E.g. it is safe to assume that the API of anti-missile system DOES NOT give information about gradual degradation

Tactics


Interoperability
Locate (Discover service)
Manage interface
Orchestrate
Tailor interface

Interoperability Tactics

- Locate (Discover service)
  - Identify the service through a known directory service. Here service implies a set of capabilities available through an interface
  - By name, location or other attributes

Interoperability Tactics

Manage interface

- Orchestrate
  - Co-ordinate and manage a sequence of services. Example- workflow engines containing scripts of interaction
  - Mediator design pattern for simple orchestration. BPEL language for complex orchestration
- Tailor interface
  - Add or remove capability from an interface (hide a particular function from an untrusted user)
  - Use Decorator design pattern for this purpose

REpresentational State Transfer (REST)

REST is an architectural pattern where services are described using an uniform interface. REST*ful* services are viewed as a hypermedia resource. REST is stateless.

REST Verb	CRUD Operation	Description
POST	CREATE	Create a new resource.
GET	RETRIEVE	Retrieve a representation of the resource.
PUT	UPDATE	Update a resource.
DELETE	DELETE	Delete a resource.

REST vs. SOAP/WSDL

	SOAP/WSDL	REST
Purpose	Message exchange between two applications/systems	Access and manipulating a hypermedia system
Origin	RPC	WWW
Functionality	Rich	Minimal
Interaction	Orchestrated event-based	Client/server (request/response)
Focus	Process-oriented	Data-oriented
Methods/ operations	Varies depending on the service	Fixed
Reuse	Centrally governed	Little/no governance (focus on ease of use instead)
Interaction context	Can be maintained in both client and server	Only on client
Format	SOAP in, SOAP out	URI (+POX) in, POX out
Transport	Transport independent	HTTP only
Security	WS-Security	HTTP authentication + SSL

Design Checklist-Interoperability

- Allocation of Responsibilities: Check which system features need to interoperate with others. For each of these features, ensure that the designers implement
  - Accepting and rejecting of requests
  - Logging of request
  - Notification mechanism
  - Exchange of information
- Coordination Model: Coordination should ensure performance SLAs to be met. Plan for
  - Handling the volume of requests
  - Timeliness to respond and send the message
  - Currency of the messages sent
  - Handle jitters in message arrival times

Design Checklist-Interoperability

Data Model

- Identify the data to be exchanged among interoperating systems
- If the data can't be exchanged due to confidentiality, plan for data transformation before exchange

Identification of Architectural Component

- The components that are going to interoperate should be available, secure, meet performance SLA (consider design-checklists for these quality attributes)

Design Checklist-Interoperability

Resource Management

- Ensure that system resources are not exhausted (flood of request shouldn't deny a legitimate user)
- Consider communication load
- When resources are to be shared, plan for an arbitration policy

Binding Time

- Ensure that it has the capability to bind unknown systems
- Ensure the proper acceptance and rejection of requests
- Ensure service discovery when you want to allow late binding

Technology Choice

- Consider technology that supports interoperability (e.g. web-services)

Other Quality Attributes

- Variability
- Portability
- Development Disreputability
- Sustainability
- Scalability
- Deployability
- Monitorability
- Safety
- Marketability

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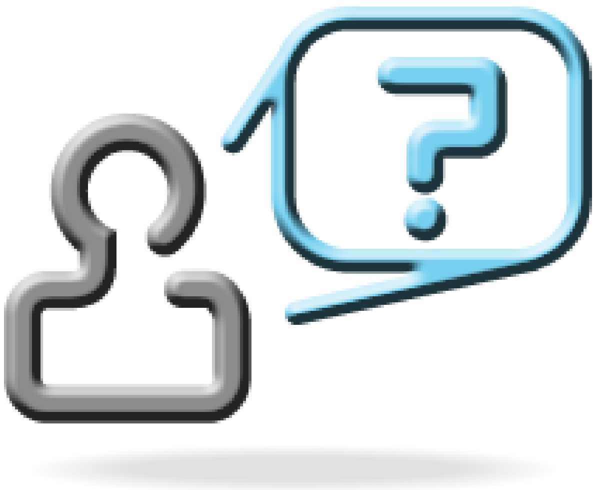
Refer the text for more.



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Thank You for your time & attention !

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