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Gestão/Management

Management of Local and Global Networks

Concepts and Protocols

Why Networks and Systems Management?

- Lower Cost – Manual management is costly
- More efficient – Automatic systems allow an efficient planning, and mechanisms to predict the utilization trends: lower errors and faster actuation
- Better service – The manager is informed at the same time the (client) is, and can make an automatic check of the situation
- Greater knowledge – more information exists about the network, allowing better decisions and planning
- Why not human intervention?
  - **Difficult to describe responsabilities**
  - **Technology rapidly evolves**
  - **Mangement systems rapidly evolve**
  - **Lack of technical resources**

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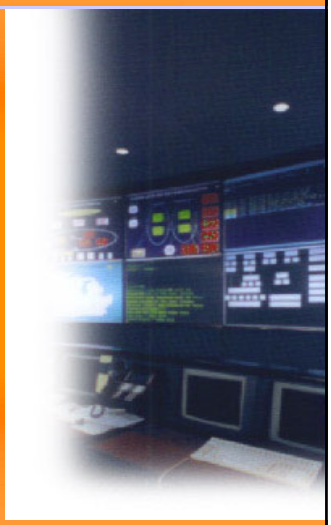
Commercial perspective

- Problems need to be quickly solved
- Management systems simplify the work of multi-functional networks (e.g. VoIP in multiple networks)
- Persons better used – they do not need to perform repetitive tasks
- Companies need to optimze their structures, and network management allow resources optimization



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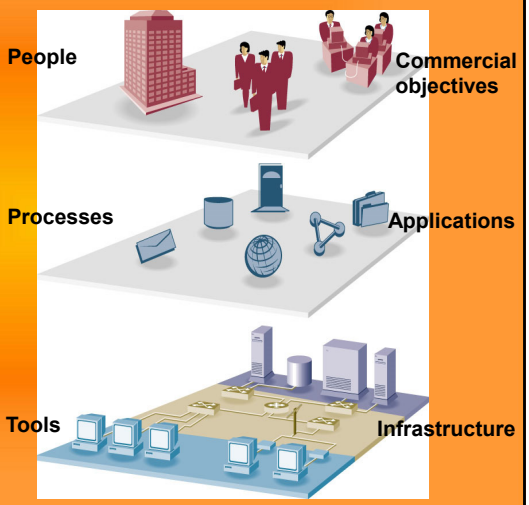
Network management is:

Implement, integrate and coordinate resources (HW, SW and people) to plan, operate, manage, analize, test, evaluate, design and expand the system to guarantee the service objectives (temporal, performance), with a reasonable cost and capacity.



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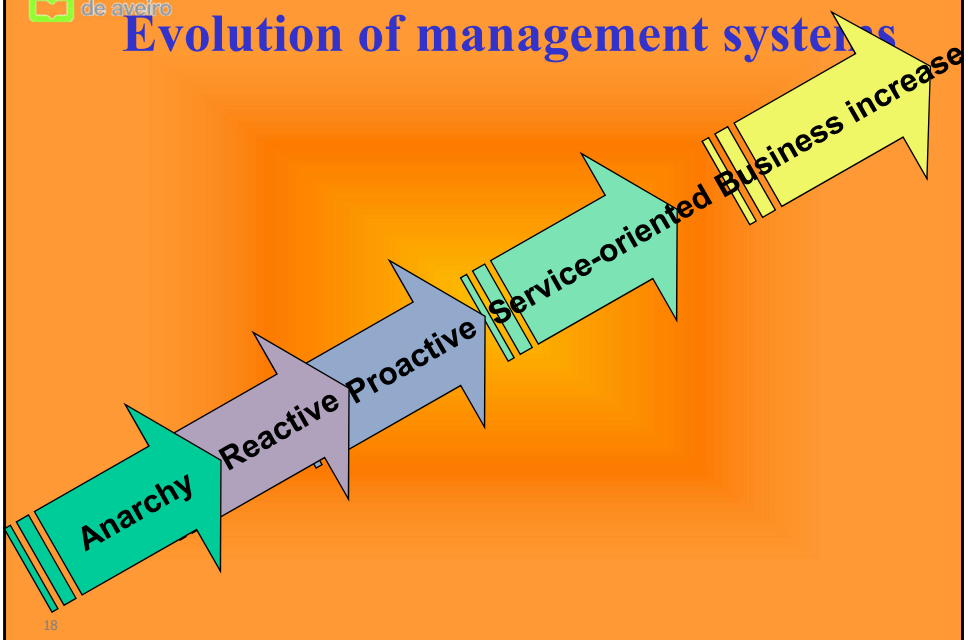
Evolution of management systems



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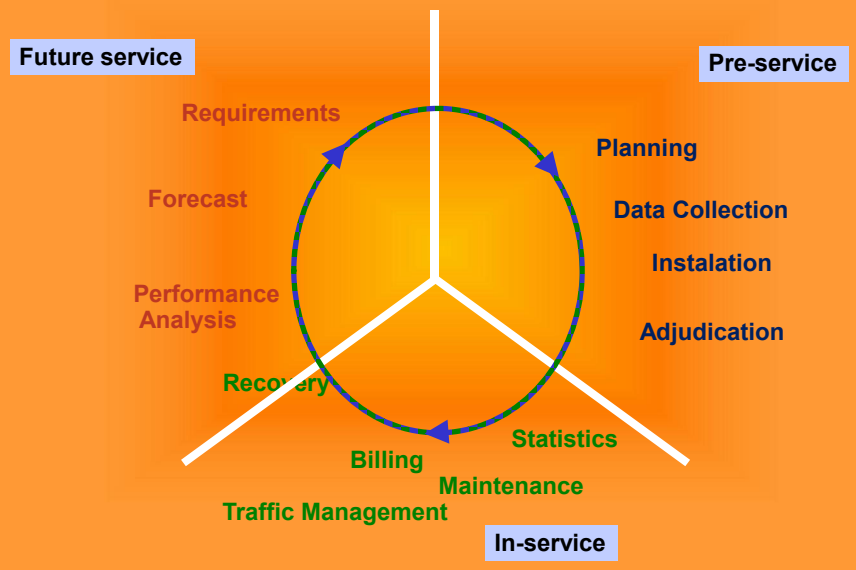
Aspects of Network Management

- **What to manage?**
  - Network, equipment, systems, users, services, applications
- **How to manage?**
  - Interfaces, actions, abstractions
- **What protocol(s) format(s)?**
  - Protocol abstraction, formats, messages
- **What information format(s)?**
  - Information type

Standards for all this – including global frameworks

Management Life Cycle



Management alternatives

- Systems management – Covers all company aspects
- Networks management – Covers mainly network aspects and communications systems and equipments

- Dedicated protocols – dedicated for networks
- Web based systems – resort to HTTP models, recently common

- Centralized models – Agent-manager model
- Distributed models – Share of the management responsabilities
- Hierarchical models – Hierarchic structure with centralized information in the root

Current structures very complex, with several operational models

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Management protocols

- **Methods to monitor and configure network equipments**
- **Do not describe how to achieve management objectives**

Simple protocols ⇒ common data and parameters formats allowing easy information transfer

Complex protocols ⇒ add flexibility and security capacity

Advanced protocols ⇒ remotely execute network management tasks, without depending on specific protocol layers

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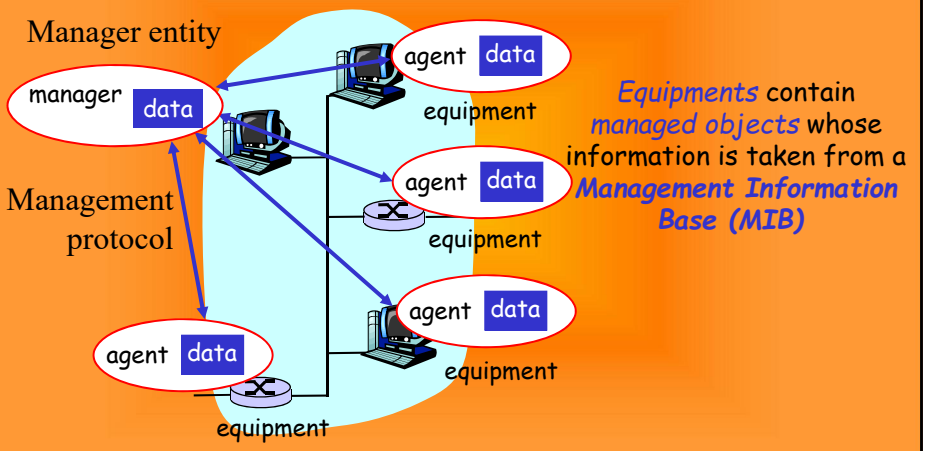
Basic Model for Network Management



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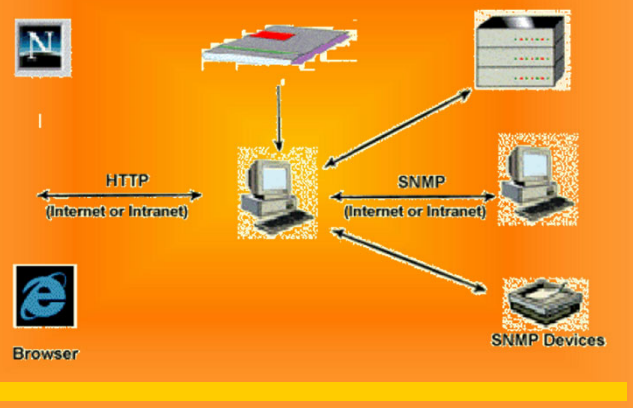
WEB-based management



Very common:
Network and device management via web interfaces

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Web-based management concept

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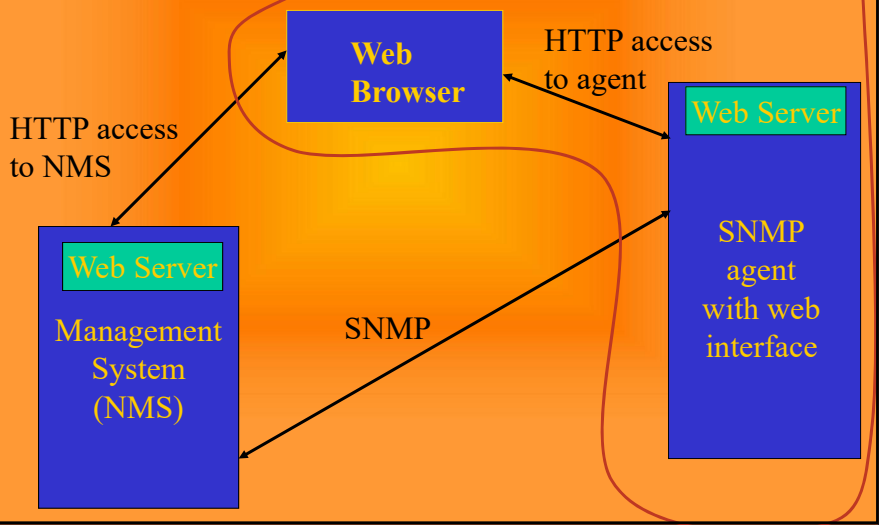

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Network management

- ISO defined five areas for network management
  - Fault management – detection, isolation, and correction of anomaly behaviors

Fault

  - Configuration management – control data for the network elements / colect data from network elements

Configuration

  - Accounting management – measure network utilization and determine network costs and user accountings

Accounting

  - Performance management – evaluate/report network equipment behavior/efficiency

Performance

  - Security management– support communications network secure management

Security

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Fault management

- Location of problems (or faults) in the communications network:
  - Fault detection
  - Fault isolation
  - Fault correction
- Faults can be:
  - Transients
  - Persistents
- Fault management includes functions to:
  - Mantain and examine error logs
  - Create and act in error notifications
  - Search, identify and correct faults
  - Perform diagnosis test sequences

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Accounting management

- Detect resource usage and its administration to assure its availability for the users
- Access control per user
- Allow costs per resource usage and association to tariffs
- It includes functions to
  - Inform users about costs and used resources
  - Establish utilization limits
  - Combine costs from multiple resources used to create the communication system

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Configuration management

- The configuration of critical elements controls the network behavior
  - The configuration management resides through these critical elements
- Configuration management identifies, acts, merges data and provides commands to systems to initialize, start, maintain in continuous operation, and terminate connections
- It includes functions to
  - Define parameters that control the system operation
  - Merge information about the actual system conditions
  - Modify the system configuration

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Performance management

- Measure the network performance (HW, SW). E.g.
  - Usage percentage, error rates, answer time, throughput
- Performance management supports the evaluation of system actions
- It includes functions to
  - Obtain statistical information
  - Maintain and examine logs of system state
  - Determine the system performance in normal and artificial conditions
  - Change working modes to perform management and performance functions

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Security management

- Access control mechanism to network information
- Monitors access points, periodically stores information and creates *logs* and alarms for security reasons
- Supports the appliance of security policies through functions to:
  - Create, remove and control of services and security mechanisms
  - Distribute information related to security
  - Report events associated to security

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Network management

- ISO defined five areas for network management
  - Fault management – detection, isolation, and correction of anomaly behaviors

Fault

  - Configuration management – configure network elements / colect data from network elements

Configuration

  - Accounting management – measure network utilization and detect network overload

Accounting

  - Performance management – evaluate/report network equipment behavior/efficiency

Performance

  - Security management– support communications network secure management

Security

Isolating the management problems in distinct areas, ISO model allows conceptual solutions optimized to specific problems in each functional area

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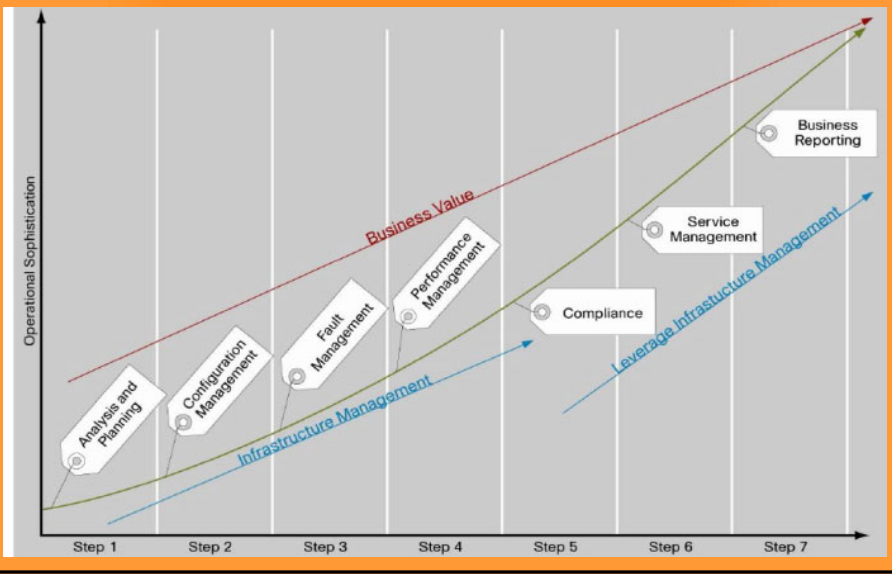
Implementation plans



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Network management: standardization

- **Internet Engineering Task Force (IETF)**
  - **Simple Network Management Protocol**
    - SNMP, disman
    - *Operations and Management Area*
- **International Telecommunications Union (ITU-T)**
  - **Telecommunications Management Network**
    - *SG IV*
- **International Standard Organization (ISO)**
  - **OSI, CMIP-CSIS**
    - *ISO-IEC/JTC 1/WG 4*
- **Others**
  - **DMTF, TM FORUM, OMG, IEEE, …**

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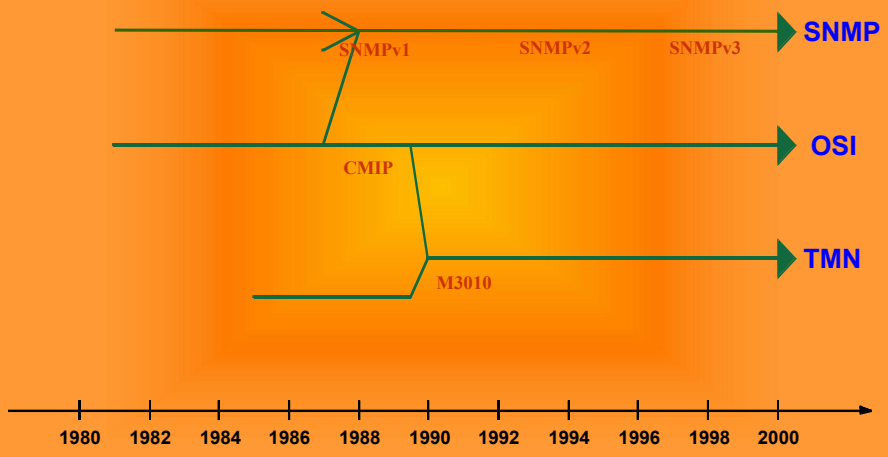
Cronology



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SNMP
(short review)

Simple Network Management Protocol

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Manager/Agent Paradigm

- **Manager/agent: common in all NMS (especially in SNMP/CMIP)**
- **Idea of a client/server, but many clients and only some servers**
  - **(manager ↔client; agent ↔server)**
- **The agent operates with the equipment**
  - **Reports problems to the manager, to control all the equipment information**
- **The manager contains the intelligence to decide what the agents should do, and gives instructions to them**
  - **It controls the agents and manages their interworking**

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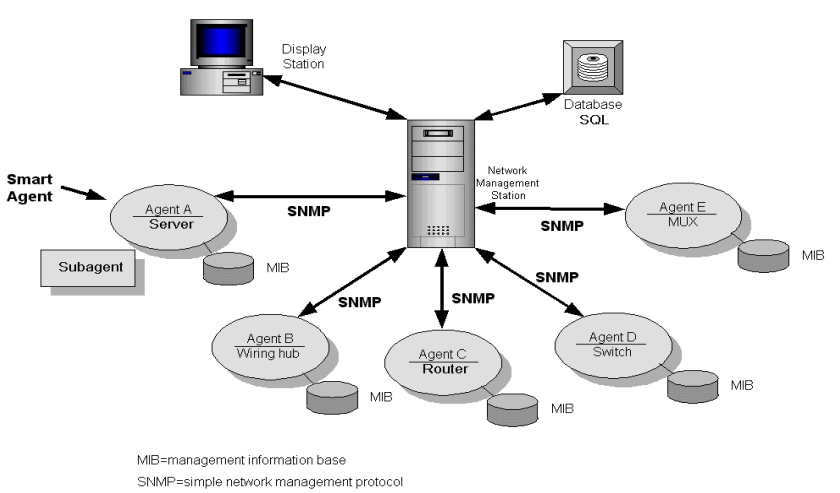
Structure of SNMP management



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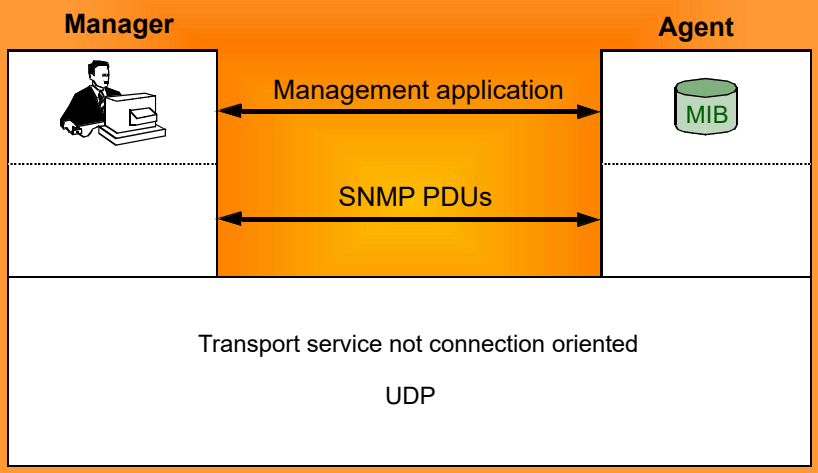
SNMP Structure



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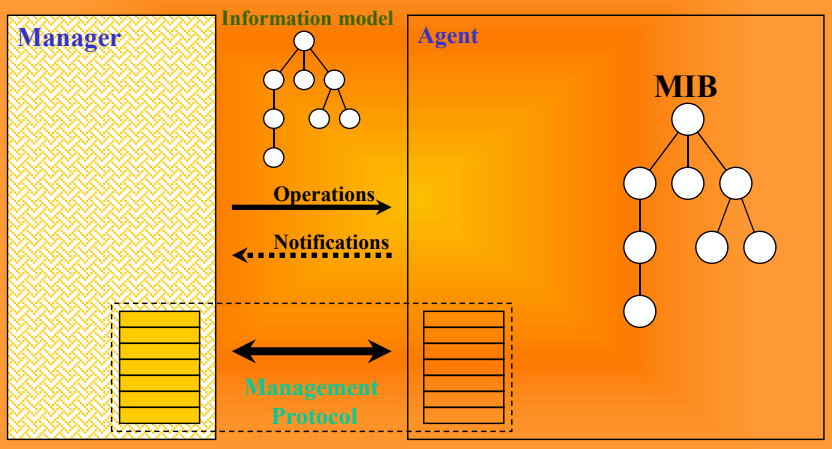
Manager/Agent model



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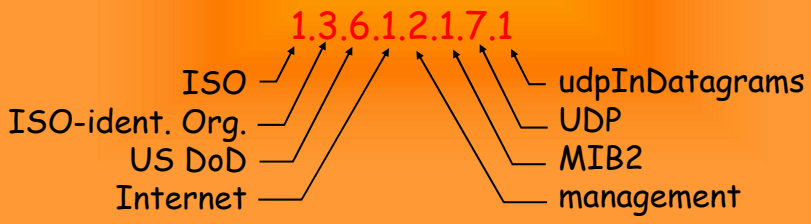
Names (numbers) SNMP

Problem: **How to name all possible objects (protocols, data, etc..) in all possible protocols??**

Answer: ***ISO Object Identifier tree:***

- **Hierarchical naming for objects**
- **Each node has a name and a number**



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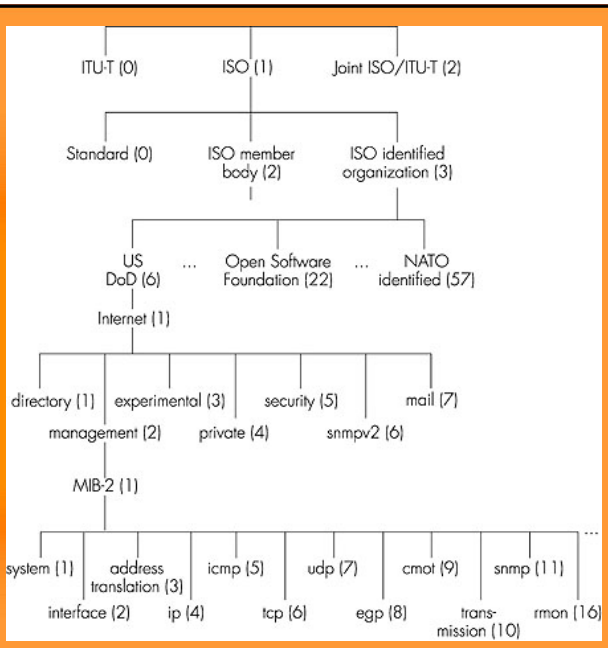
OSI Object Identifier Tree



www.alvestrand.no/harald/objectid/top.html

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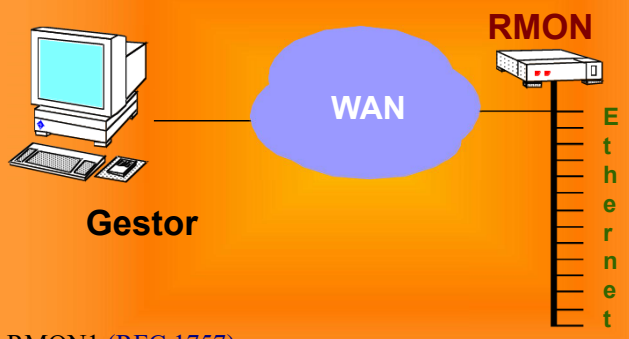
REMOTE MONITORING



- RMON1 (RFC 1757)
- Token Ring extensions to RMON (RFC 1513)
- RMON2 (RFC 2021)
- SMON (RFC 2613)

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RMON

- Remote monitoring MIB – measure network traffic
  - Agents – management interface
  - Probes – equipment for network analysis (promiscuous); usually configured to specific data types.
- Off-line operation (separated from the network)
- Preemptive monitoring, providing multiple information in the network.
- Support multiple managers and probes
- Detection and report of problems
- RMON has 9 groups:

  Statistics, History, Alarm, Host, HostTopN, Matrix, Filter, Packet Capture, and Event

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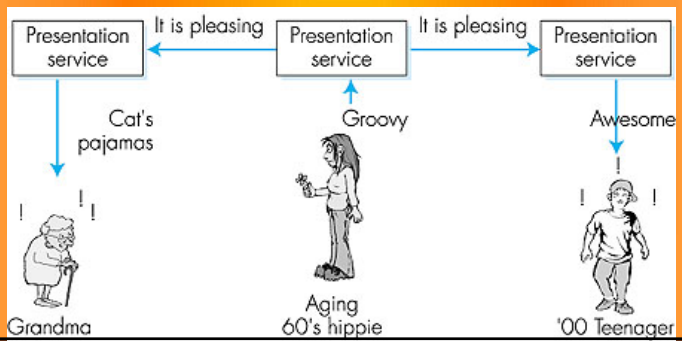
The presentation problem?

1. Translate the local format to a host-independente format.
2. Transmit the data in a host independente format
3. Translate the host-independente format in a format adequate to the new machine adequado à nova máquina.



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ASN.1

- ISO X.680 standard
  - Formal language to describe SMI
  - Frequent in Internet
  - "Heavy", but essential for heterogenous environments.
- Data types, object constructors
  - As in SMI
- BER: Basic Encoding Rules
  - Specified the format as ASN.1 data should be transmitted.
  - Each transmitted object has a coding Type, Length, Value (TLV) encoding

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TLV Coding

Idea: Data must be auto-identified
- T: data type, (ASN.1-defined)
- L: data lenght in bytes
- V: data, coded according with ASN.1 syntax.

Valor Tag	Tipo
1	Boolean
2	Integer
3	Bitstring
4	Octet string
5	Null
6	Object Identifier
9	Real

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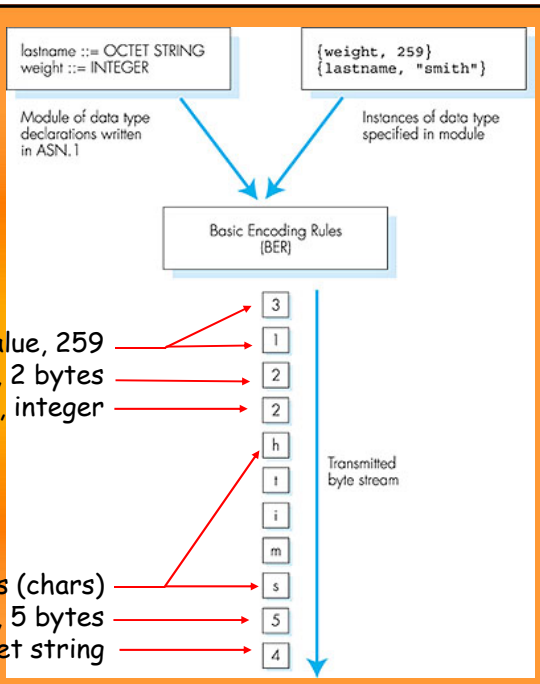
TLV coding example



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SNMP: Pros and Cons

- Agents widely used/known
- Simple to implement
- Robust e extensible
- Polling approach adequate to LAN objects

Critical requirement satisfied: available to be developed in the right time

- Very simple: does not scale
- Specifc semantics make its integration with other approaches difficult
- Large communication overhead due to polling
- Many specific implementations (private MIBs)
- In several management systems, small agents may be inadequate

Note that SNMP became a misnomer, referring both to the management protocol and the management framework. These are different things.

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PBM and COPS

Policy Based Management

Common Open Policy Service

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Policies - Example

- **Network with multiple services support**
  - **Differentiated QoS**
  - **Additional requirements in AAA functions**
    - Different levels
      - User
      - Service
      - QoS
- **Service authorized**
  - **only to some users**
  - **between authorized network points**
  - **with specific QoS requirements**
  - **between specific time intervals**
- **User also needs to be charged according to the service characteristics being received**

Management based on Policies

- **Objective: globally manage the network and not its elements.**
- **Mechanism:**
  - **Define policies (rules) to inform the network of what to do – e.g:**
    - Operation center should have access to all routers
    - Charging department has priority in the last 3 months of each year
    - In the maximum, only 10% of each link can transport video.
  - **The policy rules are translated in equipment configuration changes**

Elements of systems based on policies

Conceptual parts:

- **Management policy tools:**
  - Used to create the policy rules
- **Policies repository**
  - Store the policy rules
- **Policy consumers – *policy decision points*, PDP**
  - Make decisions and transfer the policy rules (eventually translated) to the policy targets.
- **Policy targets, *policy enforcement points*, PEP**
  - Functional elements affected by the policy rules.

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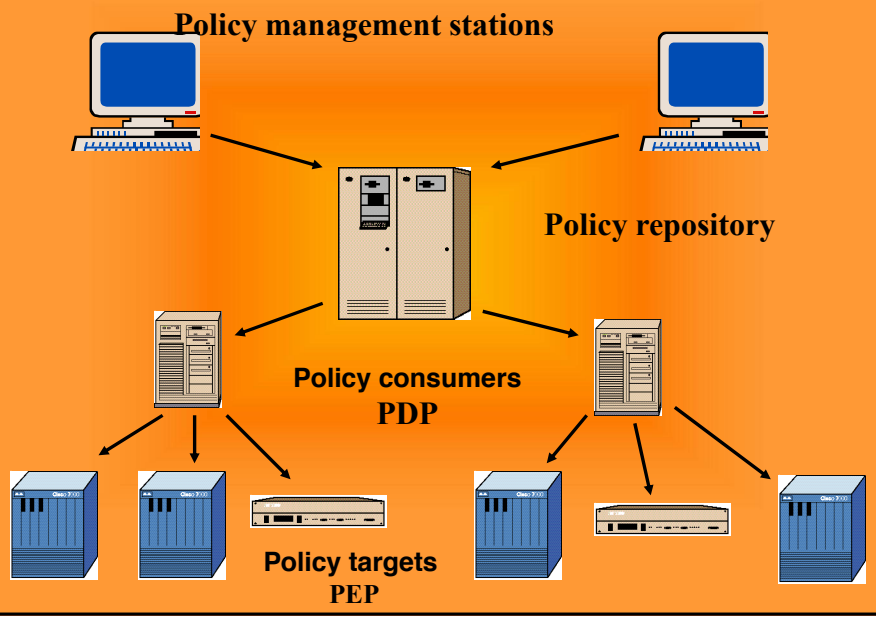
Policy management system - example



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Processing rules - sequence

- **Rules definition**
  - Verify internal conflicts
  - Include in a repository (e.g. with LDAP)
- **Get policies from policy consumers**
  - Take decisions based on policies
  - Processed to create configurations in policy targets
  - May use temporal restrictions
- **Send policies to policy targets**
  - Can be “pushed” or “pulled” (e.g. by COPS or SNMP)
- **Policy targets**
  - Instal configurations

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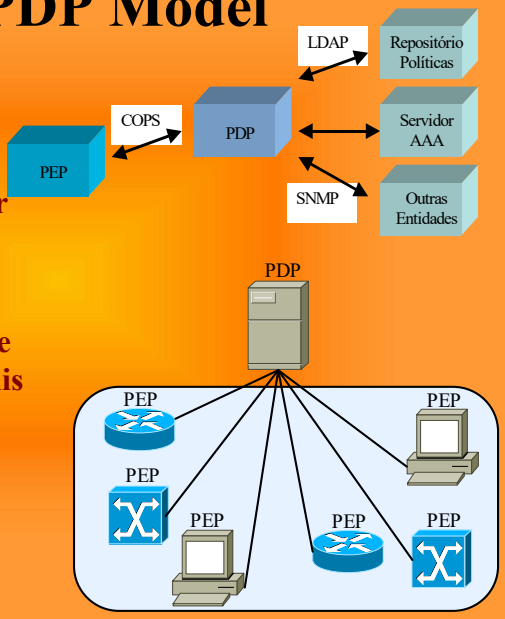
PEP-PDP Model

- Model uses (may use) different protocols
  - Abstraction levels differ
- Increasing trend
  - Software defined netwoking (SDN) can be seen as a variation of this concept

(OpenFlow is a protocol for SDN, replacing COPS in this context)



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COPS – Common Open Policy Service

- Question/answer protocol to PDP-PEP interaction
- Based on TCP
- Maintains state synchronization
  - Recovers from fault
  - State maintenance with keep-alive
- PDP can send notifications to PEP
- PDP can receive policies through LDAP and SNMP
- Supports two types of clients
  - RSVP, outsourcing model
  - Diff-serv, configuration model

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PDP-PEP Interactions

- Outsourcing (RSVP)
  - PEP contacts PDP when a decision is needed
  - Request contains relevant elements for the policy, and admission control information (e.g. flowspec)
- Configuration requests (Diffserv)
  - PDP configures PEP with specific equipment information
  - Considers a PIB (policy information base) that maintains provisioning information

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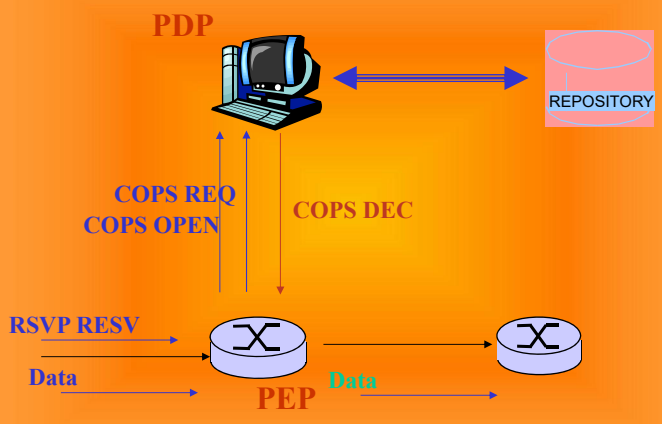
COPS with RSVP



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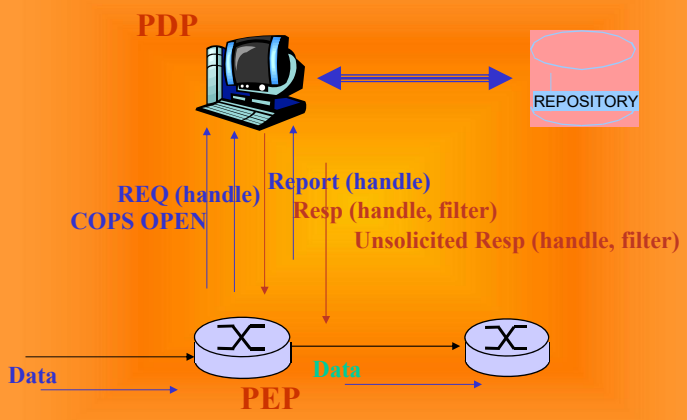
COPS with DiffServ



It is not required end-to-end signalling
It configures routers with packets lists and actions

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CMIS/CMIP

Common Management Information Services/Protocol

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Management protocolos (LAN-based)

OSI CMIP

- Common Management Information Protocol
- Designed in 1980's: *the* unifying protocol ("advanced") to network management
- Implemented very slowly

SNMP: Simple Network Management Protocol

- Internet based (SGMP)
- Very simple in the beginning
- Rapidly spreaded
- It grew in largeness and complexity
- actual: SNMPv3
- Management protocol *de facto*

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OSI Management architecture

ITU-T	Acronym	Title
X.701		*System Management Overview*
X.710	CMIS	*Common Management Information Service*
X.711	CMIP	*Common Management Information Protocol*
X.712	CMIP-PICS	*CMIP Protocol Implementation Conformance State Proforma*
X.720	MIM	*Management Information Model (defines fundamental concepts of the objects)*
X.721	DMI	*Definition of Management Information*
X.722	GDMO	*Guideline for Definition of Management Objects (techniques for specification of objects)*

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CMIS/CMIP

- Approach object-oriented - objects
  - Have attributes
  - Generate events/notifications (reliably)
  - Execute operations
- Objects with same attributes, notifications and operations belong to the same class
- Objects inserted in multiples hierarchies, with different inherits and containers
- Intelligent agents
  - Can use rules or policies defined by the manager
  - Can be changed on-line
- Actions (verbs)
  GET, SET, CREATE, DELETE, ACTION, NOTIFICATION, CANCEL_GET
- Capacity of CMIP actions is related to scoping and filtering capacities - through GDMOs

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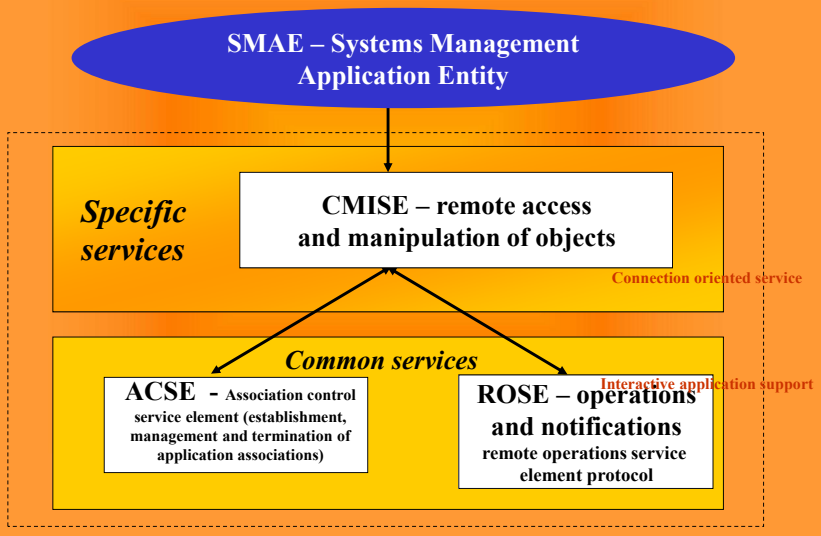
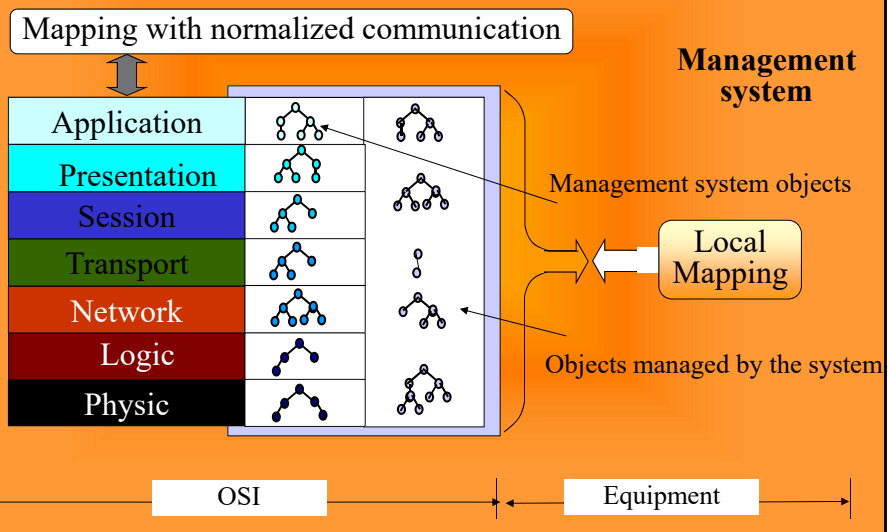
CMIP - GDMOs

- Guideline for the Definition of Managed Objects
  - The equipment through which the agent operates
- Model objects inside the equipment
  - Instantiation of GDMOs is called MIB
- Do not have well-defined behaviors, with large implementation freedom
  - Flexibility
  - Problem (complexity)
- CMIP is not polling oriented
  - Better scalability is achieved
- There are not so many defined GDMOs as MIBs

Common Management Information Service (CMIS)



OSI management architecture



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CMIP: pros and cons

- CMIP advantages
  - Object-oriented approach is flexible and extensible
  - Support from telecommunications industry and international vendors
  - Support of manager-manager interaction
  - Support of automation environments
  - Imposed in some industrial areas
- CMIP disadvantages
  - Complex and multi-layer
  - Large management overhead
  - Few management systems based on CMIP
  - Few CMIP agents in use
  - Generally rejected in the Internet.

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Frameworks: SNMP and CMIS

SNMP	CMIS
• Static MIBs • Concepts of limited models • Non-connection oriented protocol • Polling model • Implementation-oriented • Ligth • Limited functionalities • Bulk capcacity only in new versions • Completely dominating the market • Many SNMP-based products	• Dynamic MIBs • Object-oriented models • Connection-oriented protocol • Event-oriented model • Specification-oriented • Heavy • Functionalities until the system management level • Bulk capacity with scope and filtering • Some relevance in the telecommunications market • Some CMIP-based products in the market

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TMN

Telecomunications Management Network

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What is TMN ?

- **Defined in CCITT recommendation M.3010 and elaborated in the M.3xxx recommendations.**
  - **builds above the OSI- SM standards.**
- ***Objective***
  - **Support the management of the telecommunication networks and services**
- ***Concept***
  - **Create an organized structure to allow the interconnection of several operating systems and telecommunications equipments, using a well-defined architecture, with normalized protocols and interfaces**

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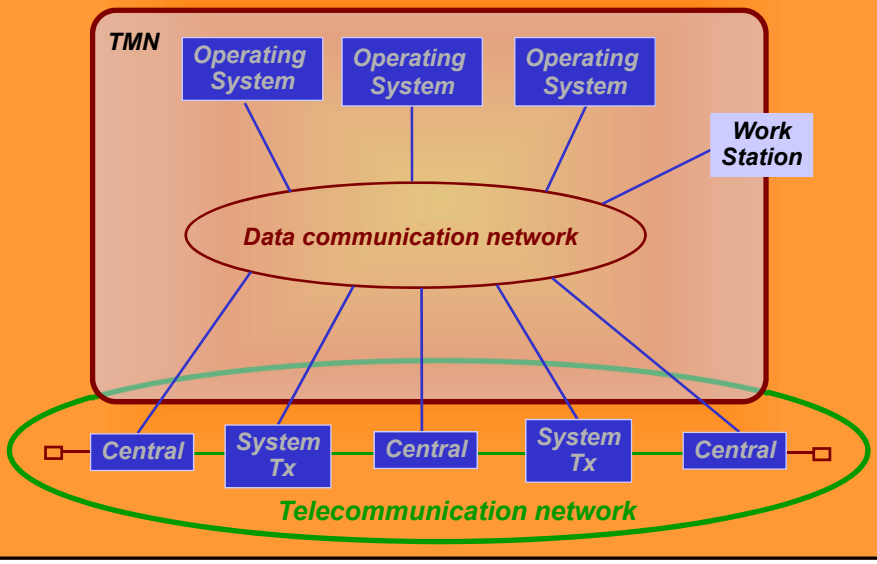
TMN and the communications network



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TMN

- **TMN is the telecommunications management network.**
  - **Relies on other management protocols and concepts.**
  - **Operations systems are where the main management functionality resides**
    - Now also known as OSS operational support systems
  - **The data communications network is where the management information flows**
  - **The TMN boundary intersects NEs (network elements) as they include some CM functionality.**
  - **Workstations provides user access to management functionality.**
    - The workstation glass interface is outside the bounds of standardisation.

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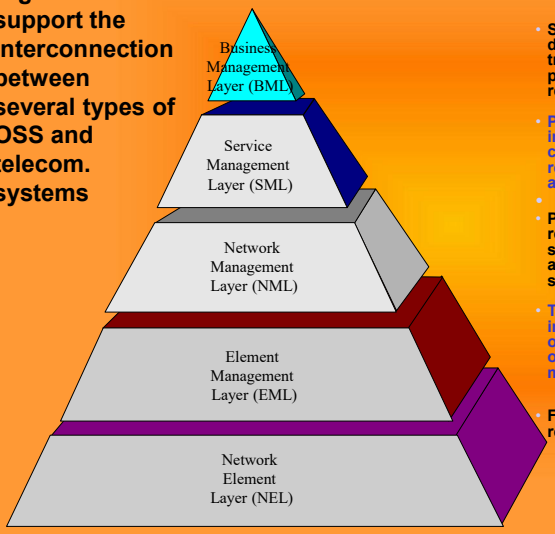
Multi-layer model

Architecture organized to support the interconnection between several types of OSS and telecom. systems



- Service levels, contact point for client reports, definition of policies for fault support, analyzes trends and quality issues, for example, or to provide a basis for billing and other financial reports
- Performs functions for the handling of services in the network: definition, administration and charging of services, scalability policies, service restore, monitoring and report of SLAs availability.
- Performs functions for distribution of network resources: configuration, control and supervision of the network, correlation of events and filtering, fault location, problem isolation, syslog management and monitor.
- This includes alarm management, handling of information, backup, logging, and maintenance of hardware and software, automatic correction of faults, polling of network elements, event management.
- Fault detection, trap generation, restoration/substitution procedures.

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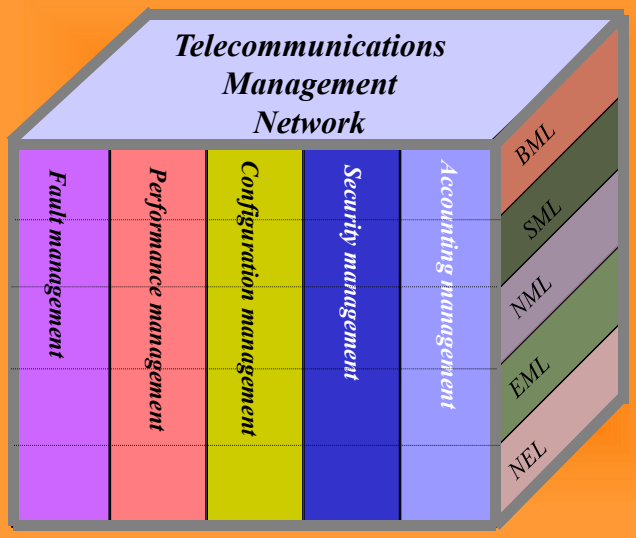
TMN Matrix



Depicts the FCAPS functionality along the TMN layers

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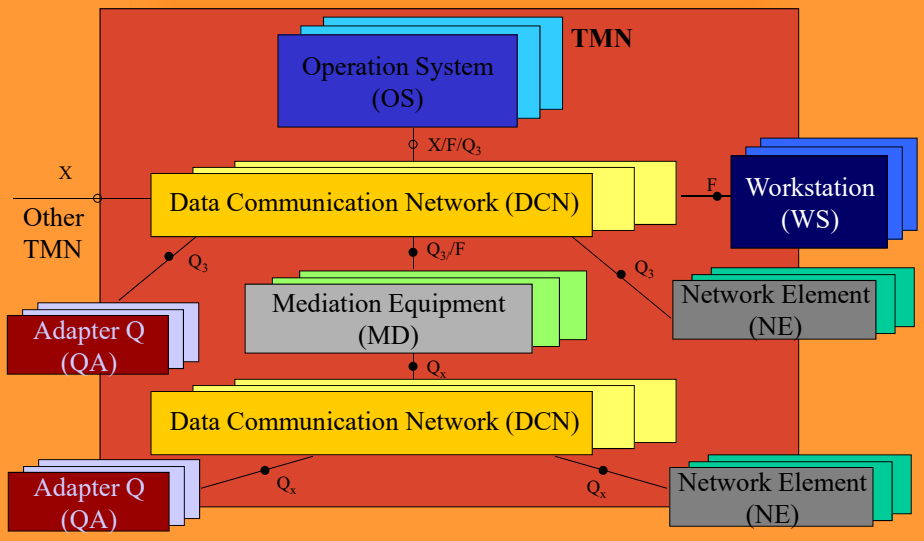
TMN Physical architecture



Reference points are exposed as interfaces (message and protocol parts) Notation - reference point lower case, interfaces upper case.

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Physical Architecture

Standard interfaces

- Interface Q_3
  - Operation System ↔ TMN elements connected to it
- Interface Q_x
  - Mediation Element ↔ Network element/adapter
- Interface F
  - Workstation ↔ Operation system / mediator (through a DCN)
- Interface X
  - TMN network ↔ TMN network / network with *interface* to TMN.

- **Communication protocols**
  - For each interface, the choice depends on the physical implementation.
  - It is normal to use CMIP protocol in the Q_3 interface.

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TMN Information model

Similar to OSI Information Model :

- Re-using of classes and templates
- Classes definition of generic objects.

Generic Network Information Model (GNIM)

- **Object classes defined by GNIM, relative to transport networks:**
  - Network fragment
  - Fragment of managed element
  - Fragment of termination point
  - Fragment of transmission
  - Fragment of *Cross-Connection*
  - Fragment of functional area
- **There are also object classes for other technologies (RDIS, SDH, ATM and mobile networks)**

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TMN and OSI

- TMN adds-on to OSI management

- **Information model – new network**
- **Organization model – extension through the concept of functional block**
- **Communication model – Correspondence between interface - protocol**
- **Functional model – new management functions (network)**

- Interworking TMN with other OSI systems

- **Atenuate differences between protocols**
- **Services functionalities and complementaring functions**
- **Increase the OSI management potentialities or restrict the TMN management potentialities**

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New network challenges

Bringing IT to networking

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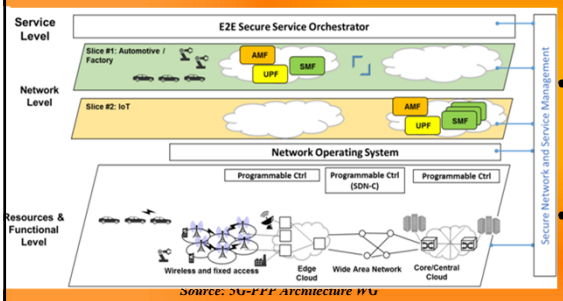
Future networks
Emerging Architecture and Enabling Technologies

Architecture Themes:
Flexibility, Scalability



Source: 5G-PPP Architecture WG View on 5G Architecture (Version 2.0)

- **Network Function Virtualization**
  - **Network realized in software: Core and RAN**
  - **Cloud resources throughout the network**
- **Programmable Network**
  - **Flexible orchestration of network resources and infrastructure: RAN, core, transport, etc.**
- **Network Slicing**
  - **Self-contained, independent network partition including all segments: radio, core, transport, and edge.**
  - **Multi-domain, multi-tenant**

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Cloud computing

"Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources […] that can be rapidly provisioned and released with minimal management effort or service provider interaction."

— NIST

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CC Essential characteristics

1. **On-demand self-service**
   - Dynamic usage of services, on-demand.
2. **Rapid elasticity**
   - Add and remove computational capability easily
3. **Ubiquitous network access**
   - Services (usually) accessible from the Internet
4. **Resource pooling**
   - Multiple customers can access the same resources
5. **Measured service**
   - Service usage is measured and reported, with cost usually in as pay-as-you-go

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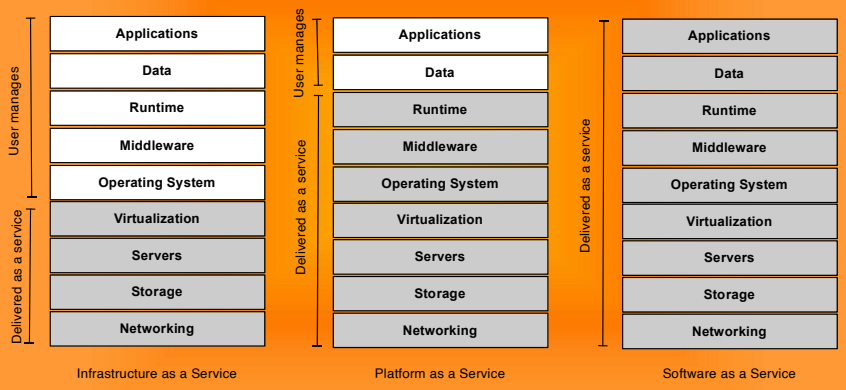
Delivery models



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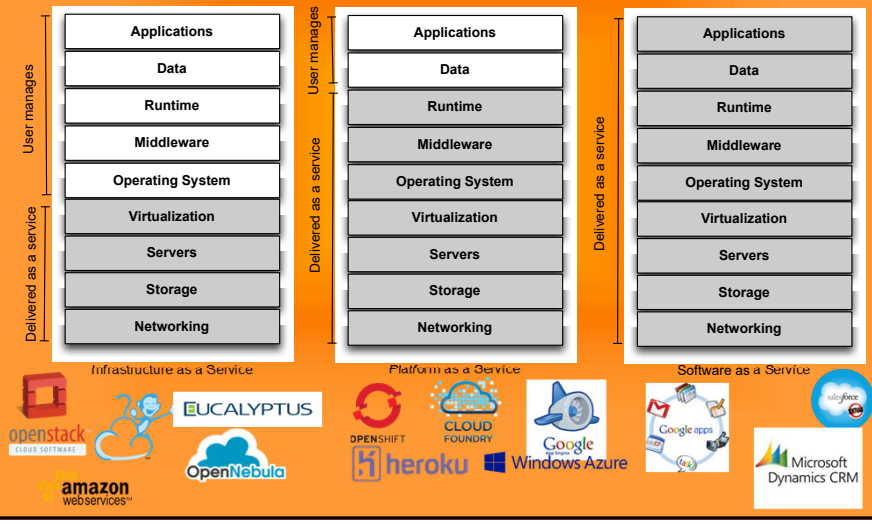
Delivery models



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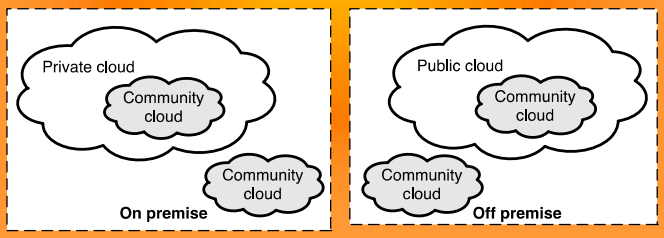
Deployment models

- Public cloud
- Private cloud
- Community cloud
- Hybrid cloud

- On-premises
- Off-premises



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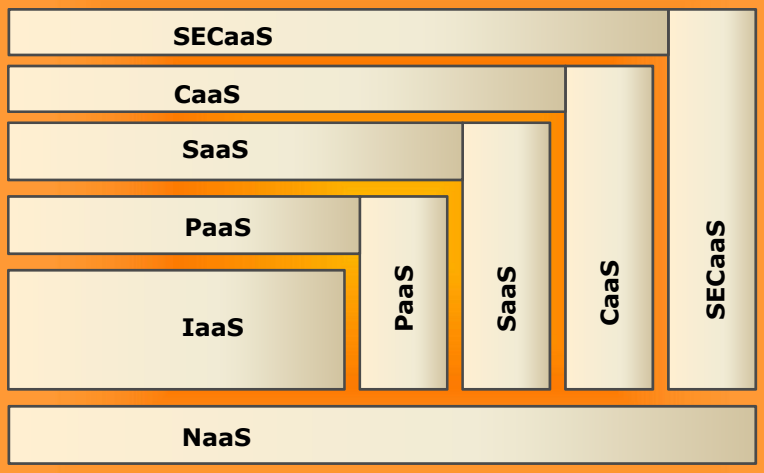
Overall: Cloud Services

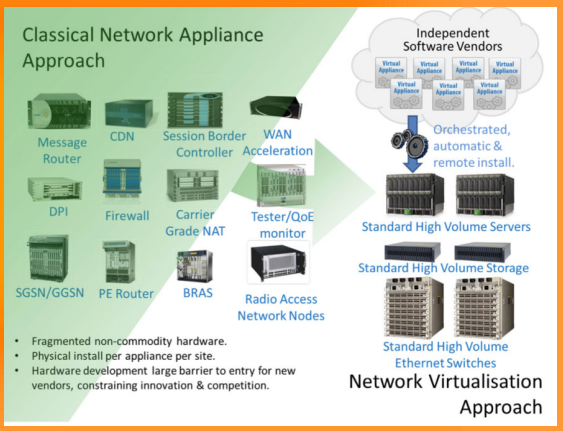


Network as as service relies on SDN – software defined networking – and NVF – network function virtualisation

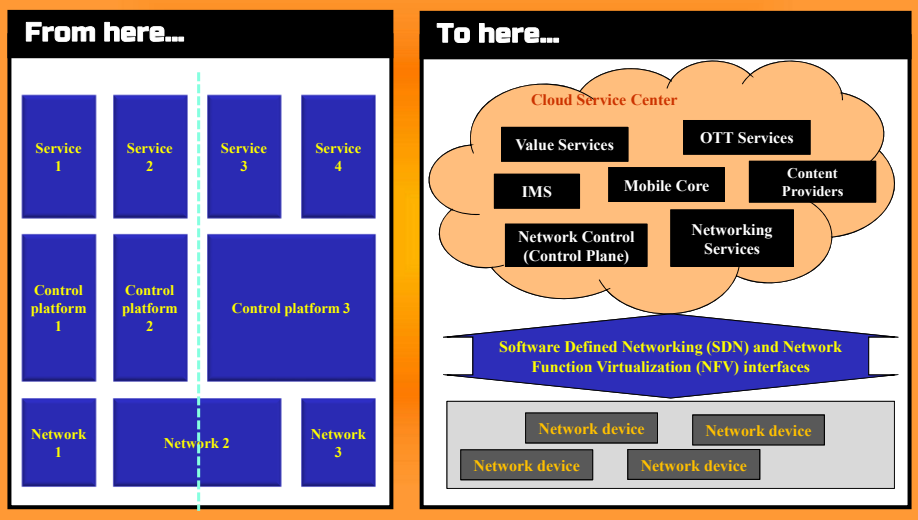
Networks require (complex) infrastructure

–Current infrastructure.
- Current network equipment designed for special use case

–Software Defined Networking and Network function Virtualization:
- Special use cases as software release running on top of standard hardware
- Virtualization will become a key issue to reduce OPEX and CAPEX



Evolving complex infrastructure



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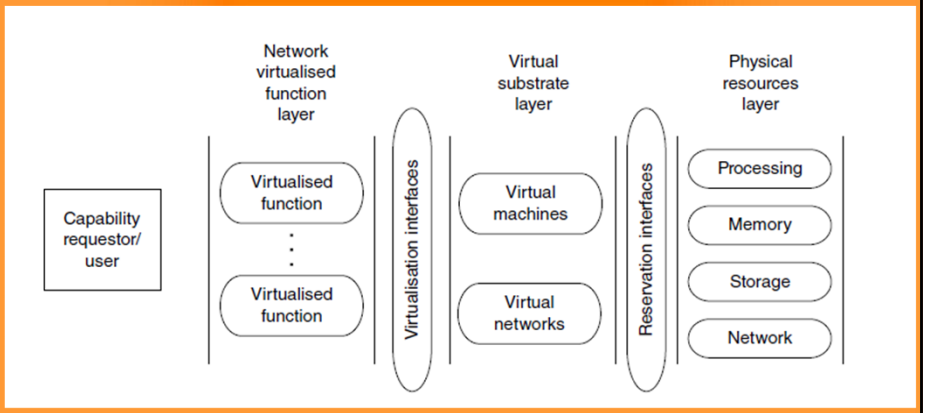
The NFV concept



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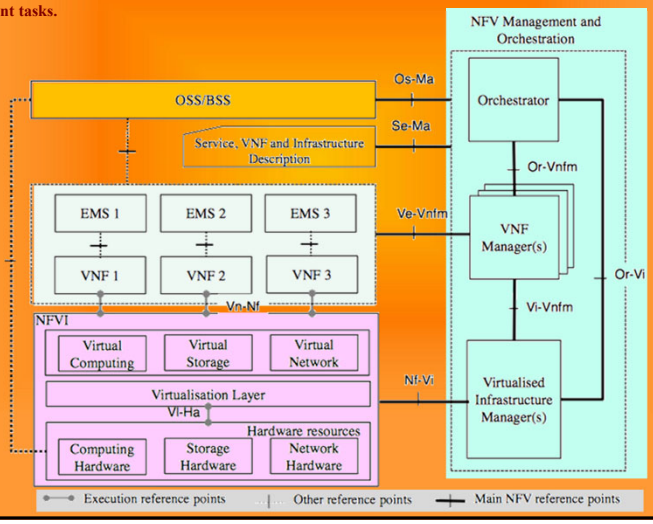
ETSI NFV

High-level functional architecture for virtualised network functions and the underlying virtualisation infrastructure.

NVF M&O: orchestration and lifecycle management of physical and/or software resources that support the infrastructure virtualisation and lifecycle management of VNFs. Focused on the virtualisation-specific management tasks.

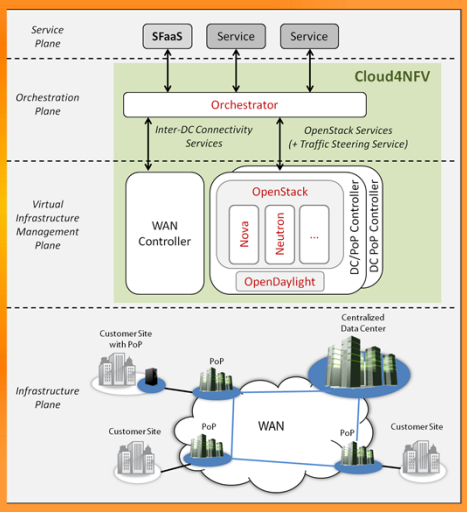


Source: ETSI

Cloud4NFV

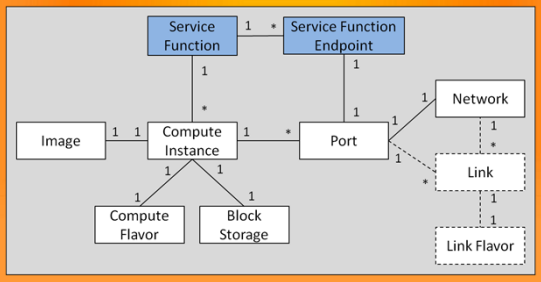
Platform built to allow Service Functions to be managed in *a as-a-Service* basis

- **Automated deployment, configuration and lifecycle management**
- **Federated management and optimization of WAN and cloud resources for accommodating SFs**
- **Supports composition of SFs through Service Function Chaining**



Virtualised Network Function

- **VNF - Software implementation of a network function capable of running over the NFV Infrastructure**
  - **Pure software free from hardware dependency**
  - **Service Function: represents an instance of a functional block responsible for a specific treatment of received packets that has well-defined external interfaces – *Service Function Endpoints* (SFEs).**
  - **Service Function Endpoint (SFE): represents an external interface of one SF instance that is always associated to a SF. Each SFE can have associated information regarding layer 1 (e.g. physical/virtual interface), layer 2 (e.g. MAC address) and/or layer 3 (e.g. IP address), or even regarding higher layers (e.g. HTTP).**



SF data model towards a Cloud infrastructure

Service Function Chaining

SFC

- ***An ordered set of Service Functions that must be applied to packets and/or frames selected as a result of classification***
- ***Defined by an orchestrator***
- ***Based on service requirements***
- ***Reliant on existing VNF***

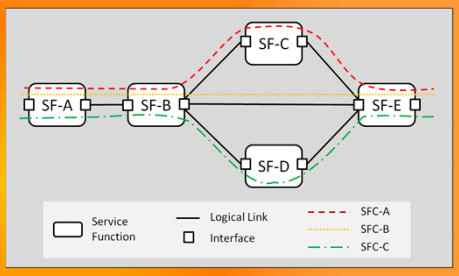
Service Function Chaining

In SFC two aspects are vital:

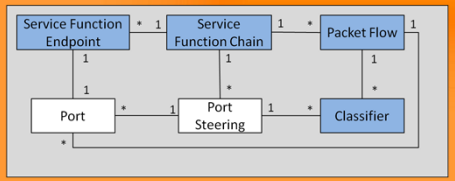
- **Classification**
- **Traffic Steering**

Combination of classification and traffic steering can be done in two ways:

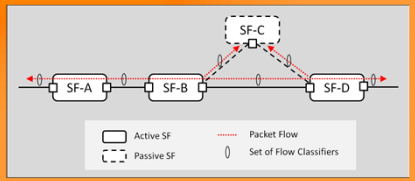
- **Tagged packet approach**
- **Non-tagged packet approach**



SF composition example



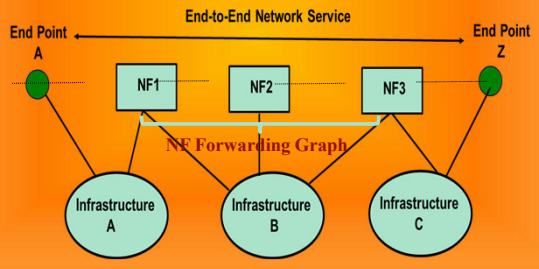
Service Function Chain data model towards a Cloud Infrastructure



Non-tagged packet approach; Active and Passive SFs

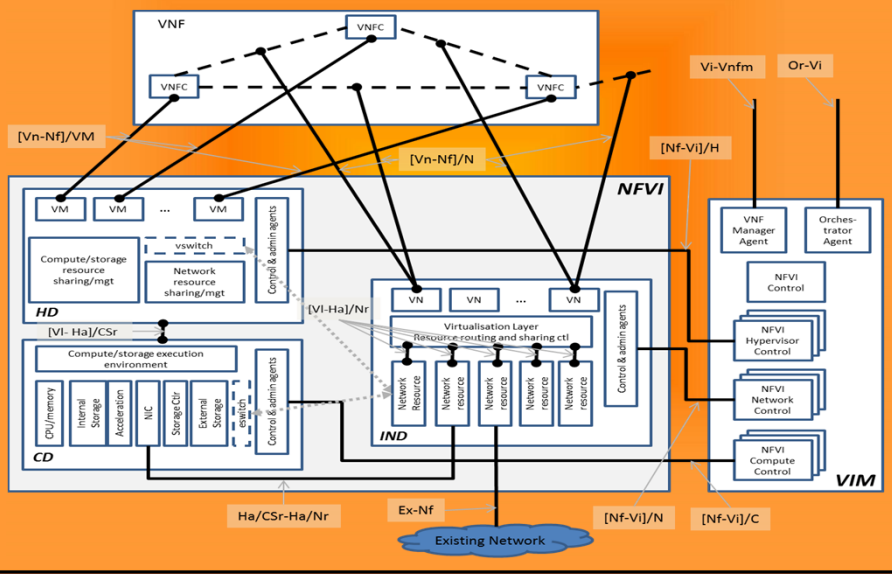
ETSI GS NFV 002 v1.1.1

- NFs are connected by logical links
- End points are connected to NFs via infrastructure resulting in a logical interface between end points and NFs



NFV Reference Architectural Framework

(ETSI GS NFV-INF 004 V1.1.1 (2015-01))



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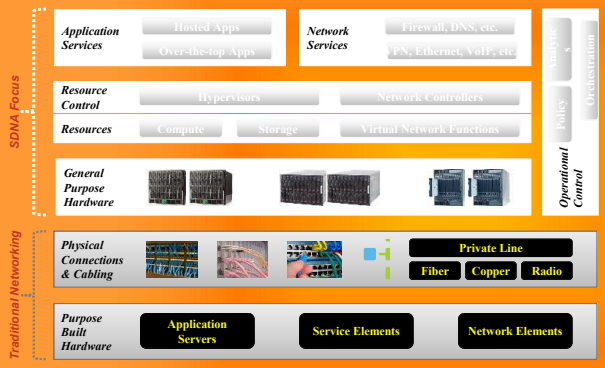
Traditional Network vs. SDN/NFV Network



Virtualized Networks

- General purpose cloud-based hardware components
- Software-based virtual network components and services
- Dynamic real-time configuration to support internal or customer activity
- Programmable network management
  - Software Defined Network controls
  - Real-time analytics and policy driven orchestration of service, network and capacity requests

Traditional Networks

- Built using purpose-built hardware coupled with physical connectivity
- Control logic largely coordinated and implemented by layers of OSSs
- Control, Forward and Data Planes are tightly integrated in Network Elements
  - OA&M, inventory views and operational controls managed in OSSs to avoid negative impact to service performance

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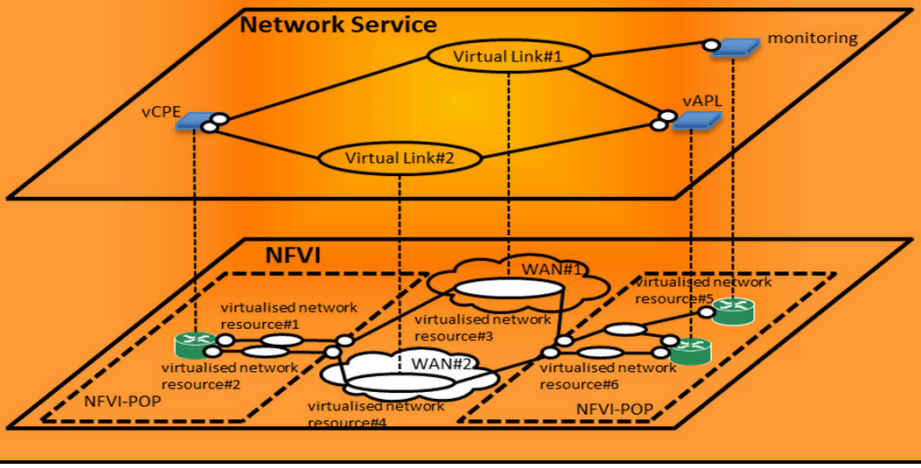
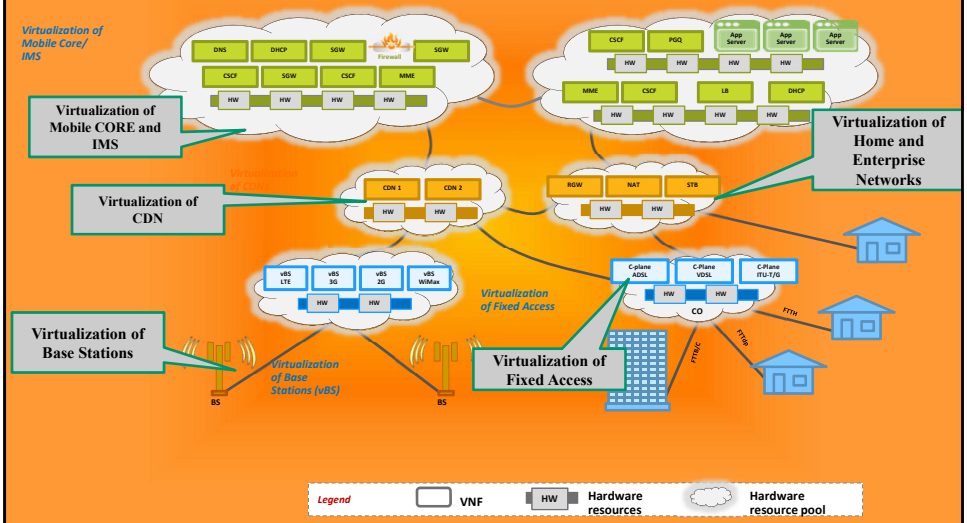
Connectivity overview

enabling End-to-End Network Service across two WANs



Overview of NFV (Network Function Virtualization) Sample Use cases



Management architectures and roles

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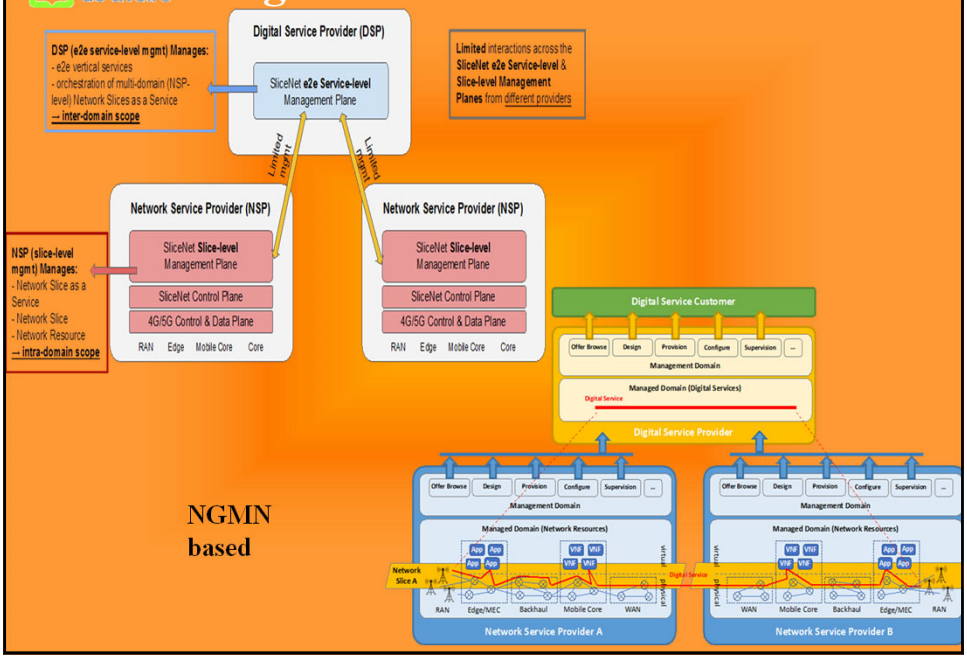

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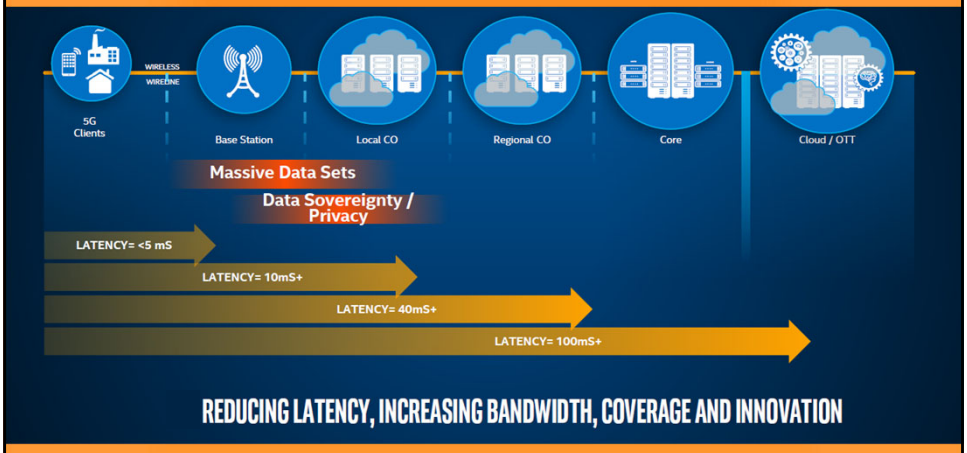
Network as a set of distributed datacenters



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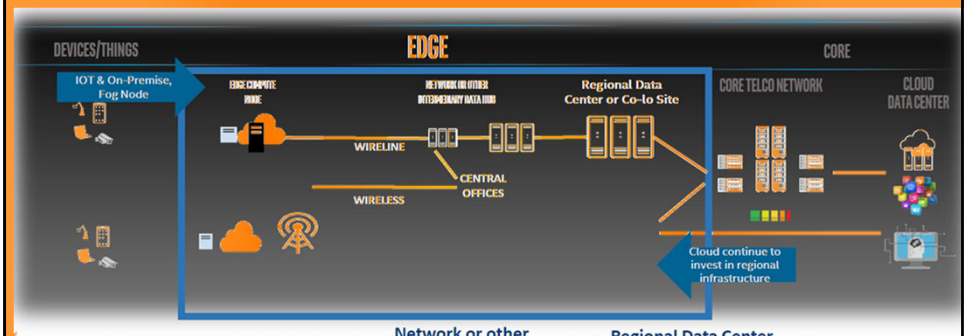
The role of "edge"



Edge Compute Nodes
Millions of on-premise sites; Typically virtualized servers, gateways, and traditional Routers/Switches/Appliances

Network or other Intermediary Data Hub
Access points & traditional network infra; transitioning to virtualized servers providing infra. & compute (NGCO)

Regional Data Center or Co-lo Site
Typically virtualized servers

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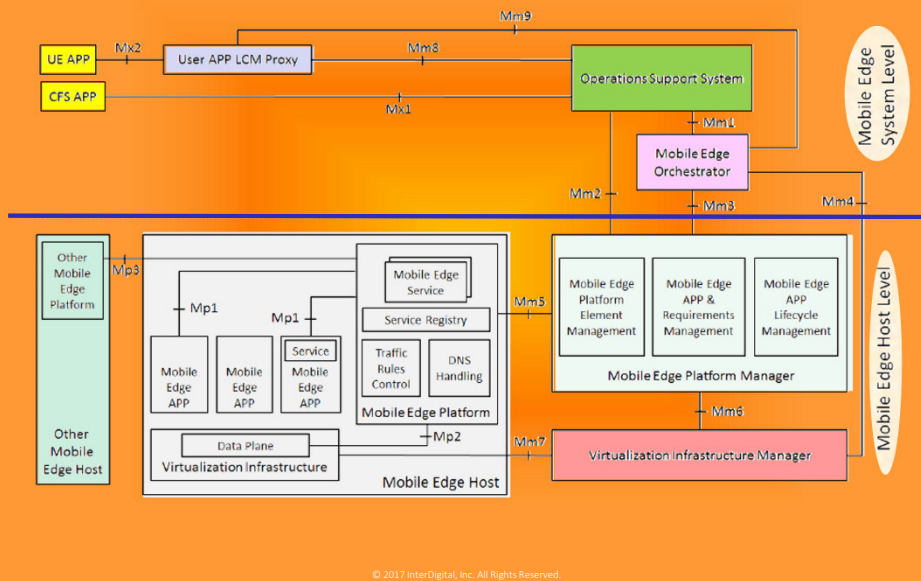
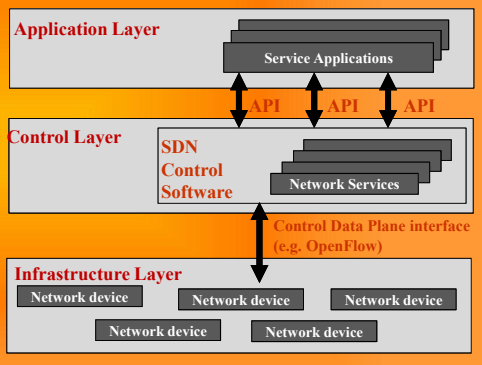
The (limited) ETSI view on MEC



The "new" purpose of SDN and NFV

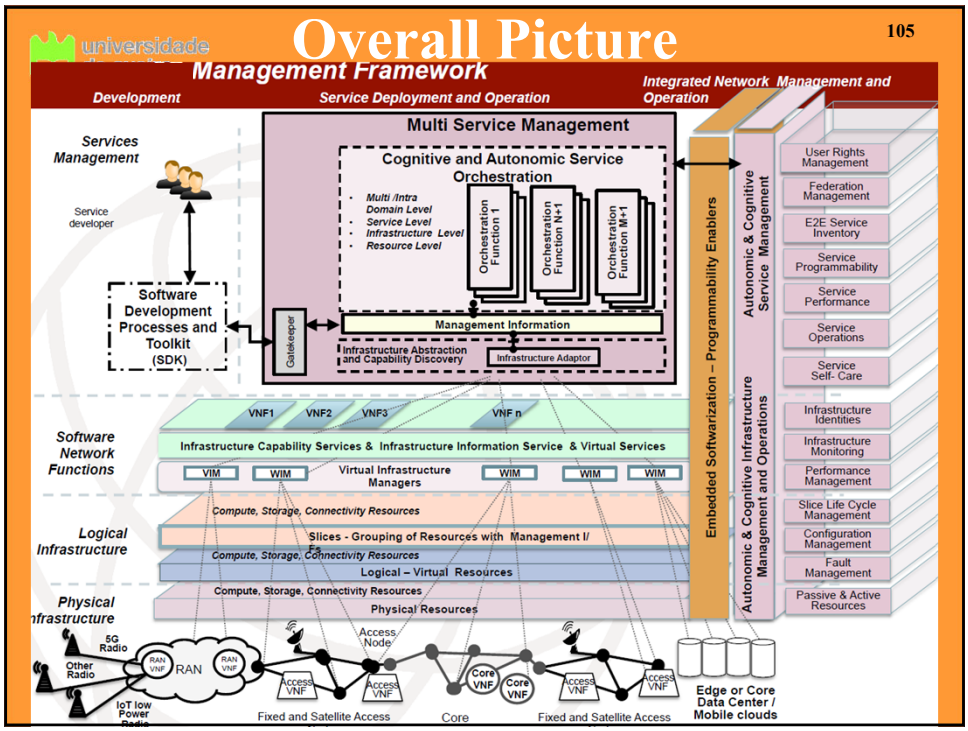
Split of the control plane from the user/data plane

- User/data plane implemented by standard (low-cost) equipment
  - Reduction on the HW cost
- Control plane implemented in the cloud – Network Function Virtualization – with standardized and open interfaces to services/business applications
  - Easy service development
- Software maintained by the operator
  - Change on the value and revenue model



Source: ONF (Open Network Foundation)

Overall Picture



Open Source Networking Landscape

[source: Linux Foundation – Arpit Joshipura]