DI-FCT-UNL
Segurança de Redes e Sistemas de Computadores
Network and Computer Systems Security

Mestrado Integrado em Engenharia Informática
MSc Course: Informatics Engineering

1º Sem, 2019/2020

1. Introduction (Part II)

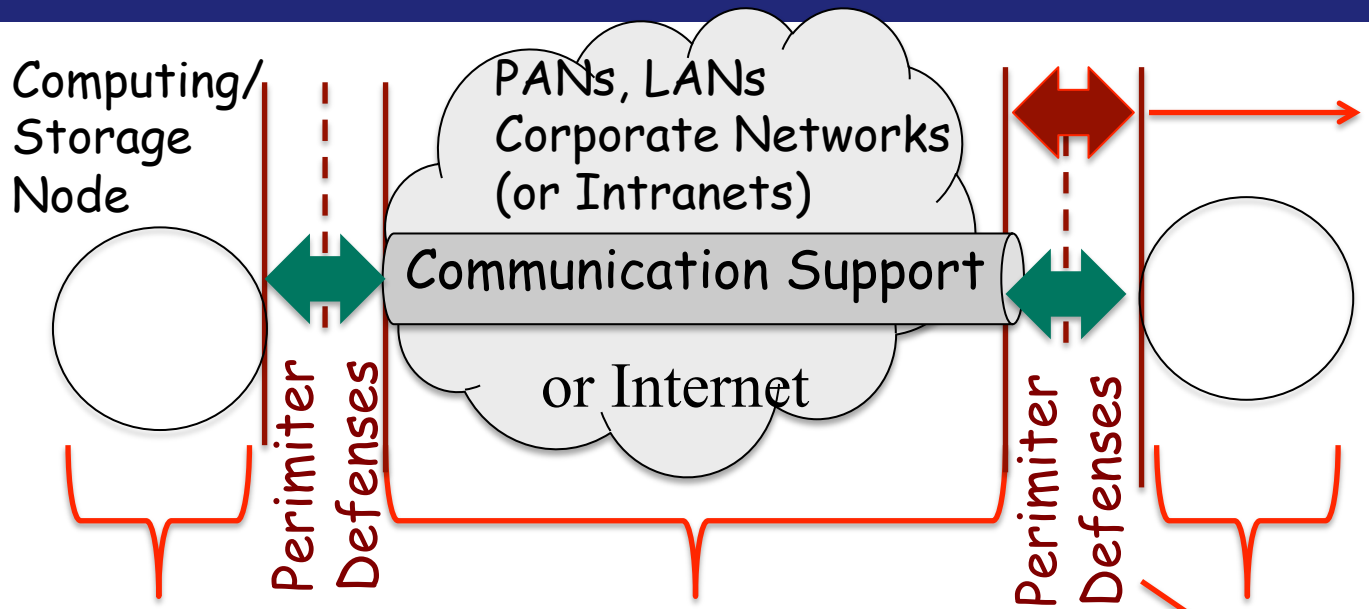
Concepts, Terminology
Frameworks

Introduction: complementary questions …

- How to address **Security in Distributed Systems**?
- **Typology of defenses** for distributed systems security ?
- What is the **OSI X.800 Framework** ? What are the main **features and orientations** in the OSI X800 framework ?
- What is a **secure communication channel** ? How to define a secure communication channel, how to address its security properties and threats, and what are the level of abstraction?
- What are the **security services and standards in the TCP/IP security Stack** ?
- What is a **layered secure channel** ? What is **tunneling security modes and security transport modes** established for **end-to-end communication security**

Computer Systems and Networks Security (A Distributed Systems Security Approach)

Distributed Systems Security Dimensions



Access Networks:
LAN, WLAN
PAN, WPAN
Net. Technology, and Network Gateways

Perimeter Defenses:
(Switches, Routers, Traffic Filters, FWs, IPSs and IDSs:
- NIDS
- HIDS

Scope of Communications Security (Traffic, Data Flows, Message-Exchanges Communication Endpoints)

Scope of Computer Systems Security (Applications and SW Processing/Execution, Data Management, MW Services. OS Resources and FW/HW Devices

Protection of involved dimensions

2 dimensions involved

(Distributed System Approach):

- **Computer Systems Security (Computing Nodes)**
  - Computer Security Services and Mechanisms
  - "In Deep Security Protection"
- **Network (Communication Security)**
  - Secure Communication Channels
  - Point-to-Point (Data-Link) vs. End-to-End (Internetworking/Internet) Security Arguments

In this dimension is particularly relevant the approach of **Internet Security and TCP/IP Security Services**

- Security Stack, with different layers of approach

Computer Systems and Network Security

Computer Systems Security Level

- **Computer Systems (Computing Nodes)**
  - Private/Dedicated/Shared/Public/Outsourced Computing
  - Stationary, Mobile, Supervised, Non-Supervised …

- Physical Level (Phys. Environment)
- HW Level (HW Devices, FW/HW)
- OS Level (SW Services)
- MW / Runtime Libraries' Level
- Application-Support Level

Secure Data Storage
Software and OS Security +
Software Attestation +
Isolation and Containment
Trusted Execution

Computer Systems and Network Security

Network (or Internetwork) Security Level

- **Communications' Protection**
  - Private/Dedicated/Shared/Public/Outsourced
  - Wired, Wireless, Supervised, Non-Supervised …
  - Internet Communication

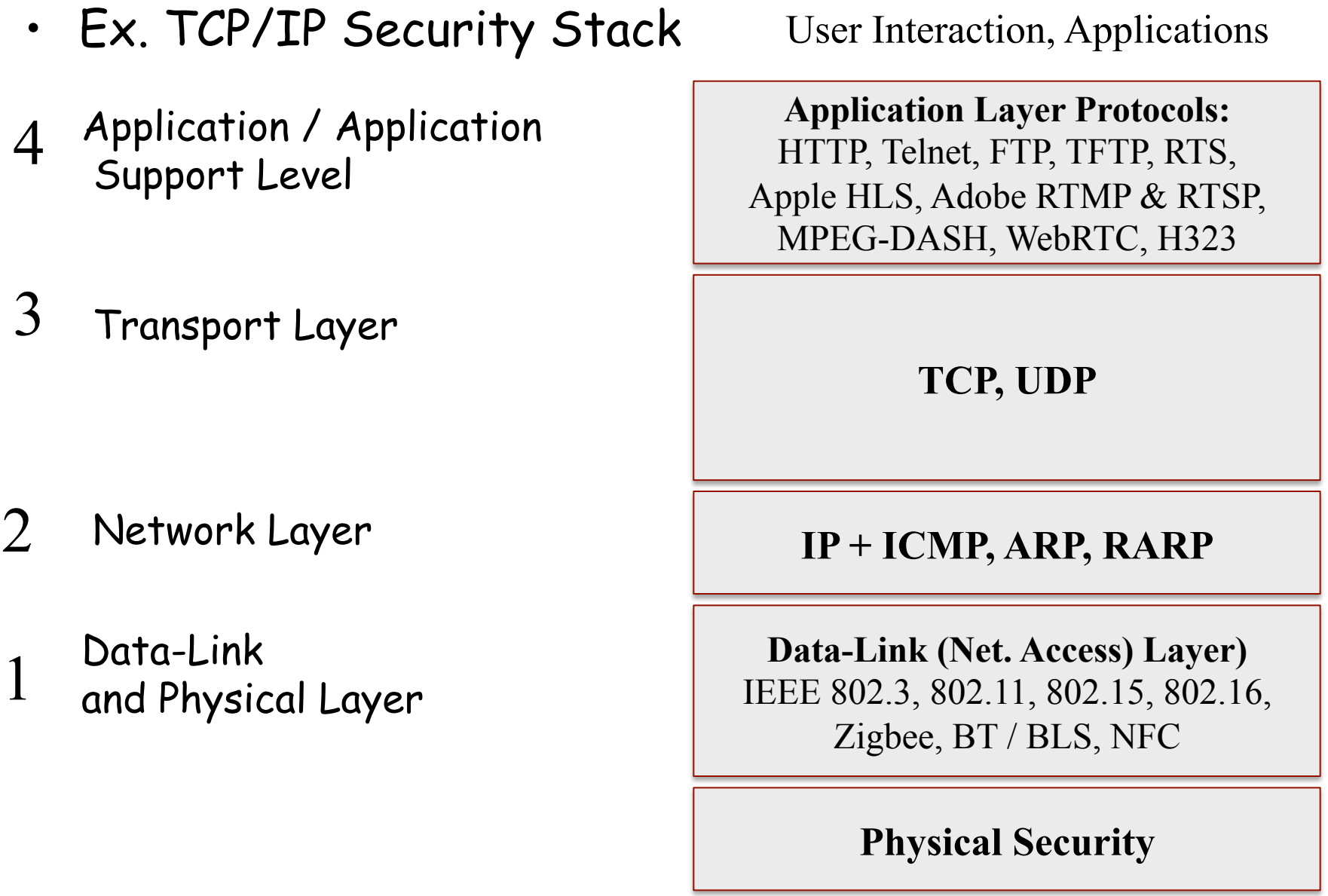
- Physical Level (Physical Resources)
- Access Level (Data Link)
- Traffic Flow Level (Net Level)
- Transport Level
- Session/Representation Level
- Application-Protocol Level

Secure Com. Channels
PtP vs. End-to-End
Secure Protocols
Secure Endpoints

TCP/IP Security Stack (and Related Standards)

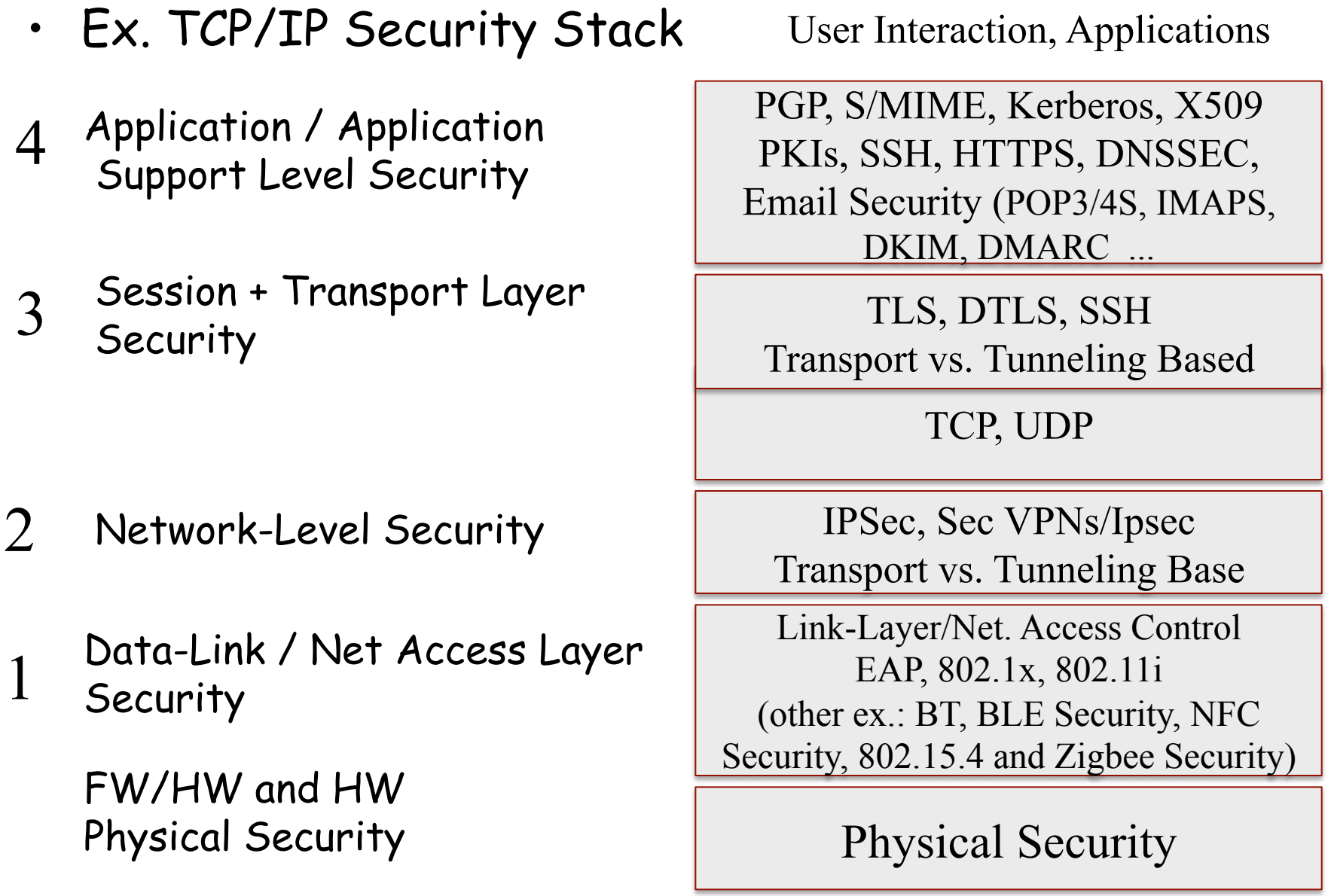
Communication Security Services and Protocols

- Ex. TCP/IP Security Stack



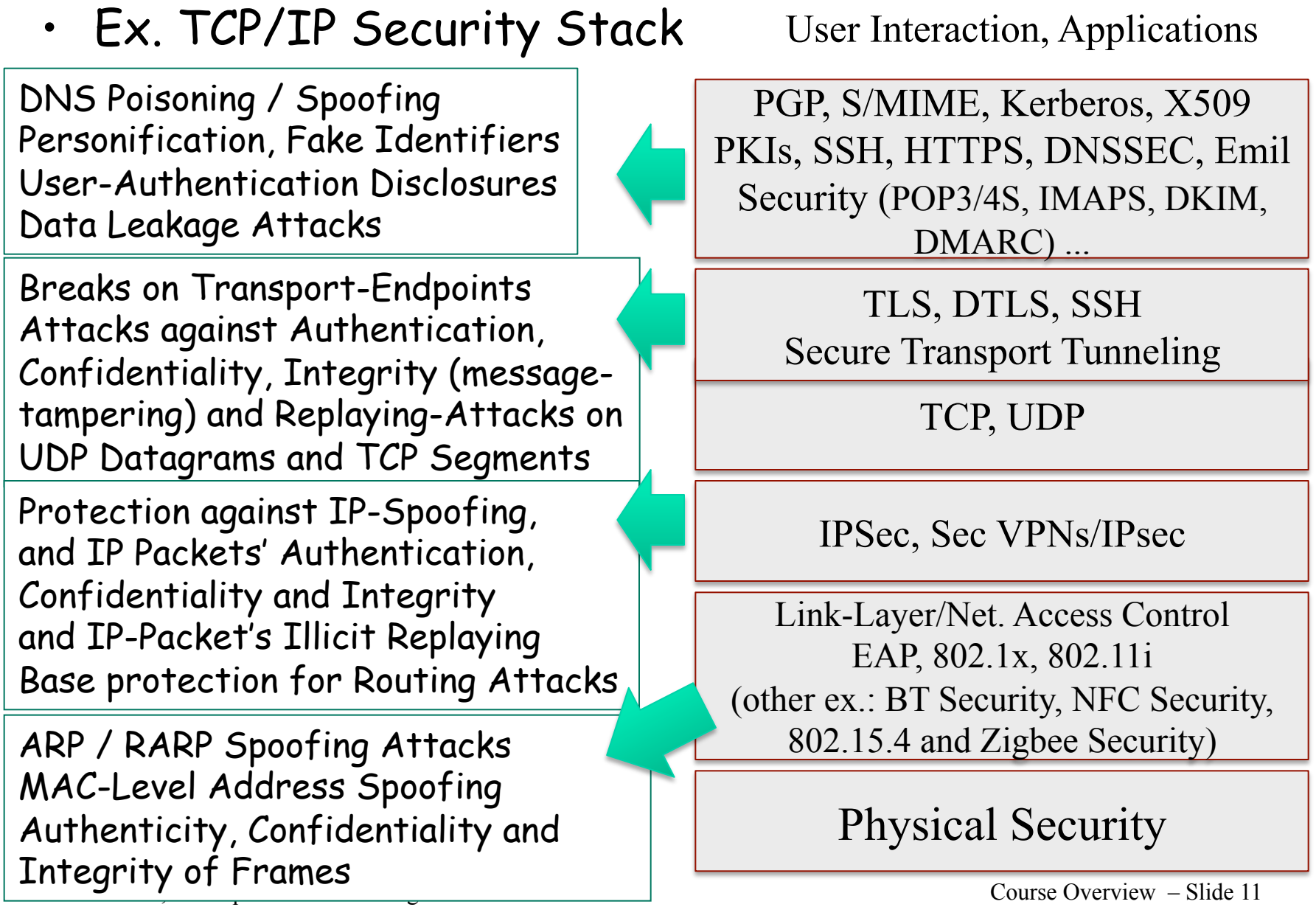
Communication Security Services and Protocols

- Ex. TCP/IP Security Stack



Some examples of countermeasures

- Ex. TCP/IP Security Stack



DoS and DDoS Threats and Protection

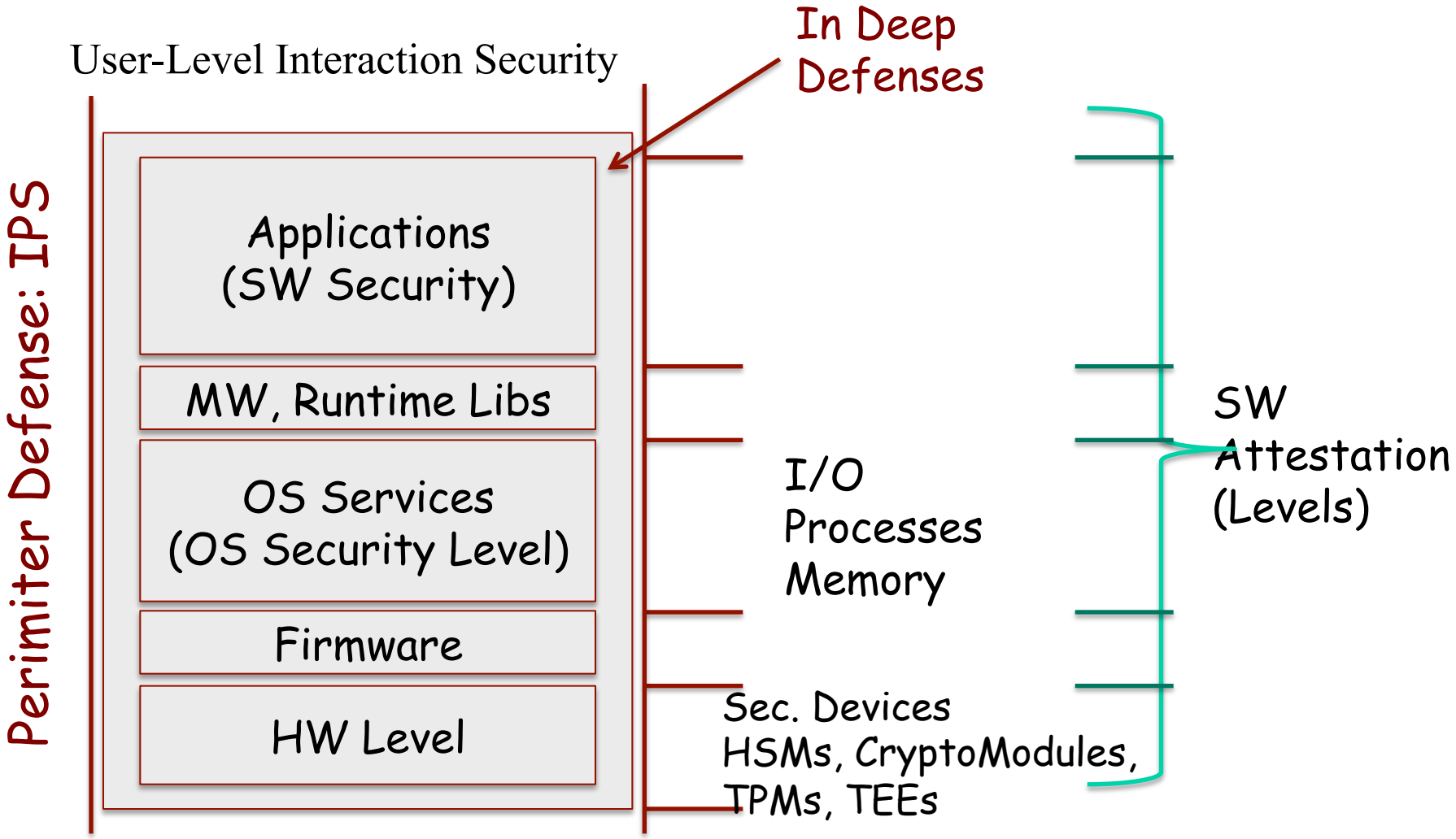
Mitigation in TCP/IP Stack Implem. and Runtime

Complex Defenses combining many Defense Types (Ex., Perimeter Defenses, Cloud DDoS Protection)

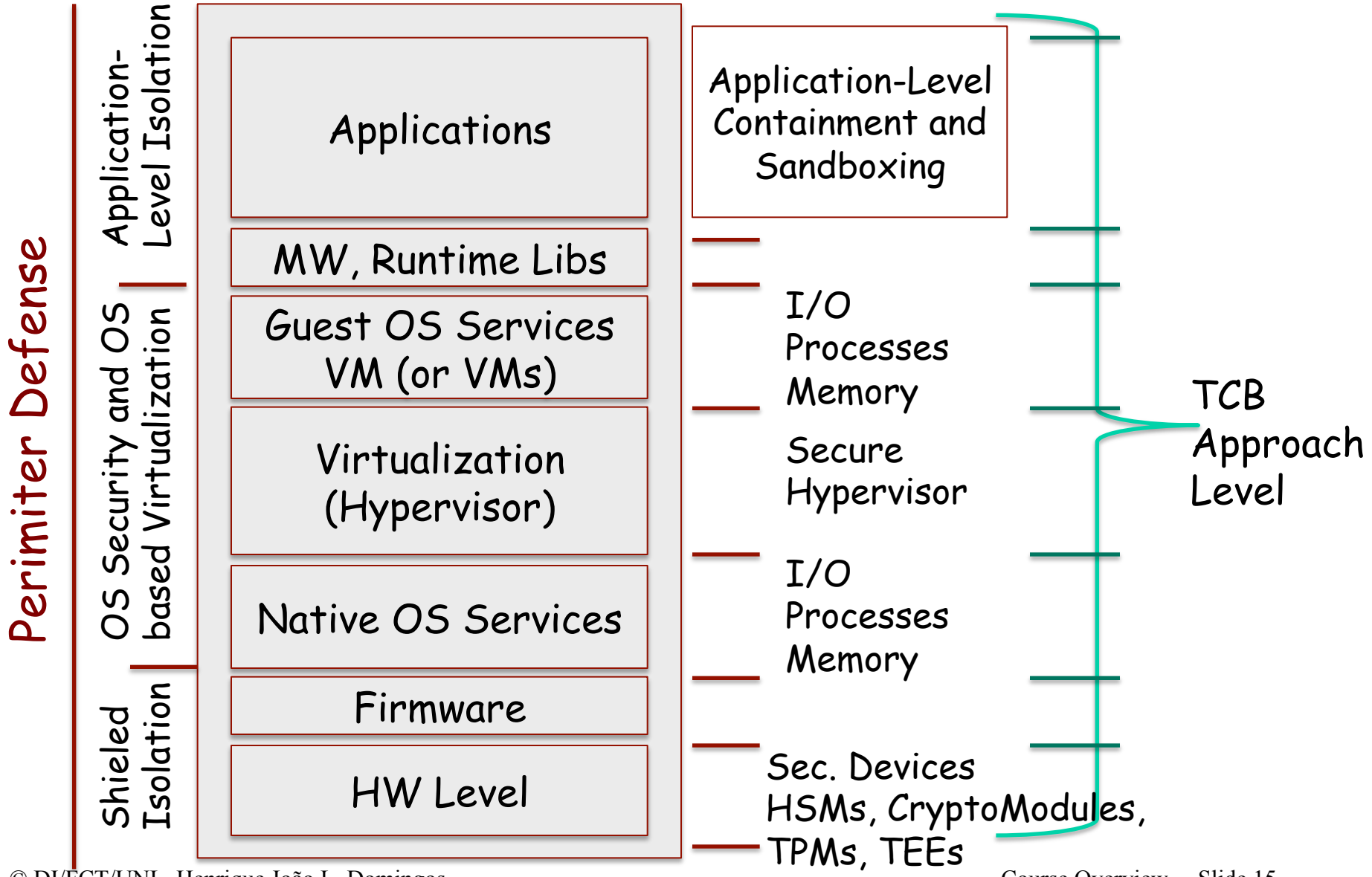
- What about not included countermeasures on TCP/IP Security Stack Standards ? Discussion
  - Simple (common) examples
    - Land Attacks, Teardrop Attacks
    - ECHO-CHARGEN and SYN Flooding Attacks
    - IP Ping-of-Death Attacks
    - Stack Smashing Attacks
    - Format/Data Representation Formats and Endpoints' Processing
  - More complex …:
    - Large-Scale DDoS / Cloud-Based DDoS Vectors of Communication Overloads ☹
      - Need Specific Network Perimeter Defense and In-Deep Defense Mechanisms
      - …. OR Cloud-Enabled Defenses ;-)

Computer Security Services and Mechanisms

Scope of Computer Security
(involving SW, FW and HW services and mechanisms)



Scope of Computer Security Isolation and TCB Level



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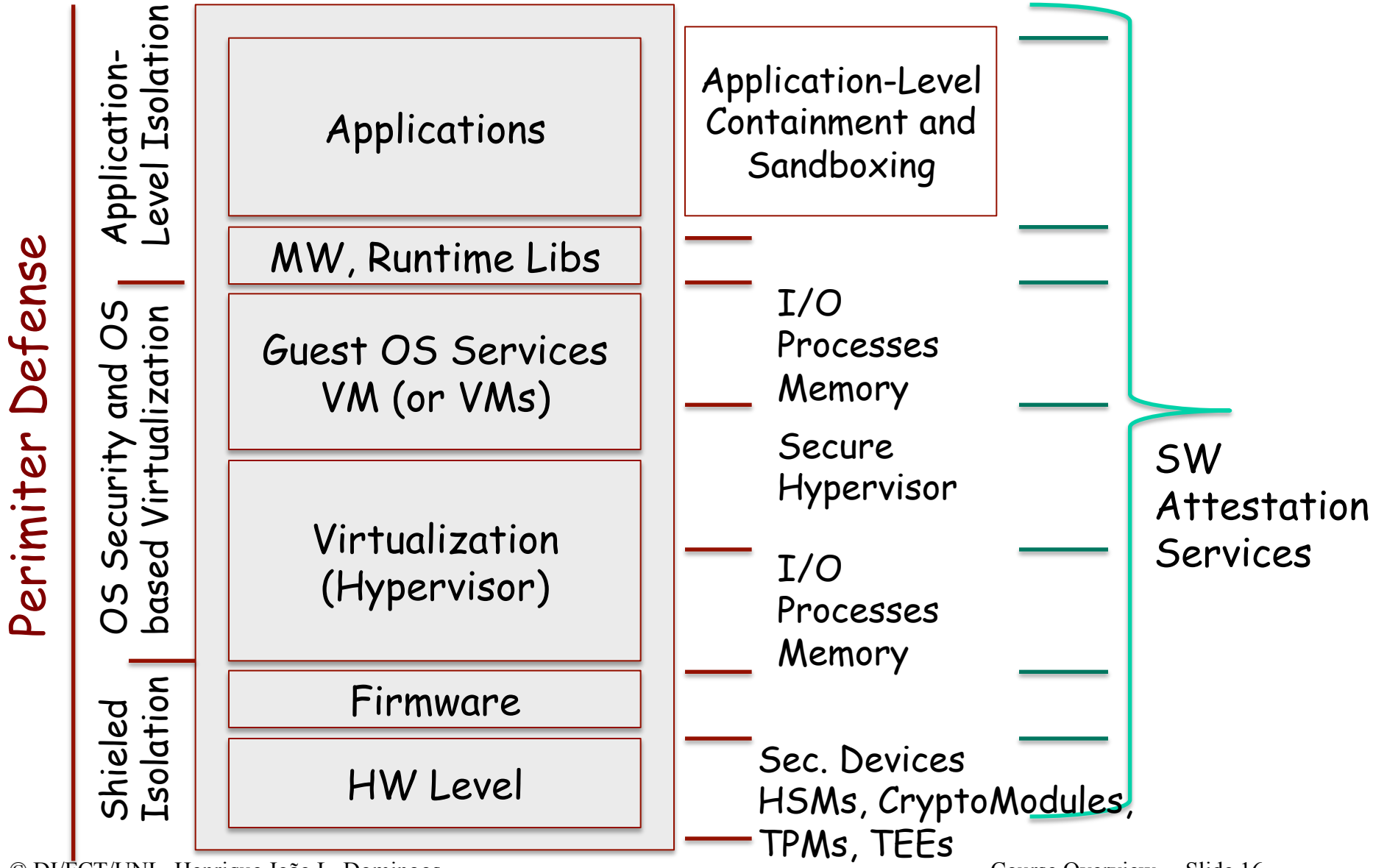
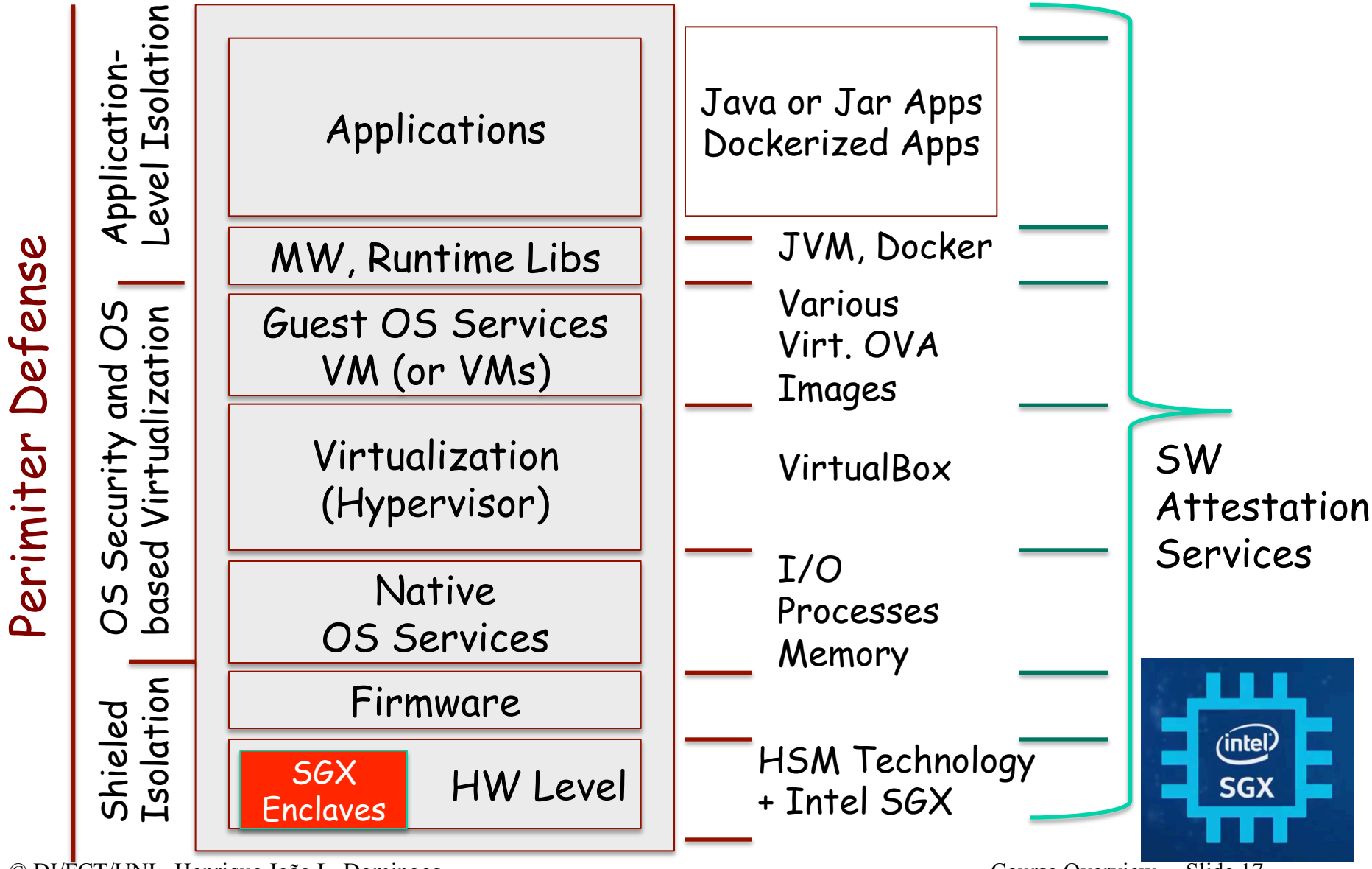
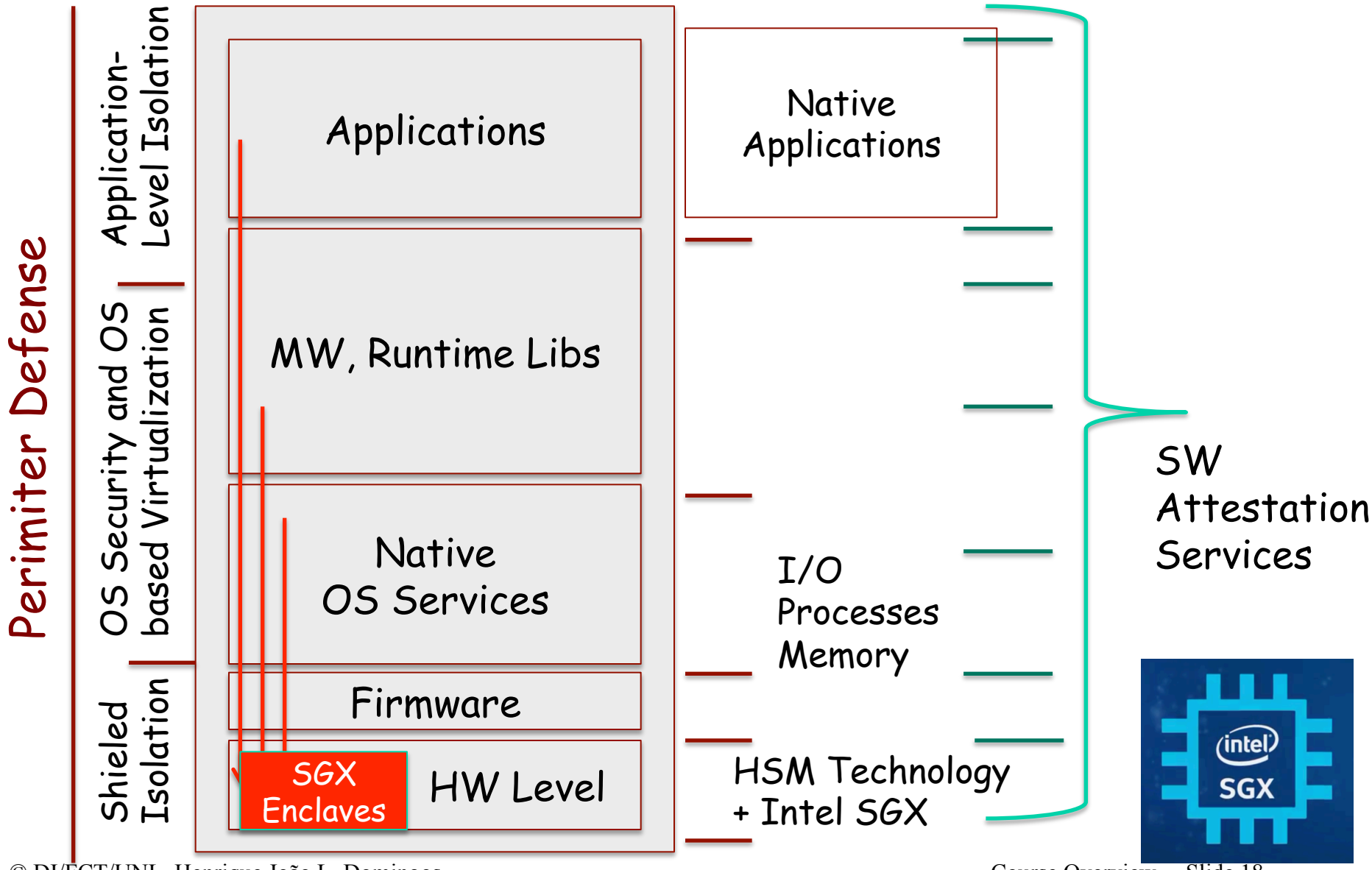


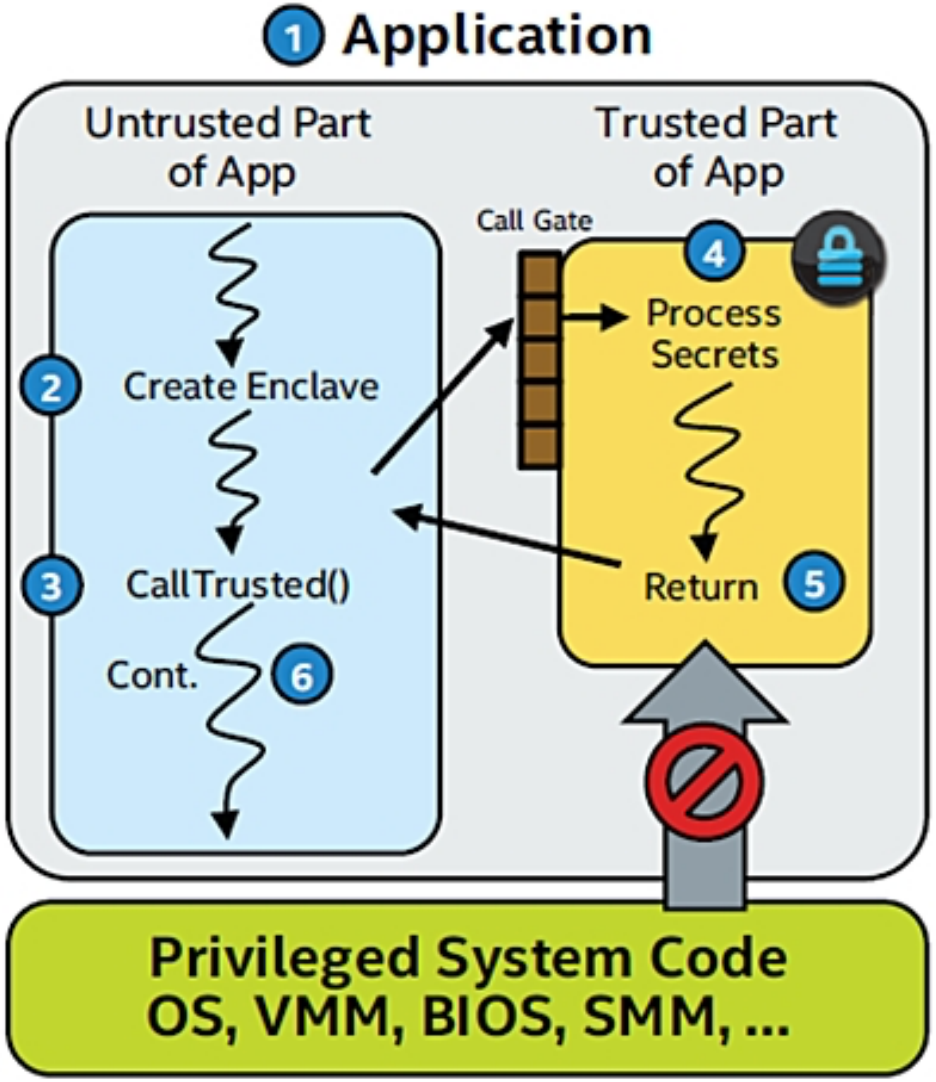
Concrete Implementation

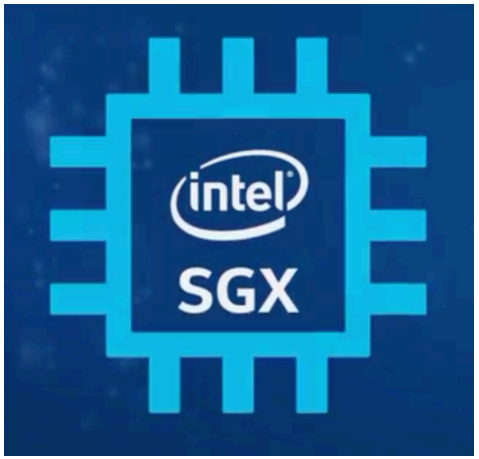


Concrete Implementation

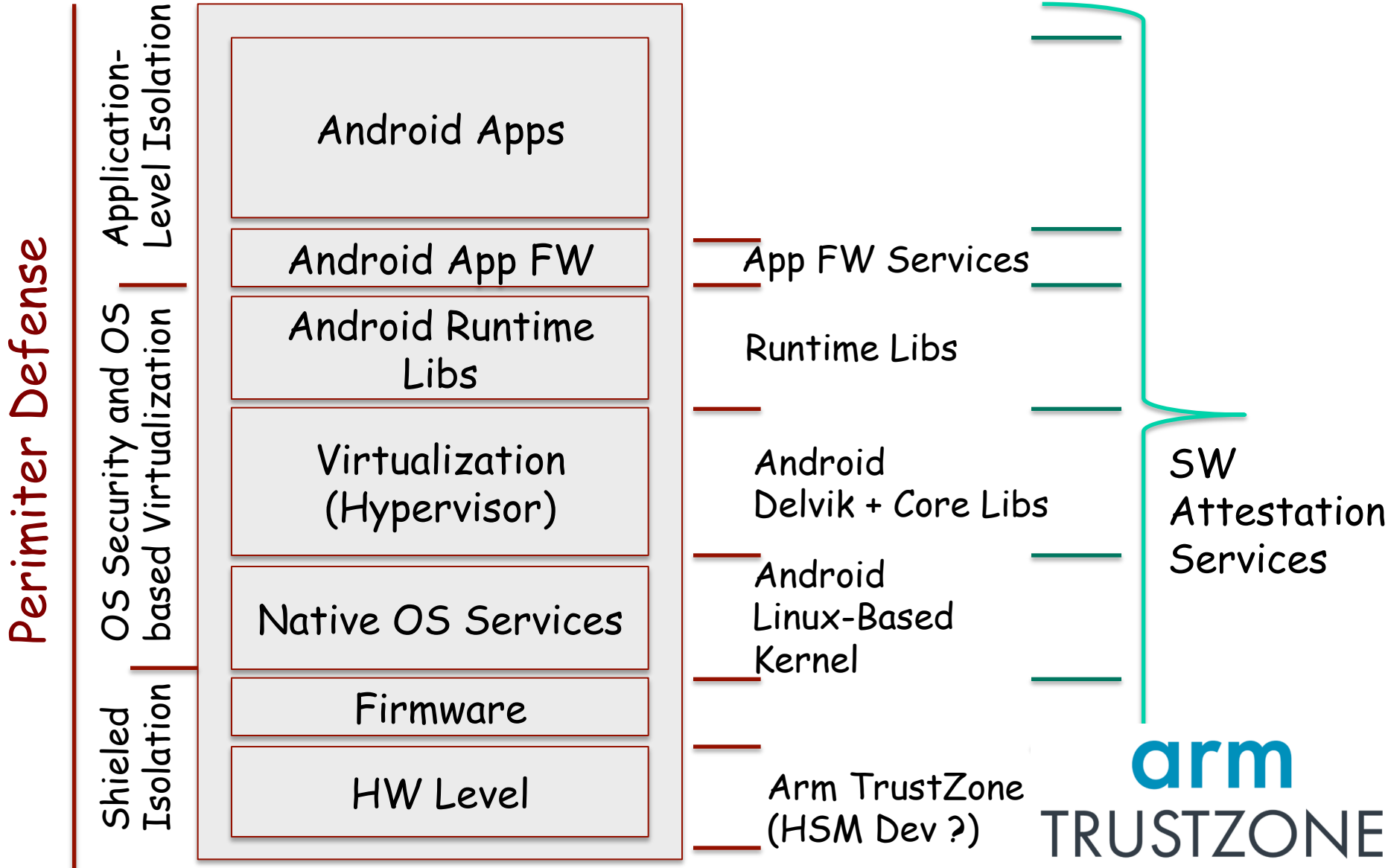


Intel SGX TEE Protection

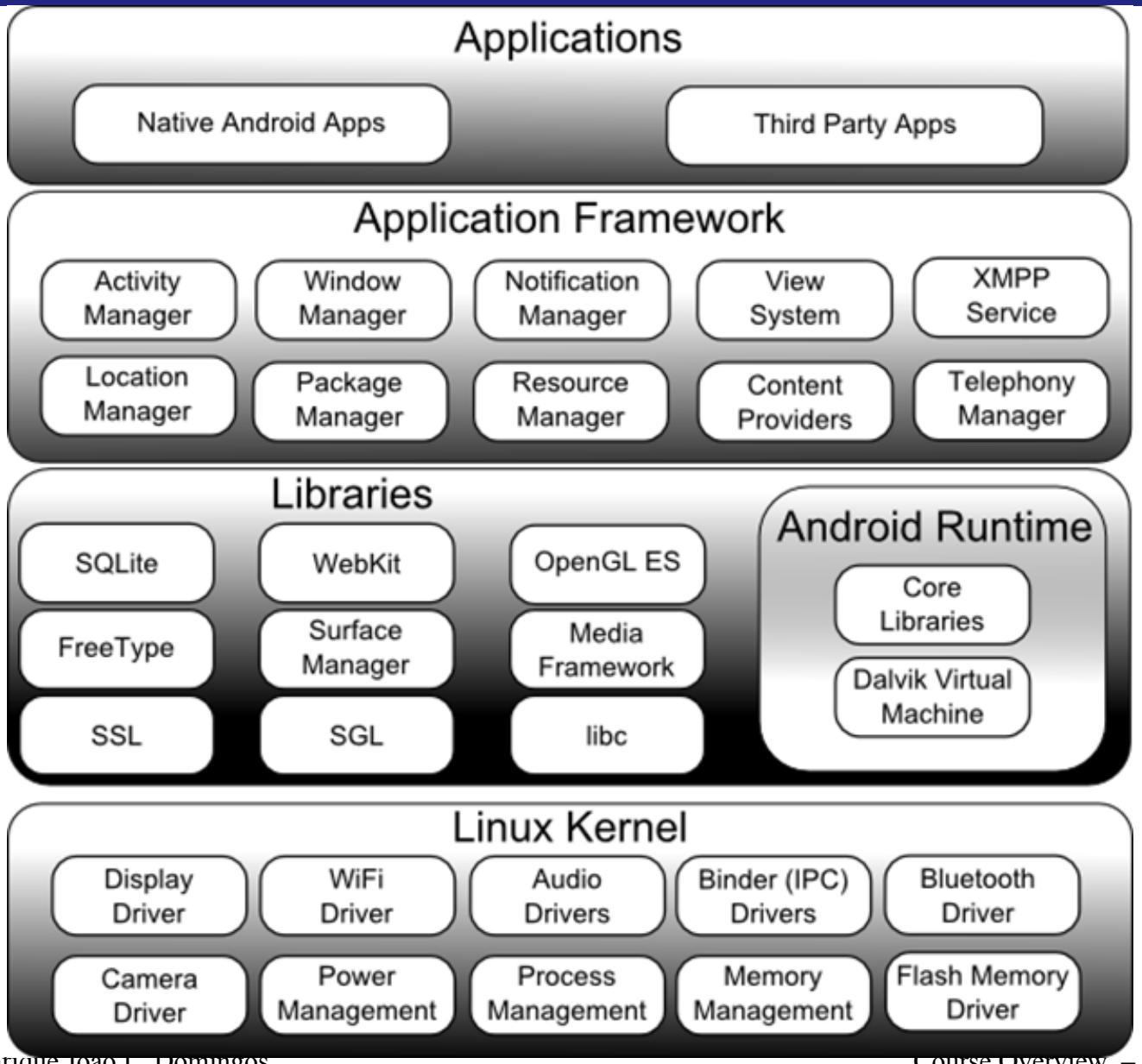




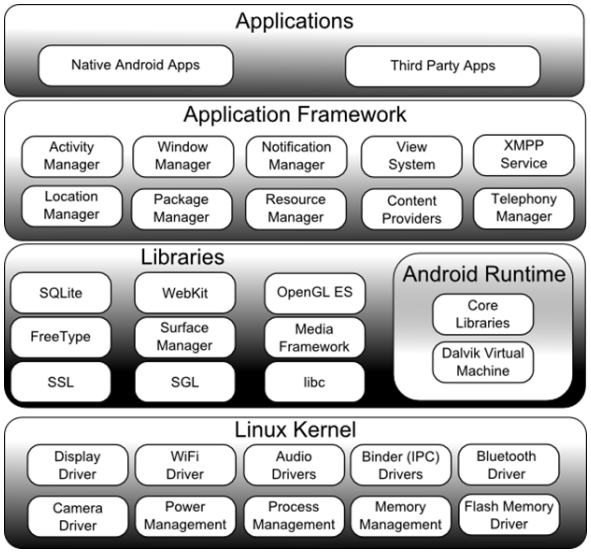
Another concrete Implementation
(ARM / Mobile Oses: Exemple w/ Android)



Android Architecture

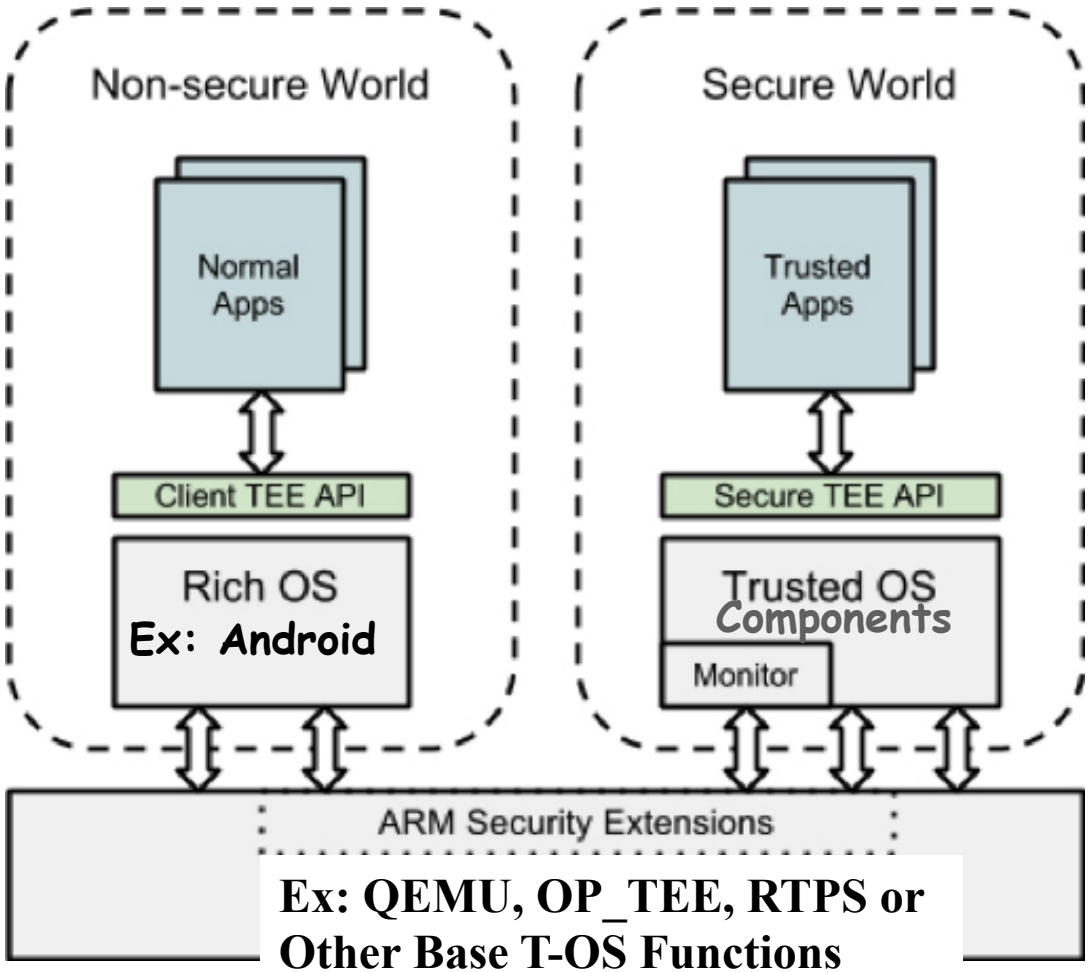


Ex: Android Architecture on HW-Shielded Trust Execution Environment



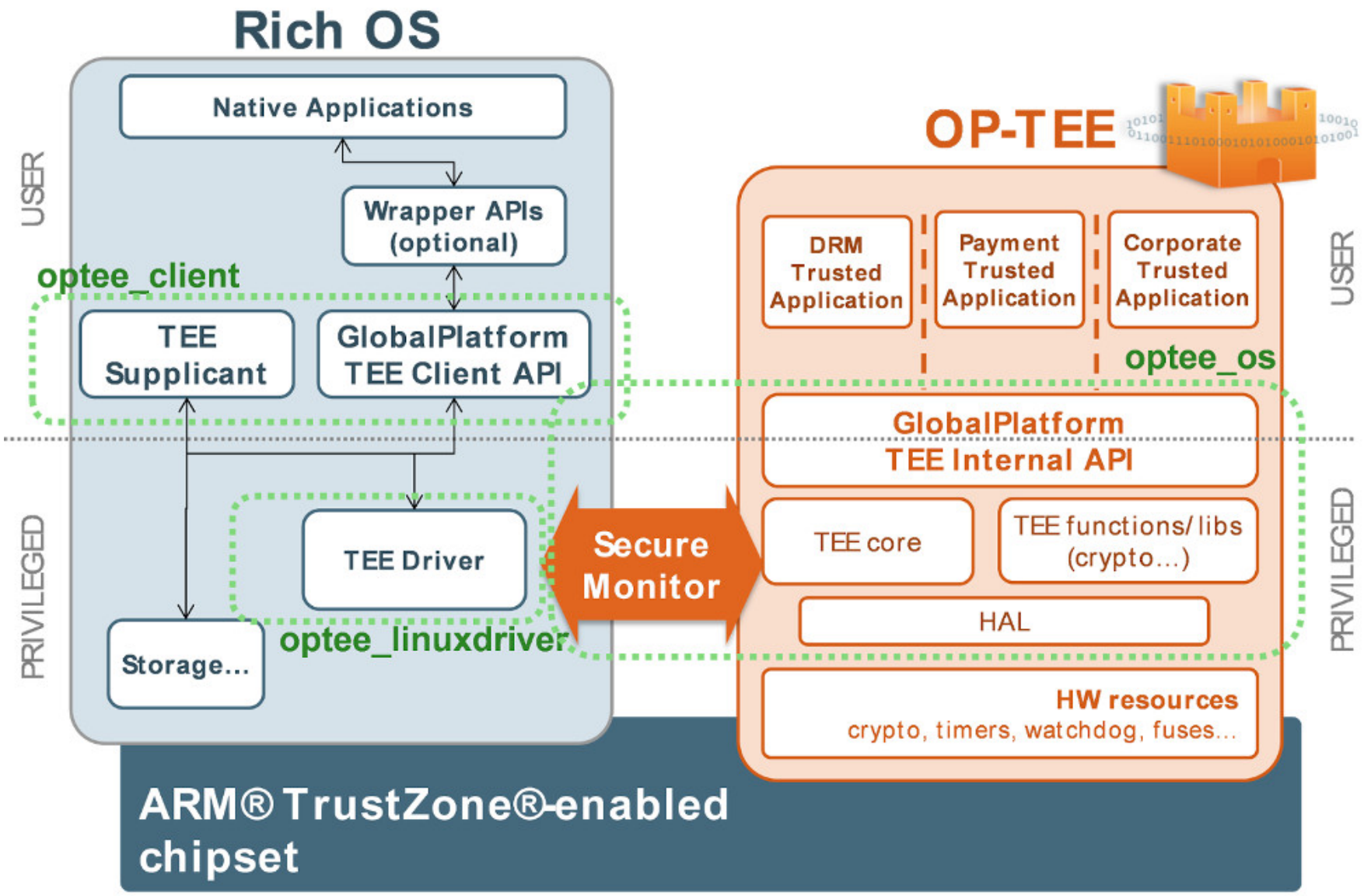
Mapping of Non-Sensitive Components

Mapping of Trusted Components



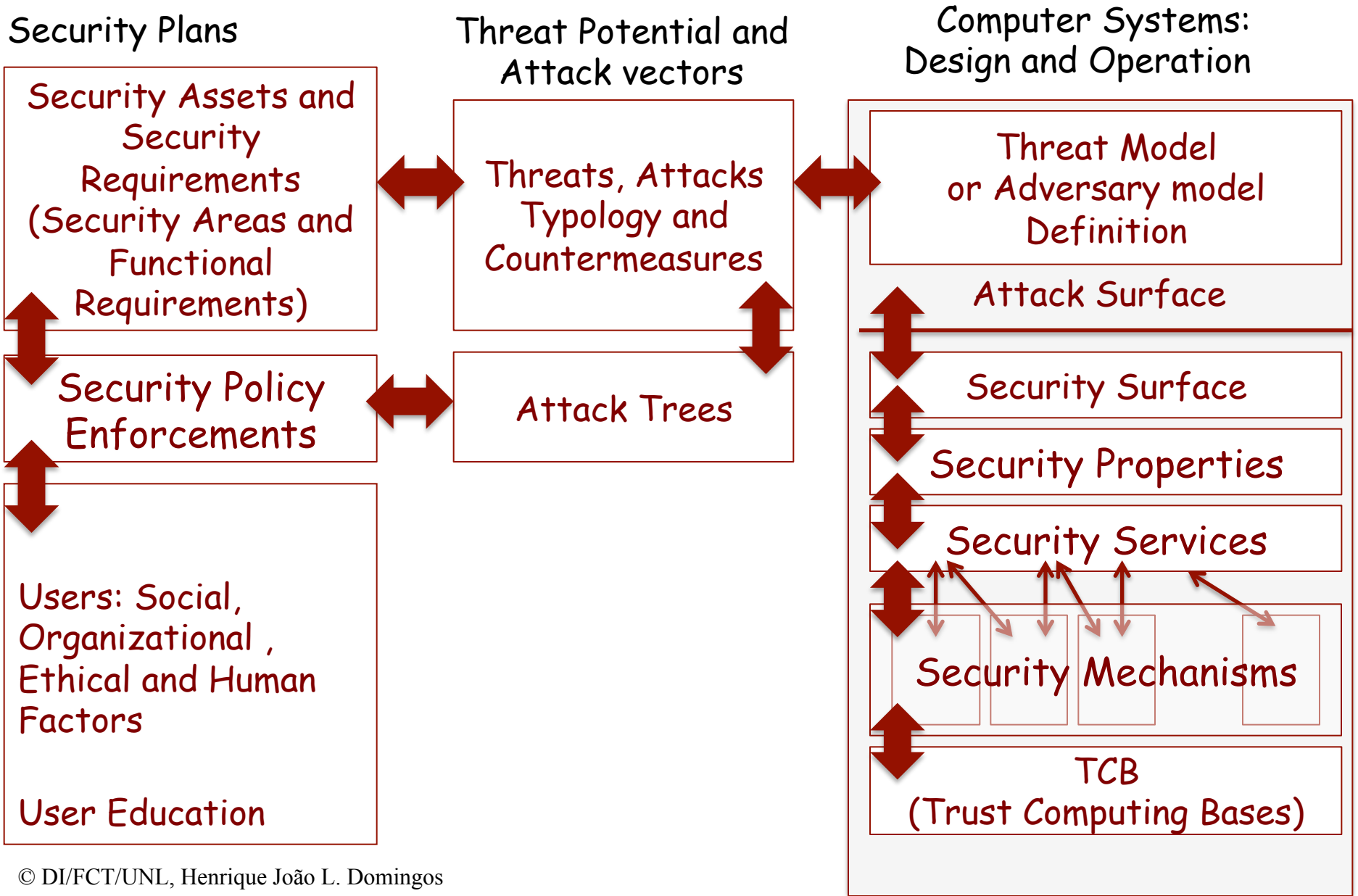
Ex: QEMU, OP_TEE, RTPS or Other Base T-OS Functions

TEE Architecture



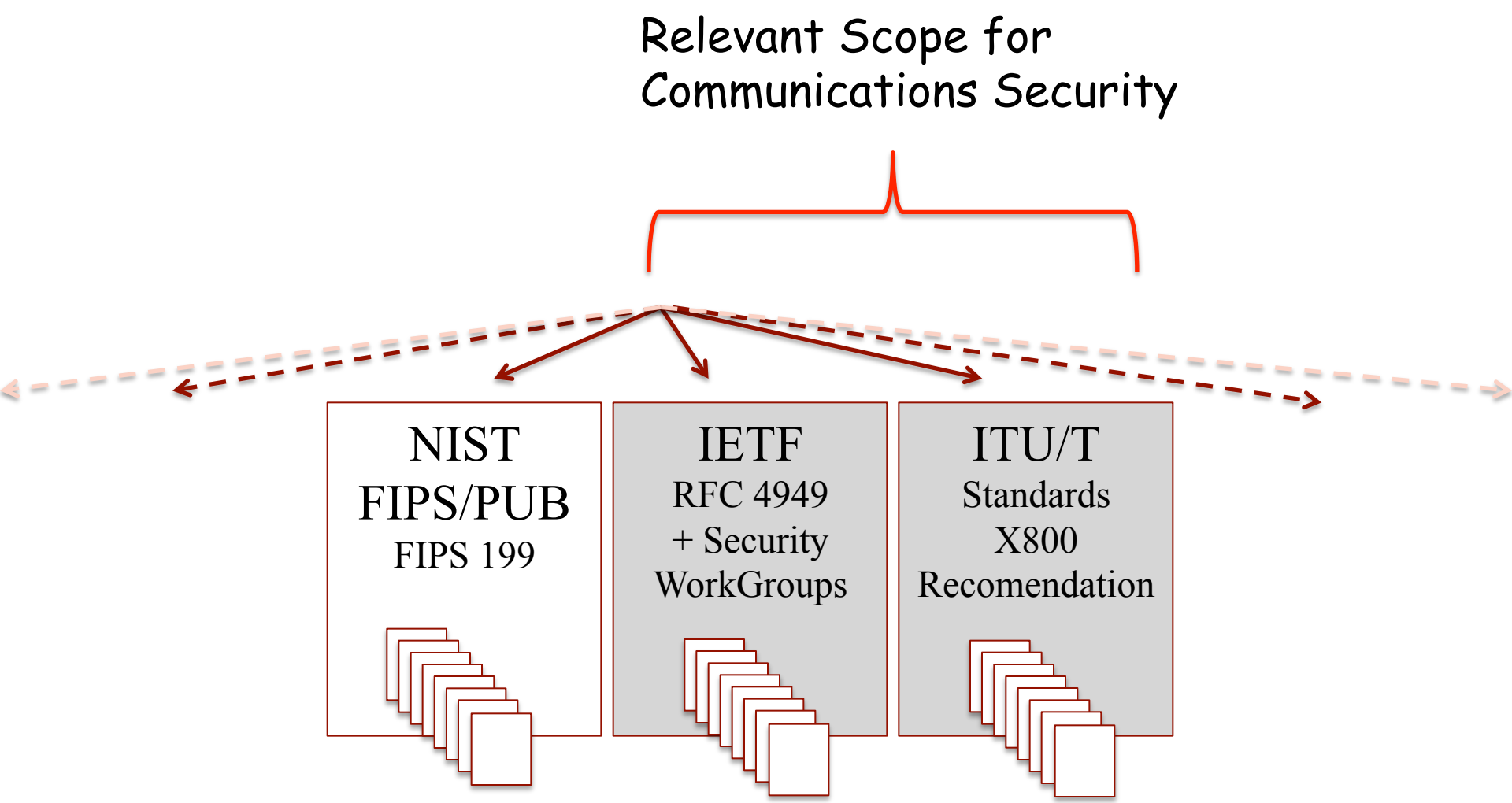
OSI X.800 Rec. IETF RFC 4949 + IETF Security Standards (RFC)

Remembering our initial (conceptual) Security Framework



Instantiation of standard frameworks

Technical Security Standardization Frameworks



Threats vs. Attacks (OSI X.800)

- Threat: Potential of security violation, when there is circumstances, vulnerabilities, capabilities, actions or events that could breach security and cause harm
  - Possible danger that might exploit a vulnerability
  - Potential exploits in the attack surface

- Attack: Assault/Break on Security, as a concrete manifestation of threats
- Intelligent action as a deliberate attempt (method, technique, use of attack tool) to evade security services and violate security policy (and related security properties) of a system
  - Induction of incorrect (non-secure) behaviour

Typology of Attacks

Communication Attack Typology

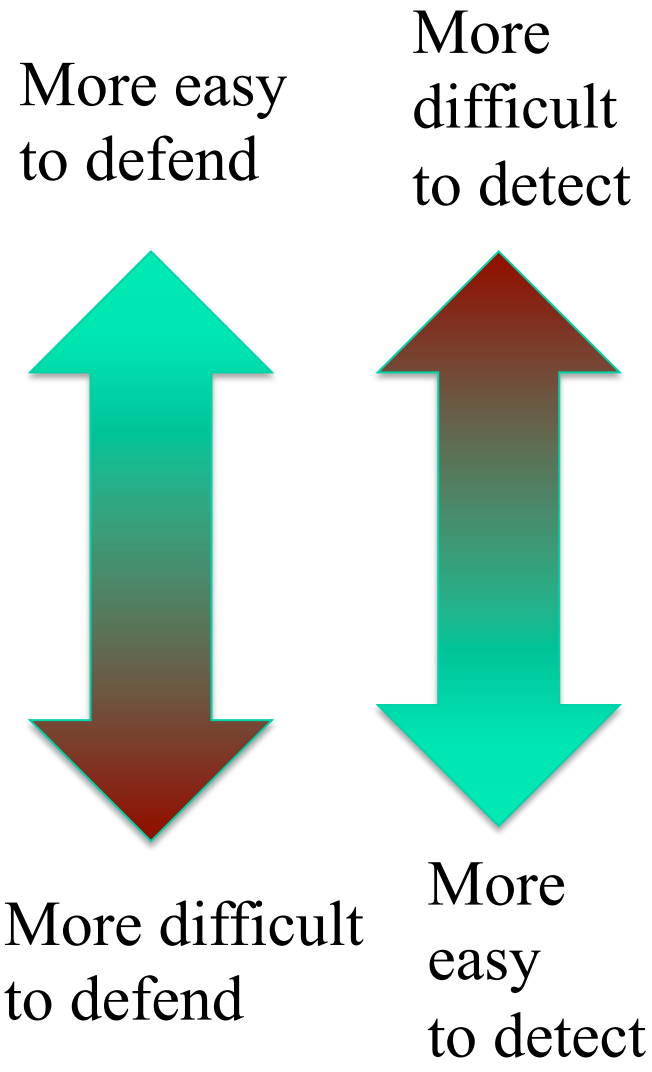
- **Passive Attacks**
  - Release of Message Contents (Payload Data Leakage)
  - Packet Analysis (Frame/Datagrams/Packet Sniffing)
    - Specific Targeted Data Packets
  - Traffic Analysis (at different stack layers)
    - Traffic Flow Inspection and Reconnaissance
- **Active Attacks**
  - Masquerade (Message Forgery)
  - Replay (or Illicit Message-Replay)
  - Modification of Messages (Message Tampering)
    - Can Include Attacks against Message Ordering
  - DoS (Message Discarding, Message Dropping, Overloading and Net. Congestion and/or Saturation)
  - Attacks inducing end-point incorrect processing

OSI X.800: Attacks

Communication Attack Typology

- **Passive Attacks**

- **Active Attacks**



OSI X.800: Security Services

- **Authentication**
  - Peer-Entity Authentication (or Principal Authentication)
  - Data Origin Authentication
- **Access Control**
  - Prevention of access to unauthorized (nor permissioned) resources
- **Data Confidentiality**
  - Connection-Oriented Confidentiality
  - Connectionless Confidentiality
  - Selective-Field Confidentiality
  - Traffic Flow Confidentiality
- **Data Integrity**
  - Connection-Integrity w/ Recovery
  - Connection-Integrity without recovery
  - Selective-Field Connection Integrity
  - Connectionless Integrity
  - Selective-Field Connectionless Integrity
- **Nonrepudiation**
  - Non-Repudiation of Origin
  - Non-Repudtaion of Destination

OSI X.800: Security Mechanisms

Specific Security Mechanisms

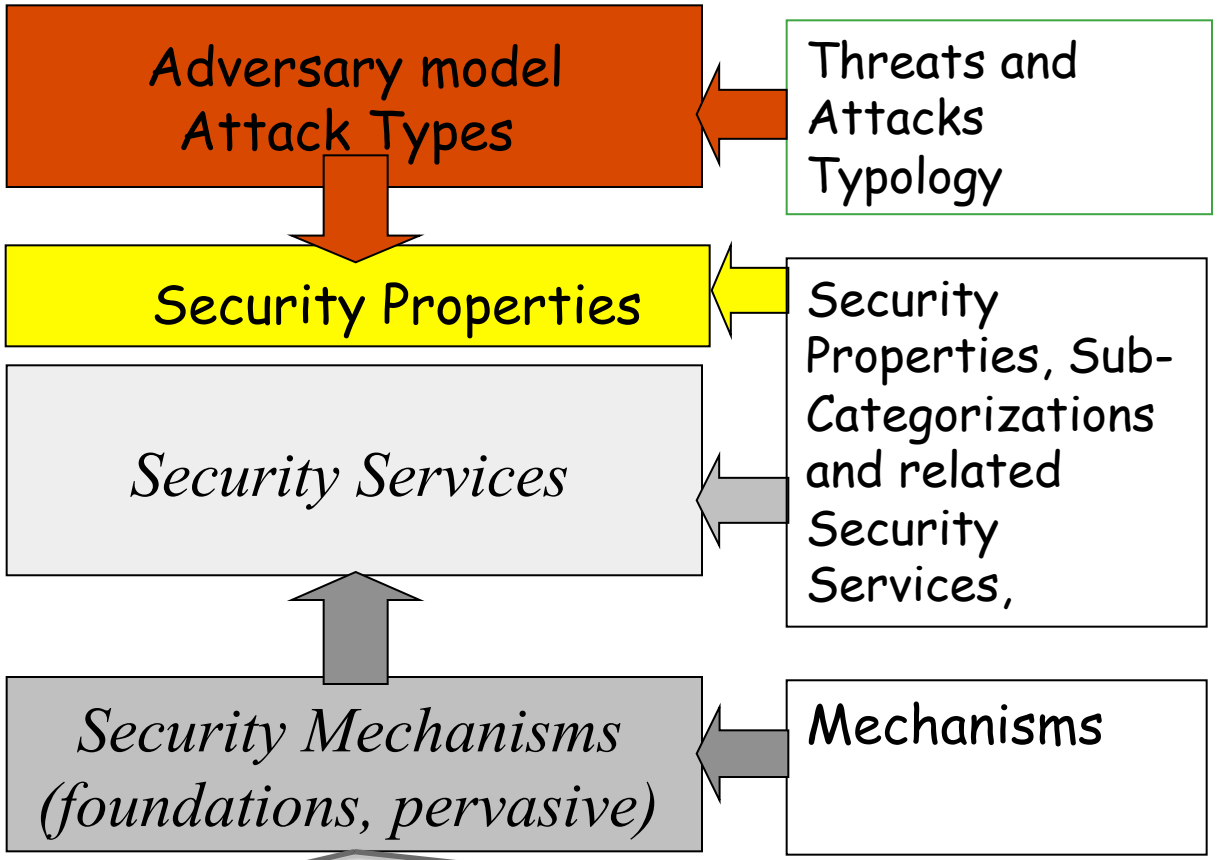
- Encipherment
- Digital Signatures
- Data Integrity
- Authentication Exchanges
- Access Control
- Traffic Padding
- Routing Control
- Notarization

Cryptographic Algorithms, Methods and Techniques

Pervasive Security Mechanisms

- Trusted Mechanisms imposed by Security Policy Enforcement
- Security Labels for Security Attributes
- Event Detection
- Security Audit Trails
- Security Recovery

OSI X.800 mappings (in a nutshell)



Mapping Attacks vs. Security Services

Security Services	Attack Typology: Release of message contents	Traffic analysis	Masquerade	Replay	Modification of messages	Denial of service
Peer entity authentication			Y			
Data origin authentication			Y			
Access control			Y			
Confidentiality	Y					
Traffic flow confidentiality		Y				
Data integrity				Y	Y	
Non-repudiation			Y			
Availability						Y

Attacks vs. Security Mechanisms

Security Mechanisms	Attack Typology: Release of message contents	Traffic analysis	Masquerade	Replay	Modification of messages	Denial of service
Encipherment	Y					
Digital signature			Y	Y	Y	
Access control	Y	Y	Y	Y		Y
Data integrity				Y	Y	
Authentication exchange	Y		Y	Y		Y
Traffic padding		Y				
Routing control	Y	Y				Y
Notarization			Y	Y	Y	

Security services vs. Security Mechanisms

Security Mechanisms

Security Services

Service	Mechanism							
	Enciph-erment	Digital signature	Access control	Data integrity	Authenti-cation exchange	Traffic padding	Routing control	Notari-zation
Peer entity authentication	Y	Y			Y			
Data origin authentication	Y	Y						
Access control			Y					
Confidentiality	Y						Y	
Traffic flow confidentiality	Y					Y	Y	
Data integrity	Y	Y		Y				
Non-repudiation		Y		Y				Y
Availability				Y	Y			

Big Picture (X.800 mappings)

	Release of message contents	Traffic analysis	Masquerade	Replay	Modification of messages	Denial of service
Peer entity authentication			Y			
Data origin authentication			Y			
Access control			Y			
Confidentiality	Y					
Traffic flow confidentiality		Y				
Data integrity				Y	Y	
Non-repudiation			Y			
Availability						Y

	Release of message contents	Traffic analysis	Masquerade	Replay	Modification of messages	Denial of service
Encipherment	Y					
Digital signature			Y	Y	Y	
Access control	Y	Y	Y	Y		Y
Data integrity				Y	Y	
Authentication exchange	Y		Y	Y		Y
Traffic padding		Y				
Routing control	Y	Y				Y
Notarization			Y	Y	Y	

Cryptography methods, Algorithms, models, techniques

	Mechanism							
Service	Enciph-erment	Digital signature	Access control	Data integrity	Authenti-cation exchange	Traffic padding	Routing control	Notari-zation
Peer entity authentication	Y	Y			Y			
Data origin authentication	Y	Y						
Access control			Y					
Confidentiality	Y						Y	
Traffic flow confidentiality	Y					Y	Y	
Data integrity	Y	Y		Y				
Non-repudiation		Y		Y				Y
Availability				Y	Y			

Cryptographic tools as base mechanisms

Authentication and Key Distribution Protocols

Service	Encipherment	Digital signature	Access control	Data integrity	Authentication exchange	Traffic padding	Routing control	Notarization
	Mechanism							
Peer entity authentication					Y			
Data origin authentication								
Access control			Y					
Confidentiality							Y	
Traffic flow confidentiality						Y	Y	
Data integrity								
Non-repudiation								Y
Availability					Y			

Symmetric Crypto Methods

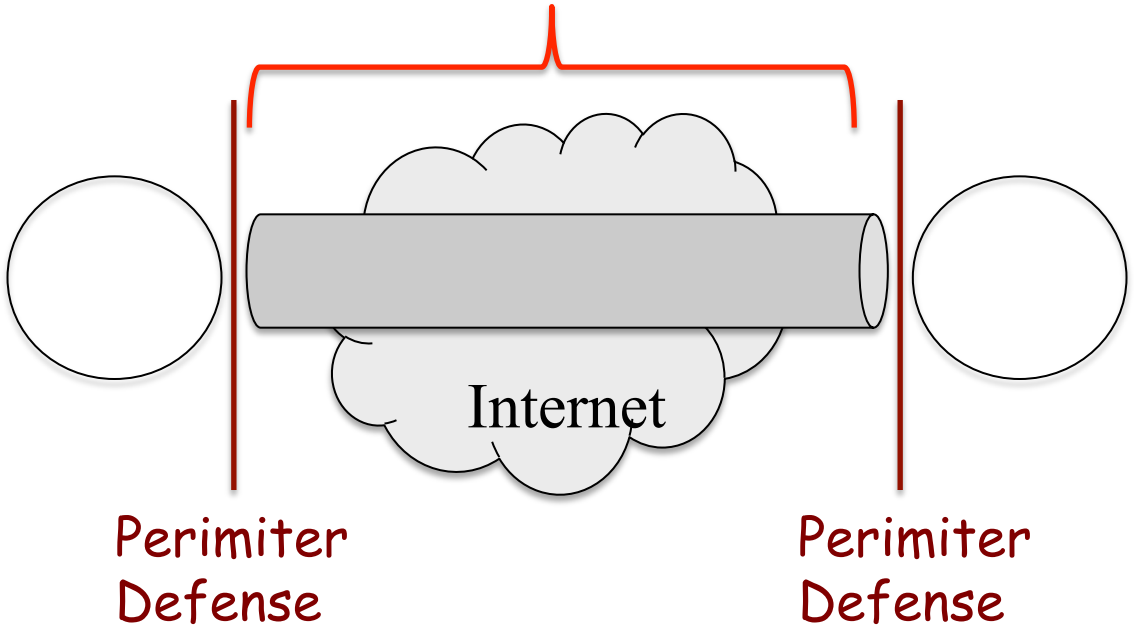
Asymmetric Crypto Methods

Secure Hash Funtions, HMACs or CMACs

Security Channel
(Definition using the OSI X.800 Reference)

How to define a Secure Channel ?

- Definition in the scope of the OSI X.800 framework
  - A communication channel immune to the Attack Typology and MiM threats, according to the OSI **X.800 attack typology and OSI X.800 defined services and mechanisms**
  - **PtP (Point-Point) vs. End-to-End Security Arguments**

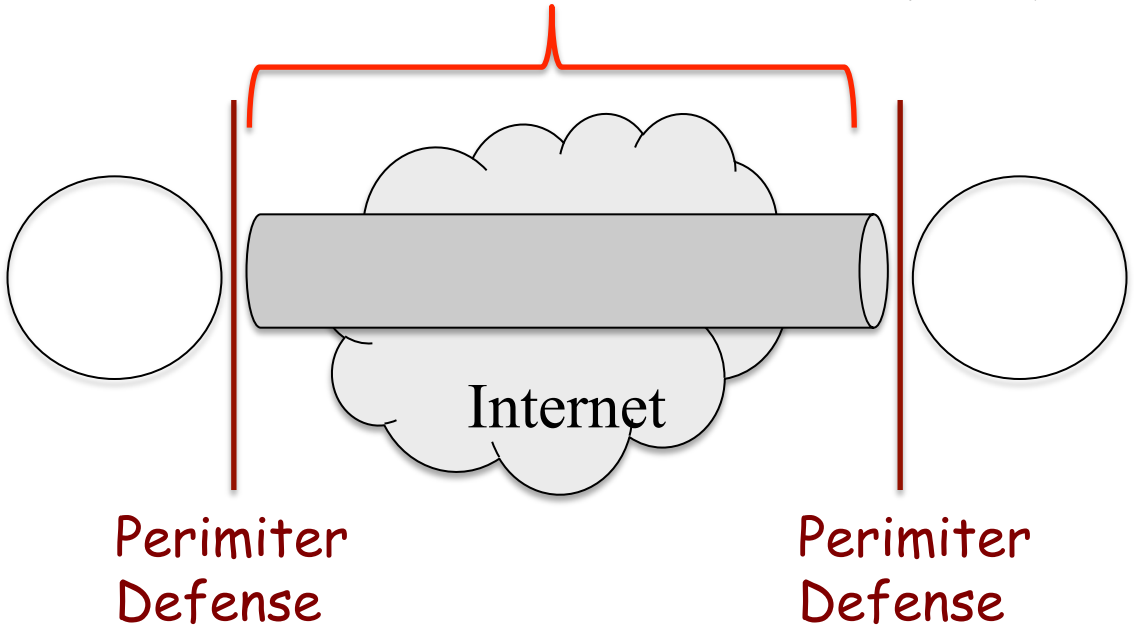


Properties in a Secure Channel ?
See the Security properties in the OSI X.800

- Authenticated endpoints (principals, mutual authentication, peer-authentication and data-authentication)
- Traffic and data flow confidentiality
  - Connection-oriented vs. Connectionless
- Traffic and data flow integrity
  - Connection-Oriented vs. Connectionless
- No replaying

Cryptography plays an important role !

Protection can be addressed at different Levels of Approach (in the Communication Stack)

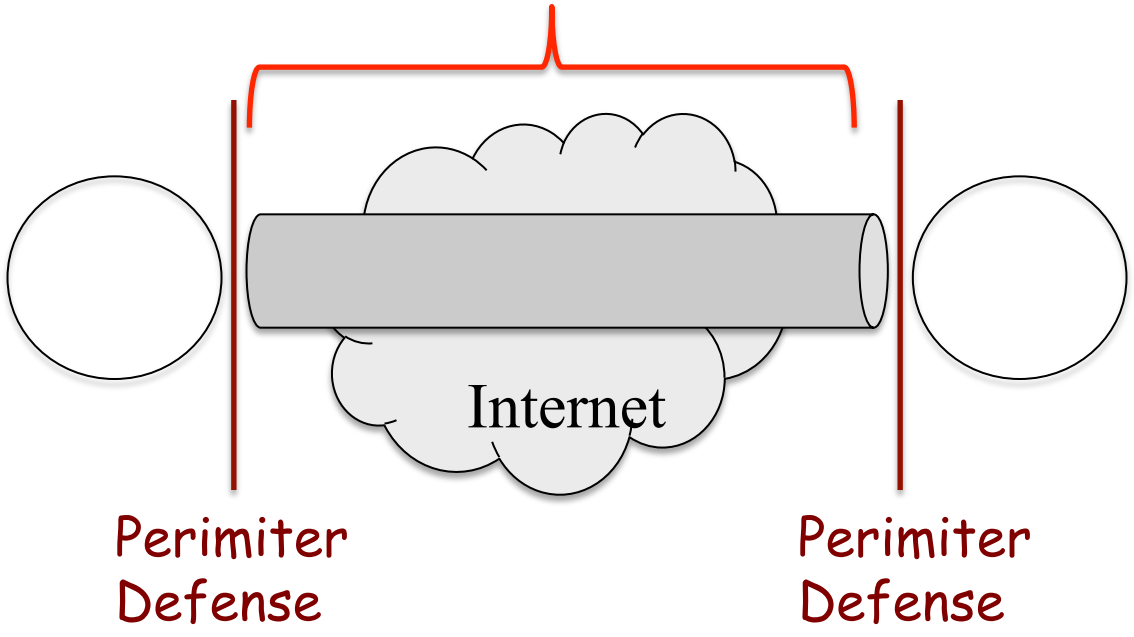


Properties in a Secure Channel ?
See the Security properties in the OSI X.800

What about …

- No Repudiation
- Routing Control
- Availability
- Net Access and Connection control
- Reliability
- …

Complementary Mechanisms and Services (out of the cryptography scpe)



The Role of Cryptographic Tools, Methods and Techniques

Important:

Cryptography is very important for Computer Systems and Network Security ! ...
... but it is not a PANACEA

Cryptosystems: Algorithms and Methods

- Foundation security mechanisms and building blocks for security services

  - Encryption: data blocks, messages
    - Symmetric cryptosystems
      - Stream Ciphers vs. Block ciphers
    - Some asymmetric crypto systems (not all)

  Confidentiality

  - Digital signatures: authentication of data blocks, messages
    - Asymmetric cryptosystems
  - Message authentication Codes
    - Sometimes called "Lightweight" Signatures
    - MACs, HMACs or CMACs

  Authentication

Cryptosystems: Algorithms and Methods

- Foundation security mechanisms and building blocks for security services
  - Integrity protection
    - Examples:

      MICs, CS, CRCs, MICs, EDCs, ECCs, etc…

      Weak Integrity Checks ?
    - More Secure Methods fopr Integrity Checks:
      - Cryptographic Hash Functions
      - Use of Cryptographic Hash Functions in HMACs

Integrity

Mappings in the X.800 framework

	Release of message contents	Traffic analysis	Masquerade	Replay	Modification of messages	Denial of service
Peer entity authentication			Y			
Data origin authentication			Y			
Access control			Y			
Confidentiality	Y					
Traffic flow confidentiality		Y				
Data integrity				Y	Y	
Non-repudiation			Y			
Availability						Y

	Release of message contents	Traffic analysis	Masquerade	Replay	Modification of messages	Denial of service
Encipherment	Y					
Digital signature			Y	Y	Y	
Access control	Y	Y	Y	Y		Y
Data integrity				Y	Y	
Authentication exchange	Y		Y	Y		Y
Traffic padding		Y				
Routing control	Y	Y				Y
Notarization			Y	Y	Y	

Cryptography methods, Algorithms, models, techniques

	Mechanism							
Service	Enciph-erment	Digital signature	Access control	Data integrity	Authenti-cation exchange	Traffic padding	Routing control	Notari-zation
Peer entity authentication	Y	Y			Y			
Data origin authentication	Y	Y						
Access control			Y					
Confidentiality	Y						Y	
Traffic flow confidentiality	Y					Y	Y	
Data integrity	Y	Y		Y				
Non-repudiation		Y		Y				Y
Availability				Y	Y			

Dependable Distributed Systems

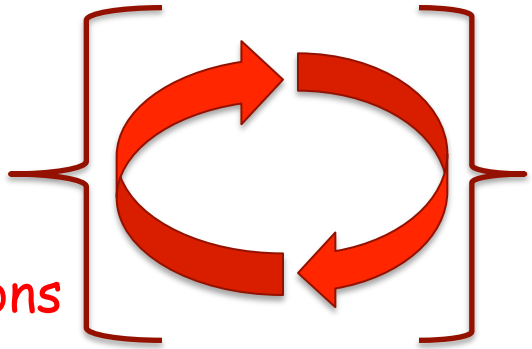
Computer Systems and Network Security

- Computer Systems (Computing Nodes)
- Network (Communication Security)

Distributed Systems Security
Dependable Distributed Systems

Failure Models and Threat Models
Security, Intrusion Tolerance and Fault Tolerance

Secure Data Storage
Software Security +
Software Attestation +
Trusted Execution +
Dependability Assumptions



Secure Com. Channels
PtP vs. End-to-End
Secure Protocols
Secure Endpoints
Dependability Assumptions

What/Where/How to Identify the Trust Computing Model

Dependable Systems

- **Dependable system:**
  - **a system we can depend on**
  - *A system is dependable if reliance can justifiably be placed on the service it delivers.*
  - **dependability** as the ability to provide services that can defensibly be trusted within a time-period.

Dependability

- In Systems Engineering: **dependability** as a measure (metrics) of the provided attributes

- In Software Engineering, **dependability** as the **ability to provide services that can defensibly be trusted within a time-period** (a certain life cycle)

- See, for ex: https://en.wikipedia.org/wiki/Dependability

Dependability and Dependable Systems

- Dependable systems are characterized by dependability attributes and metrics of their attributes:
  - **Availability:** continuity of correct operation
  - **Reliability:** readiness for correct operation
  - **Maintainability** and **maintenance support:** ability and functions for maintenance and repair (recovery)
  - **Performance:** operation provided in useful time
  - **Durability:** ability to remain functional and usable, with minimal or non-excessive maintenance or repair in a lifetime period
  - **Safety:** absence of bad / catastrophic consequences on the users and environment
  - **and Security:** Confidentiality, Integrity, Availability, Authenticity, Access Control,

    and also more and more … Privacy (including Data Privacy Privacy-Enhanced Computation)

Typology of Defenses in Distributed Systems Security for Dependability Criteria

Typology of Defenses (1)

- **Physical Defenses: Catastrophes/Disasters**
- **Prevention Defenses against Systems' Faults or Failures**
- **Prevention defenses against non-authorized activities**

Typology of Defenses

- **Physical Defenses: Catastrophes/Disasters**
  - Ex., Environmental, Political, Material, Natural/Accidental
- **Prevention Defenses against Systems' Faults or Failures**
  - Energy or Blocking faults causing stop-failures
  - Temporary faults causing intermittent failures in processing and communication (connectivity conditions)
  - Possible arbitrary faults (or byzantine faults)
- **Prevention defenses against non-authorized activities**
  - Information access, abuse of privileges
  - Tampering, fake information forging or illicit modification
  - Unfairness and abusive use of computational resources (ex., abuses in multi-shared resources
  - Service denial activities

Typology of Defenses

- **Complexity Issues**
- **Realistic Approaches**

- **Perimeter Defenses vs. "in deep" Defenses**

Typology of Defenses

- **Complexity Issues**
- **Realistic Approaches**

- **Perimeter Defenses vs. "in deep" Defenses**
- **Perimeter Defenses (ex., IPS or FWs: NIPS, HIPS; IDS: HIDS, NIDS; Hpots and HNets)**
  - Separation (no direct interaction) between:
    - Side where threats are originated or where adversaries (or attackers) act

      (regarded as "external attackers" on "external perimeters")
    - Side of protected resources on "internal perimeters)
  - What if adversaries exist in the protected perimeter ?
    - Protection of security domains / different security levels
    - Possible Fine-grained granularity

Typology of Defenses

- **Complexity Issues**
- **Realistic Approaches**

- **Perimeter Defenses vs. "in deep" Defenses**
- **In Deep Defense:**
  - More complex (but can be more effective)
  - Protection of all security levels involved (not only the externalization of systems or interfaces between securiry domains)

Security Policy Enforcements

- **Define security requirements that must be verified**

Security Policy Enforcements

- **Define security requirements that must be verified**
  - Classified information, confidentiality and access-control (permission/deniable models)
  - Protection of sensitive data: privacy guarantees, backup and recovery guarantees
  - Business or organization services' continuity
  - Trustworthy conditions for systems' operation and compliance
  - Proofs of correction, authenticity, attestation, origin, authoring, ownership in information exchanges
  - Logging and auditing of relevant events or retention of evidences for forensics and analysis of occurred actions
  - Authentication factors and proofs to authenticate roles, users and systems' principals, entities or subjects
  - Authorization rules and privileges for roles, users or principals
  - Monitoring/Auditing processes

Correct choice of security mechanisms: Different types => Different Purposes

Problem: How to choose the right mechanism for the right purpose?

Classification approach of different types of mechanisms:

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- Containment
- Access-Control
- Privileged Execution
- Filtering

- Registration
- Inspection

- Auditing

- Cryptographic mechanisms

- Secure Channels and Cryptographically Secure Protocols

Correct choice of security mechanisms: Different types => Different Purposes

Problem: How to choose the right mechanism for the right purpose?

Classification approach of different types of mechanisms:

- Containment (IPS, Sandboxing, Isolation)
- Access-Control (MAC, DAC. RBAC, ABAC, C-ABAC Models)
- Privileged Execution (Separation of Rights and Duties)
- Filtering (Ex., Filtering Rules, Tainting Analysis and Dynamic Content and Stateful Inspection)
- Registration (Event Logging)
- Inspection (IDS, Static and Dynamic in Runtime and/or Real-Time Anomalous Detection)
- Auditing (Automatic + Semiautomatic Verification and Supervision)
- Cryptographic mechanisms (Algs, Construction schemes, Secure Parameterizations, Programming Techniques and Tools)
- Secure Channels and Cryptographically Secure Protocols

Key-Criteria: No Security by Obscurity ...

NO SECURITY BY OBSCURITY !!!!

- We must choose mechanisms ...
  - Well established, well accepted and respectable in the scrutiny of the **scientific and research community and relevant venues**
  - **Published, with information sources (and possibly implementation) allowing for study**
  - **Correctly implemented with public verification and certification acknowledgement** from well-reputable entities
  - **Open (published)**, considered relevant and interesting as object of **broad study by the research, scientific and R&D communities**
  - **From certified standards** by relevant entities and organziations (ex., ANSI, NIST, FIPS-PUB, ISO, IEEE, IETF ... IACR,) or Certified Labs (ex., NIST/NVLAP and accreditaded CMTLs, compliant implementations with valid/updated IETF/RFCs , RSA Labs, ...)

Revision: Suggested Readings

Security Objectives and Challenges

Suggested Readings:

W. Stallings, L. Brown, Computer Security – Principles and Practice, Person, Chap. 1

W. Stallings, Network Security Essentials – Applications and Standards, Chap 1

Complementary reading (*in Portuguese*)

- Targets of Defense
- Vulnerability vs. Risk Management Issues
- Typology of Defenses in CSNS
- Perimeter vs. "in Deep" Defenses
- Security Policy Enforcement
- Types of Security Mechanisms
- Distributed Systems Security Principles and Risks

Suggested Reading (Portuguese Language):
A. Zúquete, Segurança em Redes Informáticas, Cap. 1 – Introdução (pp 11-16), FCA, 5ª Ed., 2018