MIRAGE: A Management Tool for the Analysis and Deployment of Network Security Policies

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Joint work with

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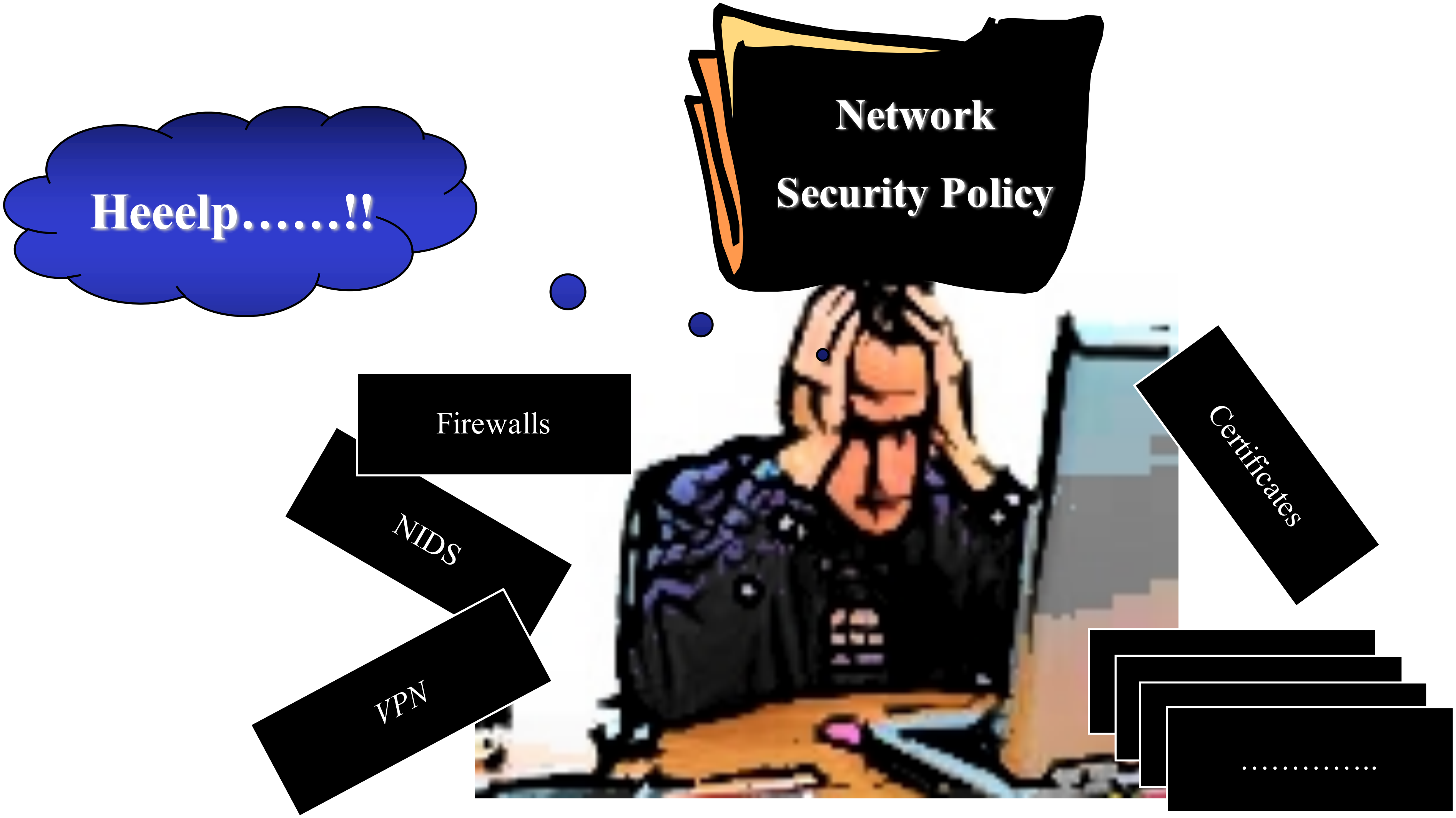
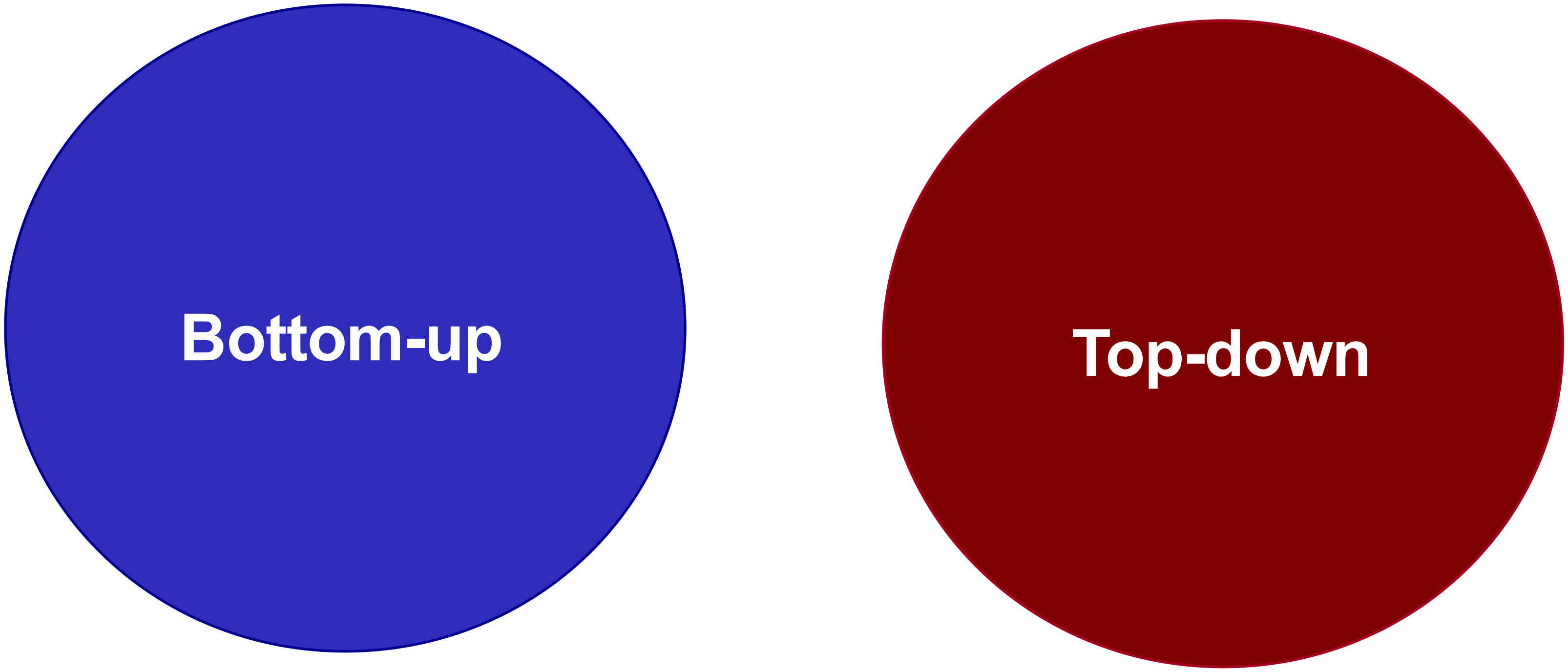
Brief introduction

Management of configuration conflicts (or configuration anomalies in general) is a (very) complex task



Two main strategies



Bottom-up

Top-down

Outline

- **Brief introduction**

- **Bottom-up analysis of filtering configurations**
  - Intra-component analysis
  - Inter-component analysis

- **Top-down refinement of general security policies**

- **Conclusion / Perspectives**

Bottom-up analysis

- **Configuration of Firewalls**
  - When processing packages, conflicts due to rule overlaps can occur within the same policy

  - We can solve this problem by ordering the rules
    - First/Last matching strategy

  ⇒It introduces, however, some other problems
    - Shadowing (i.e., rules that are never applied)
    - Redundancy (i.e., if removed, policy does not change)

Definitions

- **Format of rules**

Condition → accept

or

Condition → deny

Where *condition* is a conjunctive set of attributes in the form:

@source ∧ @destination ∧ port-source ∧ port-destination ∧ protocol

- **Example of Shadowing**

$R_1 : s \in 1.0.0.0/24 \wedge d \in \text{any} \wedge \text{sport} \in \text{any} \wedge \text{dport} = 80 \wedge p = \text{tcp} \rightarrow \text{accept}$

$R_2 : s \in 1.0.0.0/24 \wedge d \in 2.0.0.0/16 \wedge \text{sport} \in \text{any} \wedge \text{dport} = 80 \wedge p = \text{tcp} \rightarrow \text{deny}$

- **Example of Redundancy**

$R_1 : s \in 1.0.0.0/24 \wedge d \in 2.0.0.0/16 \wedge \text{sport} \in \text{any} \wedge \text{dport} = 80 \wedge p = \text{tcp} \rightarrow \text{accept}$

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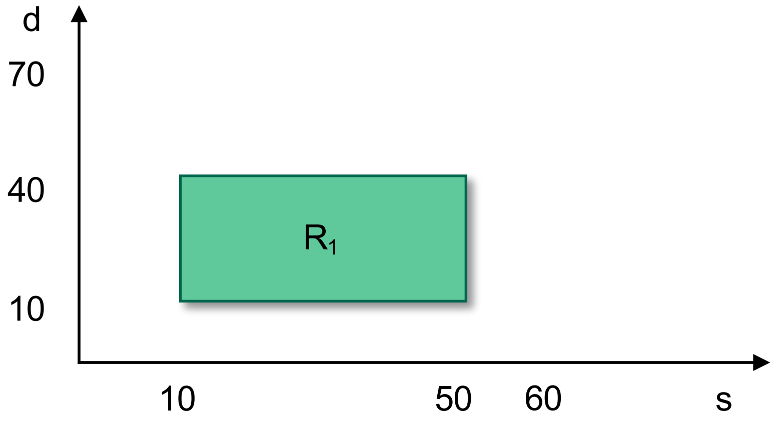
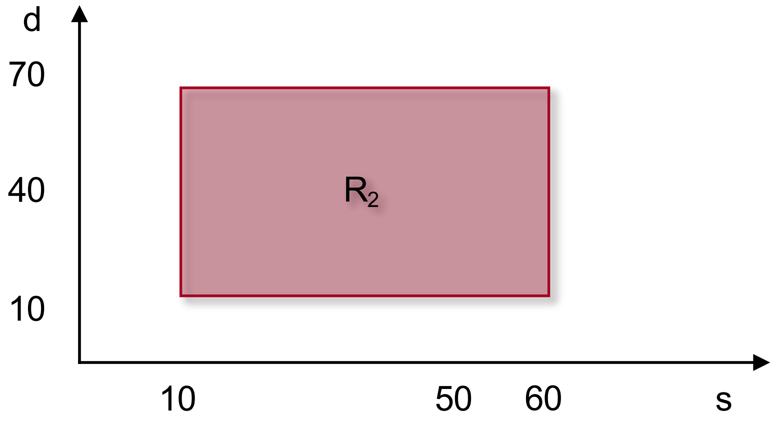
Bottom-up analysis of MIRAGE

- Detection & removal of configuration anomalies
- Based on *rewritting* of rules:
  - Detection: existence of relationships between attributes
  - Removal: transformation from an initial set of rules to an equivalent one which rules free of dependencies
- Example:

R_1 : s ∈ 1.0.0.[10,50] ∧ d ∈ 2.0.0.[10,40] → accept

R_2 : s ∈ 1.0.0.[10,60] ∧ d ∈ 2.0.0.[10,70] → deny





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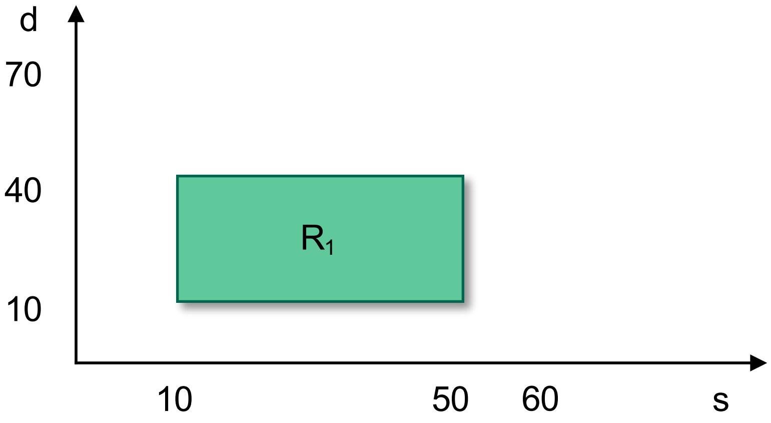
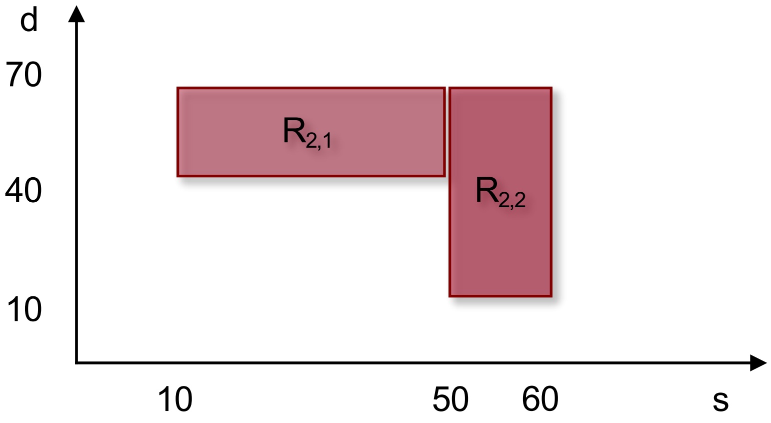
R_1 : $s \in 1.0.0.[10,50] \wedge d \in 2.0.0.[10,40]$ → accept

$R_{2,1}$: $s \in 1.0.0.[51,60] \wedge d \in 2.0.0.[10,70]$ → deny

$R_{2,2}$: $s \in 1.0.0.[10,50] \wedge d \in 2.0.0.[41,70]$ → deny





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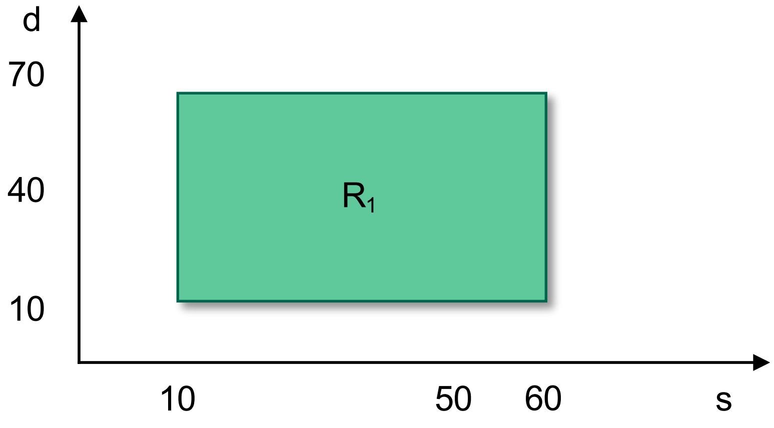

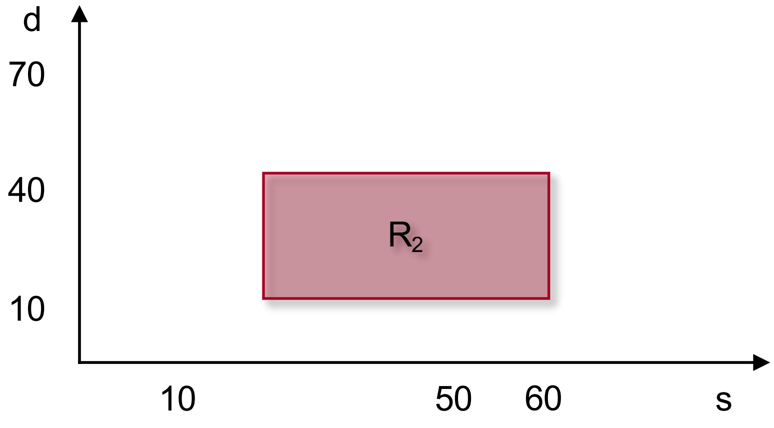

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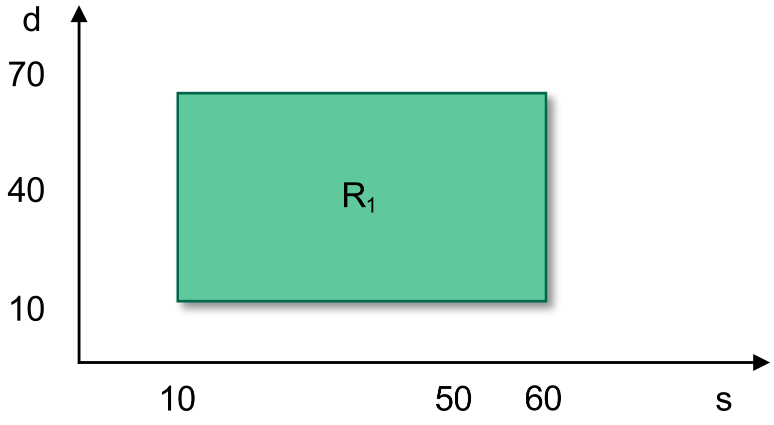
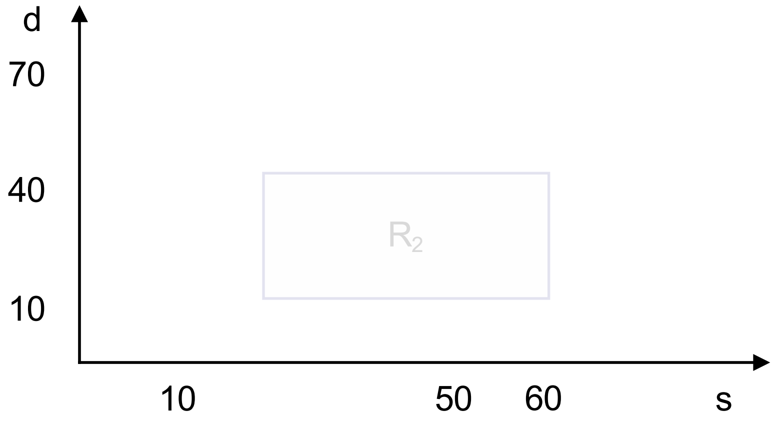
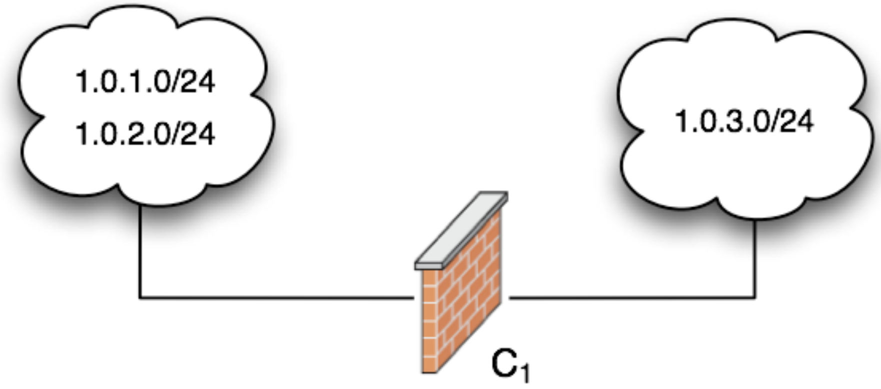




Intra-component Analysis (1/2)

- Deterministic analysis of standalone configurations
- Taxonomy on anomalies:
  - Intra-component Shadowing
  - Intra-component Redundancy
- Example:



$C_1\{R_1\}$: {tcp,1.0.2.[1,30]:any, 1.0.3.[20,45]:any} → true

$C_1\{R_2\}$: {tcp,1.0.2.[20,60]:any, 1.0.3.[25,35]:any} → false

$C_1\{R_3\}$: {tcp,1.0.2.[30,70]:any, 1.0.3.[20,45]:any} → false

$C_1\{R_4\}$: {tcp,1.0.2.[15,45]:any, 1.0.3.[25,30]:any} → true

... ...

Intra-component Analysis (2/2)

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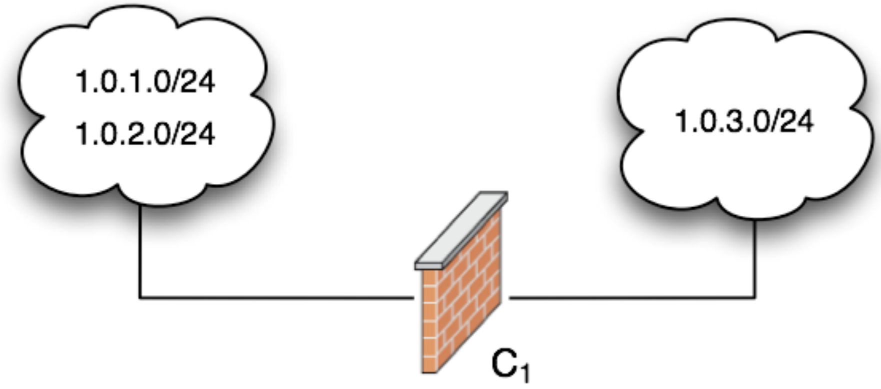
- Example:



R_2 is redundant to R_1, R_3
R_4 is shadowed by R_2, R_1

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Topology of the System

- MIRAGE also manages the description of the security architecture topology, to guarantee the proper execution of the audit processes

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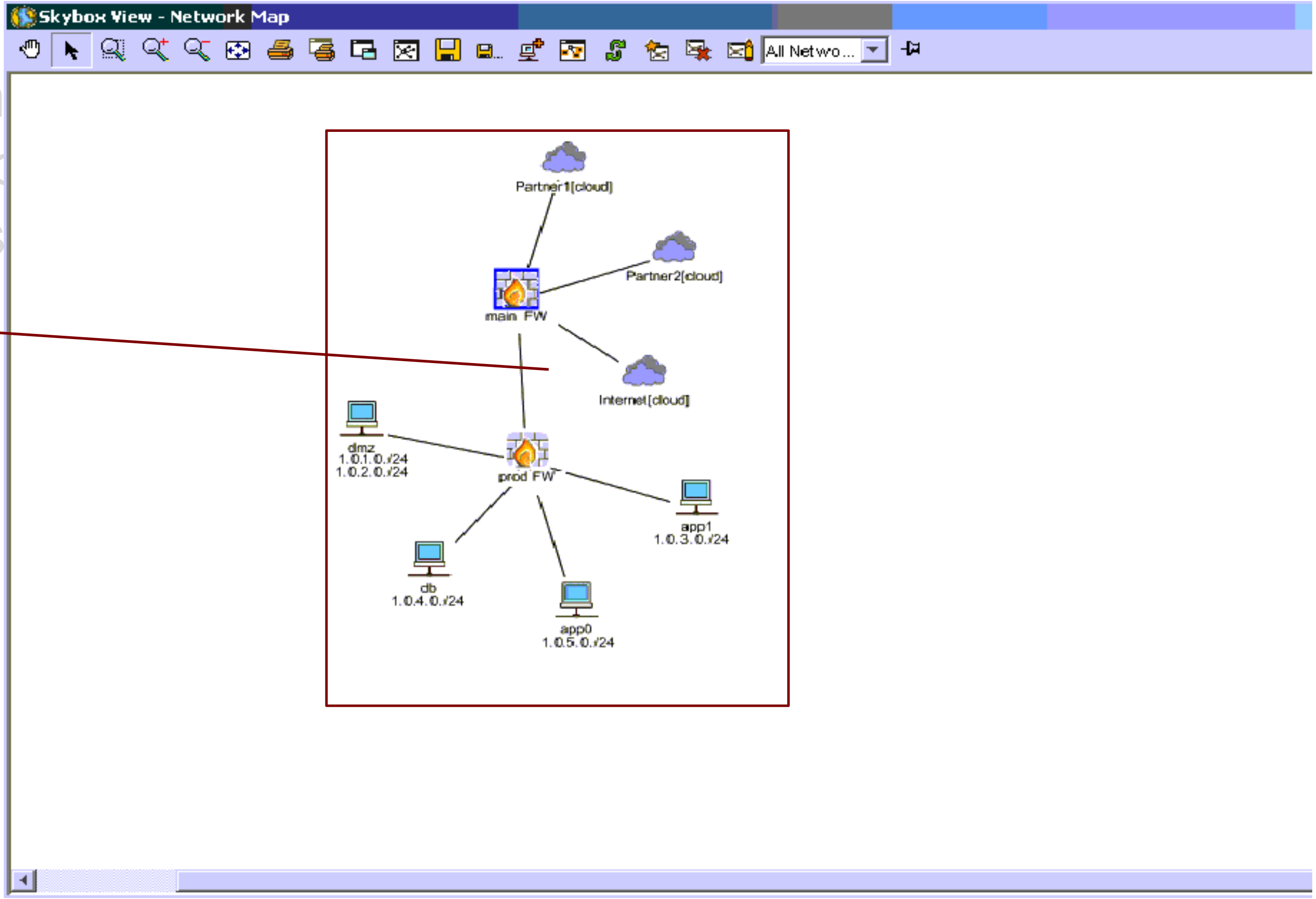
topology.xml



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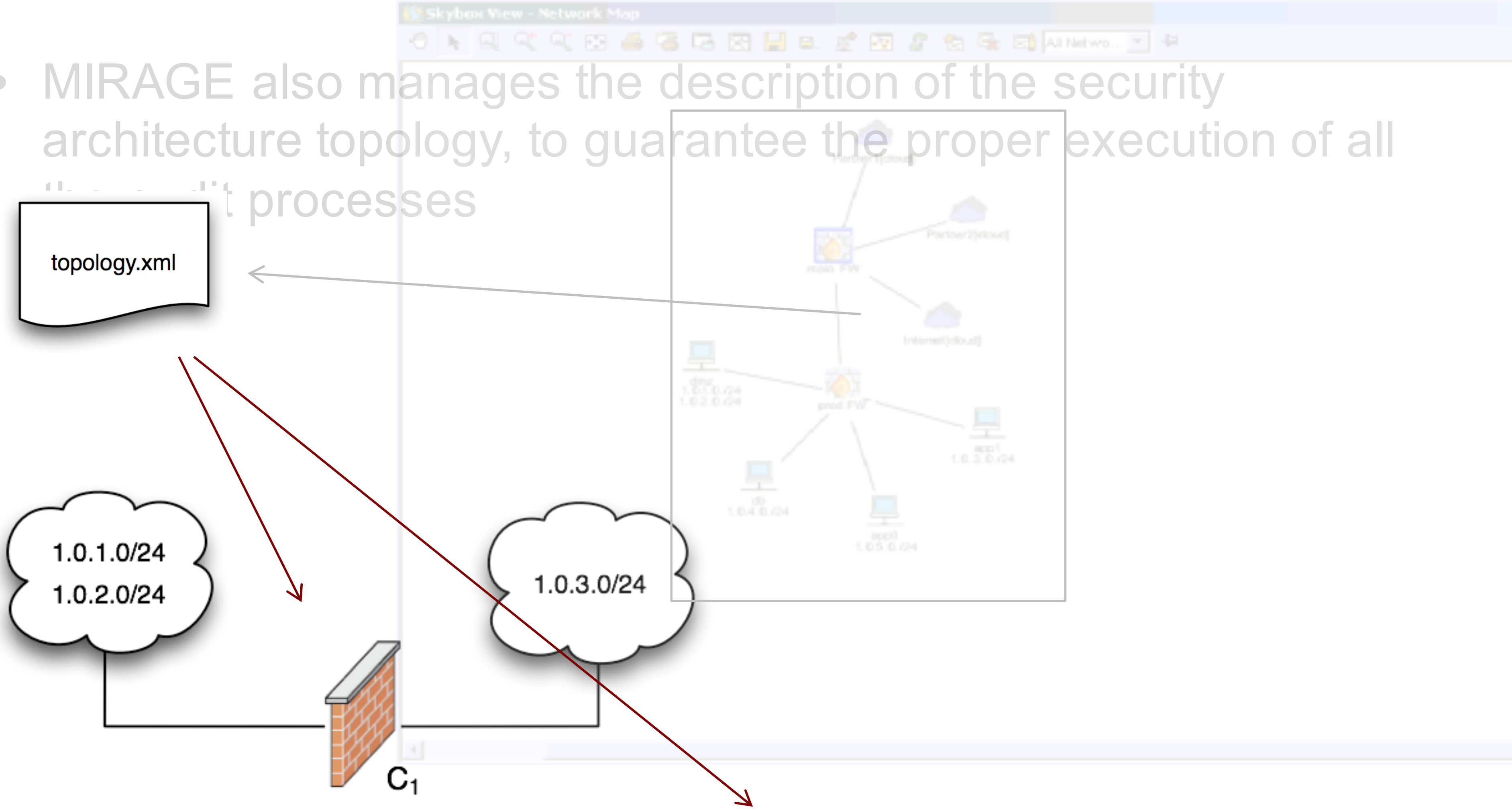

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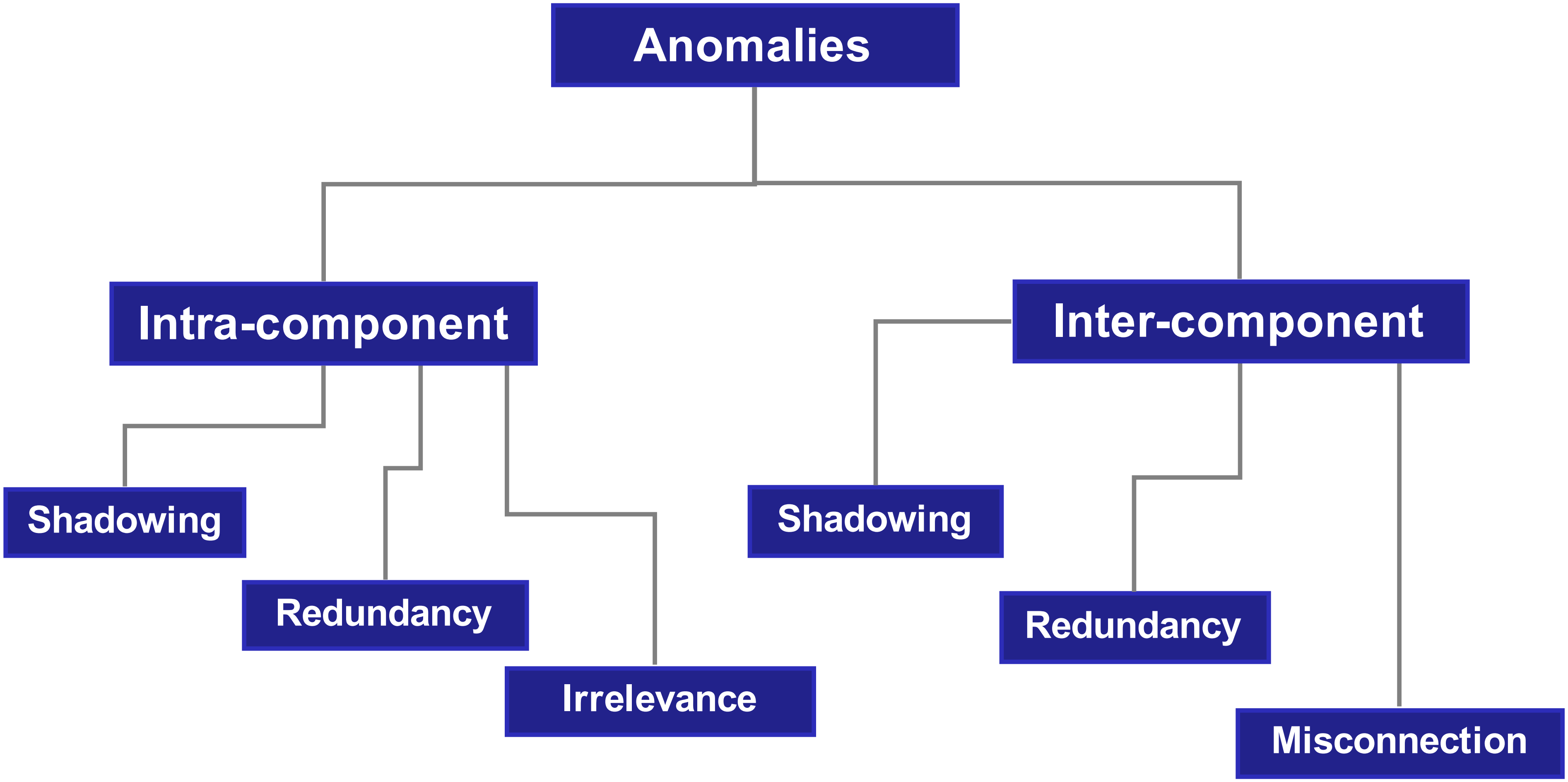
Complete taxonomy of Anomalies


Anomalies

Intra-component

Inter-component

Shadowing

Redundancy

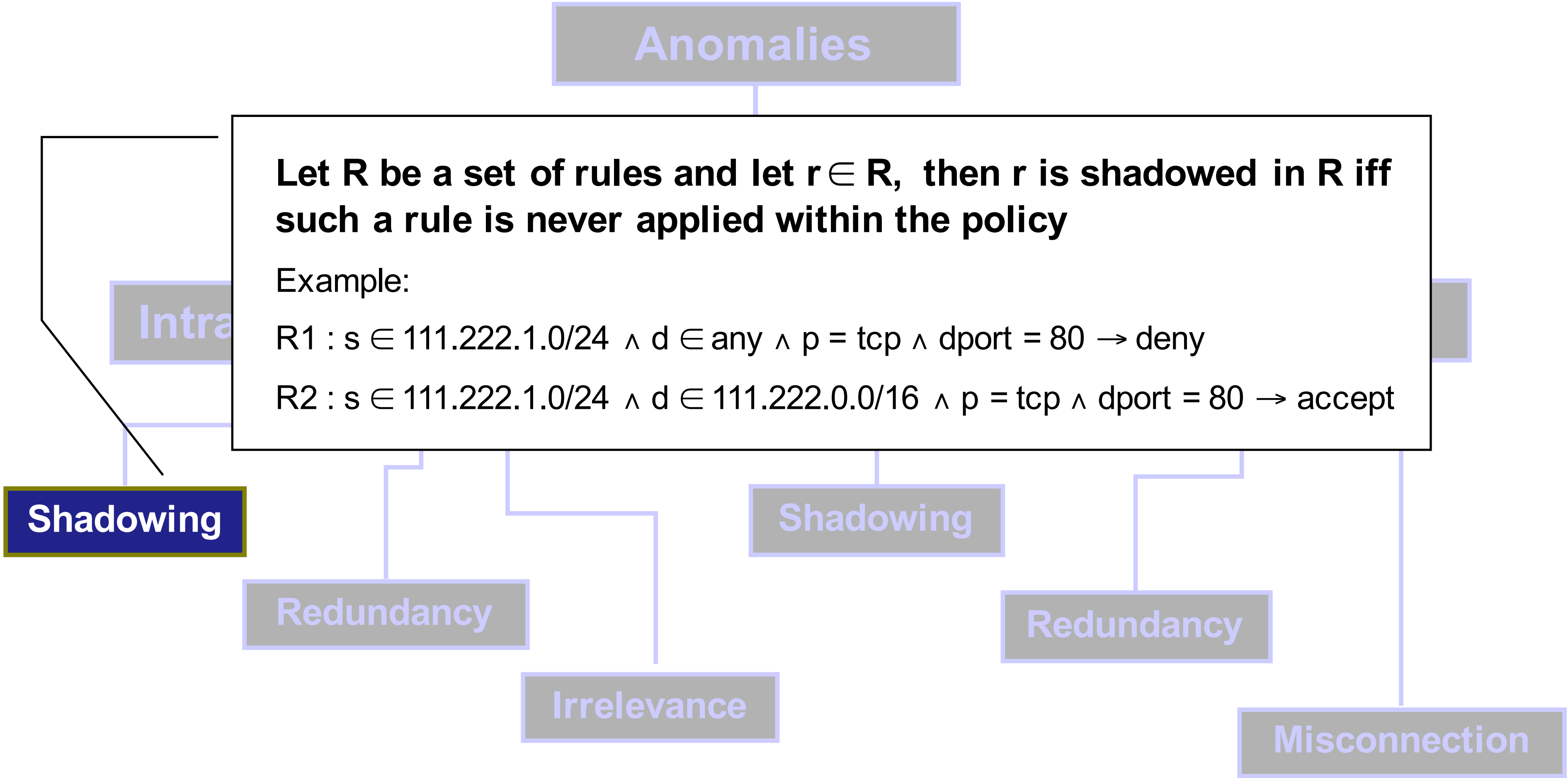
Irrelevance

Shadowing

Redundancy

Misconnection

Complete taxonomy of Anomalies



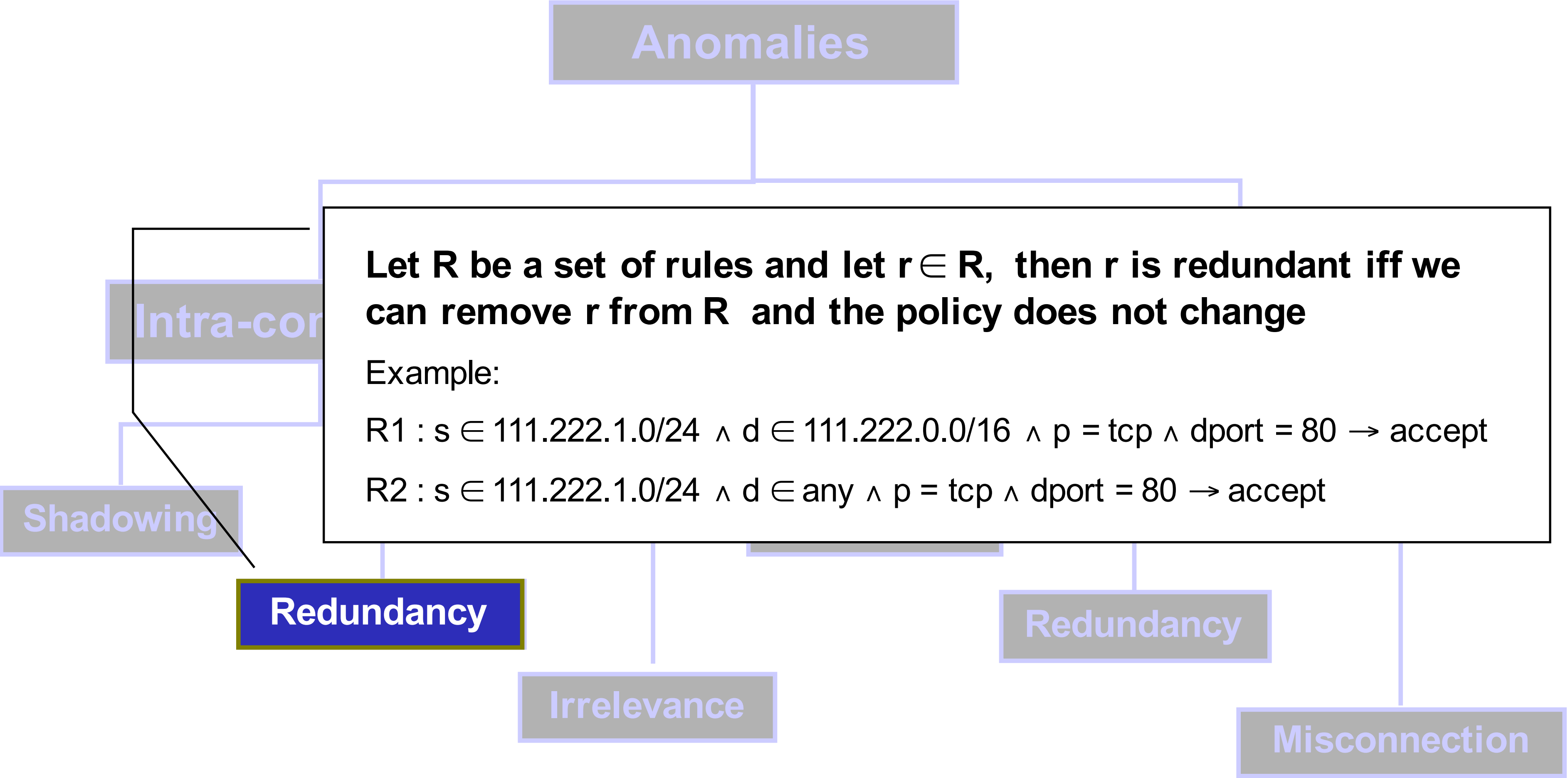
Let R be a set of rules and let r ∈ R, then r is shadowed in R iff such a rule is never applied within the policy

Example:

R1 : $s \in 111.222.1.0/24 \wedge d \in any \wedge p = tcp \wedge dport = 80 \rightarrow deny$

R2 : $s \in 111.222.1.0/24 \wedge d \in 111.222.0.0/16 \wedge p = tcp \wedge dport = 80 \rightarrow accept$

Complete taxonomy of Anomalies



Let R be a set of rules and let $r \in R$, then r is redundant iff we can remove r from R and the policy does not change

Example:

R1 : $s \in 111.222.1.0/24 \wedge d \in 111.222.0.0/16 \wedge p = tcp \wedge dport = 80 \rightarrow accept$

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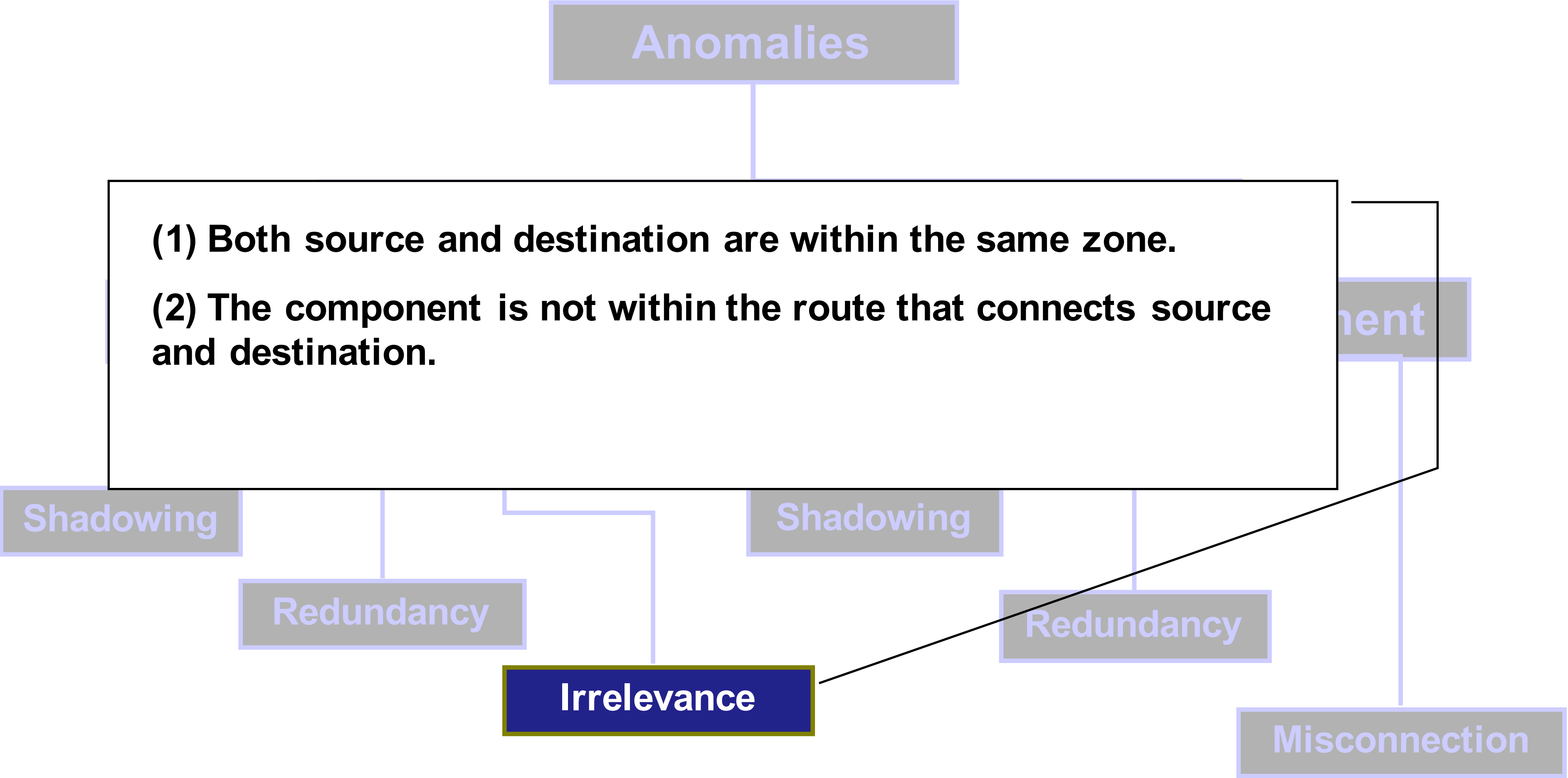
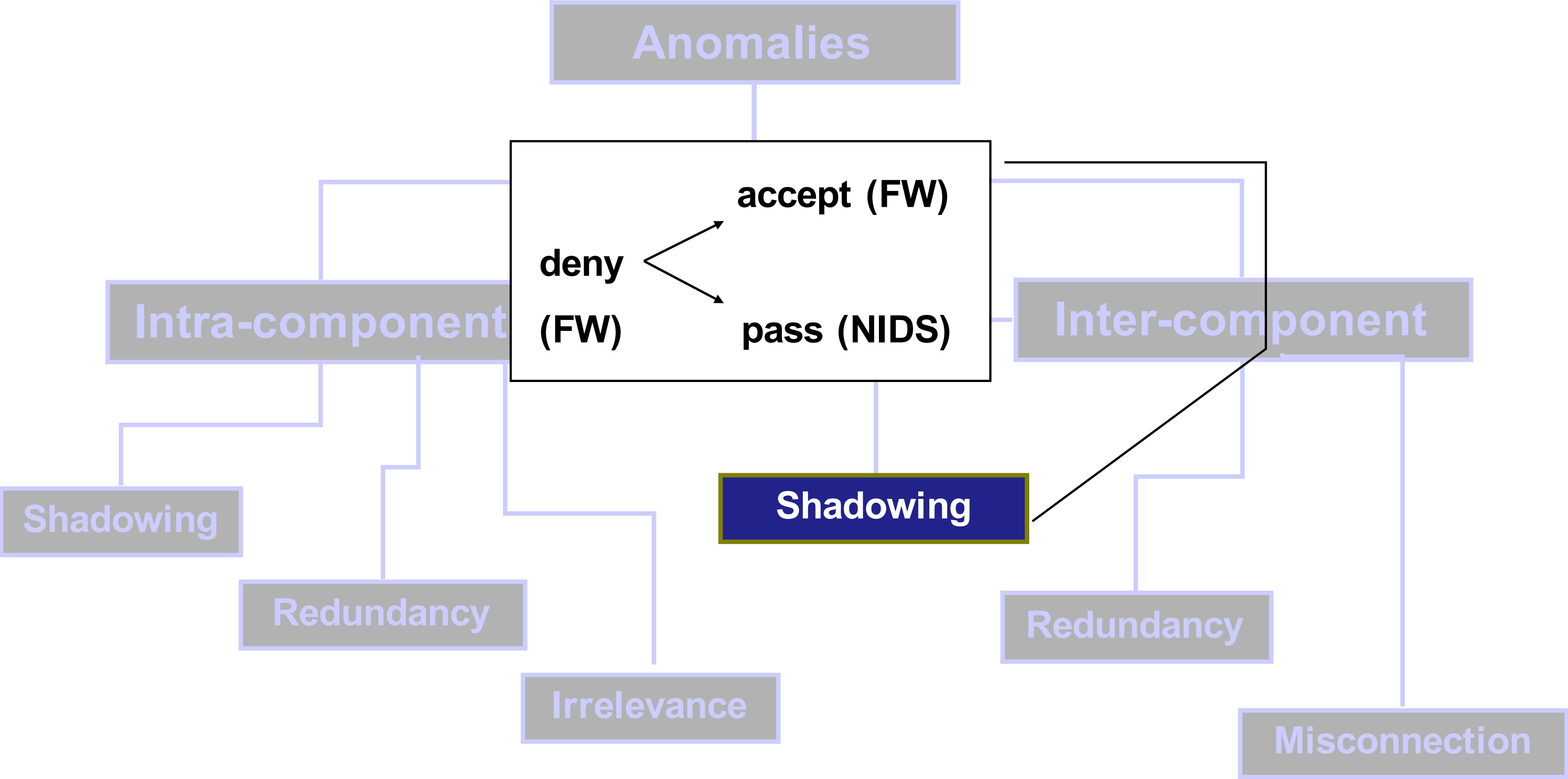


(1) Both source and destination are within the same zone.

(2) The component is not within the route that connects source and destination.

Complete taxonomy of Anomalies



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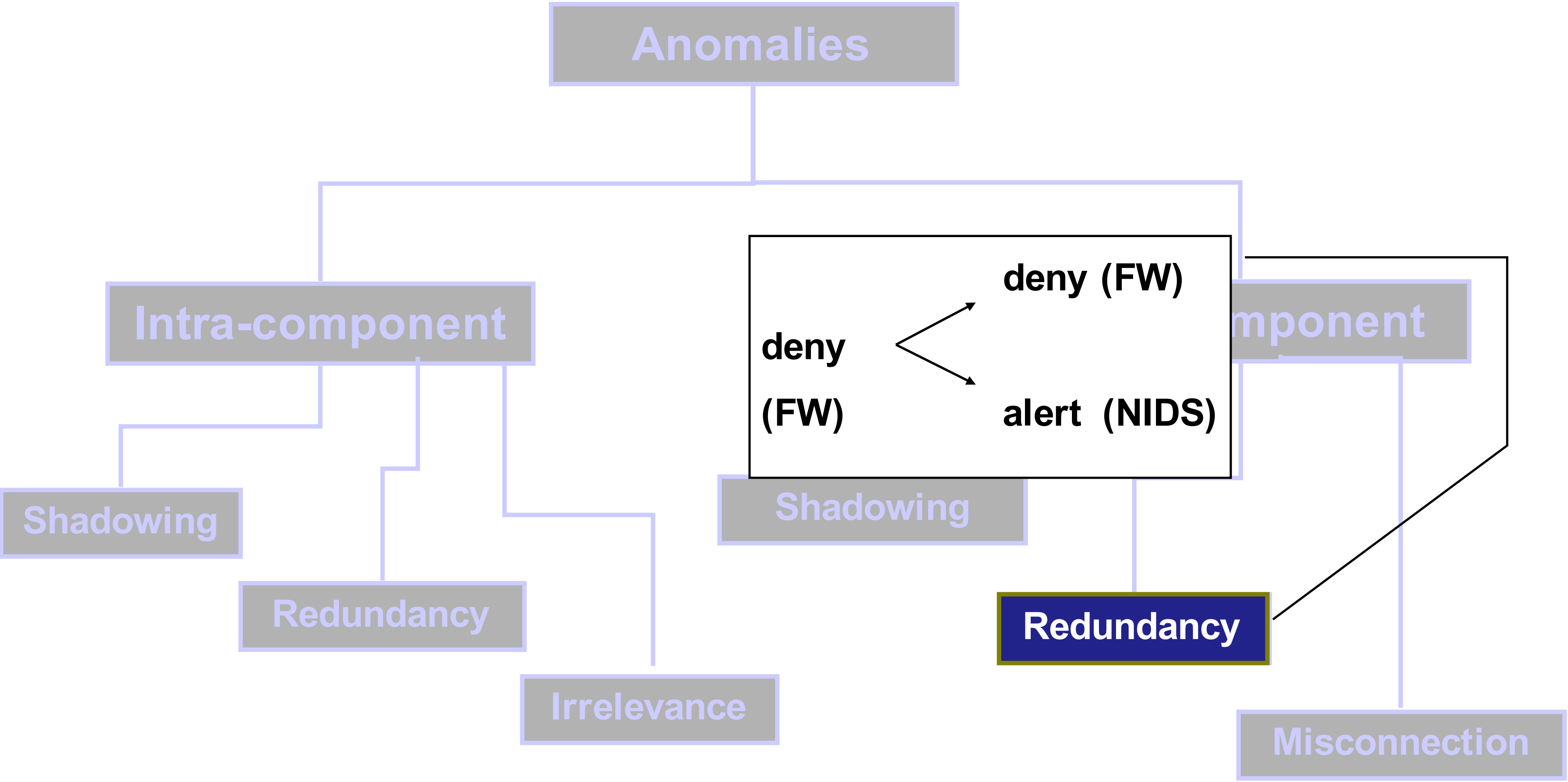

Anomalies

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mponent

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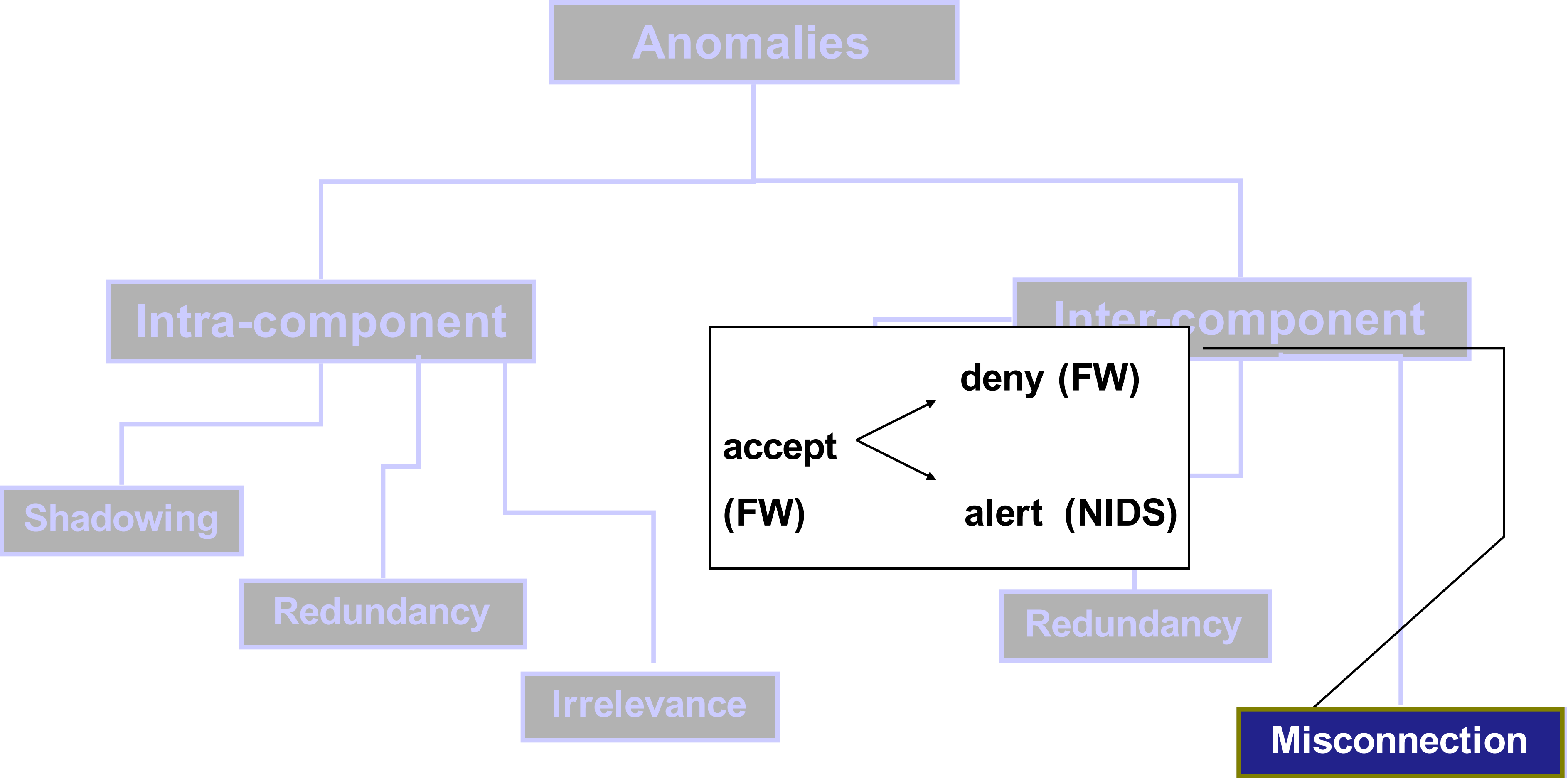
deny

(FW)

deny (FW)

alert (NIDS)

Complete taxonomy of Anomalies



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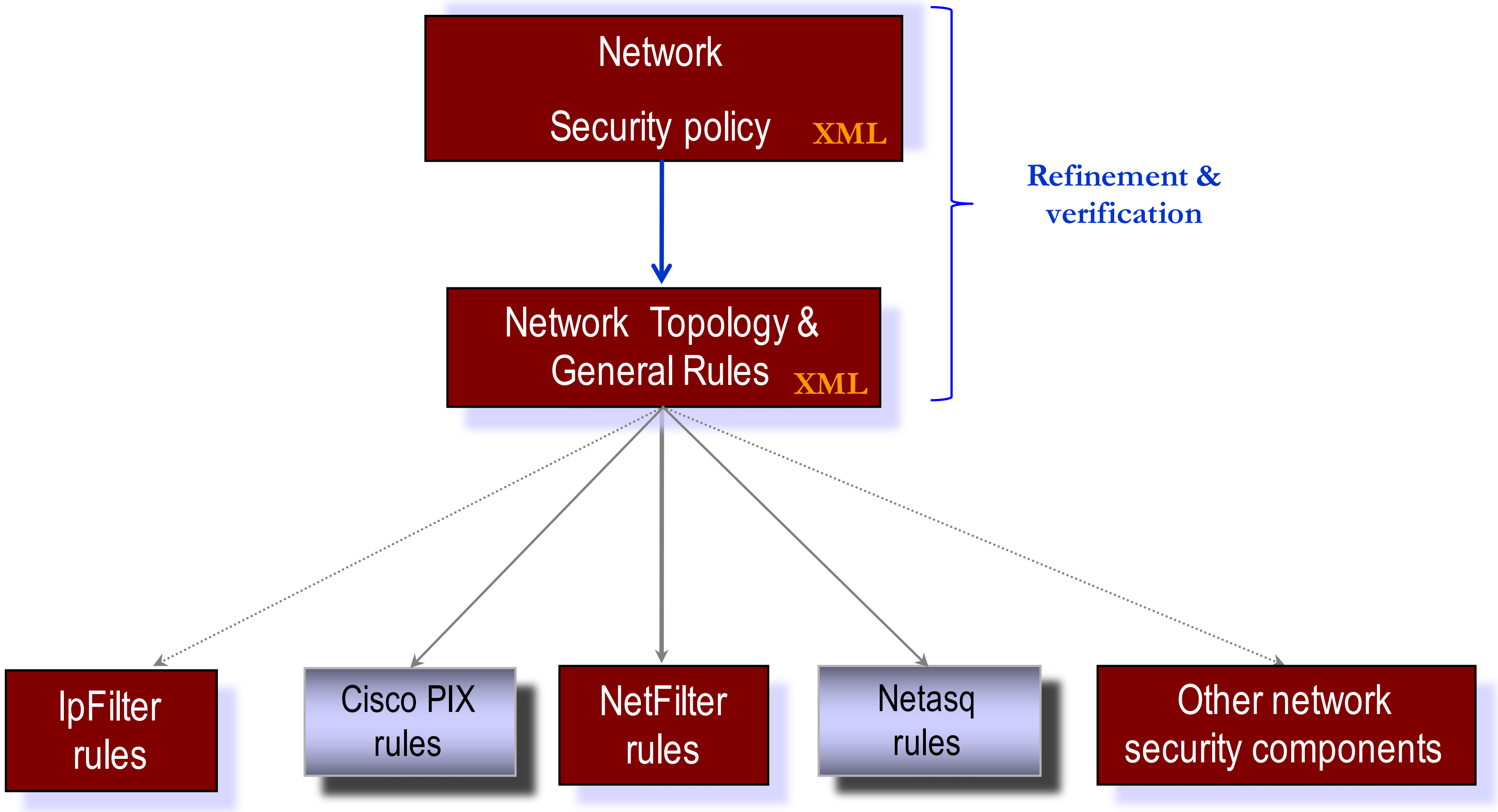
- **Top-down refinement of general security policies**
- **Conclusion / Perspectives**

Top-down Approach



Network

Security policy XML

Network Topology & General Rules XML

Refinement & verification

IpFilter rules

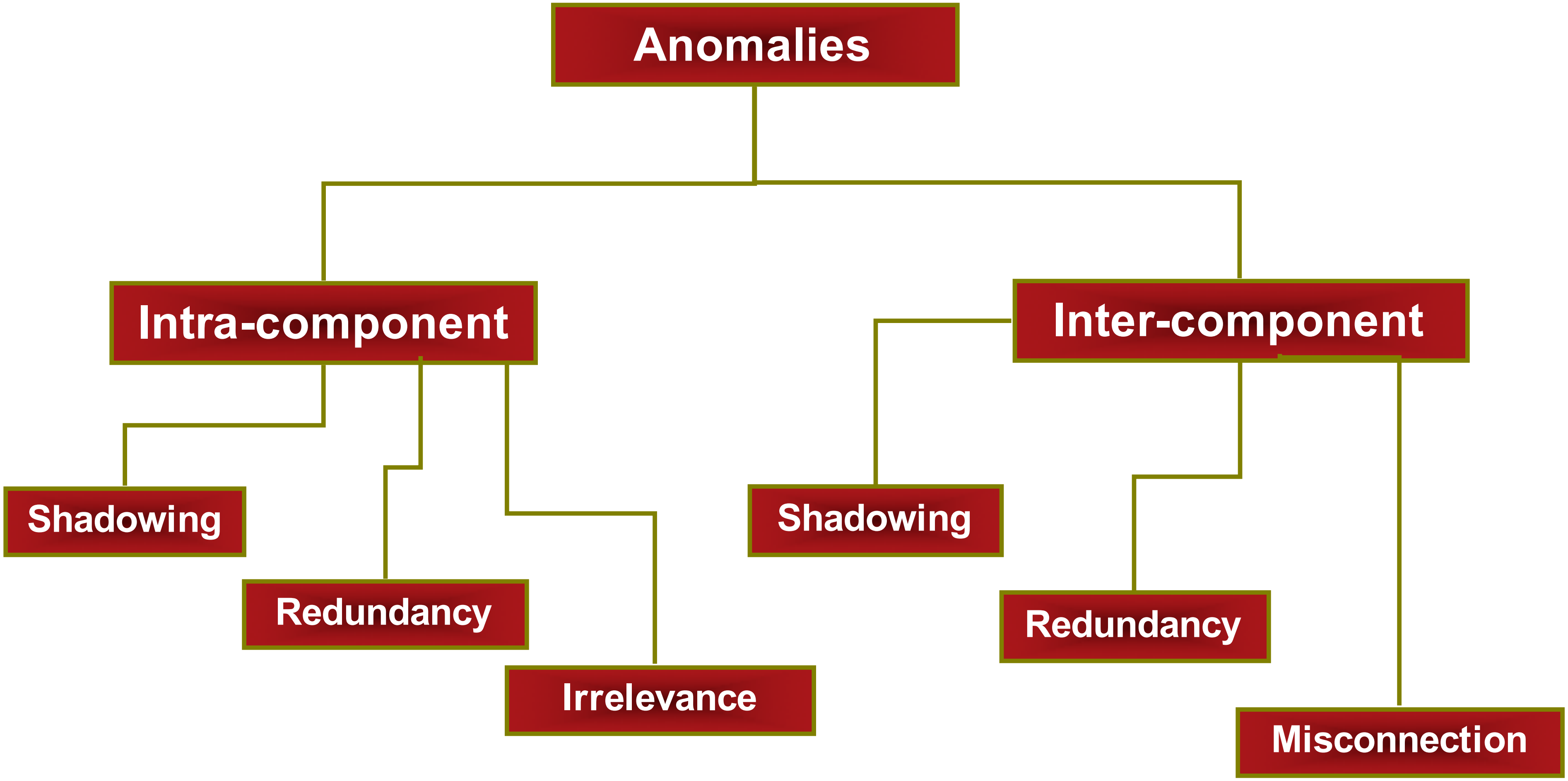
Cisco PIX rules

NetFilter rules

Netasq rules

Other network security components

Address same taxonomy of Anomalies



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Refinement of Global Policies

Security Policy

- Definition of a global security policy for the whole information system
- Then, perform a transformation process in order to configure a specific instance of the security policy for every component within the information system

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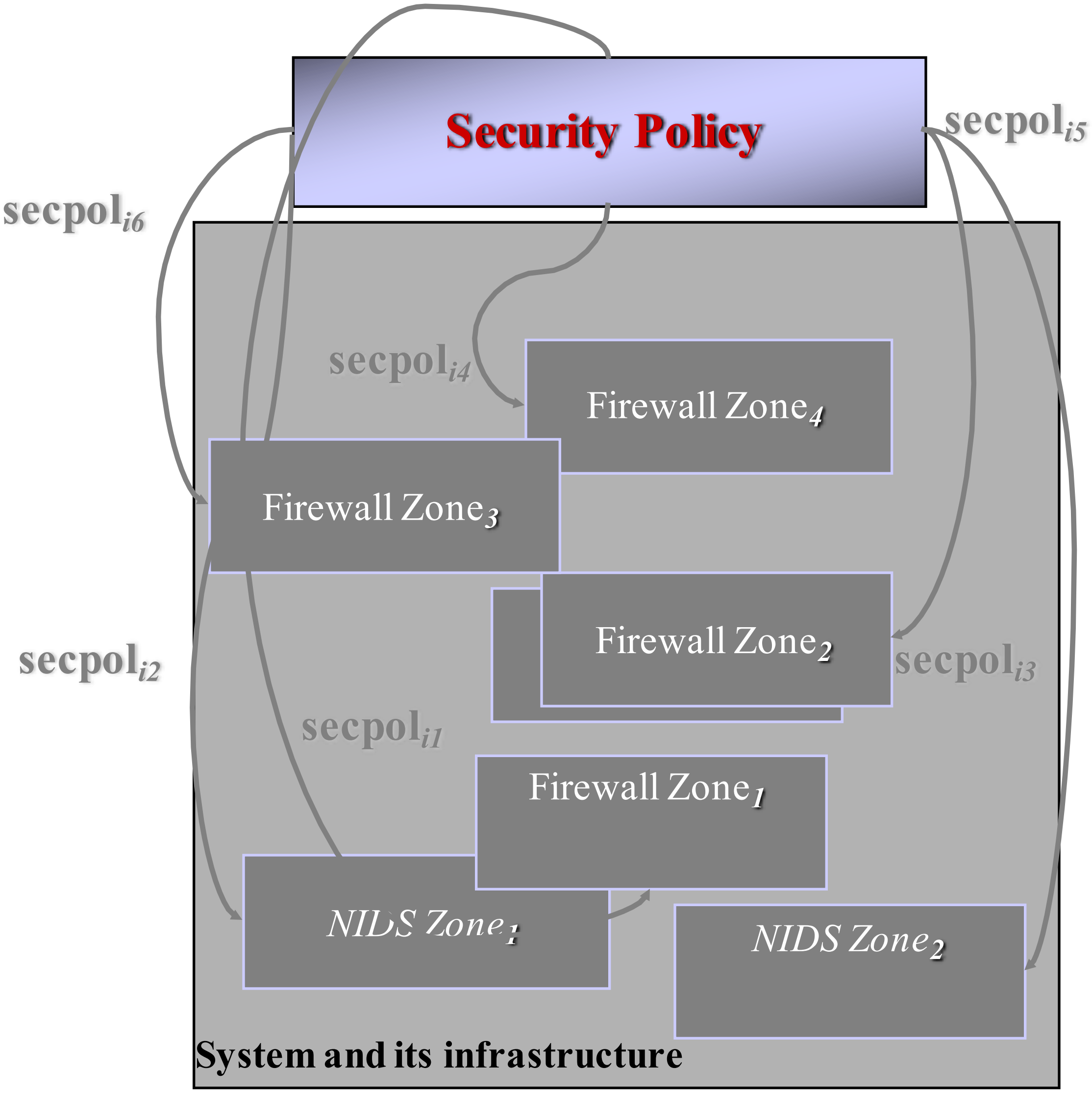

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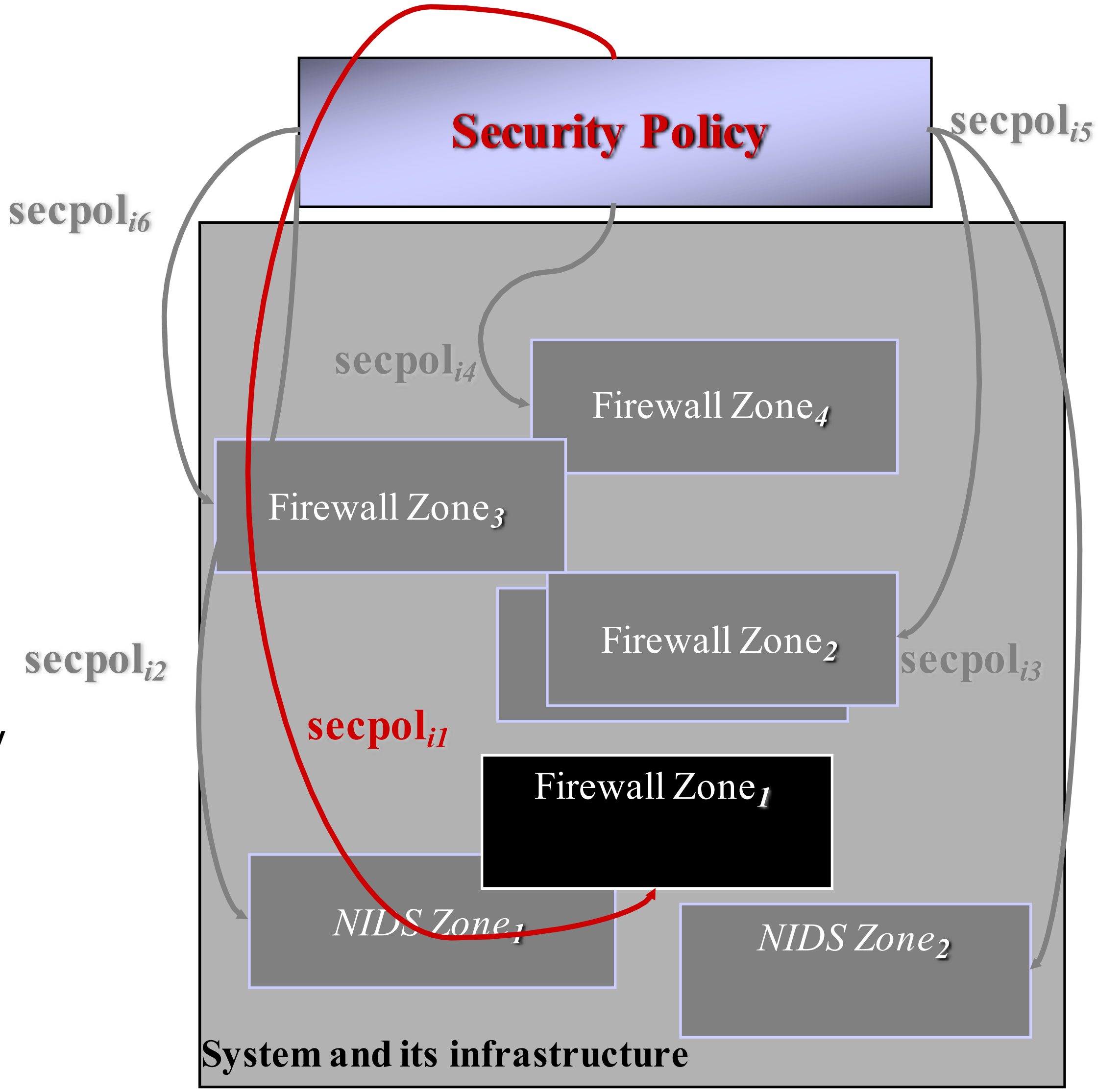

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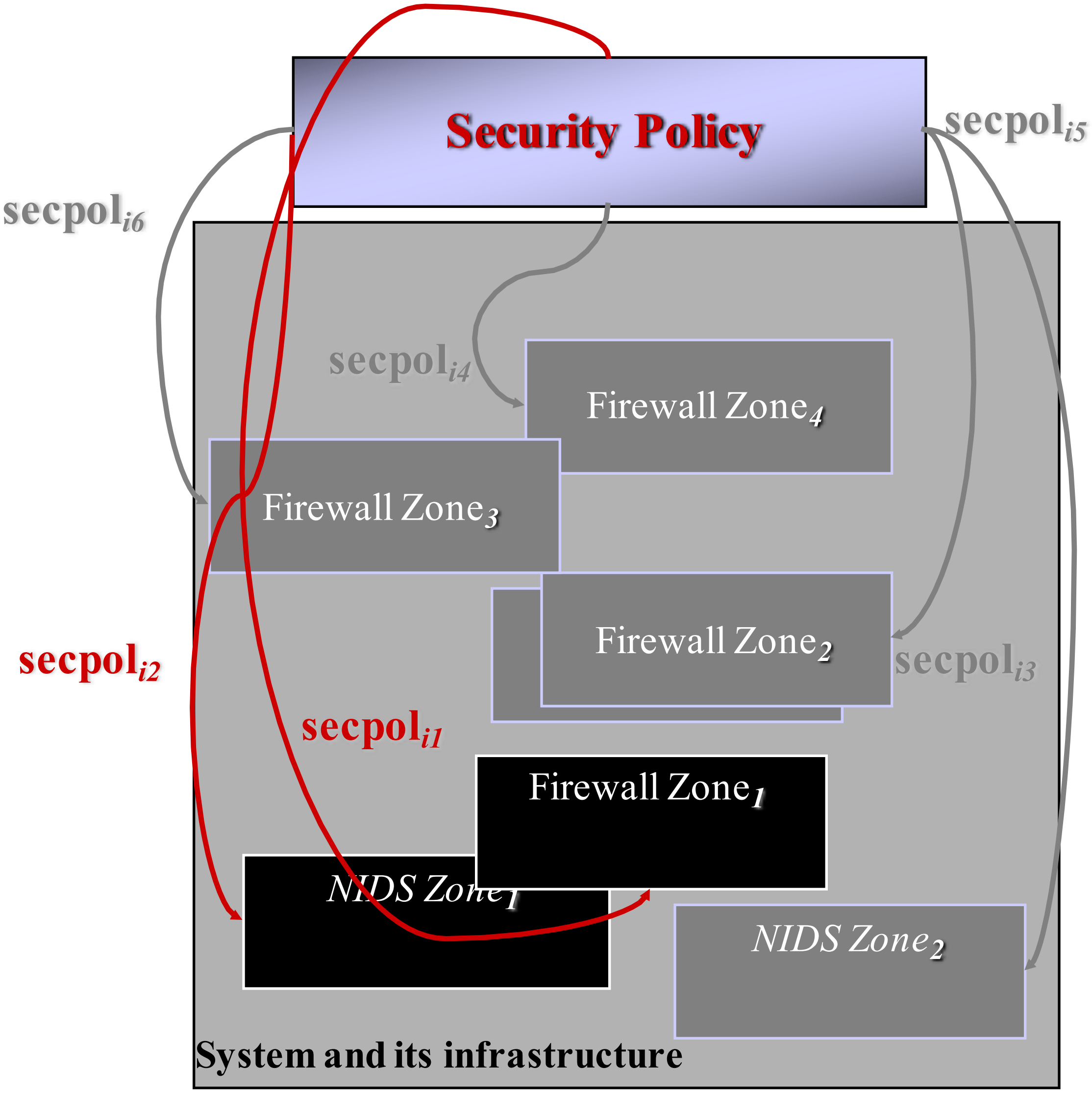

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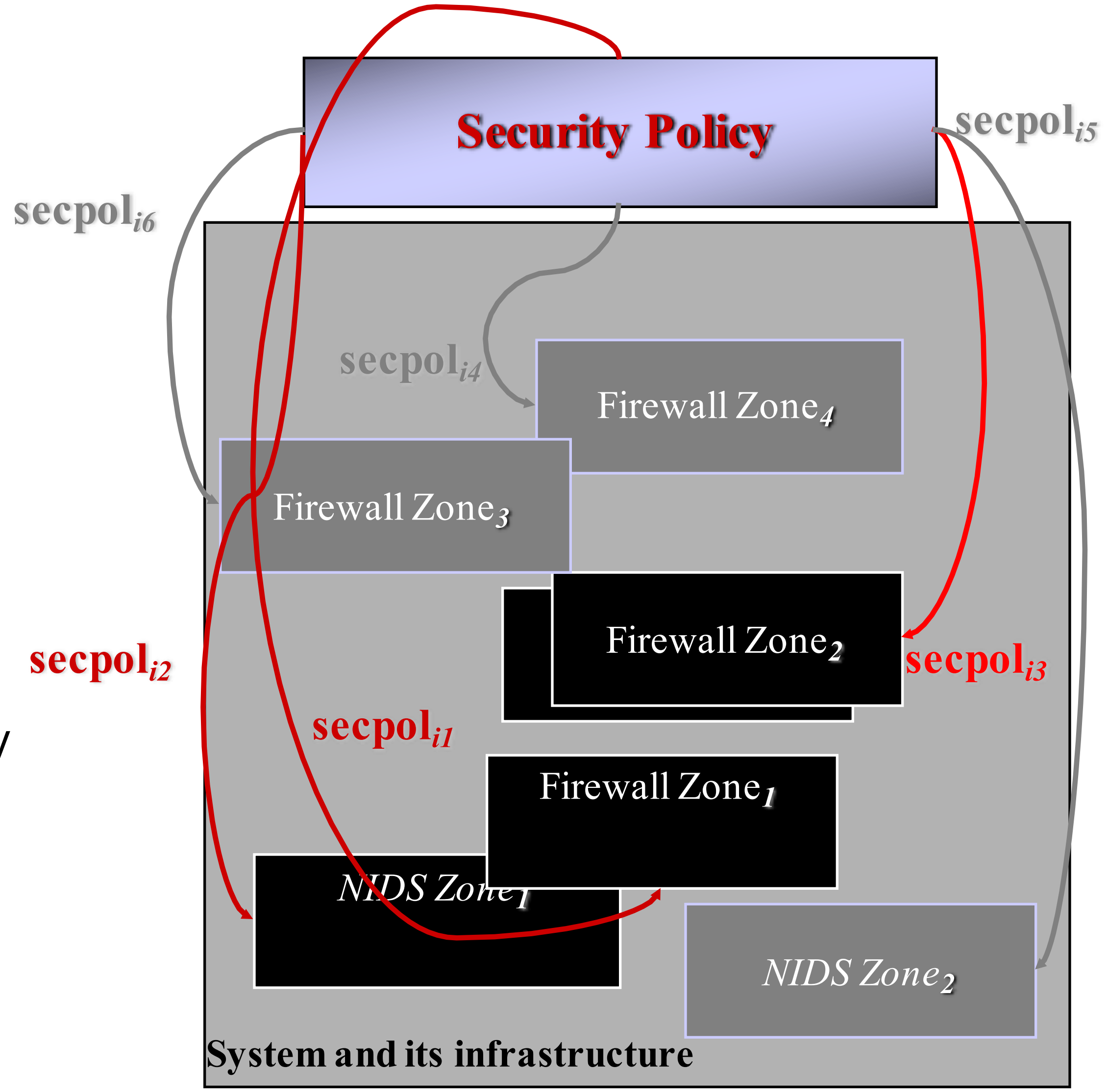

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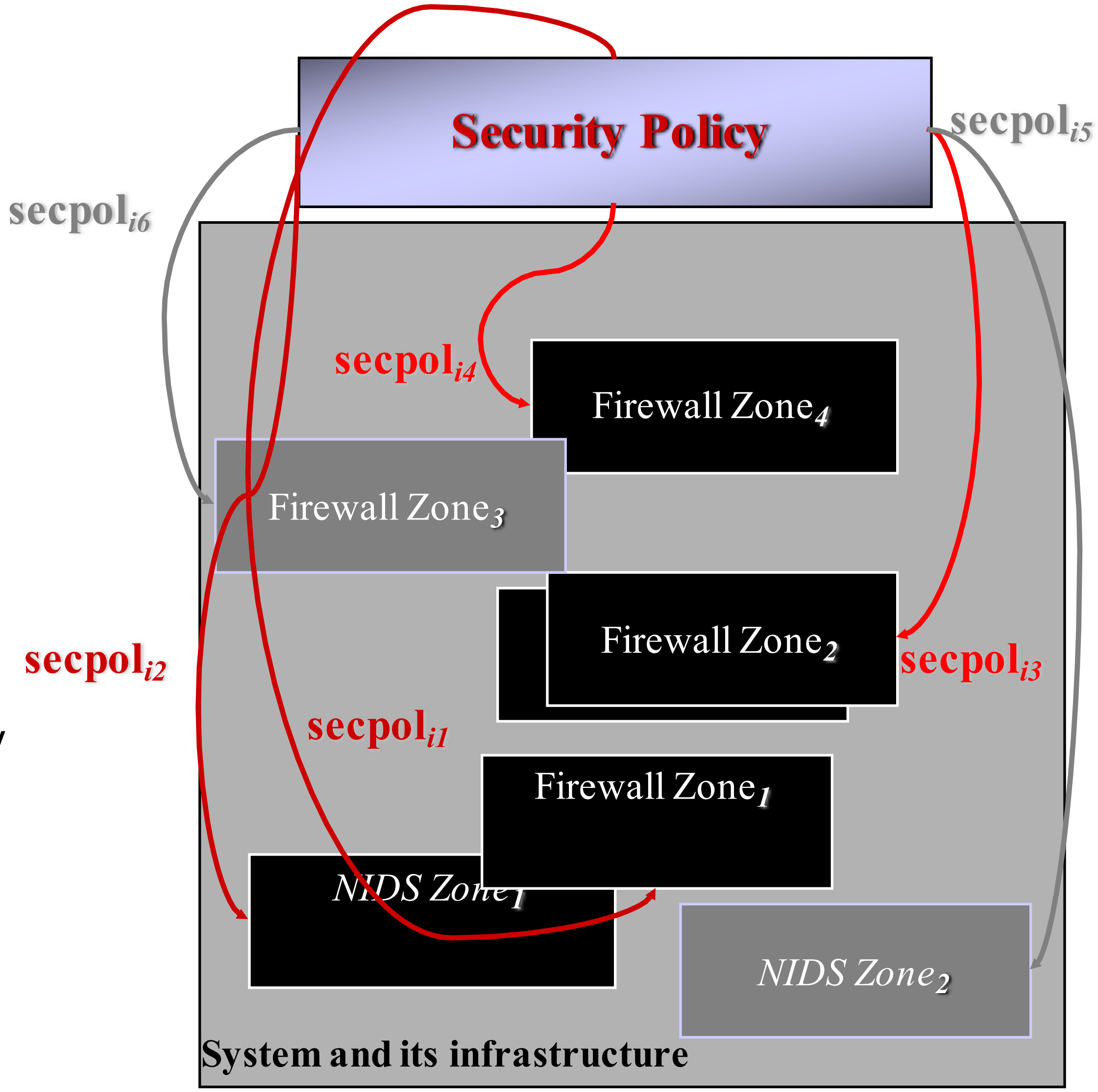

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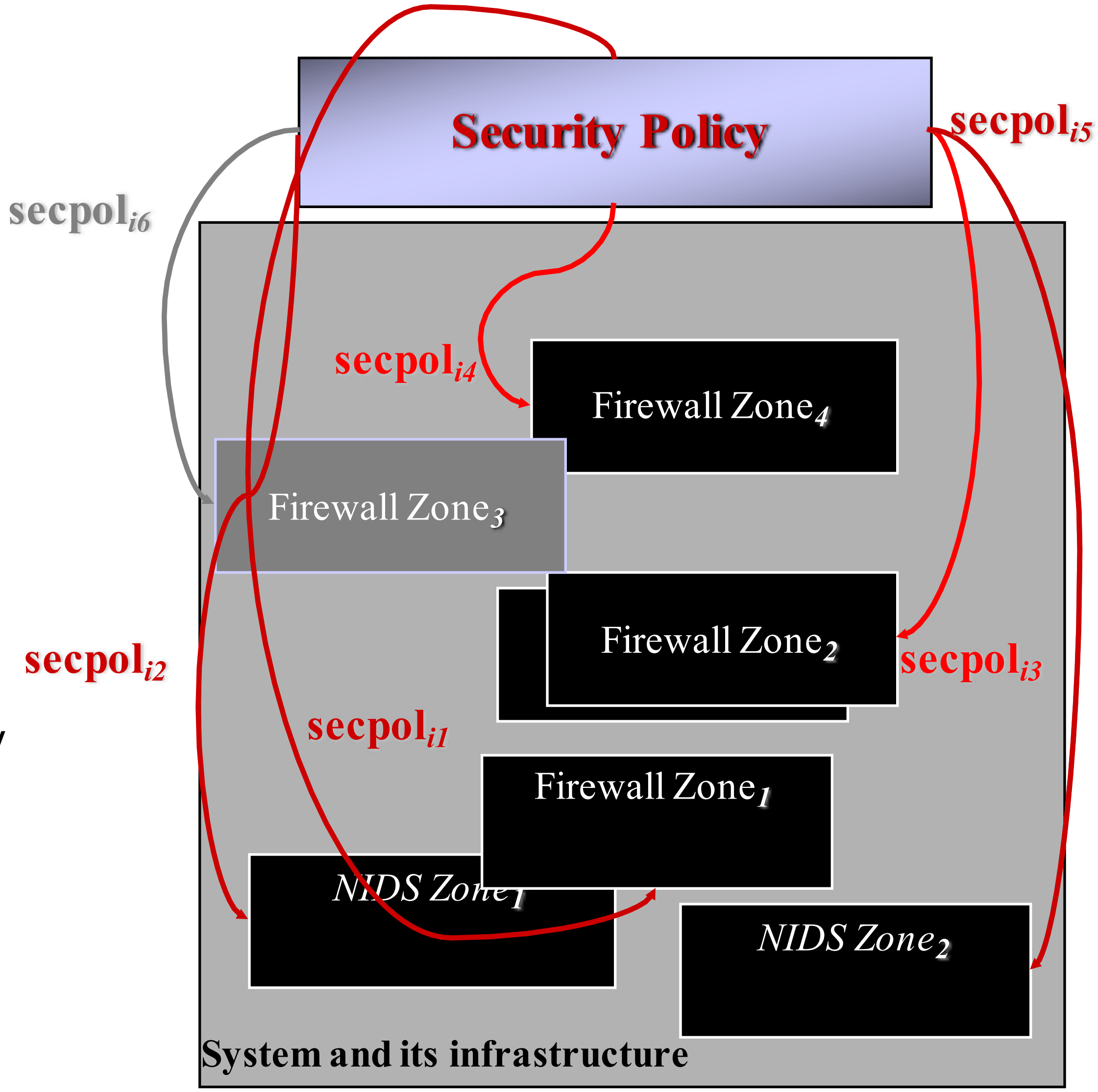

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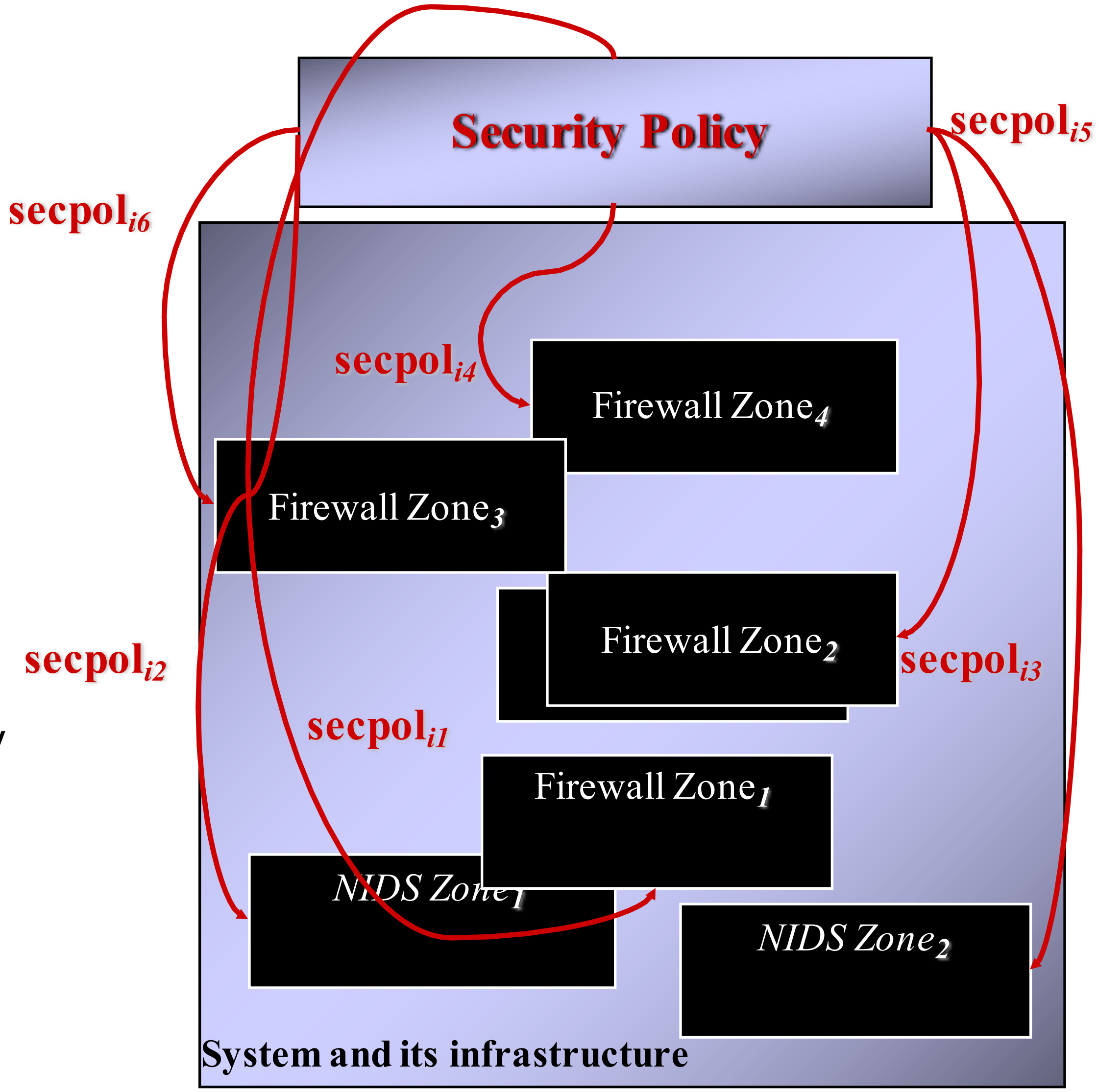


Specifying network security policies with OrBAC

- Objective of a network security policy
  - *Specify rules to control interaction between hosts that use network services to send messages.*

- Define concrete entities in network domain
  - **SUBJECT:** a host, a group of hosts, a (sub)network, etc. (all identified by their IP addresses)
  - **ACTION:** a network service (e.g., tcp, udp, HTTP, ...)
  - **OBJECT:** a message sent to destination hosts (i.e., subjects)

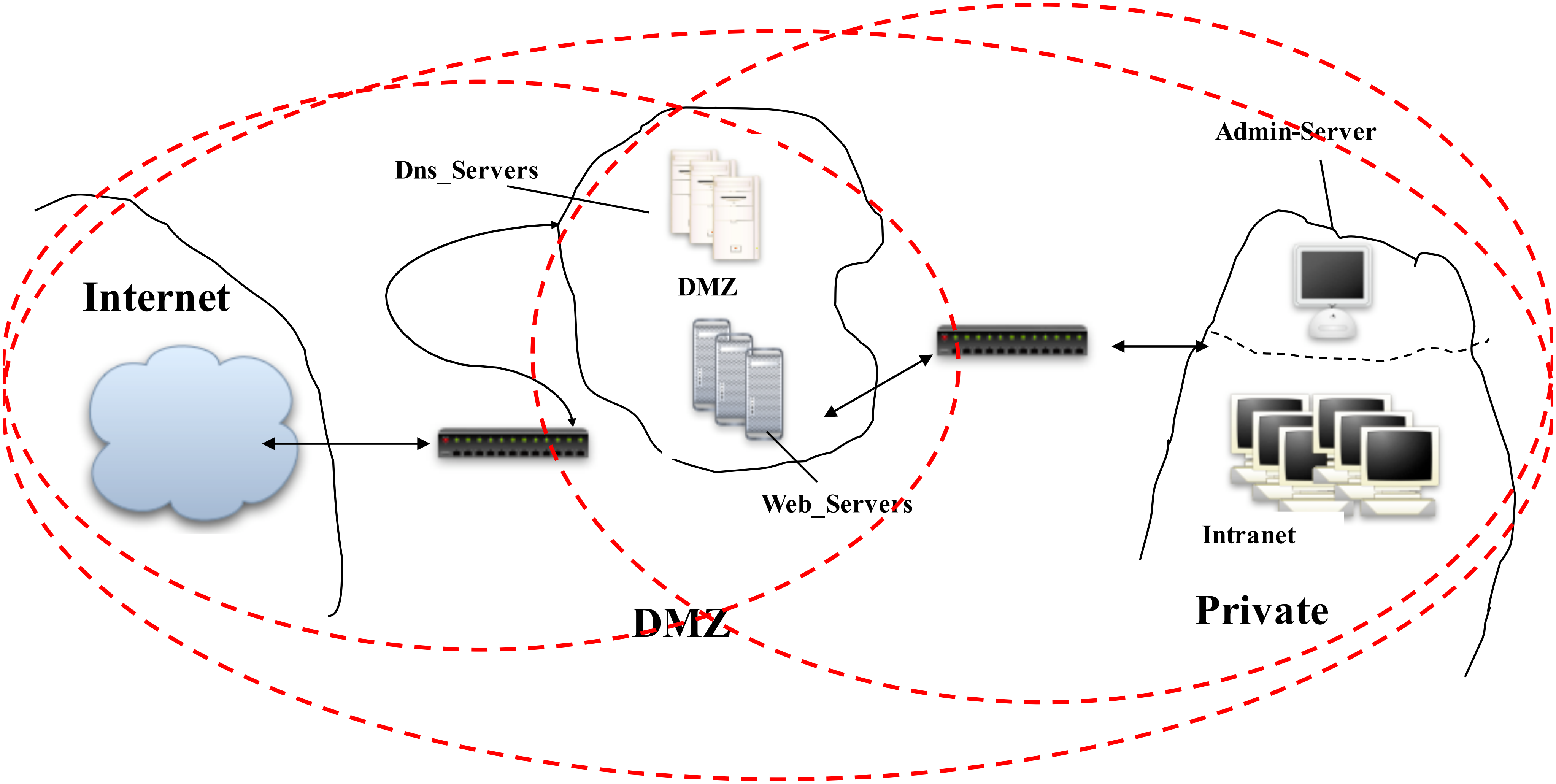
Examples based on the previous network

- **Roles:** abstraction of subjects (i.e., hosts):
  - *Web_servers, DNS_Servers, Admin_server, Internet, Intranet.*

- **Activities:** abstraction of actions (i.e., network services):
  - *Web_http, DNS_resolution, Administration, Mail_SMTP.*

- **Views:** abstraction of objects (i.e., network messages):
  - *to_Web_servers, to_DNS_Servers, to_Admin_server, to_Internet, to_Intranet .*

Sample network



How to specify permissions

- **Example**:

In the *Corporate network*, *Intranet hosts* can send *web requests* to *Internet hosts*

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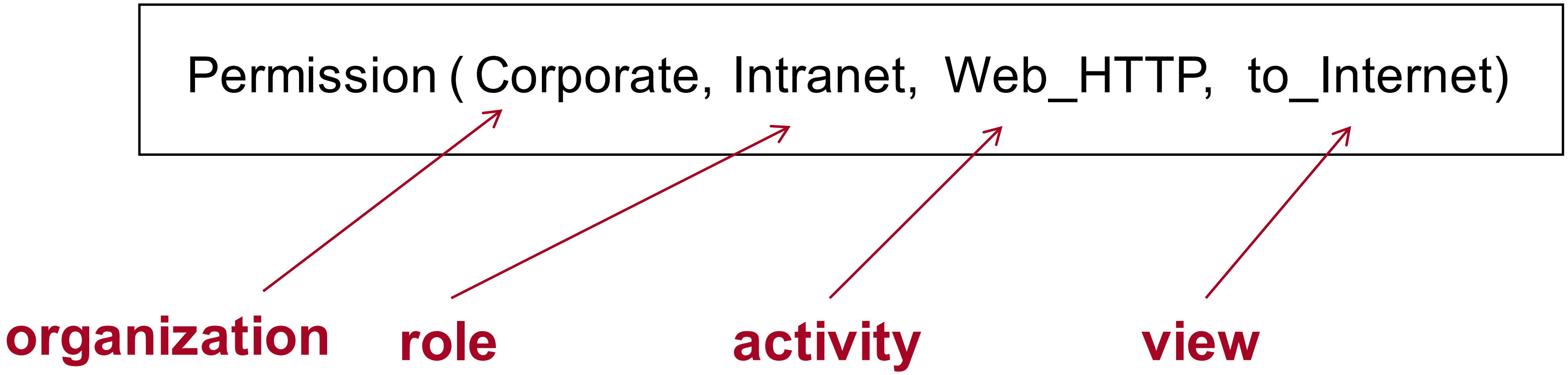
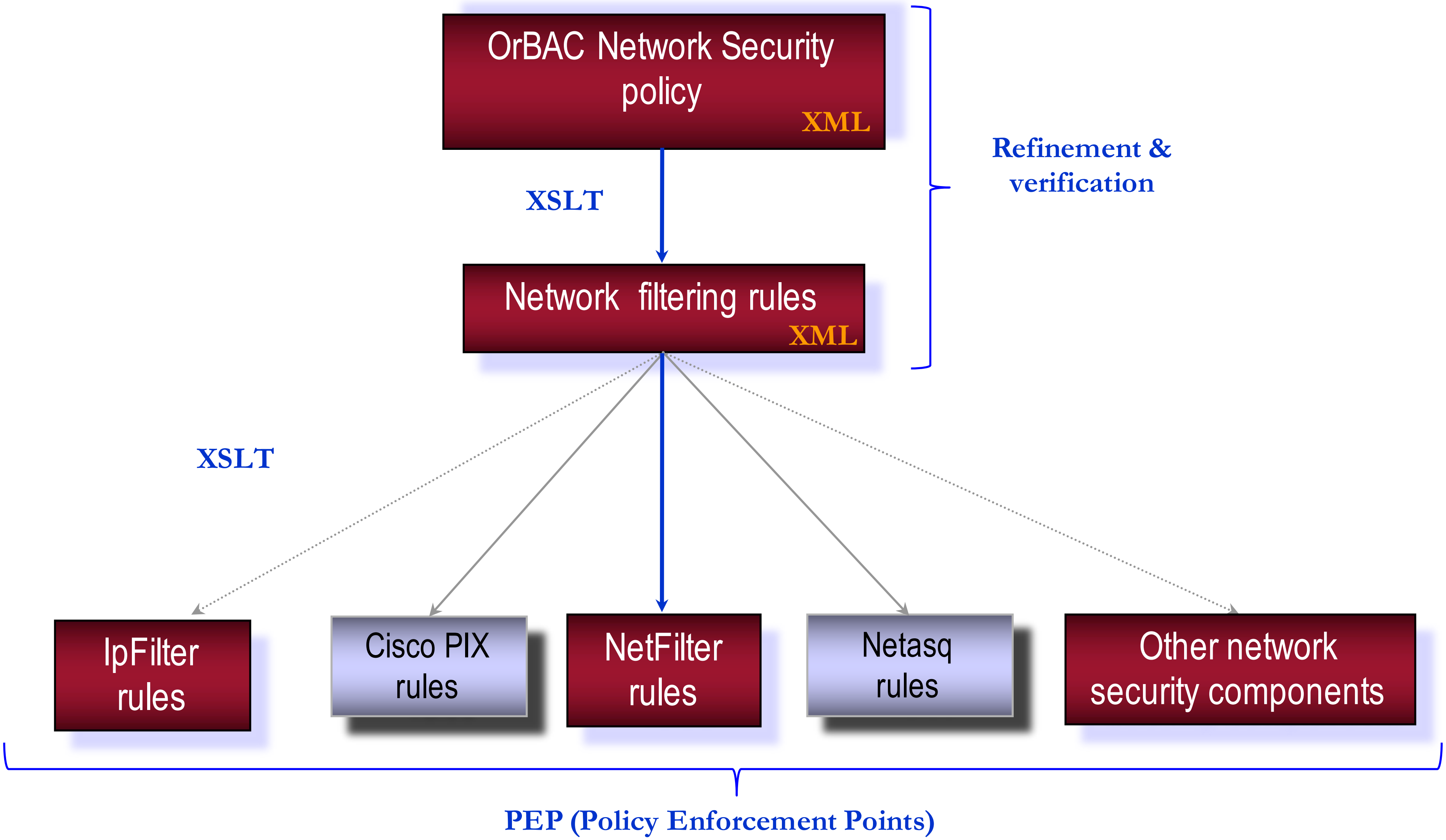


Permission (Corporate, Intranet, Web_HTTP, to_Internet)

organization **role** **activity** **view**

Refinement (MIRAGE example)



OrBAC Network Security policy XML

XSLT

Network filtering rules XML

Refinement & verification

XSLT

IpFilter rules

Cisco PIX rules

NetFilter rules

Netasq rules

Other network security components

PEP (Policy Enforcement Points)

Conclusion

- **Bottom-up approach**
  - Ad hoc analysis of network configurations
  - Analysis of other security components (e.g., VPN routers)

- **Top-down approach**
  - Global approach
  - Dynamic reconfiguration

- **Combining & improving both approaches**