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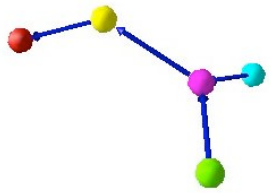

SANA - Network Protection through artificial Immunity

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Protection System

- Protects a network against intrusions
- Intrusions are e.g. viruses, worms, trojans, and hackers
- Intrusions are defined as all attacks towards a network, i.e. also intrusive behaviour from users
- Facilitates, organizes, and connects different protection components

Protection Components

Host-based:

- Antivirus Software
- Firewall
- Intrusion Prevention System (IPS)
- Spam Filter

Network-based:

- Packet Filter
- Intrusion Detection System (IDS)
- Spam Filter

Current Situation

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- A static collection of unconnected protection components is used:
  - Host-based: antivirus software and firewall
  - Network-based: packet filter and IDS
- Protection Components work supervised
  - lots of warnings and alerts
  - time-intensive maintenance workflows
- No collaborative work in order to find mutated or even novel intrusions

SANA approach

- Distributed approach with redundant installed infrastructure
- Elimination of single points of failures
- Easy and fast maintenance workflows, i.e. administration, update, extension
- Use a better organization with cooperation in order to cope with upcoming intrusions

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Protects all nodes

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Easy Updateable
and Expandable

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Adaptive
Self-Learning

Self-Repairing
Self-Healing

Self-Checking

SANA approach

Migration task:

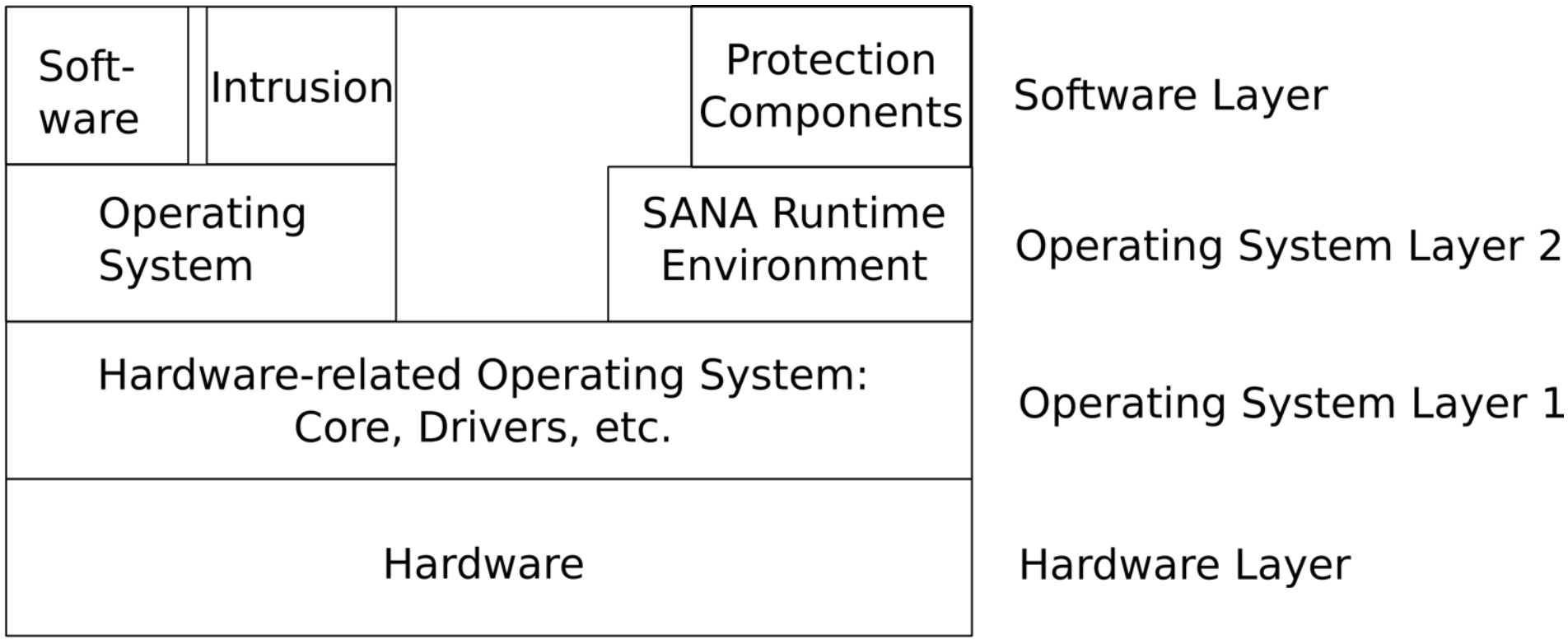
- Currently:
  client-server architecture; server manages the client software performing the required tasks

- Goal:
  - distributed architecture with autonomous artificial cells performing the required tasks and enable additional features

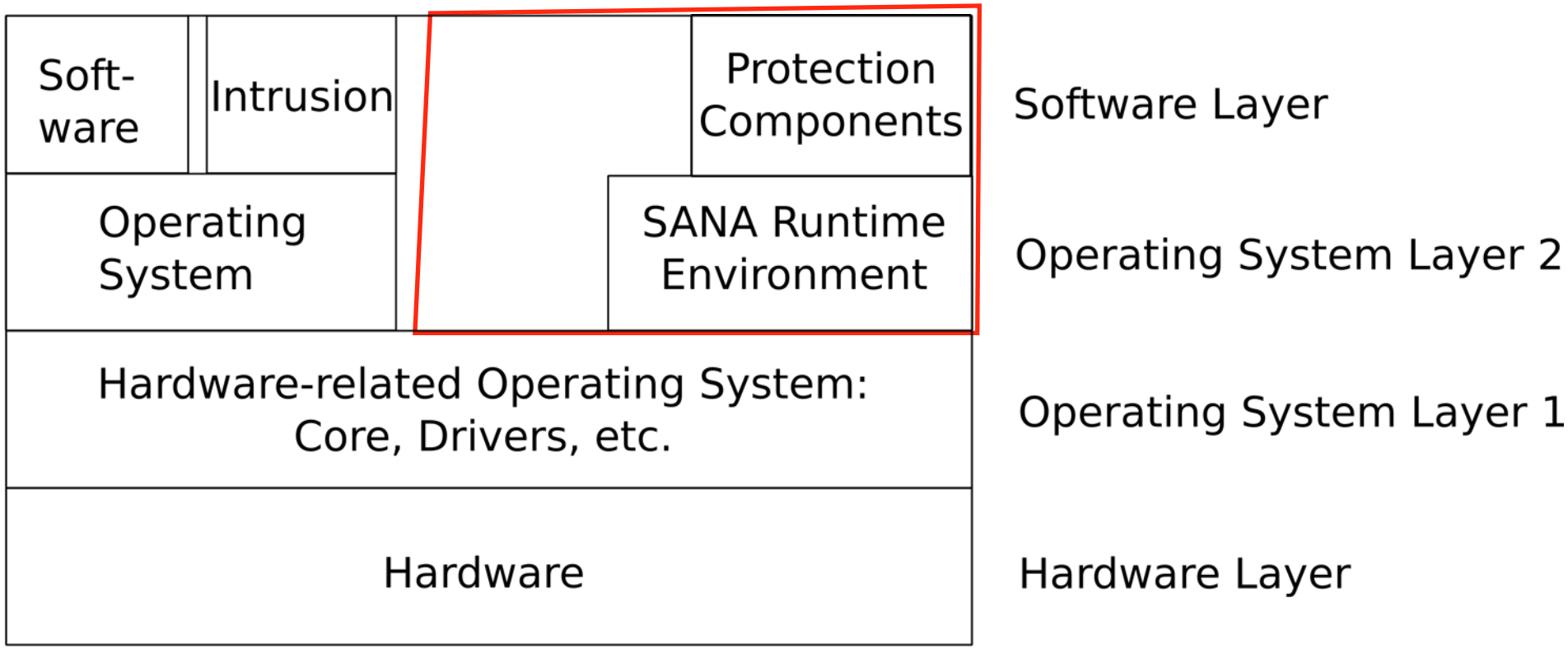
Security Environment

- Installed in each node as a middleware between protection components and resources
- All protection components run in this environment
  - Protection components are platform independent, which leads to a faster implementation

Implementation Security Environment



Implementation Security Environment



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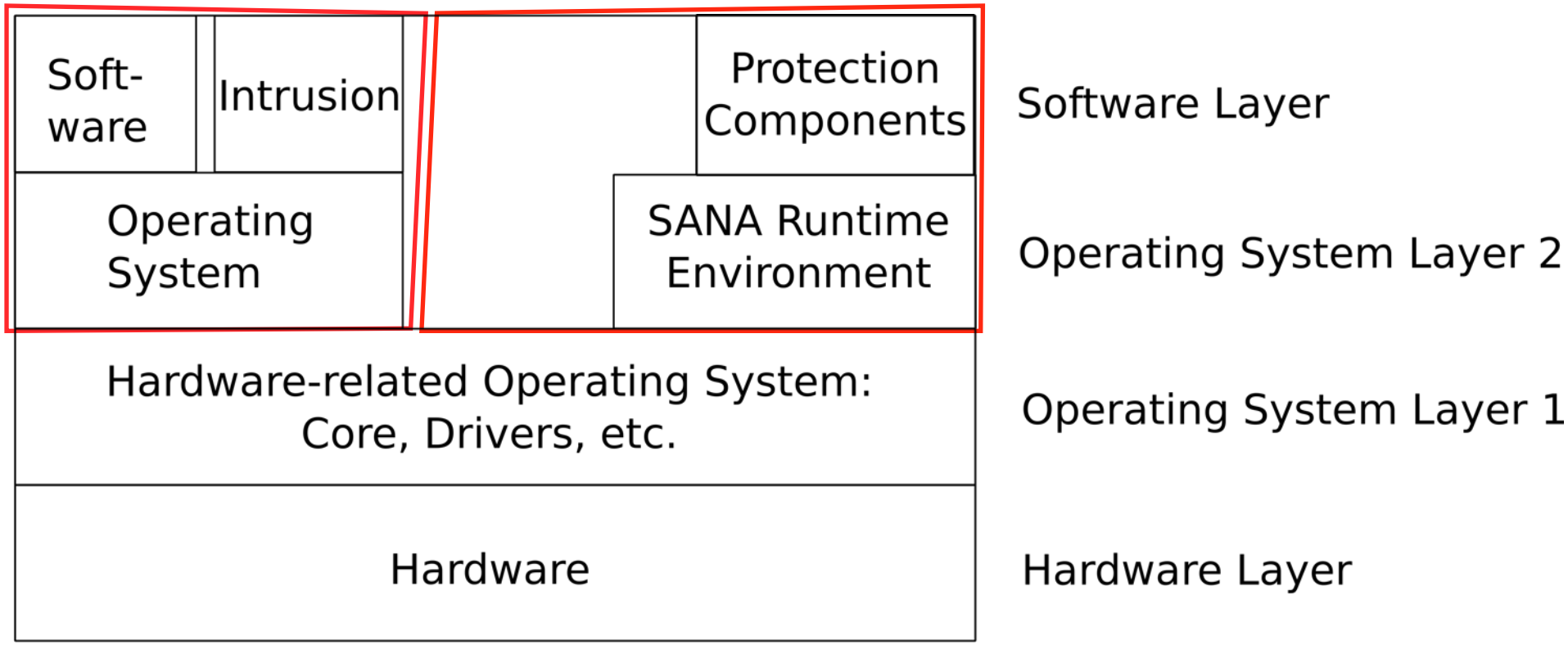

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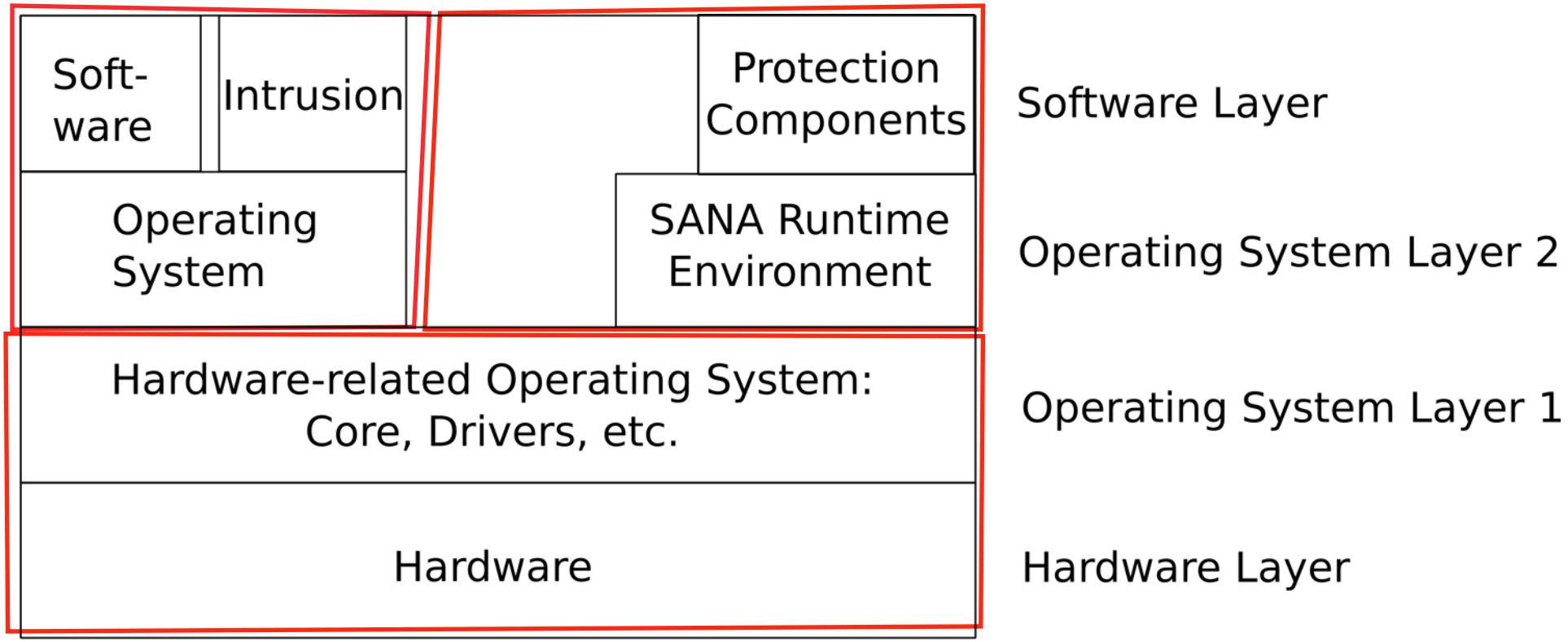

Artificial Cells

- Novel type of protection components performing certain tasks for network security
- Tasks are e.g.
  - packet/file/process checking
  - identification of infected nodes or not proper working components
  - performing regular checks
  - information as well as data collecting
- Artificial cells (Agents) move through the network in order to provide a highly dynamic protection system

Examples of artificial Cells

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  Uses a network-like structure in order to store signatures of intrusions. Analyses and evaluates network packets.

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  Reuses the information gathered through distributed network traffic analysis for the identification of infected nodes, which is motivated by artificial ant colonies.

Examples of artificial Cells

- ANIMA for Intrusion Detection
  Uses a network-like structure in order to store signatures of intrusions. Analyses and evaluates network packets.
- AGNOSCO
  Reuses the information gathered through distributed network traffic analysis for the identification of infected nodes, which is motivated by artificial ant colonies.
- Checking Cells
  Perform regular checks in order to identify infected nodes, not proper working and outdated components, and even abnormal behavior - implementation of self-checking.

Examples
Checking Cell

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Checking Cell

```
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/bin/sh
bin:x:2:2:bin:/bin:/bin/sh
sys:x:3:3:sys:/dev:/bin/sh
sync:x:4:65534:sync:/bin:/bin/sync
toor:x:0:0:root:/root:/bin/bash
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Characteristics of known intrusions:

- Existing files
- Running processes
- Registry entries

E.g. Bagle:

- File bbeagle.exe in system-dir
- Process bbeagle.exe running
- Registry:
  - [HKCU\SOFTWARE\Microsoft\Windows\CurrentVersion\Run\d3dupdate.exe]
  - [HKCU\Software\Windows98\frun]
- Email propagation

Artificial Lymph Nodes

- Supply on demand the artificial cells with additional information and resources
- Response to messages sent by the artificial cells
- Manage the communication between the different cells
- Redundant installed so that a breakdown is compensated by other artificial lymph nodes and that the distance from cell to lymph node is short
- Collect status information about the supplied network part

Central Nativity and Training Stations

- Motivated by the bone marrow and thymus
- Generate and release continuously novel artificial cells containing the newest information and approaches of network security where existing artificial cells shutdown over time
- Supply the artificial lymph nodes with additional information and resources
- Collect status information, which are on demand sent to the administrators

Artificial Cell Communication

- Robust and efficient communication protocol for exchanging messages between a sender a set of receivers - point to multi-point communication
- Uses no communication server
- Efficient when a message is sent in a small area; e.g. notifying nearby artificial cells about a certain event
- Adapts so that a partly breakdown does not implicit a breakdown of the whole communication in the network
- Artificial receptors (public/private key pair) identify the receivers of a message

Self-Management

- Organizes the artificial cells so that each node has enough but not too much cells
- Manages the cells so that regular checks are done on all nodes but not too often on one node
- Adapts the system to the current situation and protects important nodes with a higher security

Collaborative Work

- Splitting of workflows in small tasks:
  - Information collection
  - Information evaluation
  - Response
- Second signal:
  two components have to evaluate a packet
  as malicious so that it is removed

Collaborative Work Danger Theory

- Information sharing between different security components, which are mostly nearby
- Each cell releases to the neighbors summary status information - the signals - about its current view of the situation
- Use the information in order to adapt the internal thresholds and the organization of the protection components
- Collect important information for reporting to the administrator

Adaptive System

- SANA identifies infected nodes:
  - Disinfection
  - Isolation
- SANA recognizes hotspots of attacks and adapts with a higher concentration of cells
- Self-checking and afterwards self-repairing/-healing
- Internal adaption on current situation - danger theory

Maintenance Workflow

- Administrators demand regularly information from the security system
- Administrators also configure the system
- Through a GUI-interface, the administrators can connect to the security environments of all nodes. In the environment, the administrators can access the protection components.
- Artificial lymph nodes and CNTS collect status information, which can be demanded by the administrators
- Important information (e.g. alerts) are immediately sent to the administrators

Maintenance Workflows Updates & Extensions

- Artificial cells are renewed over time including the newest information
- Other security components are updated using two workflows

    1. Updating artificial cells

    2. Direct installation into the security environment by the administrator

- Extensions are released through a new population of artificial cells or direct connection to the security environment

Simulations

- System is implemented on top of a network simulator implementing a packet-oriented network (TCP/IP)
- Different attack-scenarios are implemented, e.g. worm and virus attacks
- Various other attack-scenarios like hacker attacks are theoretically discussed

Results

- SANA's performance is more than acceptable
- SANA facilitates the same protection components as common used protection systems supplemented with the novel artificial cells

% of identified infected packets	Current Security System	SANA
Worm Attack	75% - 85%	95% - 99,9%
Virus Attack	60%	78%-85%

Results

- The behavior of SANA is dynamic and adaptive
- Hard-to-attack through the distributed architecture, reduced single points of failures, and autonomous workflows
- SANA provides a framework that can be quickly extended by novel approaches of network security

Results

- SANA identifies quickly infected nodes and not proper working/outdated components
- Infected nodes are either disinfected or quarantined and then disinfected by the administrator
- Abnormal behavior is identified through analyzing information from various nodes with different techniques
- Tasks are distributed so that a partly breakdown does not implicit a complete breakdown of the system

Attack Scenario
Worm Attack

- Uses the network for propagation
- Infects a node, influences the production, and sends infected packets in order to infect other nodes
- SANA identifies the infected packets and prevents the propagation
- SANA identifies the infected nodes and disinfects these
- Adapts the workflows to prevent attacks
- After some time, SANA disinfects and immunizes the network

Attack Scenario
Virus Attack

- Arrives at the node without usage of the network
- Infects the node and propagates to other nodes using data transmission
- SANA identifies the infection using regular checks and the detection of infected packets
- SANA isolates and disinfects the node
- Immunization through updating the security components

Attack Scenario Hacker Attack

- Attacks the node directly over the network, with physical access, etc.
- Installs mostly a backdoor (e.g. VPN-server with IPsec) for further attacks
- Uses the infected node to access resources all over the network
- SANA identifies the backdoor using regular checks and traffic analysis
- Observing of access to resources identifies not allowed access and inference to node and user
- Closing of backdoor and immunization

Resource Management

- Tasks are distributed over all nodes
  - Resource need on a single node is reduced
- Efficient implementation of the security environment reduces required resources
- Self-management reduces redundant tasks and thus also reduces the required resources

Conclusion

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Artificial Immune System

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Dynamic System

Adaptive System

Conclusion

- SANA is a framework to implement a distributed security system. It provides a library of non-standard approaches for protection components combined with common-used components. The organisation and the information management is more sophisticated for lots of collaboration between the components.
- Middleware for security components
- Artificial cells - small components - collaborating for the performance of the overall system

Next Steps

- Discussion how to implement the security environment so that adversaries cannot use the security system for attacks
- What are the challenges in bringing an artificial immune system for network security from an academic research to a productive status?
- Danger Model - continous exchange of status information in order to adapt the internal thresholds

Acknowledgments

- Organizers of TCV 2007, esp. Jean-Yves Marion, Eric Filiol, Guillaume Bonfante
- FSTC, ILIAS, and INTRA
- Fonds National de la Recherche
- Ministère de la Culture de l'Enseignement Supérieur et de la Recherché

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