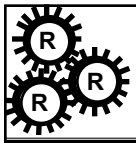
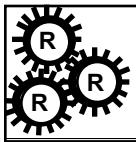


Security Patterns

Acknowledgements: Ronald Wassermann

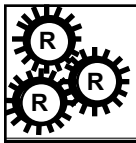


Motivation

- Today's systems have various communication features
- Many security-critical dependencies exist
- Security is a non-functional requirement that is difficult to evaluate (e.g., metrics, etc.)
- Which security features are necessary in certain domains?

→ **It is difficult to design secure systems [Bis02]**

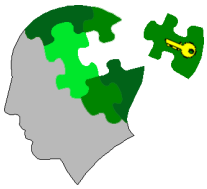
→ **Expert knowledge is needed**

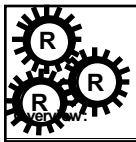


Approach

- In order to overcome the knowledge gap among developers we use patterns to
  - provide relevant information in a structured way
  - convey experience
- We use a variation of the well-known design pattern template [Gam94] to present more security-specific information

Our goal is to enable the reuse of security knowledge



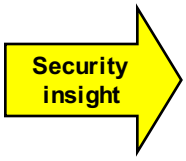


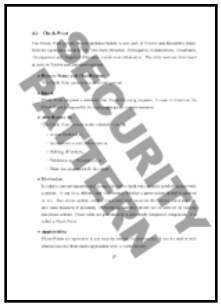
Security Principles (1)

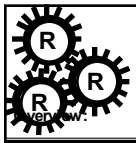
- References ten guiding security principles [Viega and McGraw 2002]

Ten Security Principles

- Secure the weakest link.
- Practice defense in depth.
- Fail securely.
- Follow the principle of least privilege.
- Compartmentalize.
- Keep it simple.
- Promote privacy.
- Remember that hiding secrets is hard.
- Be reluctant to trust.
- Use your community resources.

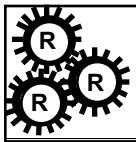






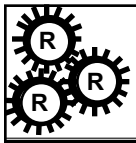
Security Principles (2)

- 1. *Secure the weakest link*
  - Intruders will attack parts that are most likely to break
  - Identify and strengthen weak parts to improve overall security
- 2. *Practice defense in depth*
  - Implement overlapping security mechanisms
  - Every protection layer adds to overall security
- 3. *Fail securely*
  - Failures are not avoidable
  - Security flaws are often inherent to system failures
  - Plan failure modes that assure that the system's security is not compromised by exceptional behavior



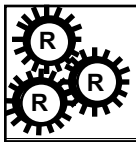
Security Principles (3)

- 4. *Follow the principle of least privilege*
  - Grant only the minimum set of permissions
  - Thereby reducing the risk of privilege-abuse
- 5. *Compartmentalize*
  - Structure your system in a way that protects different parts independently.
  - Reduces amount of damage that is caused by a security breach in one unit.
- 6. *Keep it simple*
  - Avoid unnecessary complexity
  - Usability is an important part of simple design



Security Principles (4)

- 7. *Promote privacy*
  - Minimize the information that can be gathered about a system and its users
  - Use misinformation to deter attackers
- 8. *Remember that hiding secrets is hard*
  - A system's security depends on certain secrets being kept
  - Be aware of critical information that could compromise security
- 9. *Be reluctant to trust*
  - Do not extend trust unnecessarily
  - Design systems that mistrust information of other parts



Security Principles (5)

- 10. *Use your community resources*
  - Public scrutiny improves code as it exploits weaknesses and errors
  - Code written by individuals is usually less secure

Tradeoffs:

Compartmentalize (P5) ⟺ Keep it simple (P6)

Usability (P6) ⟺ Promote privacy (P7)

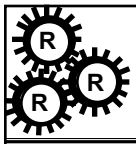
Practice defense in depth (P2) ⟺ Keep it simple (P6)

Patterns

"Each pattern **describes a problem** which **occurs over and over again** in our environment, and then **describes the core of the solution** to that problem, in such a way that you can use this solution a million times over, **without ever doing it the same way** twice."

Christopher Alexander [Ale77]

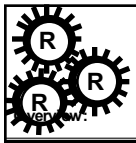
- Essential elements of a pattern [GHJV94]
  - Name
  - Problem
  - Consequences
  - Solution
- Benefits
  - Improves communication and establish terminology
  - Provides structured information and captures knowledge
  - Unifies design and improves comprehensibility



Design Patterns

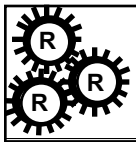
- "Design patterns are patterns that *express solutions to recurring software design problems* in terms of objects and interfaces" [GHJV94].
- Gamma *et al.* propose template structure

- Pattern name and Classification
- Intent
- Also known as
- Motivation
- Applicability
- Structure
- Participants
- Collaborations
- Consequences
- Implementation
- Sample Code
- Known Uses
- Related Patterns



Previous work

- Other pattern-based approaches to security problems
  - Fernandez [Fer02]
    - Collection of security patterns (using few UML diagrams)
  - Kienzle et al. [KETE02]
    - Tutorial for writing security patterns
  - Schumacher and Roedig [SR01]
    - Propose the use of patterns in security engineering (no specific template)
  - Yoder and Barcalow [YB97]
    - Collection of security patterns (no diagrams)



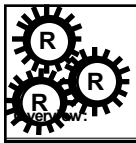
Security Pattern Definition

"A Security Pattern describes a particular recurring security problem that arises in a specific context and presents a well-proven generic scheme for its solution."

Schumacher and Roedig [SR01]

- How can the information be structured to reflect the needs of the security domain?

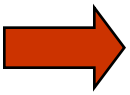
New template that is customized for use in the development of secure software



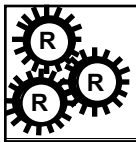
Security Pattern Template

- We use the design pattern template of Gamma et al. [GHJV94] and extend and modify it to fit our needs:

Design Pattern Template
•Pattern name and Classification
•Intent
•Also known as
•Motivation
•Applicability
•Structure
•Participants
•Collaborations
•Consequences
•Implementation
•Sample Code
•Known Uses
•Related Patterns



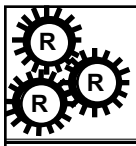
Security Pattern Template
•Pattern name and Classification
•Intent
•Also known as
•Motivation
•Applicability
•Structure
•Participants
•Collaborations
•Behavior
•Constraints
•Consequences
•Known Uses
•Related Security Patterns
•Related Design Patterns
•Related Security Principles



Classification

- Similar to design patterns [GHJV94] we organize security patterns by purpose in
  - structural,
  - behavioral, and
  - creational

  patterns
- Furthermore, we denote the following abstraction levels for patterns:
  - Application level (objects are deployed at a client)
  - Host level (objects are running on a server)
  - Network level (objects are distributed over a network)



Overview

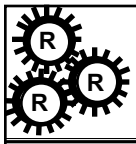
- Several patterns were identified by the security pattern community [Fer01][YB97]

Patterns	Purpose[1]	Abstraction level[2]	1. Secure weakest link	2. Practice defense in depth	3. Fail securely	4. Principle of least privilege	5. Compartmentalize	6. Keep it simple	7. Promote privacy	8. Hiding secrets is hard	9. Be reluctant to trust	10. Use community resources
Single Access Point	S	AHN	x			x		x			x	
Check Point	S	AHN	x	x		x					x	
Roles/RBAC	S	AHN				x		x	x			
Session	C	A		x				x	x			
Limited View	B	A		x		x		x	x	x	x	
Full View with Errors	B	A			x			x				
Security Layers	S	A	x	x			x				x	
Authorization	S	AHN				x	x		x			
Multilevel Security Pattern	S	AHN				x	x		x	x	x	
			Viega's and McGraw's 10 principles									

[1]Purpose:
C: Creational
S: Structural
B: Behavioral

[2]Abstraction levels:
A: Application-level
H: Host-level
N: Network-level

- We present the *Single Access Point, Check Point* and the Role-Based Access Control pattern

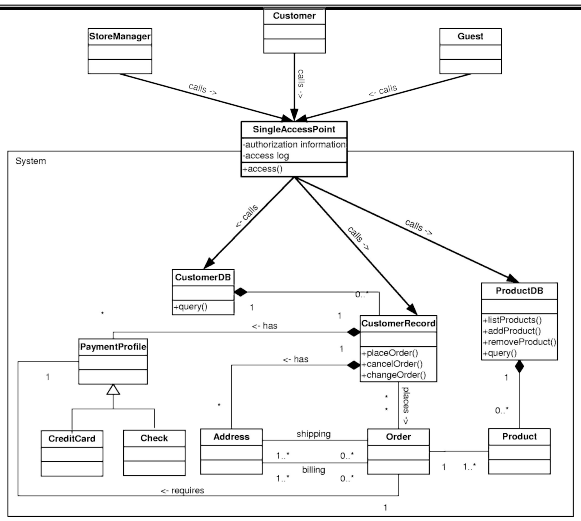


Single Access Point (SAP) (1)

- SAP was introduced by Yoder and Barcalow [YB97]
- **Name and Classification**
  - Single Access Point, structural pattern
- **Intent**
  - Proposes single interface to the system to improve control
- **Also known as**
  - Guard Door, Login Window, One Way In, or Validation Screen
- **Motivation**
  - Various access points and hidden back doors make protection difficult
  - Monitoring of external communication should be possible
- **Applicability**
  - For self-contained systems that communicate with external entities
  - Several entry points for greater flexibility cannot be realized with this pattern

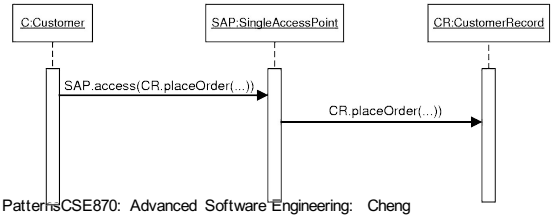
Single Access Point (SAP) (2)

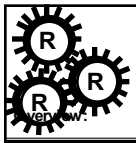
- **Structure**



Single Access Point (SAP) (3)

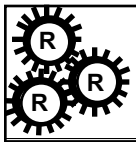
- **Participants**
  - External Entities
  - Internal Entities
  - Single Access Point
- **Collaborations**
  - SingleAccessPoint is contacted by external entities
  - It works as mediatior
- **Behavior**





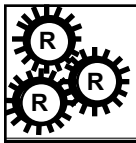
Single Access Point (SAP) (4)

- **Constraints**
  - Authenticity: A message that is directly sent to an internal component originates either from a system internal component or the SAP
  - Confidentiality: Communication between internal components is not disclosed to outside entities
  - Integrity: Messages inside the system cannot be modified by external entities
- Consequences
  - Accountability: The SAP could perform logging tasks and thereby improve accountability
  - Confidentiality, Integrity: SAP provides a place for monitoring of communication
  - Availability: If the SAP cannot handle all accesses, availability might be reduced; information for the detection of DoS attacks can be gathered
  - Performance: Substantial logging operations at the SAP can affect the performance of a system



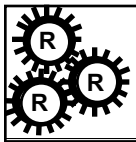
Single Access Point (SAP) (4)

- Consequences (cont'd)
  - Cost: Depending on the extent of communication with external parties, development can be more difficult and expensive
  - Manageability: Security-code not scattered over the entire system
  - Usability: Access to system might be more inconvenient for a user
- Known uses
  - Linux telnet application
  - Windows NT login application
- Related Security Patterns
  - Check Point (monitors communication that passes the SAP)
  - Role-Based Access Control (is initialized upon login)
  - Session (is created upon login)
- Related Design Patterns
  - Singleton (to implement the SAP)



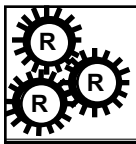
Single Access Point (SAP) (5)

- Related Security Principles
  - Principle 1: *Secure the weakest link* (the pattern considers the interface to external entities to be a possible weakness)
  - Principle 6: *Keep it simple* (the SAP pattern propagates a simplification of the systems access)
  - Principle 9: Reluctance to trust



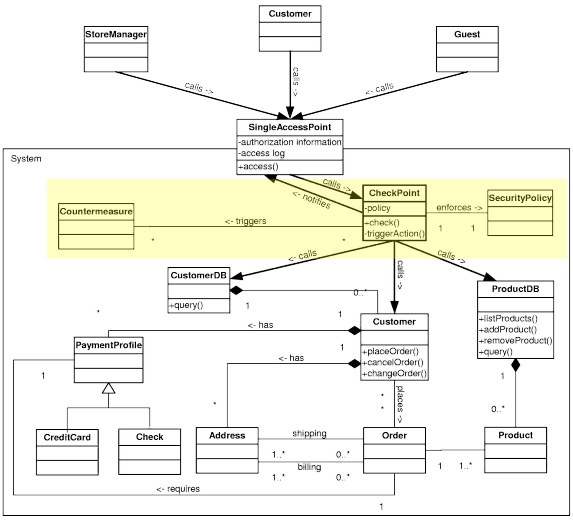
Check Point (1)

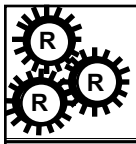
- The Check Point pattern was first presented in a framework by Yoder and Barcalow [YB97]
- **Name and Classification**
  - Check Point, structural pattern
- **Intent**
  - A structure for checking incoming requests and handling violations
- **Also known as**
  - Access Verification, Authentication and Authorization, Holding off hackers, Validation and Penalization, or Make the punishment fit the crime
- **Motivation**
  - Systems that communicate with external entities have to take into account illegal requests and attacks
  - Monitoring and access validation is necessary



Check Point (2)

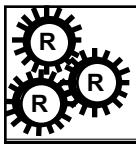
- **Structure**





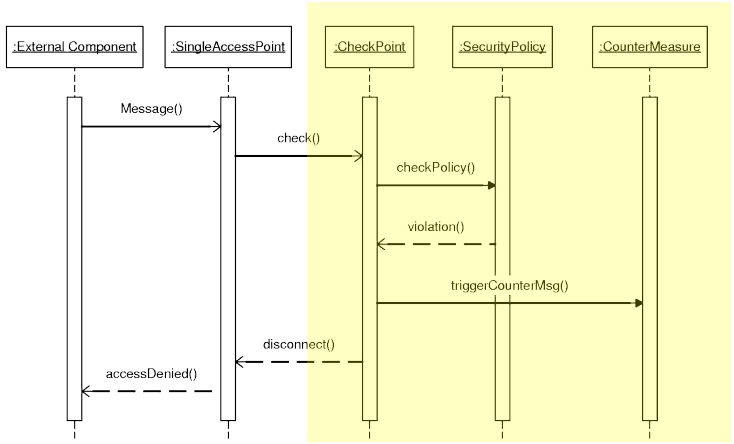
Check Point (3)

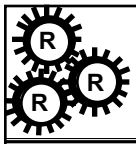
- **Applicability**
  - Check Point can be applied in any system that needs to monitor communication
  - In order to perform checks the system needs a security policy
- **Participants**
  - Check Point
  - Countermeasure
  - Security Policy
- **Collaborations**
  - The Check Point monitors if messages are consistent with the Security Policy
  - Countermeasures are triggered if necessary



Check Point (4)

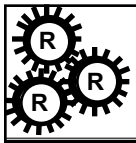
- **Behavior**





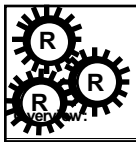
Check Point (5)

- **Constraints**
  - **Authenticity:** Check Point's policy requests may only be answered by the Security Policy object
  - **Integrity**: Messages that are sent between Check Point and Security Policy cannot be modified
  - **Confidentiality, Integrity**: External requests are not forwarded until the Security Policy approves it



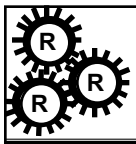
Check Point (6)

- **Consequences**
  - **Confidentiality:** unauthorized access can be prevented
  - **Integrity**: malicious modification can be filtered
  - **Availability**: Check Point can trigger countermeasures to prevent DoS attacks (e.g. delays, blacklists)
  - **Performance**: Complex checks slow down the system
  - **Cost**: Development of a effective check algorithm is difficult and expensive
  - **Manageability**: combining security code in one place simplifies maintenance
  - **Usability**: depending on the check algorithm, harmless requests may be blocked if they match a certain pattern



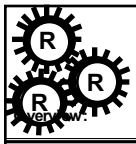
Check Point (7)

- **Known Uses**
  - During the login to an ftp server a Check Point is usually used to control the access of users
- **Related Security Patterns**
  - Single Access Point
  - Session
  - Role-Based Access Control
- **Related Design Patterns**
  - Strategy (decouple Check Point from actual implementation of the security policy)



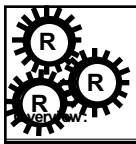
Check Point (8)

- **Related Principles**
  - Principle 1: *Secure the weakest link* (by applying the Check Point)
  - Principle 2: *Practice defense in depth* (further security measures should be considered in addition to the Check Point)
  - Principle 4: *Principle of least privilege* (should be reflected in the Security Policy)
  - Principle 9: *Reluctance to trust* (that all requests are harmless)



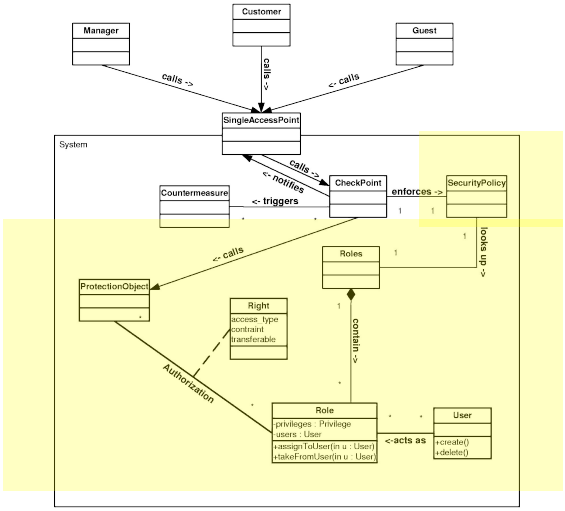
Role-Based Access Control (1)

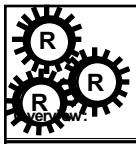
- The Role-Based Access Control pattern was first presented in [YB97] and later in [Fer01]
- **Name and Classification**
  - Role-Based Access Control, structural pattern
- **Intent**
  - Facilitates the representation and maintenance of access structures
- **Also known as**
  - Roles, Actors, Groups, Projects, Profiles, Jobs, or User Types
- **Motivation**
  - The use of resources usually underlies certain restrictions
  - In order to facilitate enforcement restrictions need to be represented in some structure inside the system
- **Applicability**
  - Applicable in any system that restricts subjects' access on resources



Role-Based Access Control (2)

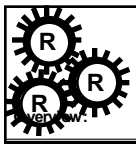
- **Structure**





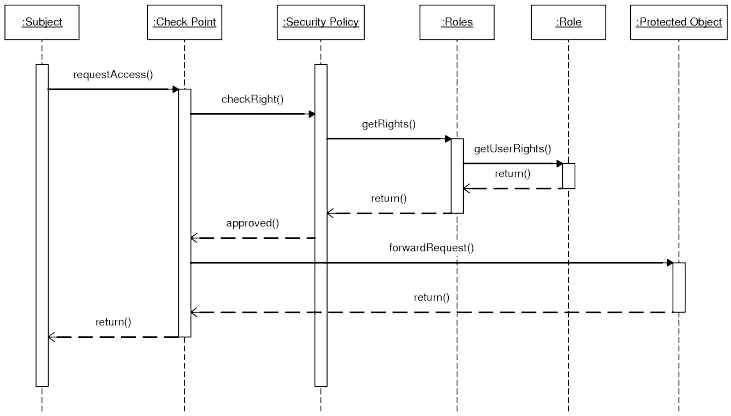
Role-Based Access Control (3)

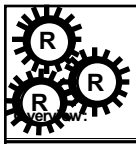
- **Participants**
  - ProtectionObject
  - Right
  - Role
  - Roles
  - User
- **Collaborations**
  - Roles are associated to a set of Objects; a Right object defines the properties of each relationship (type, constraint, transferable)
  - Each user can be associated to Roles that determine his/her privileges
  - This information about access privileges can be queried by other system components



Role-Based Access Control (4)

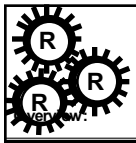
- **Behavior**





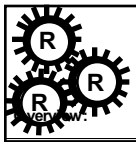
Role-Based Access Control (5)

- **Constraints**
  - **To be determined**
- **Consequences**
  - **Confidentiality,Integrity**: An right structure enables definition of access privileges that protect confidentiality and integrity
  - **Availability:** Restriction of access to resources enhances availability
  - **Performance:** can be improved by reducing the overall amount of relationships that reflect the access structure
  - **Cost:** higher development cost, reduced maintenance
  - **Manageability:** Maintenance is simplified as subjects can be managed in groups
- **Known Uses**
  - Several applications, including various Database Management Systems (DBMS) and Windows 2000



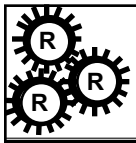
Role-Based Access Control (6)

- **Related Security Patterns**
  - **Check Point**
  - **Session**
  - **Limited View**
- **Related Design Patterns**
  - Strategy (implement different behavior depending on users role)
  - Observer (keep structure consistent)
- **Related Security Principles**
  - Principle 4: *Principle of least privilege* (should be reflected in the right structure)
  - Principle 6: *Keep it simple* (by reducing relationships)
  - Principle 7: *Promote privacy* (by restricting access)



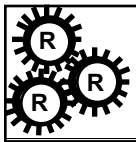
Conclusions

- Security patterns help to keep track of non-functional security requirements from the beginning of design
- A well-structured template can enhance the effectiveness of the pattern approach
- Avoiding errors is extremely important in security critical applications



Open problems

- Facilitate formal verification during the application of security patterns by providing formalized constraints that can be checked against the system model
- Continue to scan for security patterns
- Domain-specific security patterns
  - Medical applications?
  - Automotive?
- Explore how extending modeling languages (such as UML) can/should be extended for security.



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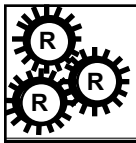
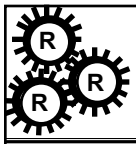


Appendix

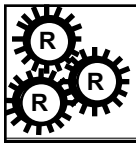
Overview of Gamma *et al.* Design Patterns

for Reference



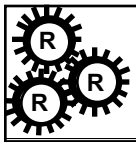
Creational Patterns

- Factory Method:
  - method in a derived class creates associations
- Abstract Factory:
  - Factory for building related objects
- Builder:
  - Factory for building complex objects incrementally
- Prototype:
  - Factory for cloning new instances from a prototype
- Singleton:
  - Factory for a singular (sole) instance



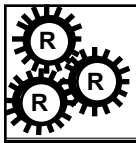
Structural Patterns:

- Adapter:
  - Translator adapts a server interface for a client
- Bridge:
  - Abstraction for binding one of many implementations
- Composite:
  - Structure for building recursive aggregations
- Decorator:
  - Decorator extends an object transparently
- Facade:
  - simplifies the interface for a subsystem
- Flyweight:
  - many fine-grained objects shared efficiently.
- Proxy:
  - one object approximates another



Behavioral Patterns

- Chain of Responsibility
  - request delegated to the responsible service provider
- Command:
  - request is first-class object
- Iterator:
  - Aggregate elements are accessed sequentially
- Interpreter:
  - language interpreter for a small grammar
- Mediator:
  - coordinates interactions between its associates
- Memento:
  - snapshot captures and restores object states privately
- Observer:
  - dependents update automatically when subject changes
- State:
  - object whose behavior depends on its state



Behavior Patterns (more)

- Strategy:
  - Abstraction for selecting one of many algorithms
- Template Method:
  - algorithm with some steps supplied by a derived class
- Visitor:
  - operations applied to elements of a *heterogeneous* object structure