Chair of Network Architectures and Services
Department of Informatics
Technical University of Munich

Collaborative Incident Handling Based on the Blackboard-Pattern

Nadine Herold, Holger Kinkelin and Georg Carle

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Motivation

- Amount and variants of attacks on networks is growing
- Defending networks manually is impossible
- Automated incident handling is highly beneficial
  - Continuously defend the network
  - Respond quickly
  - Less error-prone
  - Systematical incident response
- We focus on intrusion handling

Background: Typical Intrusion Handling Steps

- Network Monitoring (NMS) and Intrusion Detection Systems (IDS) collect information about the network and its healthiness
  - NMS: collect infrastructure information
  - IDS: raise alerts when an intrusion is detected
- Alert Processing Systems (APS) aggregate, correlate and prioritize alerts
  - Gain more insights into the intrusion by analyzing the situation
- Intrusion Response Systems (IRS) counteract automatically
  - Identify suitable responses
  - Execute reponses on the target network, e.g., block a rogue host

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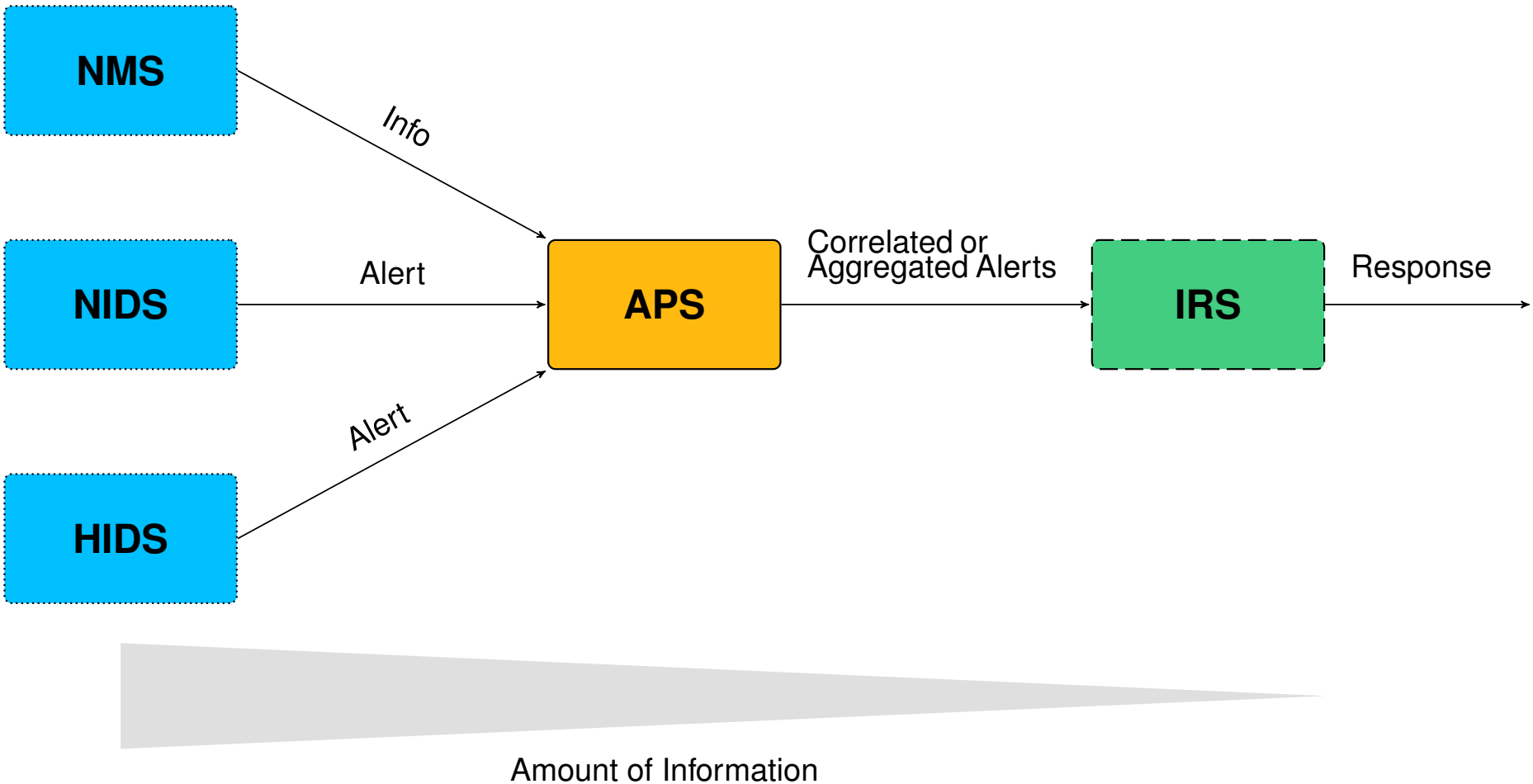
Execution Model: Pipelined Intrusion Handling



Other Execution Models

- Pipelined intrusion handling
  - Information loss from step to step
  - Limited information sharing capabilities
- Intrusion handling using Complex Event Processing (CEP)
  - Window size difficult to determine
    (too large $\rightarrow$ low performance; too small $\rightarrow$ information loss)
  - Limited information sharing capabilities
- Agent-based systems for intrusion handling
  - Central intelligent master component needed to dispatch information to agents

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- Significant effort has been made to improve each intrusion step individually
- No solution exists that interleaves steps and creates a comprehensive view on the target network
  - Information already collected/computed in previous steps is lost for being used by subsequent steps
  - Information and intermediate results cannot be shared efficiently between single steps
- Post-incident forensics of intrusion handling activities difficult

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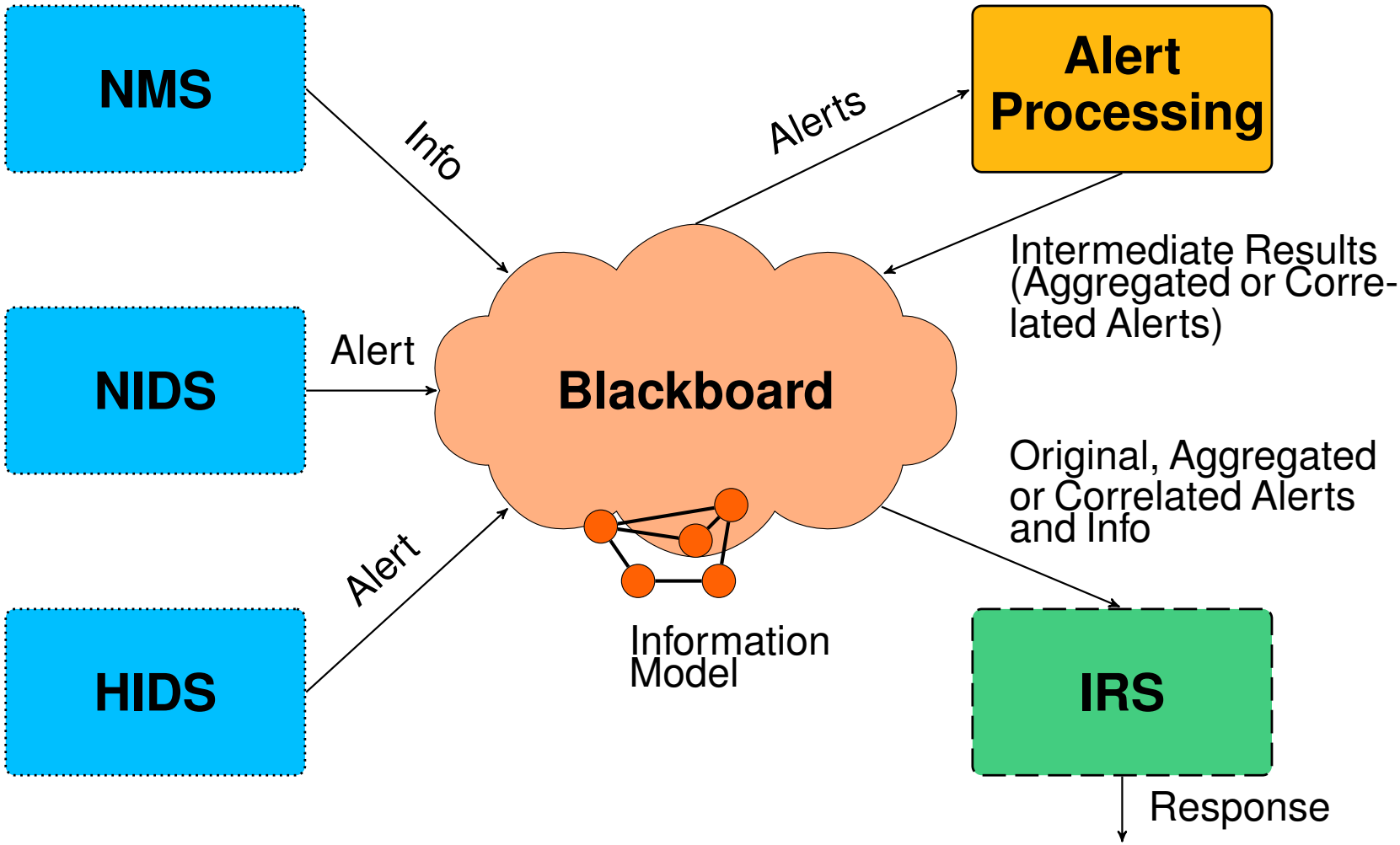
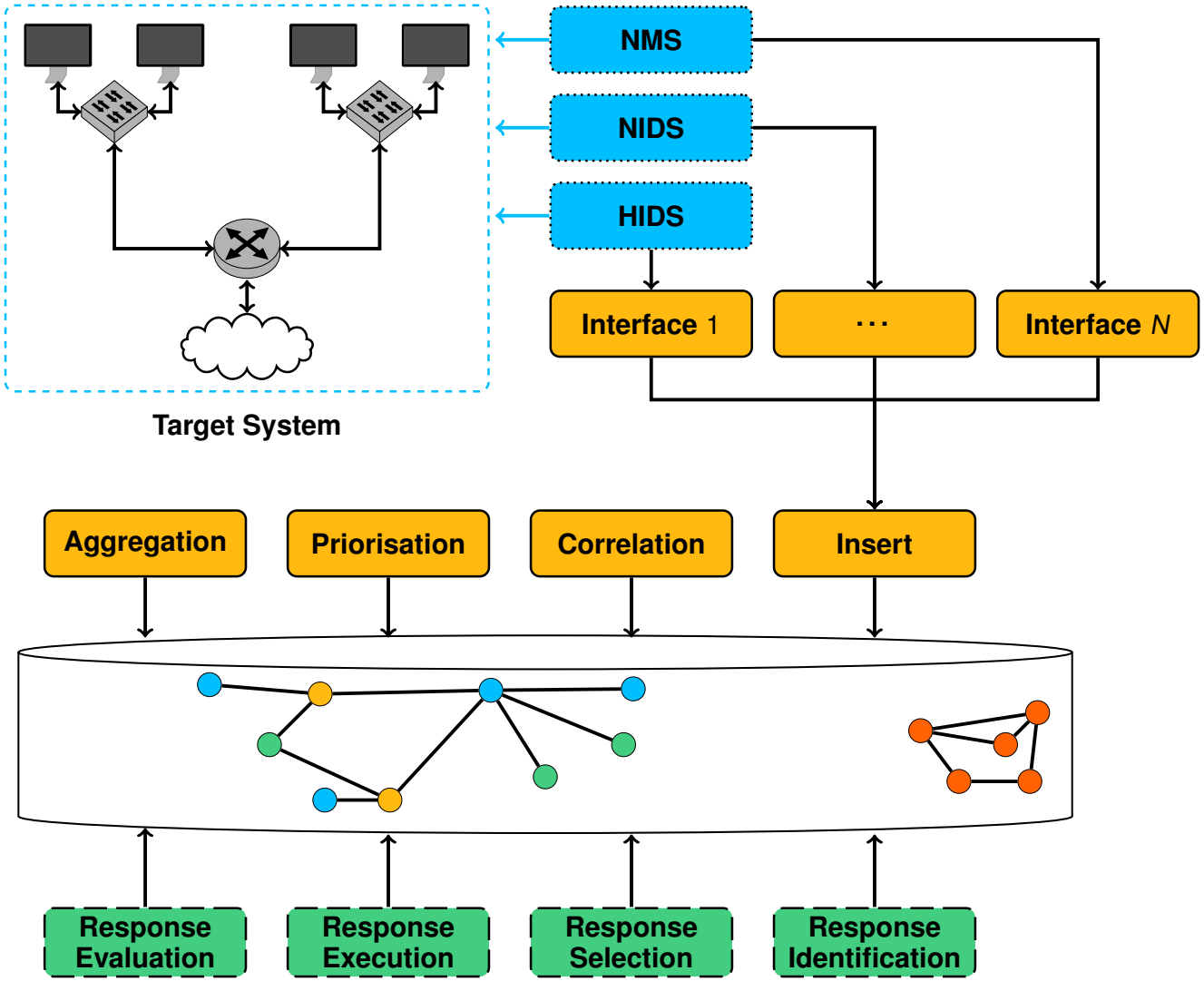
Introducing the Blackboard Pattern

- The blackboard pattern is applicable to problems that can be decomposed into smaller sub-problems / sub-tasks
  - Example: (distributed) incident handling / intrusion handling
- Sub-tasks solve their sub-problem and share their intermediate results with other sub-tasks
- Original information remains untouched
- Original information + intermediate results can be reused by sub-tasks to further tackle the problem
- Blackboard needs an Information Model specifically designed for the problem domain

Blackboard-based Intrusion Handling



System Overview



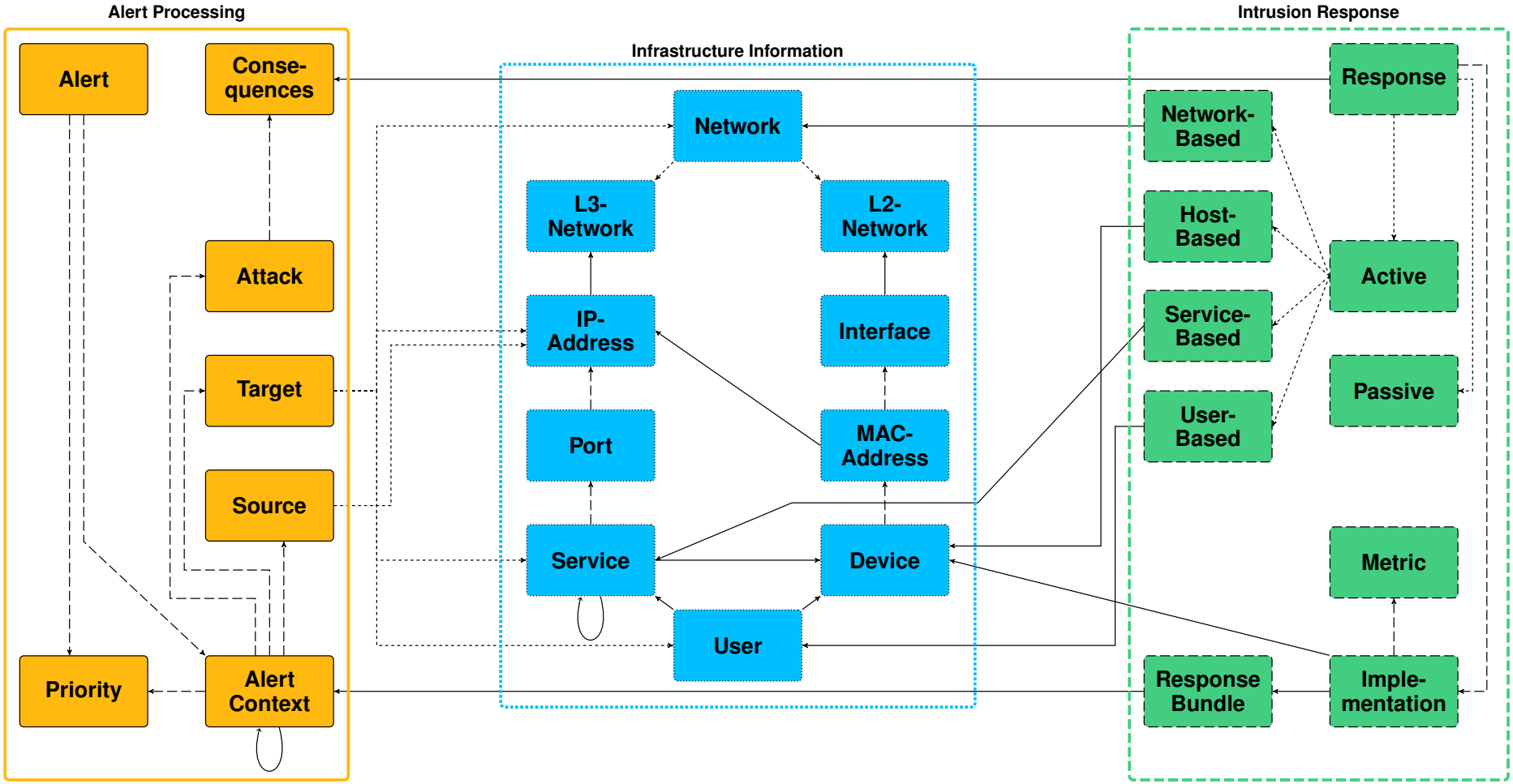
Requirements on an Information Model

... suitable for intrusion handling

- R1: Separation – Segmentation of information enables updating/adding of information by different modules
- R2: Completeness – Information for all steps of Incident Handling needs to be present
- R3: Compatibility to the IDMEF standard[1] used by many IDSes

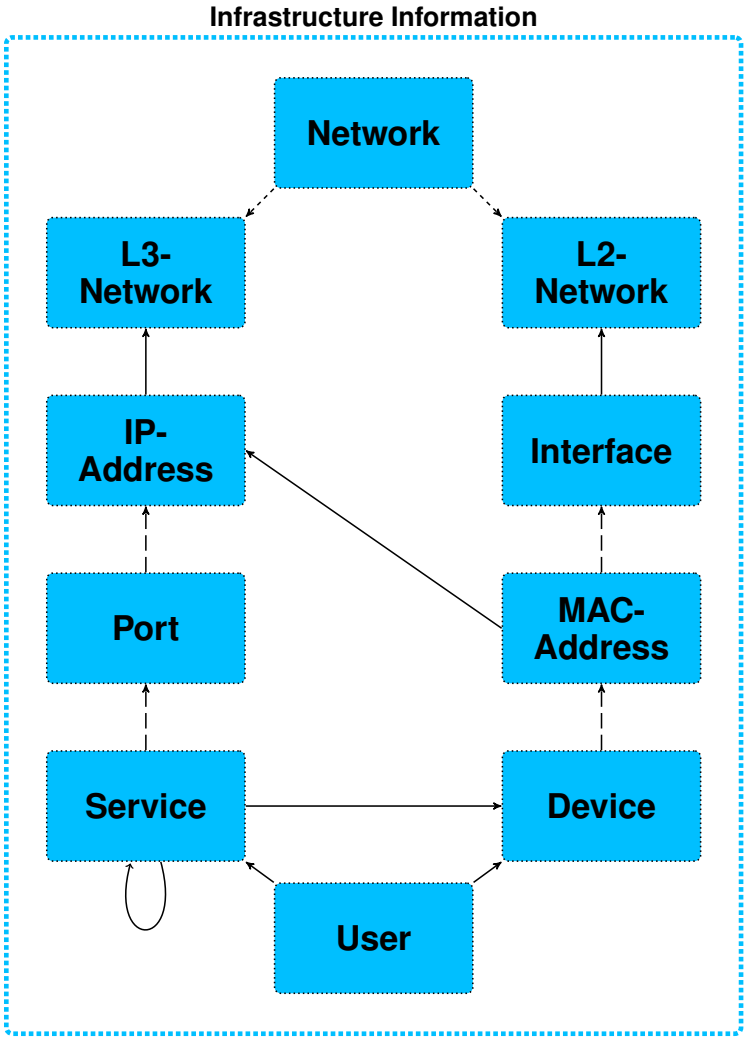
[1] Intrusion Detection Message Exchange Format, RFC 4765

Information Model for Intrusion Response - Overview



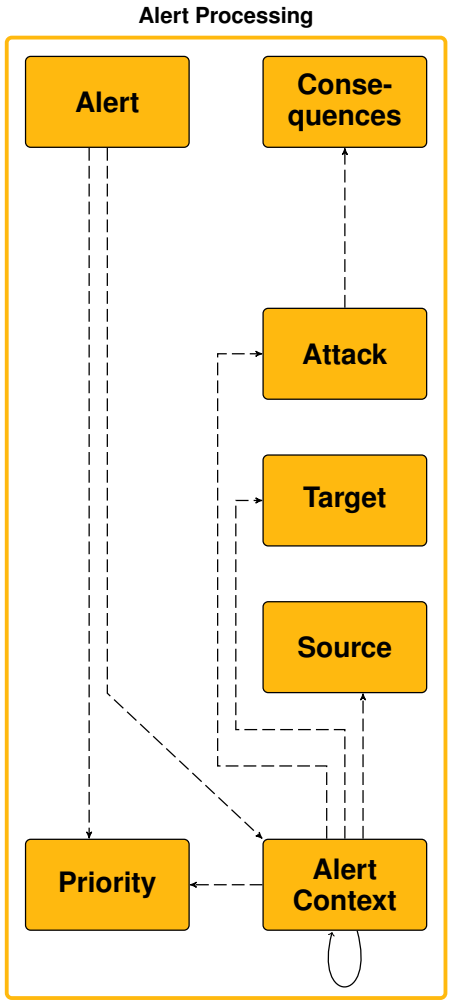
Infrastructure Information Model – Examples

- NMSes send their scanning results to specific interfaces which add the info to the Blackboard
- A `Service` runs at a `Port` opened on a NIC with an `IP-Address` belonging to a `L3-Network`
- A `Device` has a `NIC` with `MAC-Address` and assigned `IP-Address`
- A `User` is logged into `Device`
- A `User` uses `Service`



Alert Information Model – Examples

- IDSes send IDMEF messages containing alerts to specific Blackboard Interfaces
- IDMEF alerts are normalized and combined into an `Alert Context`
  - `Source` (of attack)
  - `Target` (of attack)
  - `Attack` (type)
- `Alert` and `Alert Context` nodes have a `Priority`



Implementation

- Python 3
- Object oriented implementation of Information Model
- Automatic translation of class structures to suitable database design
- Two different databases/database types used:
  - Relational: postgreSQL
  - Graph-based: OrientDB

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Evaluation – Test Data Sets and Test Cases

→ Measure the prototype's performance under varying conditions

- Test data sets simulate different attacks:

DDoS DDoS: many sources attack a small number of targets
AP Attack path: an attack spreads in the network
F Flooding: Mulitple IDSes raise the same alert

- Test data set size: from 1000 to 5000 alerts

- Test cases simulate typical tasks of the intrusion handling system

ins Node Insertion – Adding of `Alert` and `Alert Context` nodes
prio Node Prioritization – Updates `Priority` attribute of `Alert` and `Alert Context` nodes with random number
comb Node Combination – Combining related `Alerts Context` nodes

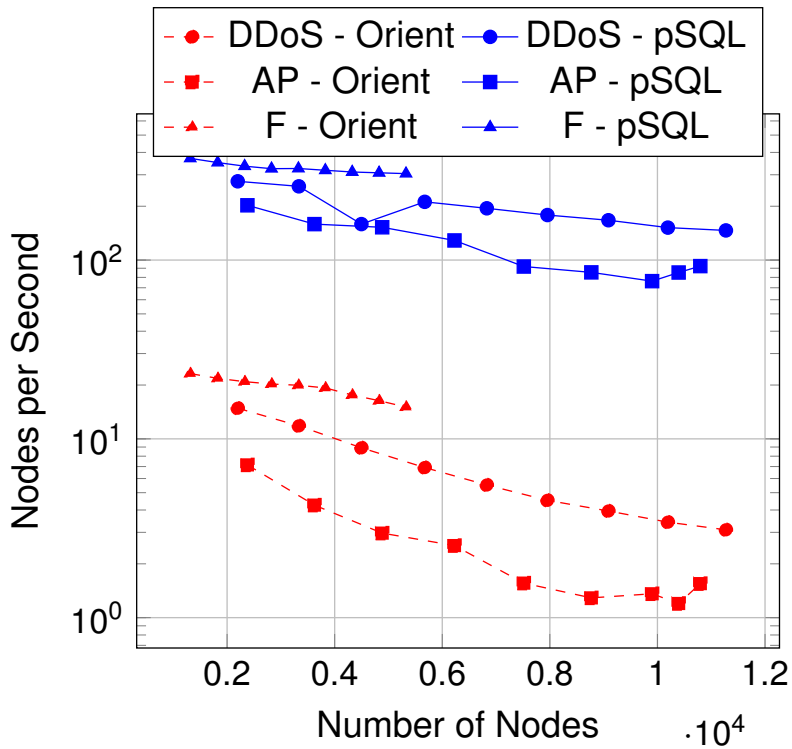
- Test cases are cumulative, e.g., t3 contains t1 and t2

Measurement Results: Alerts per Second

Exp.	$pSQL_{min}$	$pSQL_{max}$	$pSQL_{avg}$	$Orient_{min}$	$Orient_{max}$	$Orient_{avg}$
$DDoS_{ins}$	287.09	354.72	320.75	11.4	19.72	14.73
$DDoS_{prio}$	228.61	307.27	257.8	8.4	16.24	11.55
$DDoS_{comb}$	64.97	125.44	86.15	1.37	6.75	3.12
AP_{ins}	299.4	355.76	324.76	12.5	19.35	15.13
AP_{prio}	230.36	287.86	250.71	8.91	16.23	11.62
AP_{comb}	30.80	85.12	49.59	0.51	3.01	1.1
F_{ins}	370.32	396.63	384.58	37.88	50.87	44.77
F_{prio}	318.1	330.31	325.04	15.4	35.29	23.38
F_{comb}	281.78	293.31	287.73	14.13	18.00	16.97

Table contains min, max and average rates of all test data set sizes

Measurement Results: Nodes per Second



Graph shows results of node combination test case

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- Related work has drawbacks: information sharing is difficult between intrusion handling steps, information loss, ...
- **Our contributions:**
  - Blackboard-pattern for intrusion handling
  - Suitable information model
  - $\rightarrow$ Enables Information sharing between intrusion handling steps
  - Proof-of-concept implementation using two different DBs
- Future Work:
  - Information security of the data on the Blackboard
  - Improving performance

Contact

Thank you for the audience!

Nadine Herold, Holger Kinkelin and Georg Carle

Technische Universität München
Department of Informatics
Chair of Network Architectures and Services
Boltzmann Straße 3
85748 Garching bei München
Germany

{lastname}@net.in.tum.de
https://github.com/Egomania/BlackboardIDRS