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Cyber Defence
Universität der Bundeswehr München

Smart Attacks require Smart Defence

Moving Target Defence

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Virtual, Connected, Smart World

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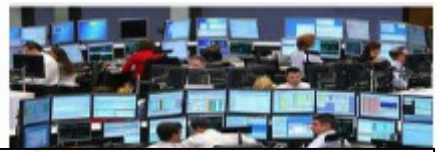
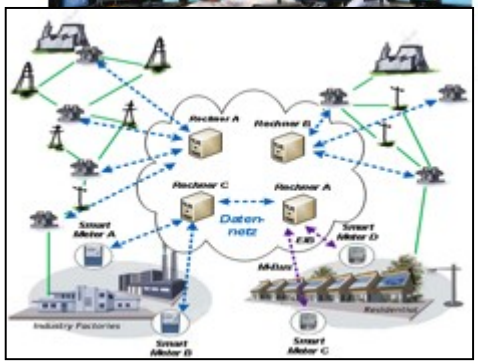
- **Real World**
  - Billions of connected devices
  - 163 Zettabyte of data until 2025
  - Systems are getting “smarter” (with AI) and autonomous

Paradigm Shift

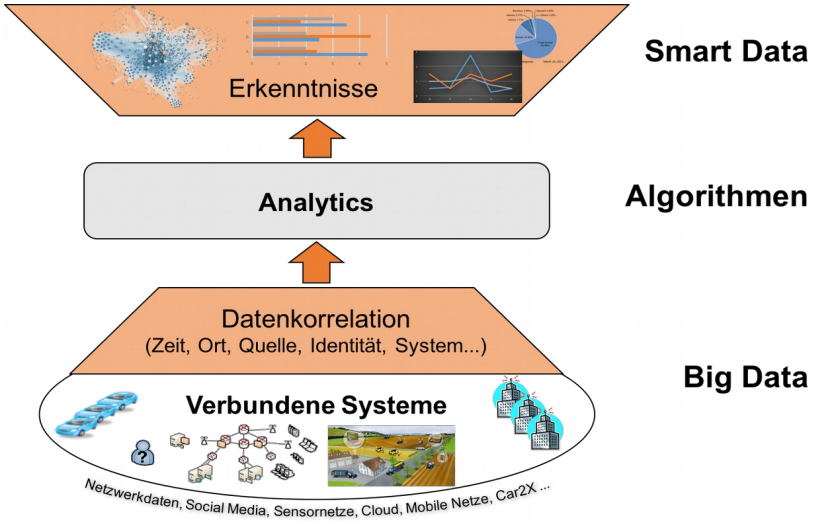
Smart Grid, Connected Car / Connected Plane, Financial Sector, e-Health, Industry 4.0, Military (connected) operations, ...

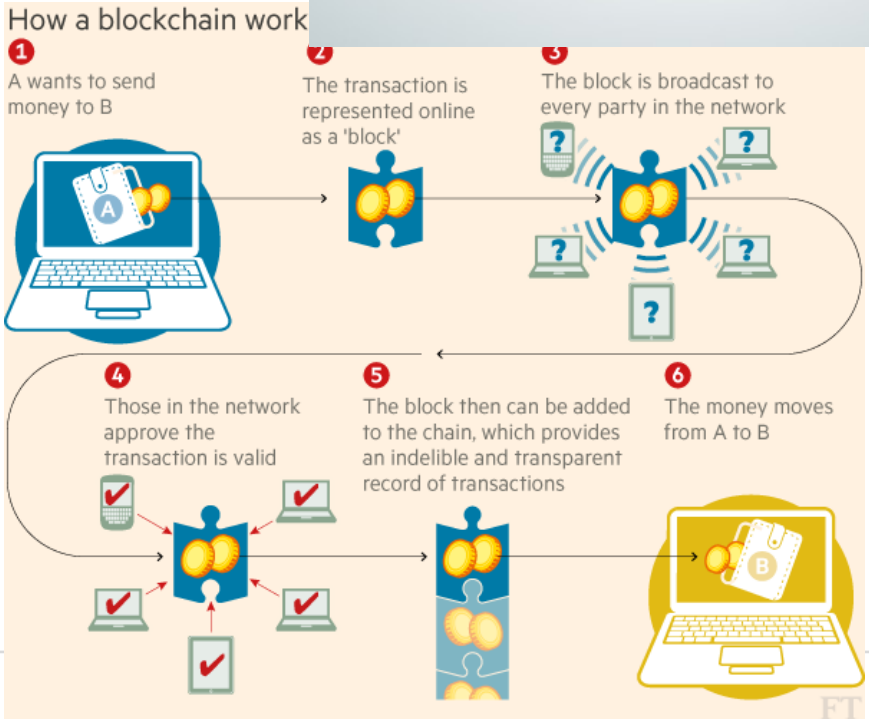




ICT is the key technology of the digital society!
Cyber security is fundamental for digital society!

ICT is developing with tremendeous speed





Smart Attacks:
Advanced Persistent Threats (APT)

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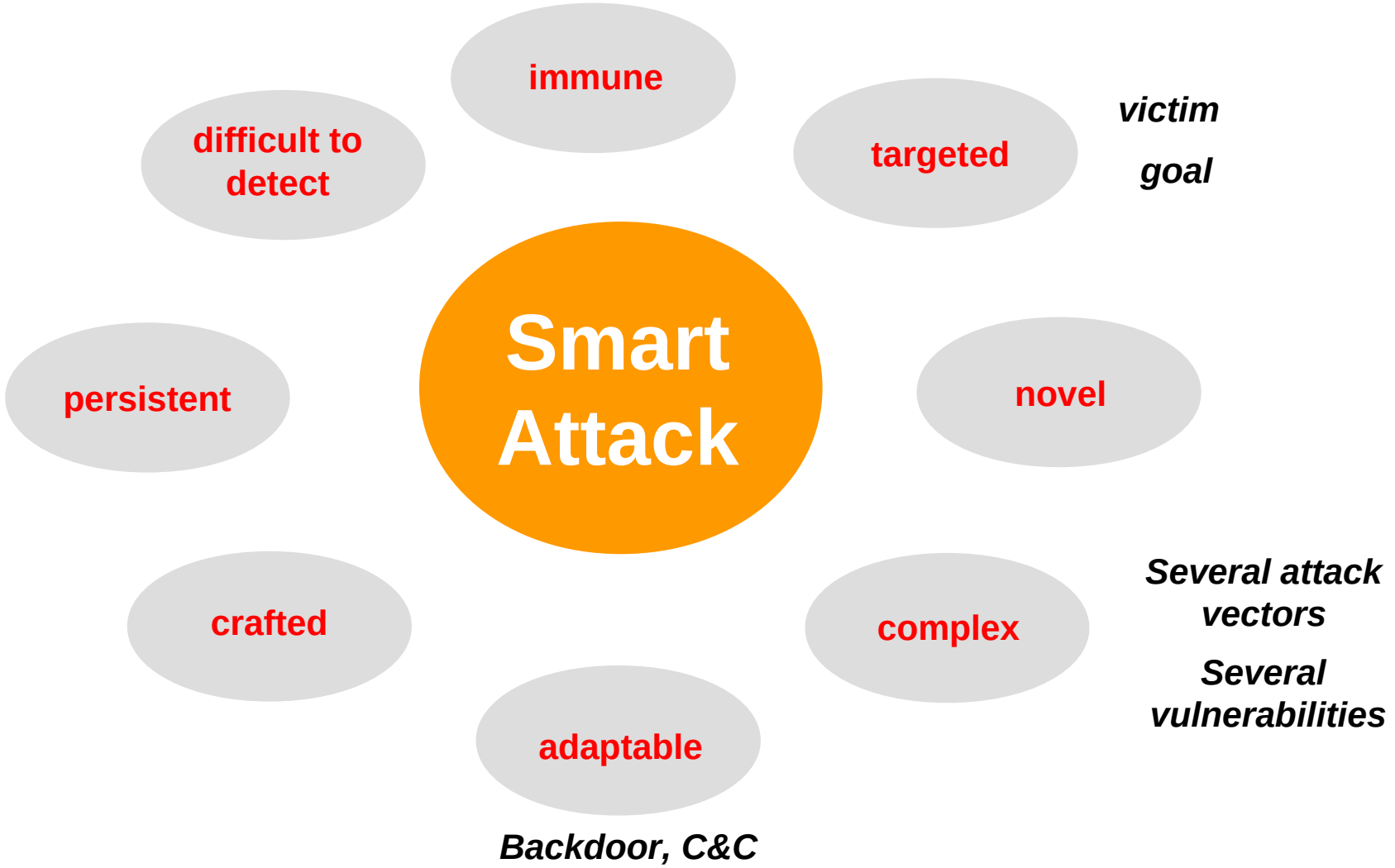
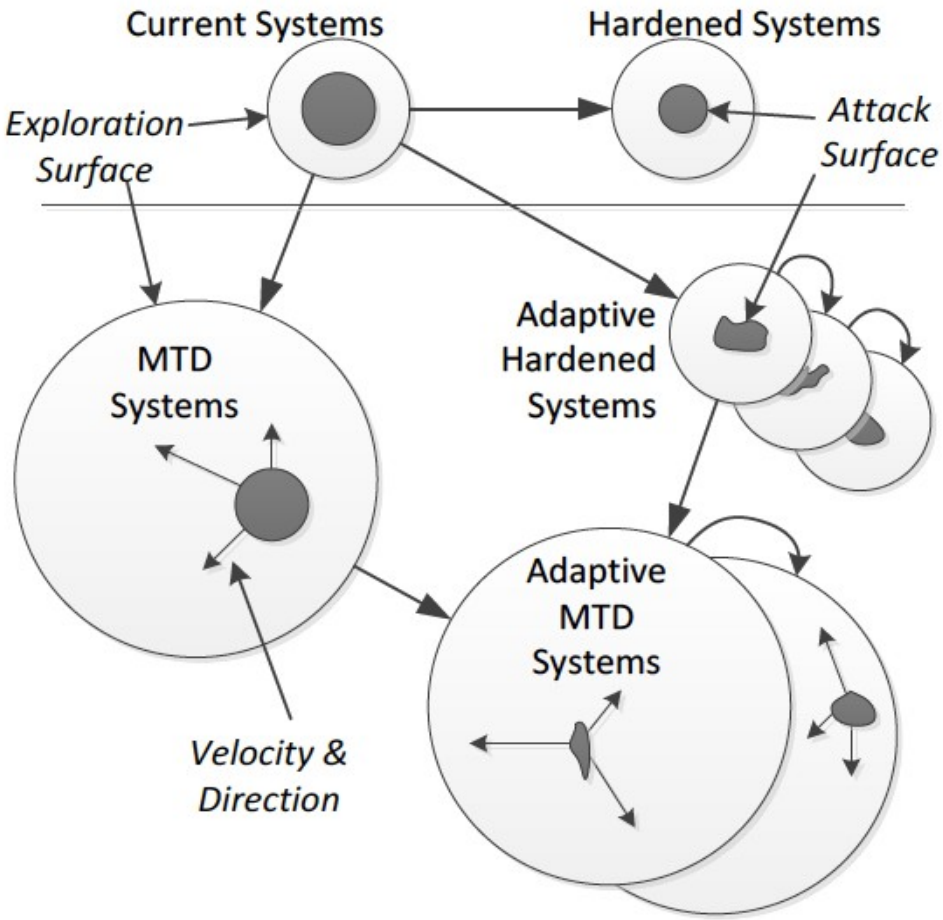


Current State of Cyber Defence

- **Attackers have natural advantage**
  - "Static" attack surface
  - Near-unlimited time for reconnaissance / preparation
  - Access to 0-day vulnerabilities
  - Attacker only needs to find a single vulnerable entry point
  - Adversaries have an **asymmetric advantage** in that they have the time to study a system, identify its vulnerabilities, and choose the time and place of attack to gain the maximum benefit

Attack Surface



Cyber Kill Chain

1. Reconnaissance: The attacker collects useful information about the target

2. Access: The attacker tries to connect or communicate with the target to identify its properties (versions, vulnerabilities, configurations, etc.)

3. Exploit Development: The attacker develops an exploit for a vulnerability in the system in order to gain a foothold or escalate his privilege

4. Attack Launch: The attacker delivers the exploit to the target. This can be through a network connection, using phishing-like attacks, or using a more sophisticated supply chain or gap jumping attack (e.g., infected USB drive)

5. Persistence: The attacker installs additional backdoors or access channels to keep his persistence access to the system

Towards Moving Target Defence

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Changing the Paradigm:

- Aim to substantially increase the cost of attacks by deploying and operating networks/systems to makes them less deterministic, less homogeneous, and less static
- Continually shift and change over time to increase complexity and cost for attackers, limit the exposure of vulnerabilities and opportunities for attack, and increase system resiliency
- Dynamically altered in ways that are manageable by the defender yet make the attack space appear unpredictable to the attacker
- Introduce asymmetric uncertainty that favors defender over attacker
- Attackers do not have adequate time to find vulnerabilities / create exploits

MTD Categories

- **Very diverse, specialized against specific attack vectors, yet mostly isolated**

- **System-based MTD**
  - Software-based
    - Application, OS, Data
  - Hardware-based: processor, FPGA
- **Network-based MTD**
  - MAC layer: changing MAC address
  - IP layer: IP randomization
  - TCP (Traffic) layer: changing network protocol
  - Session layer

Software-based MTD

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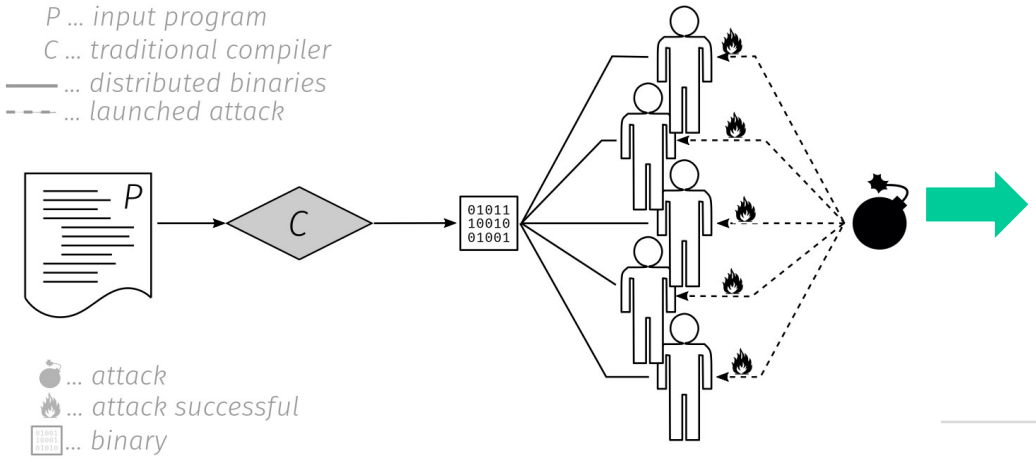
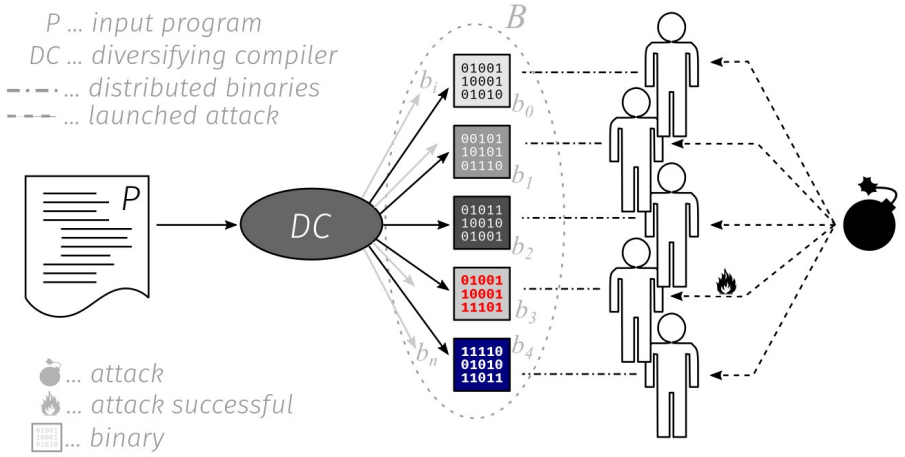
- **Goals**
  - Prevent unwanted modification, protect software against analysis
- **Types**
  - Dynamic Runtime Environment: Address Space Layout Randomization (ASLR), Instruction Set Randomization
  - Dynamic software: In-place code randomization, Compiler-based Software Diversity

Software Monoculture



Software Diversity



Network-based MTD

- **Network reconnaissance is the first step for attackers to collect network and host information and prepare for future targeted attacks**

- **Goal: make the scanning results expire soon or give the attacker a different view of the target system**
  - IP address randomization, Port randomization

Threat Model

- **Data leakage attacks**, **e.g., steal crypto keys from memory**
- **Denial of Service attacks**, **i.e., exhaust or manipulate resources in the systems**
- **Injection attacks**
  - Code injection: buffer overflow, ROP, SQL injection
  - Control injection: return-oriented programming (ROP)
- **Spoofing attack**, **e.g., man-in-the-middle**
- **Authentication exploitation**: **cross-cite scripting (XSS)**
- **Scanning**, **e.g., port scanning, IP scanning for targeted attack**
- **Physical attack**: **malicious processor**

Dynamic Virtualized Network Topology

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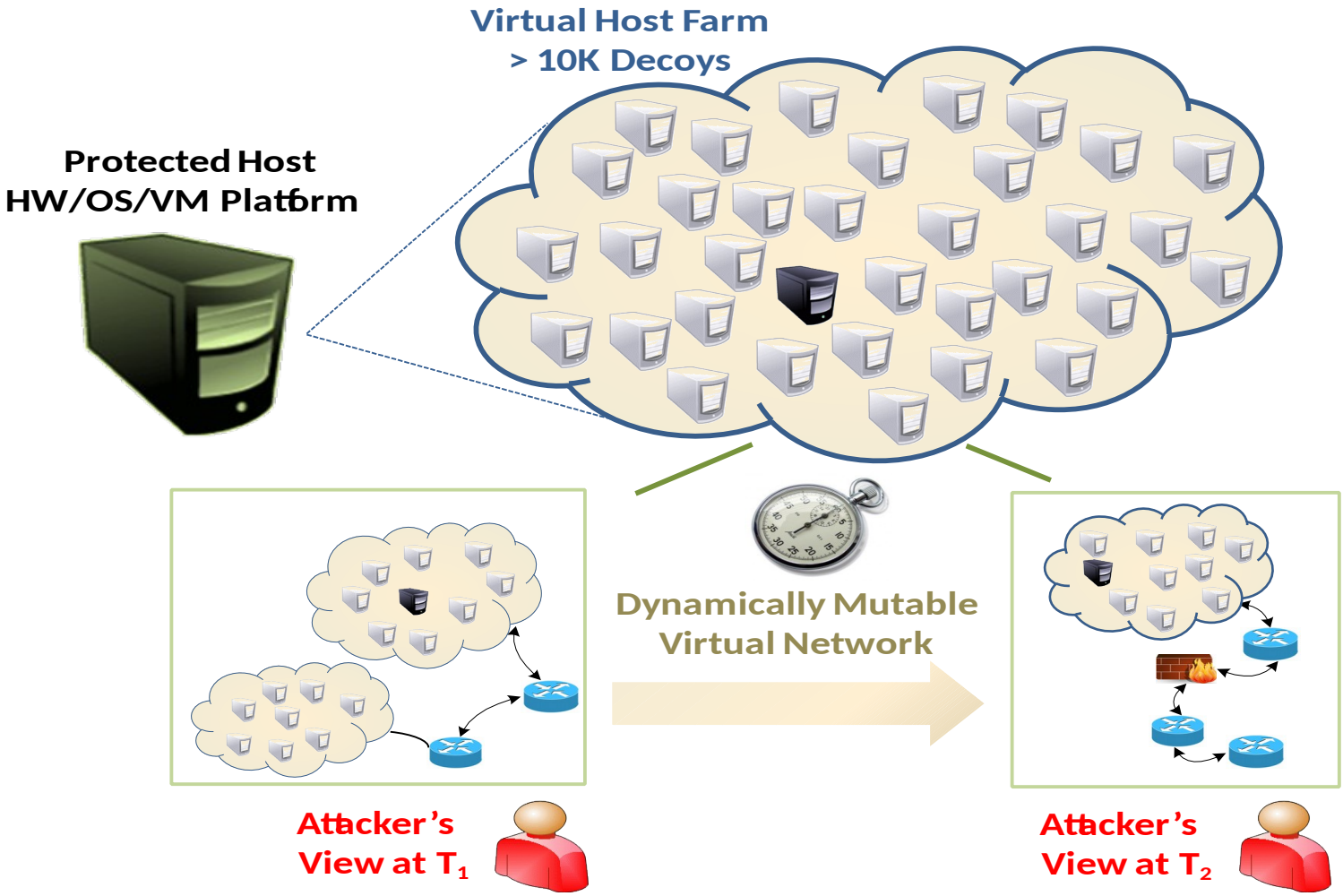
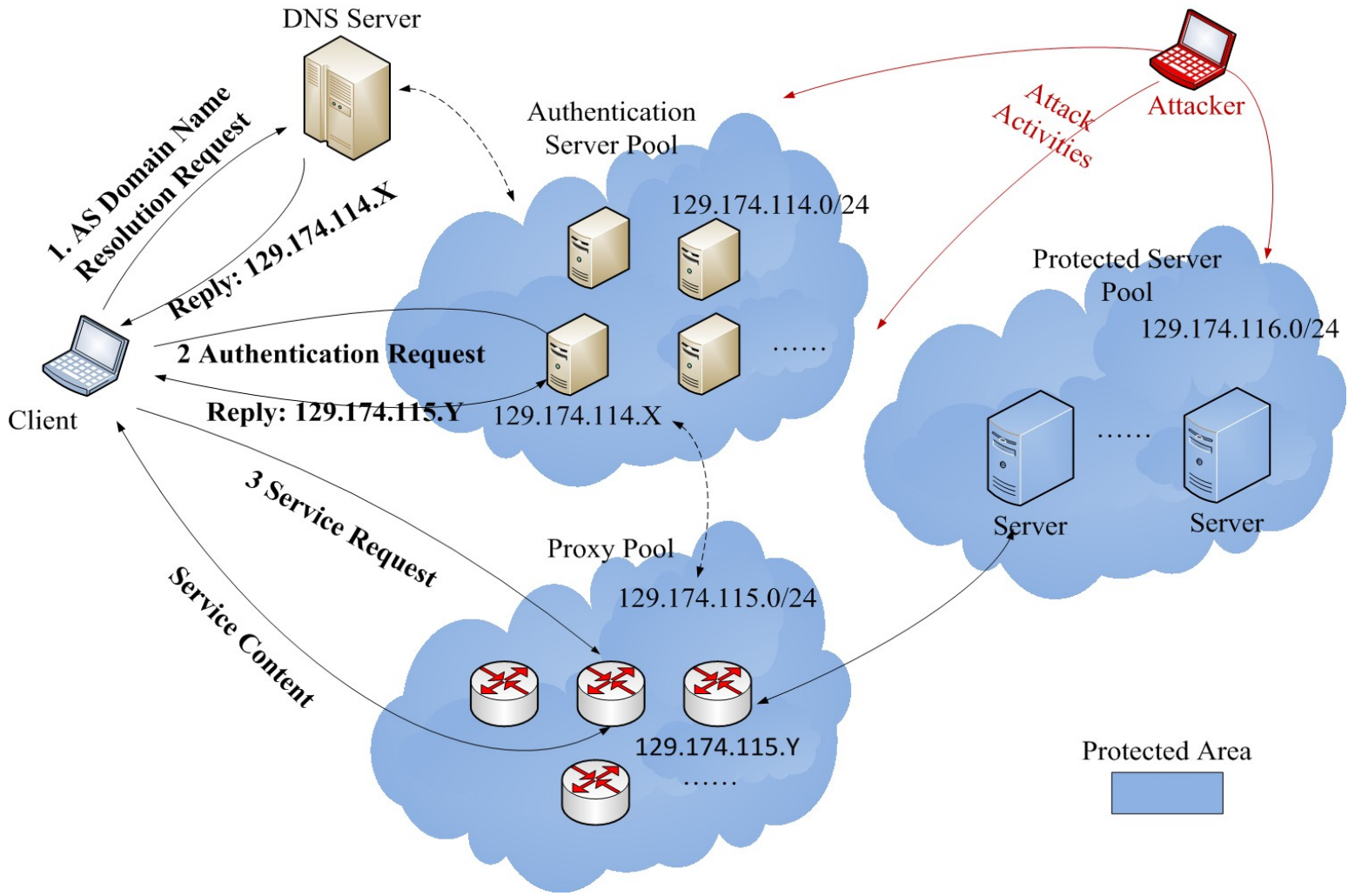


Two Challenges in Network-based MTD

1. **Service availability**
   - Authenticated clients should always know the new IP address/port number
   - When the IP and port changes, the connection still maintained, minimizing service downtime
2. **Service security**
   - Only the authenticated users can access the service
   - How to mitigate insider attacks?
3. **Service Quality**
   1. Meeting Service Level Agreements

Three layer protection: Decoys in each layer



Seamless TCP Connection Migration

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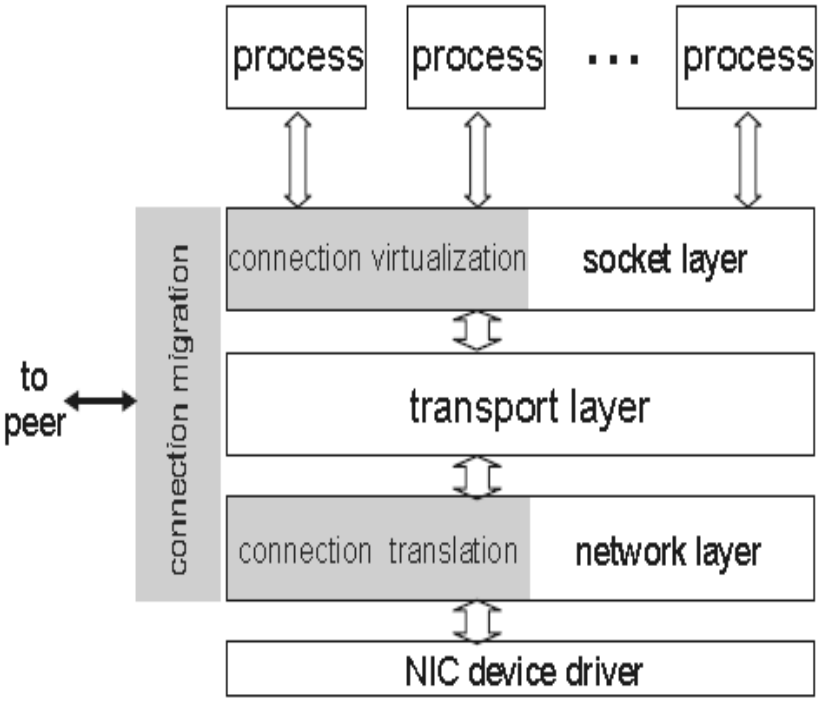
- **Keep end-to-end transport connection alive through separating transport endpoint identification from network endpoint identification.**

- **Three components**
  - Connection virtualization
  - Connection translation
  - Connection migration



Connection Virtualization

- **Internal address for applications**
  - IP address and Ports
  - never changes for one connection
- **External address for communications**
  - IP addresses and Ports
  - may change according to MTD requirements
- **A map to translate between Internal address and External address**

Connection Translation

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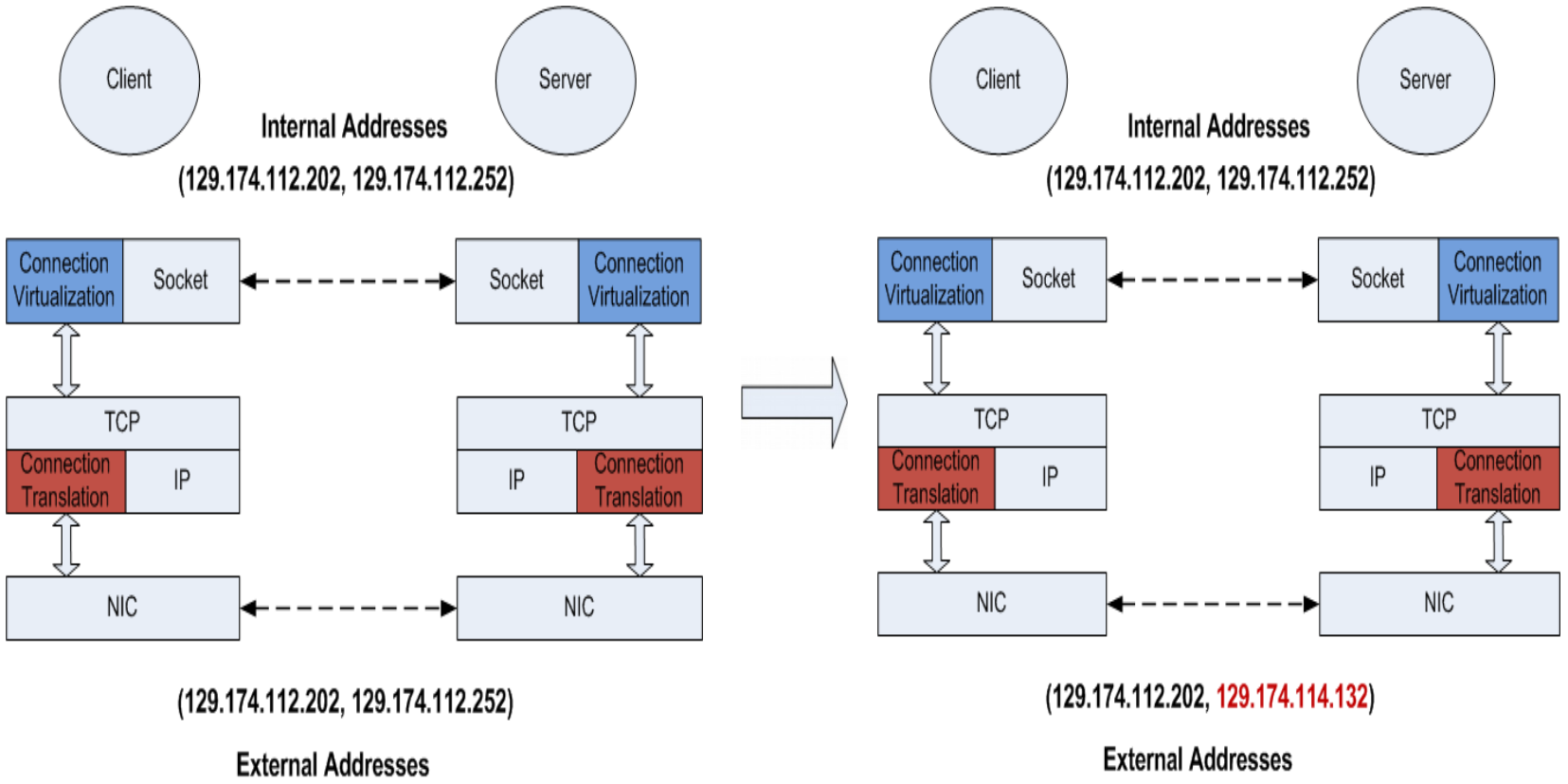
At beginning,
internal address = external addresses

Server changes its IP address



Network Migration

- **After the server changes its IP address and port, it will inform the client to update the internal-external address mapping**
- **Migration Steps: protected by a shared secret key**
  - Suspend a connection
    - Keep connection alive
  - Resume a connection
    - Update internal-external endpoints mappings
    - Server sends UPDATE packet
    - Client sends UPDATE_ACK packet
- **Both endpoints need to know the same internal address pair**

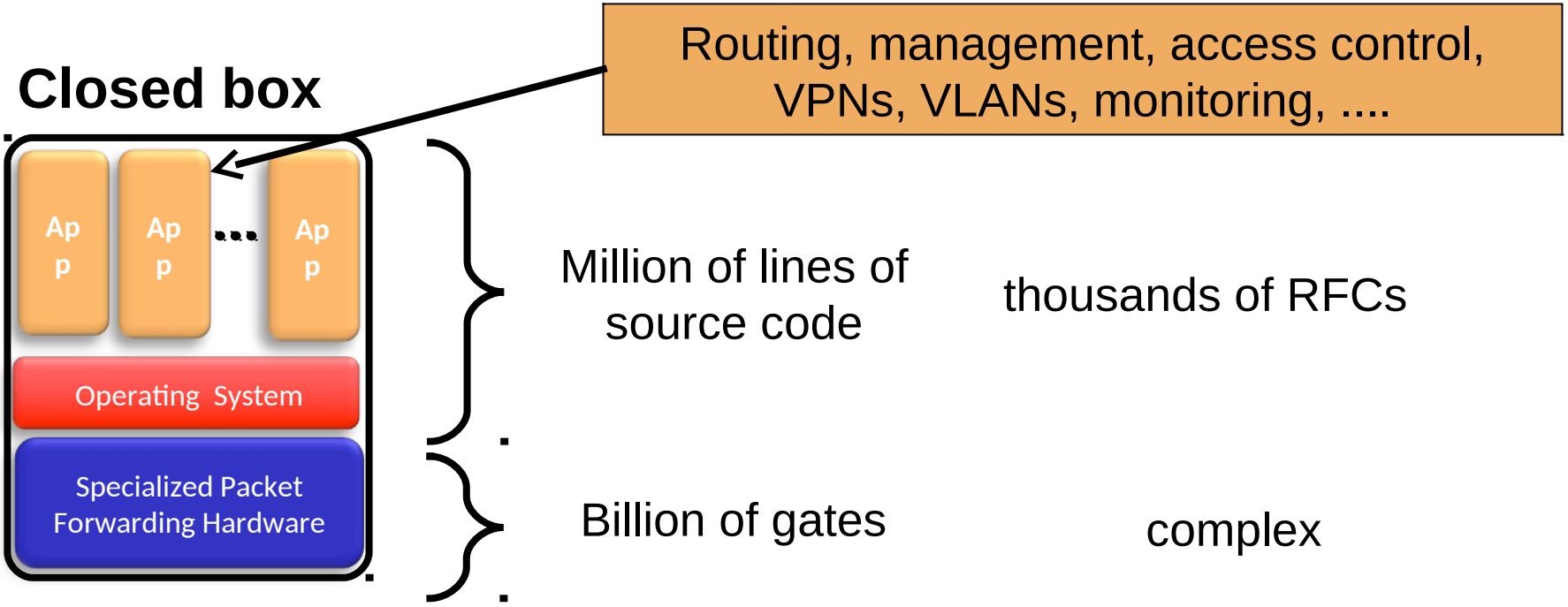
We need more flexibility on the network layer

HOW?

Software-Defined Networking (SDN)

Software Defined Networking

Situation today: closed „boxes“



- Closed, vertically integrated
- Many complex functions baked into infrastructure (OSPF, firewalls, NAT, ...)

The idea: Separate “Control“ from „Switching“

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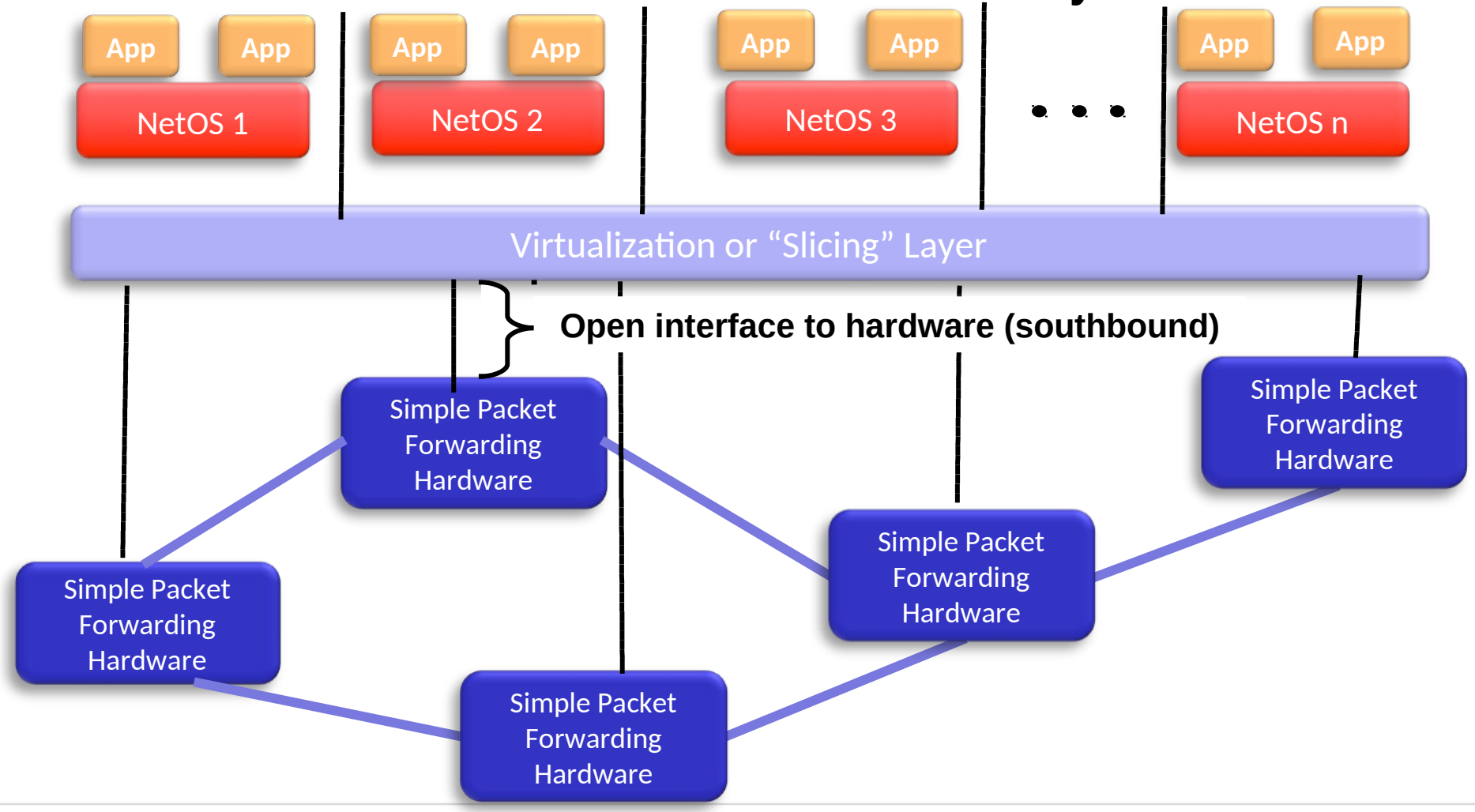
- Serveral NetOS → virtualized centralized Layer



SDN Controller vs SDN Switch

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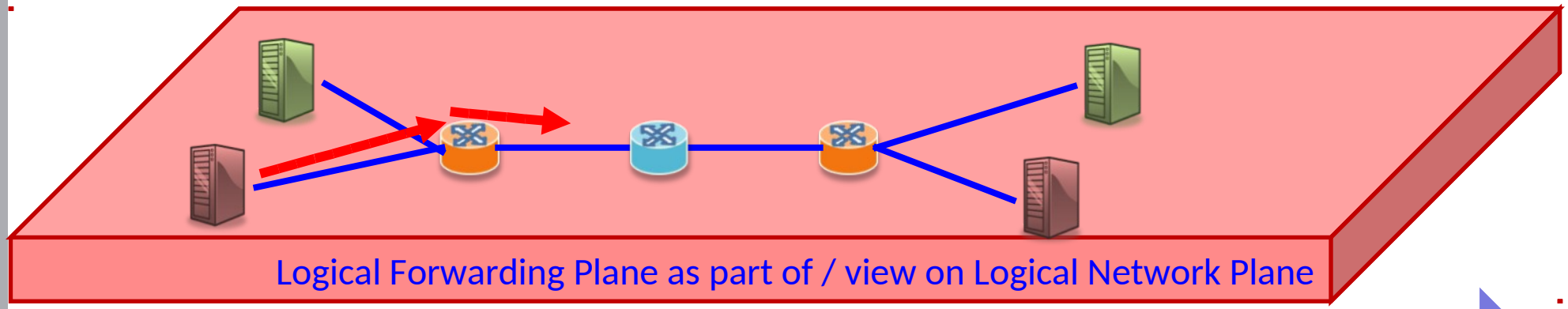
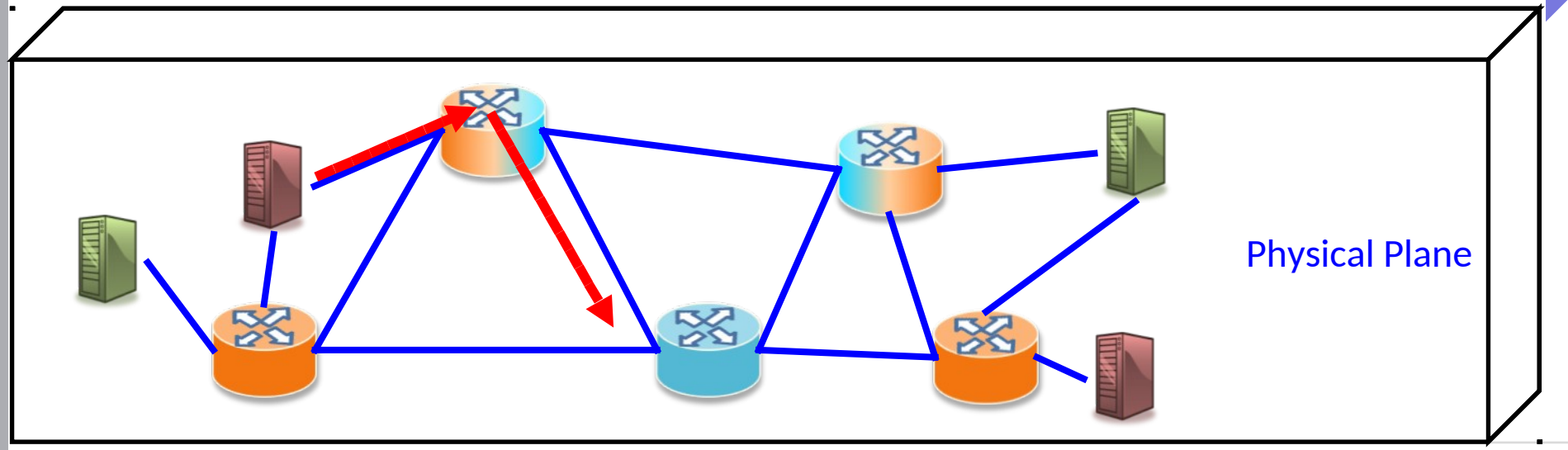


Packets traversing the network = Moving in logical + Physical Plane



Port Obfuscation (MTD) with SDN Controller

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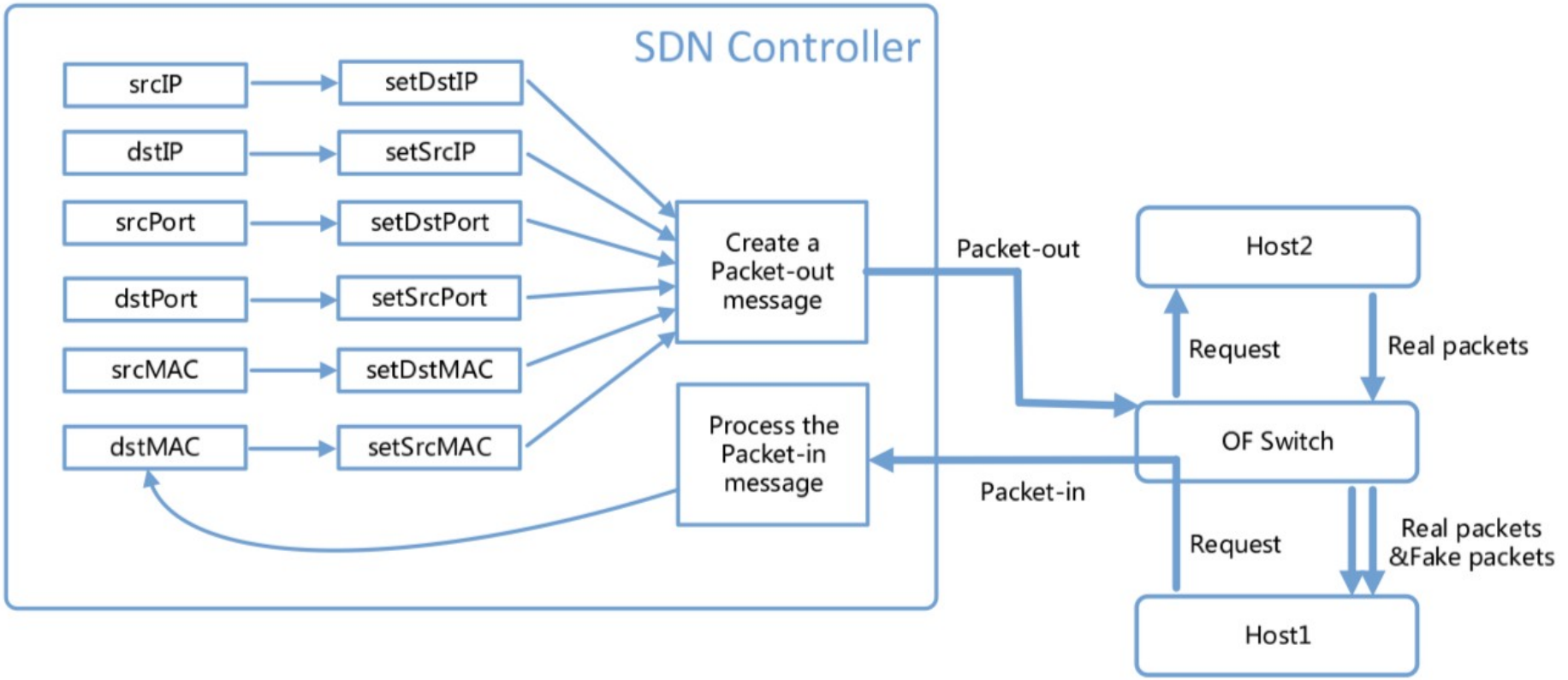

MTD: a Game Changer

- **A promising approach with several techniques and open questions**
  - **Definition of the attack surface and the possible transformations**
  - **Redundancy**
  - **Actuality**
    - What part (critical) should be changed at a specific time? What are the most important transformations at a time? What happend if a transformation is not successful?
  - **Functional equivalency**
  - **Cooperation between different MTD techniques**
  - **Integration with existing tools, like Intrusion Detection / Prevention Tools, Firewalls, ...)**
  - **...**