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Gestão/Management

Management of Local and Global Networks

Concepts and Protocols

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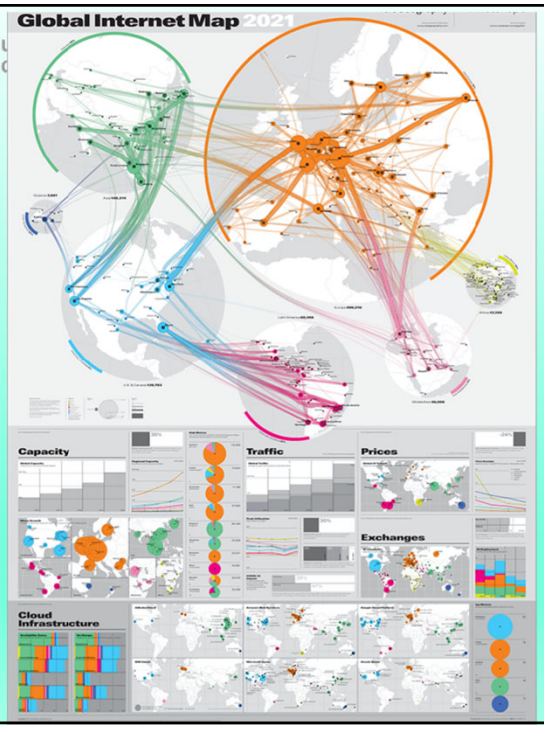

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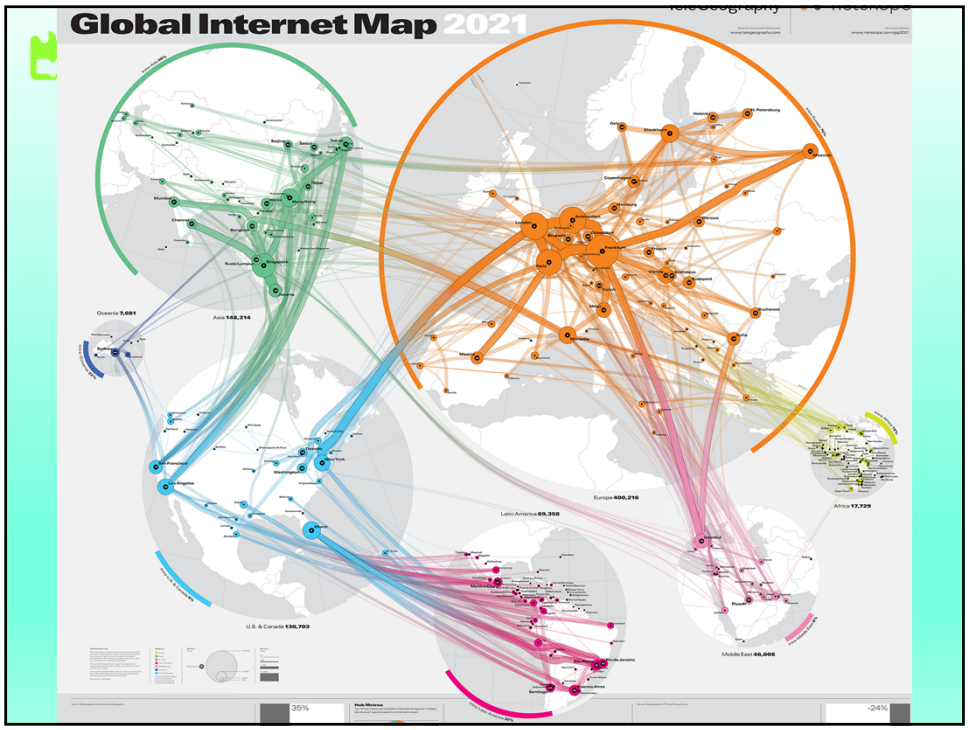
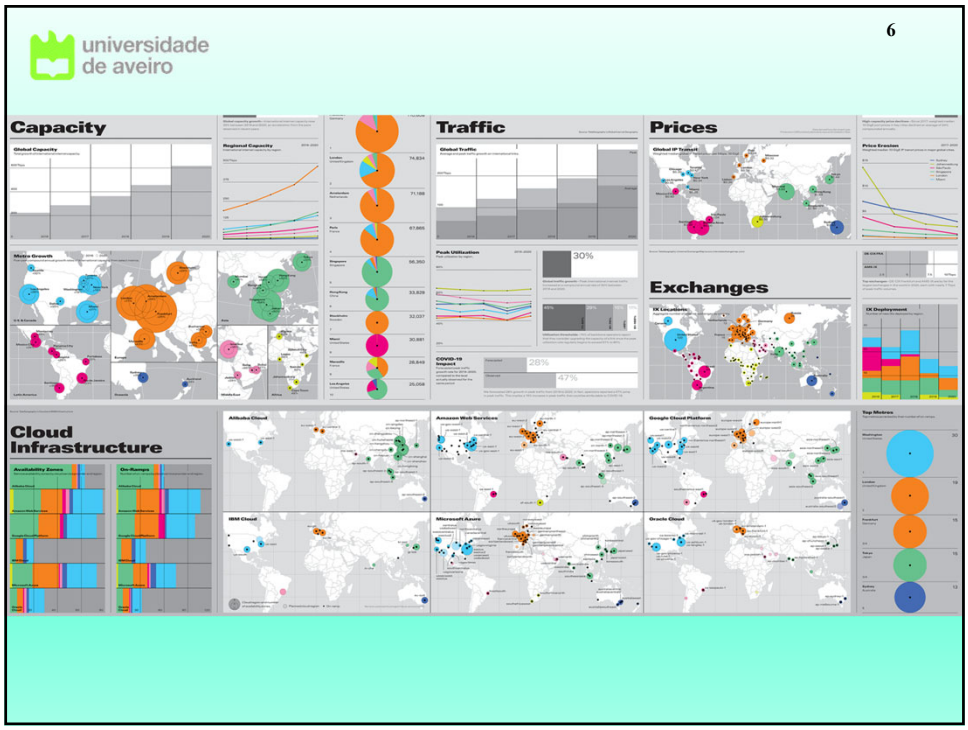

Global Internet Map 2021
Oceania 7,681
Asia 140,214
Europe 400,216
Latin America 69,358
U.S. & Canada 130,703
Middle East 46,008
Africa 17,729
35%
-24%

5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6
Capacity
Traffic
Prices
Exchanges
Cloud Infrastructure
30%
28%
47%

6

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Why Networks and Systems Management?

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- 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

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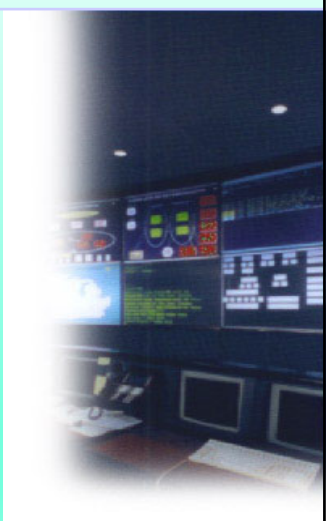
- **Problems need to be quickly solved**
- **Management systems simplify the work of multi-functional networks (e.g. VoIP in multiple networks)**
- **Persons better used – they do not need to perform repetitive tasks**
- **Companies need to optimze their structures, and network management allow resources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



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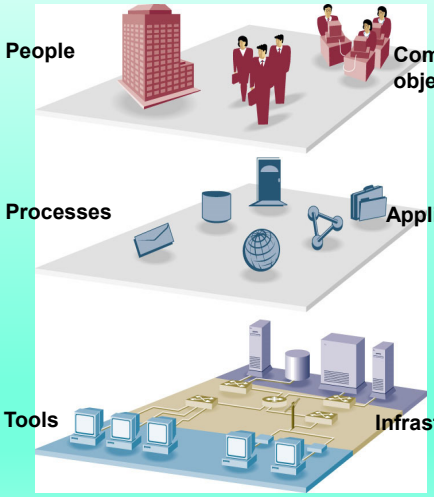
9

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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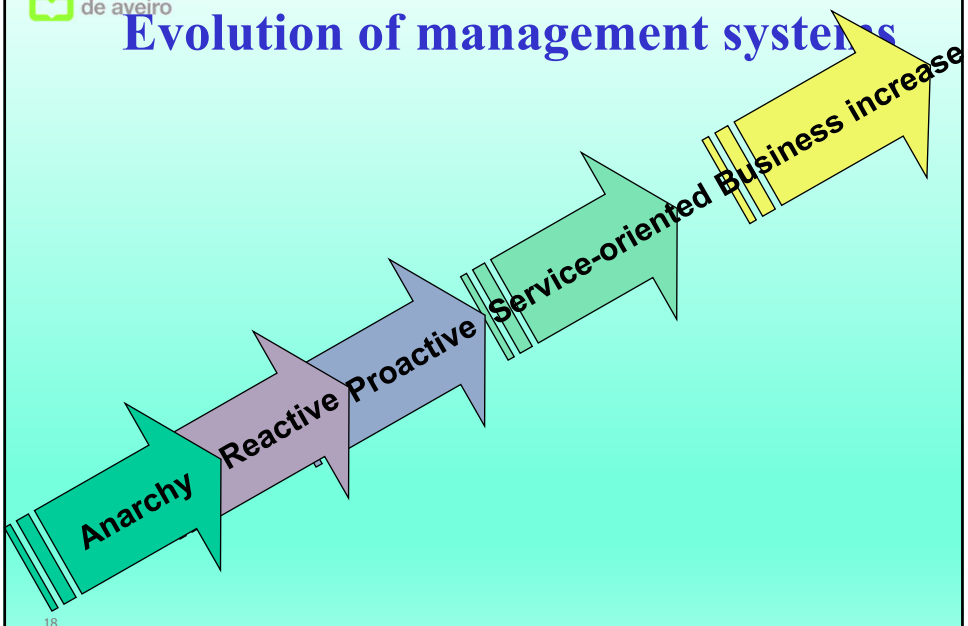
Evolution of management systems



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Management alternatives

scope

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

comunication protocol

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

Decision model

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

Current real management structures very complex, with several operational models simultaneously

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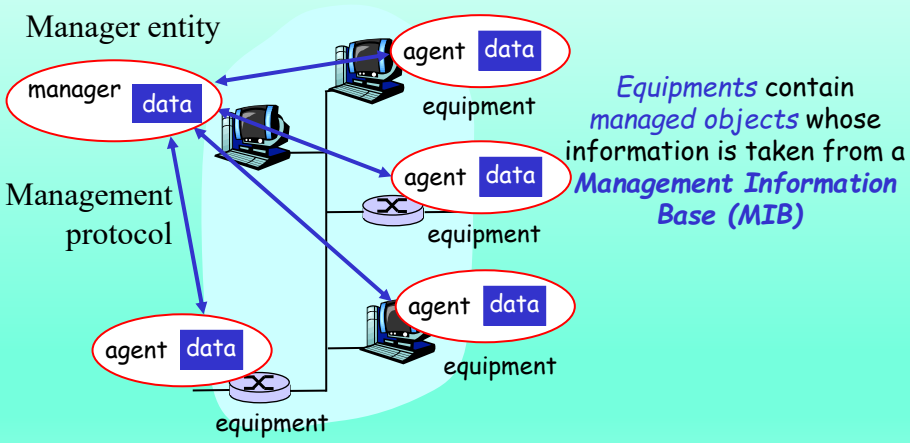
Basic Model for Network Management



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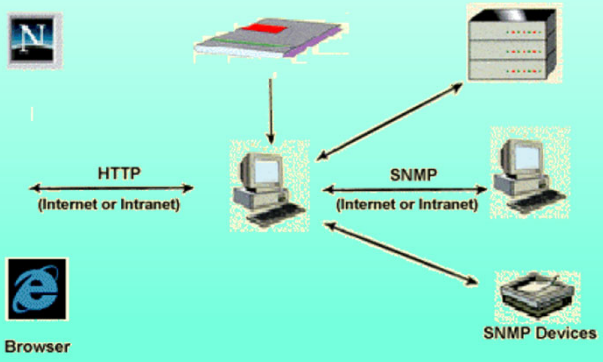
WEB-based management



Very common:
Network and device management via web interfaces

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Web-based management concept

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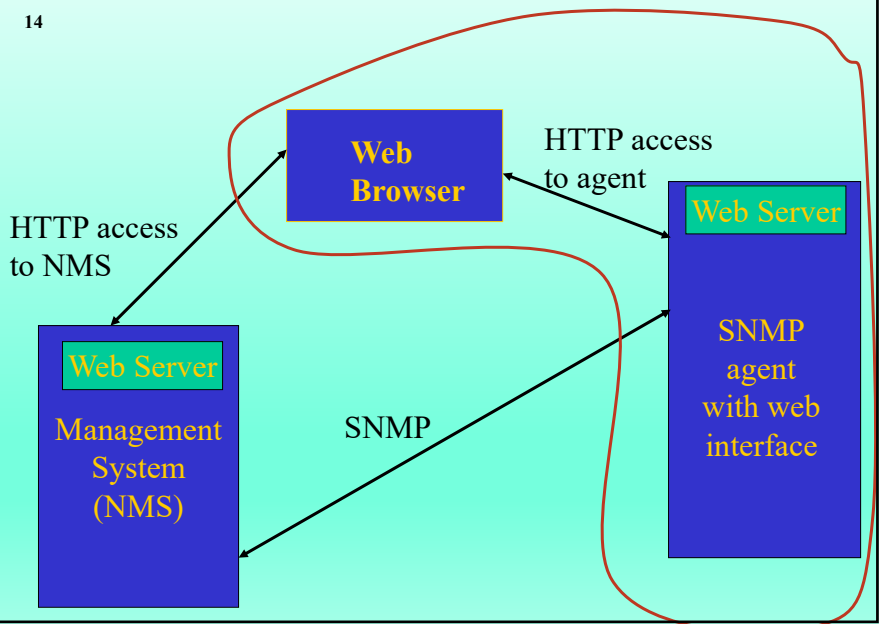

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Network management

- 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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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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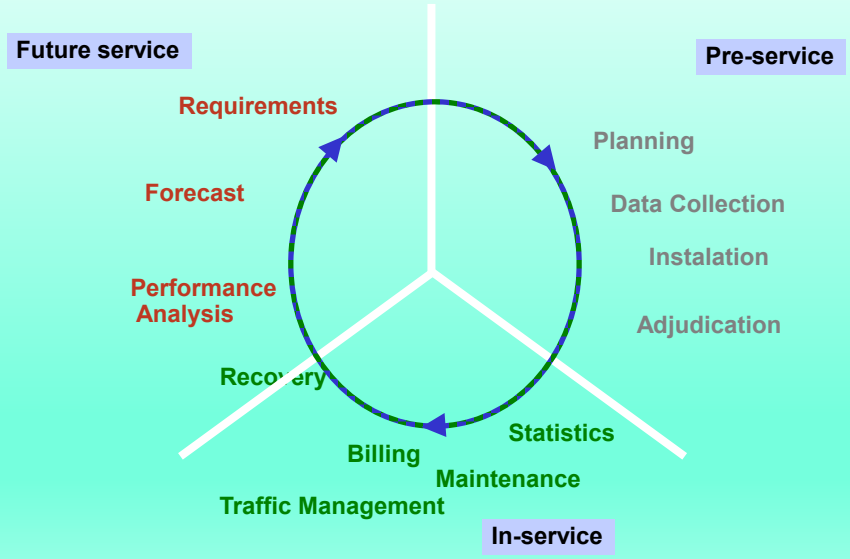
Management Life Cycle



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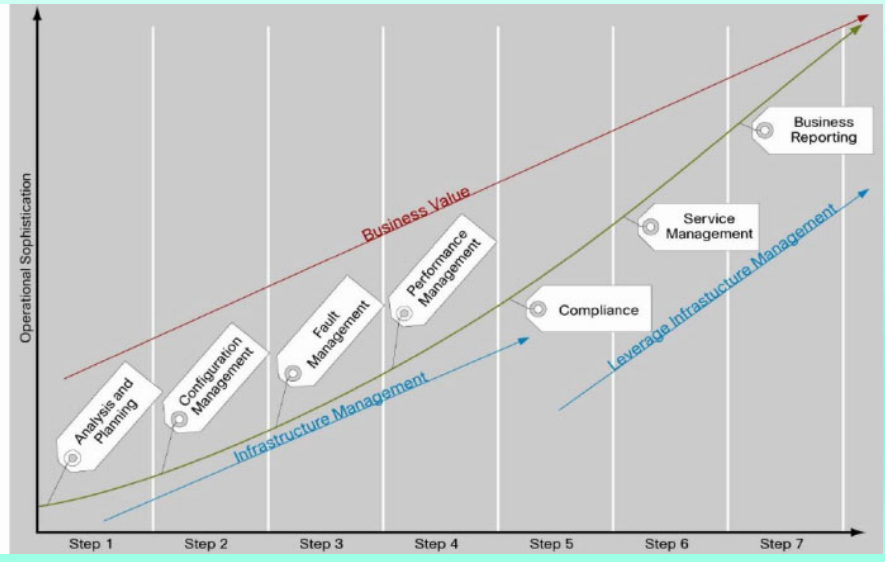
Implementation plans



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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

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Management protocols

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

Simple protocols ² common data and parameters formats allowing easy information transfer

Complex protocols ² add flexibility and security capacity

Advanced protocols ² remotely execute network management tasks, without depending on specific protocol layers

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Tools for network management

- WAN/LAN monitoring and analyzers
- Software monitors
- Security managers
- Documents, presentations and administrative instruments
- Tools for cross-analysis
- Databases, tools for information management
- Console emulator
- Tools for systems modelling
- Toolkits for development

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Network management standardization global models

- 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, …

Early discussions across bodies. Now cooperation is the normal across bodies.

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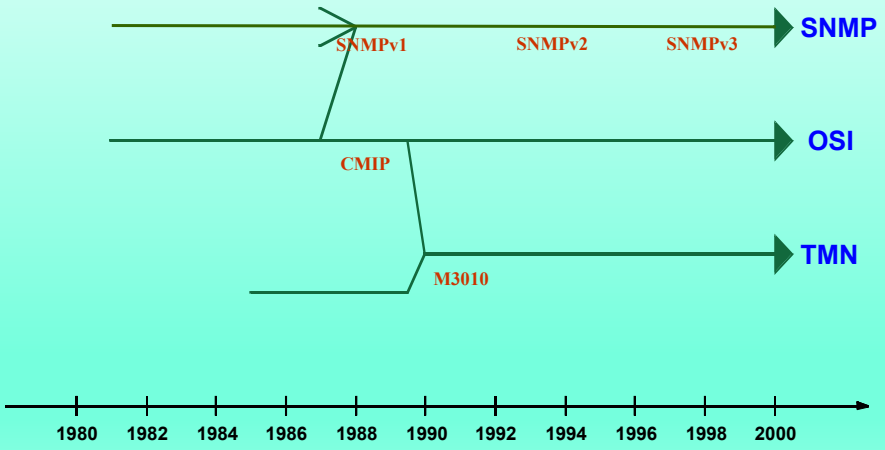
Early Cronology

(why we reached here)



Note that concepts are different: SNMP copes with part of the OSI management framework, and the TMN expands the OSI framework into a focused environment (telecomunication operators)

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TMN

Telecomunications Management Network

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What is TMN ?

- *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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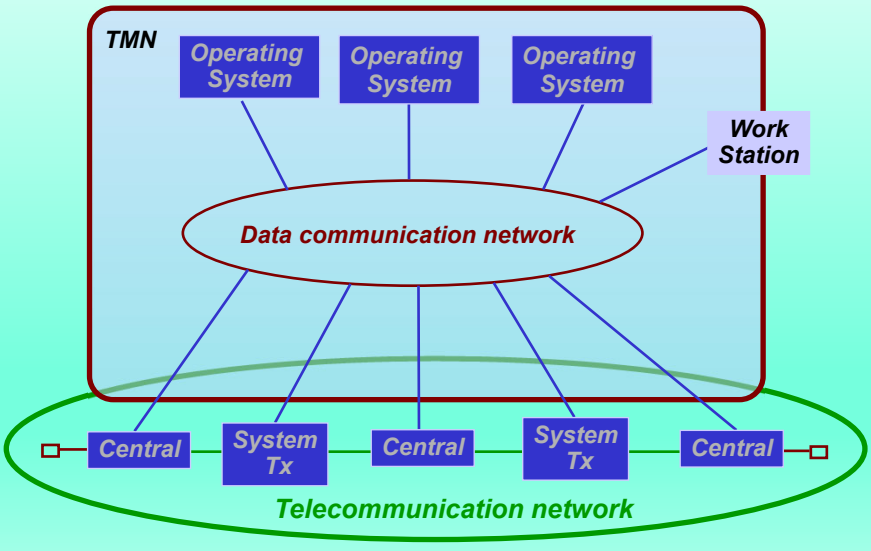
TMN and the communications network



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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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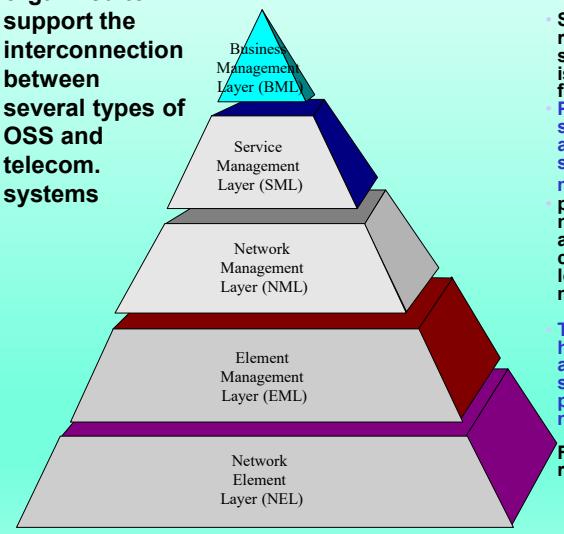
Multi-layer model

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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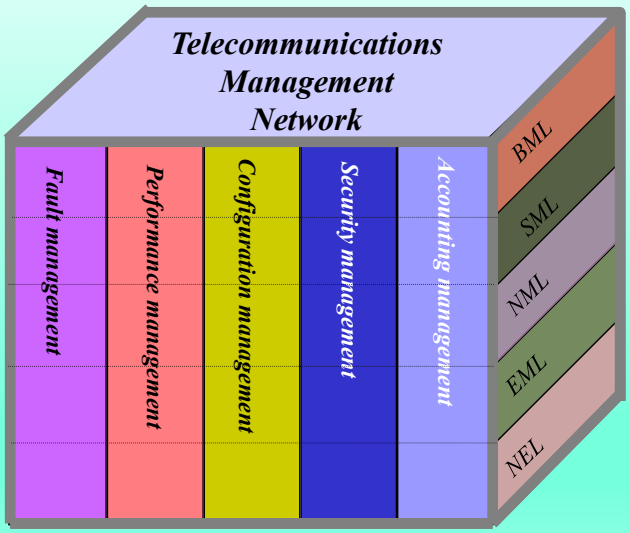
TMN Matrix



Depicts the FCAPS functionality along the TMN layers

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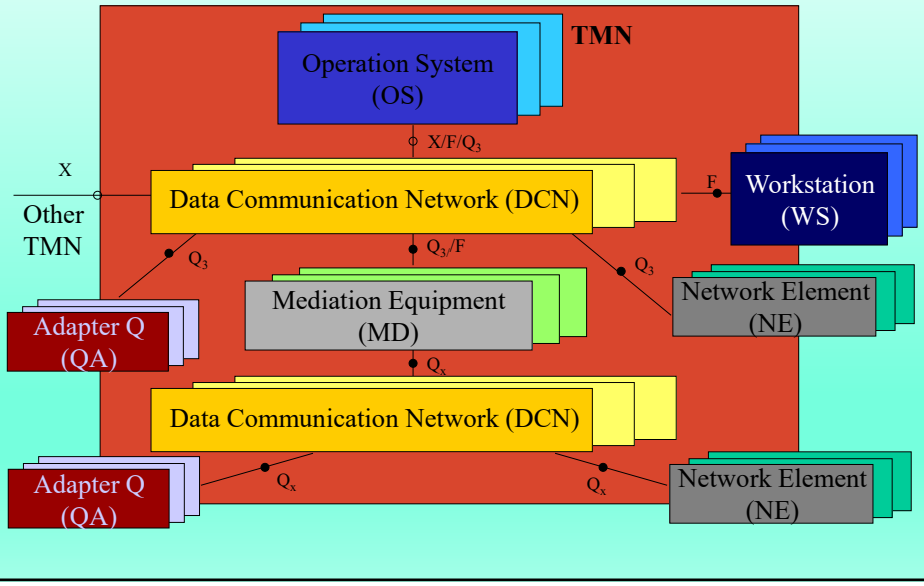
TMN Physical architecture



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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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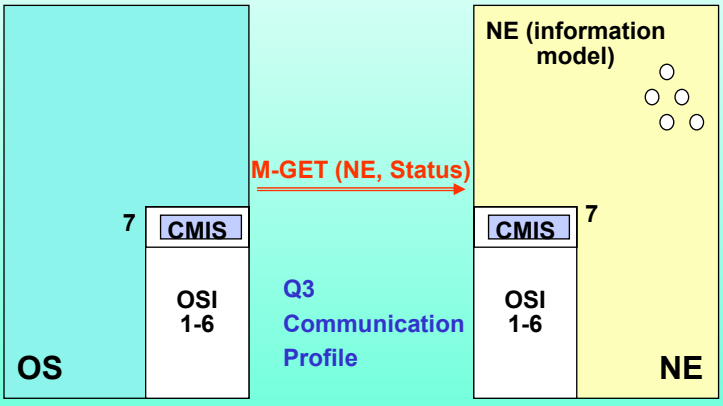
TMN: Interface Q3



Q3 Interface is supported by CMIS/CMIP!!

The scope of the available access is defined by the NE information model (its MIB)

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CMIS/CMIP

Common Management Information Services/Protocol

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Management protocolos (LAN-oriented)

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

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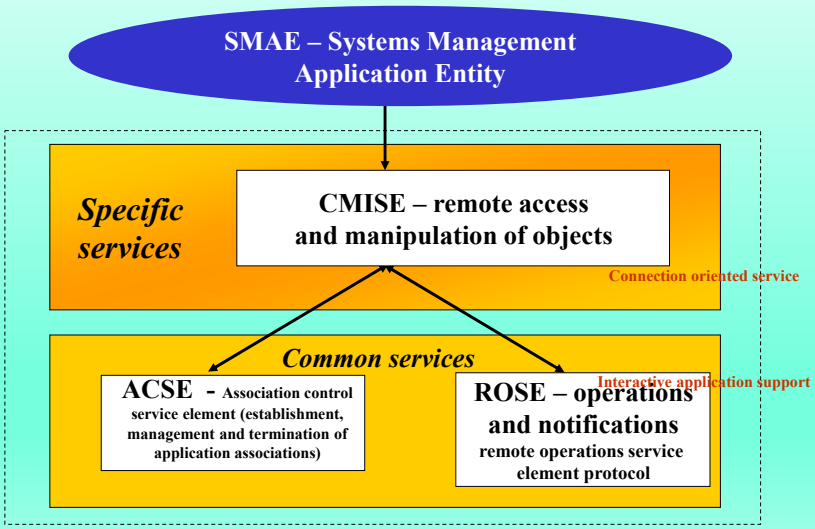
Common Management Information Service (CMIS)



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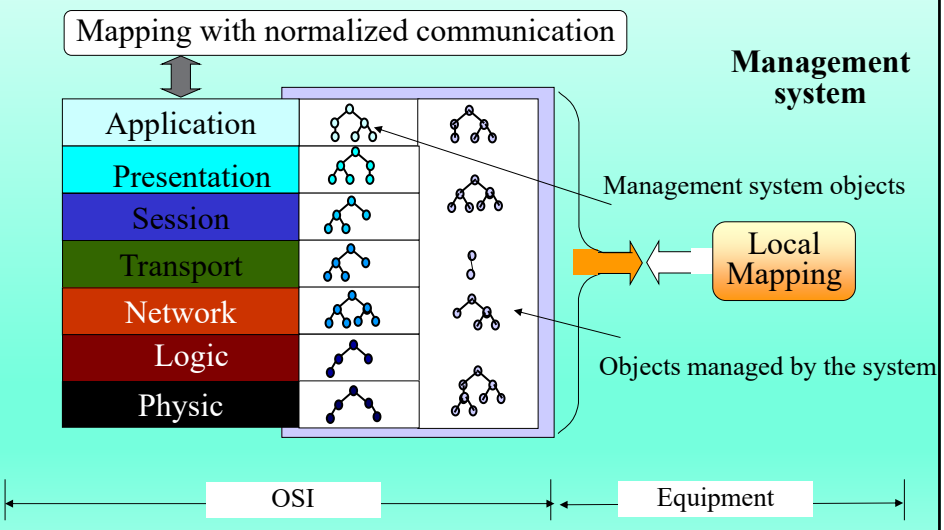
OSI management architecture



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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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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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PBM and COPS

Concept: Policy Based Management

Protocol: 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**

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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**

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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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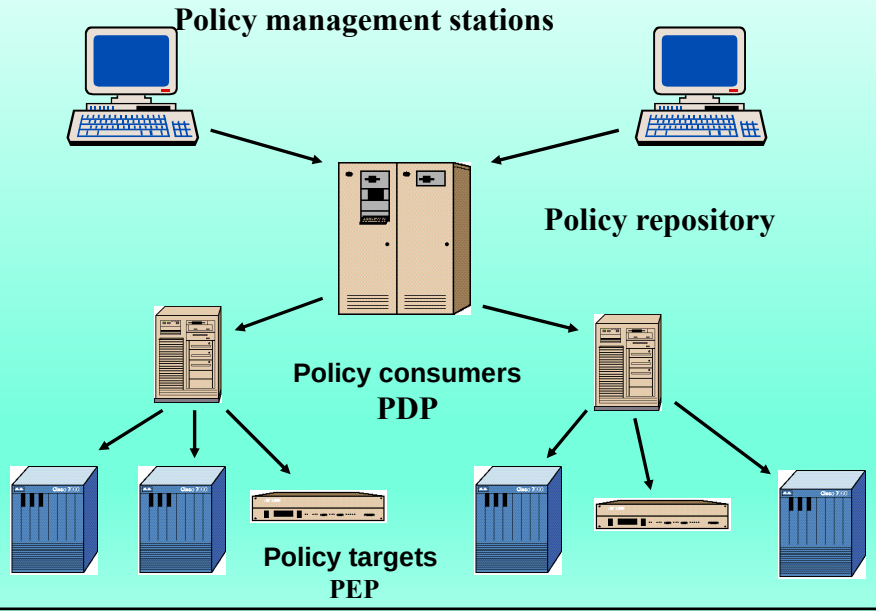
Policy management system - example



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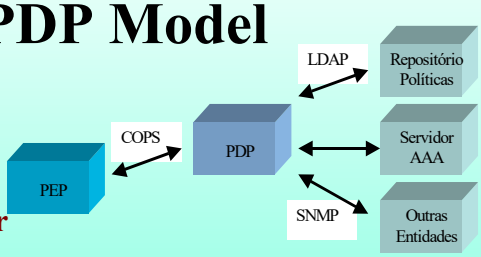
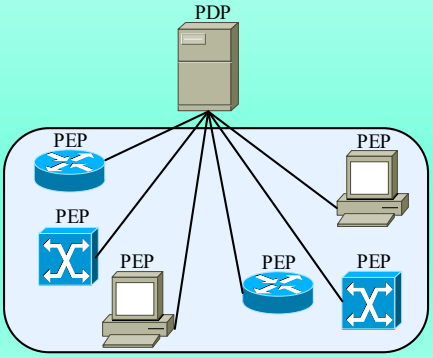
LEMBRAR modelos de QoS na Internet!!!

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)





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

COPS – Common Open Policy Service

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- 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
  - Default concept was for QoS support/control
- 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

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

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COPS Session

- PEP opens a COPS session
  (specifying a client type: RSVP, DiffServ)
- PEP sends requests and receives answers
- PEP can also send non-solicited commands
- PDP can change commands previously sent
- PEP sends messages related to resources utilization (charging)
- *KeepAlives* are sent if there is no activity

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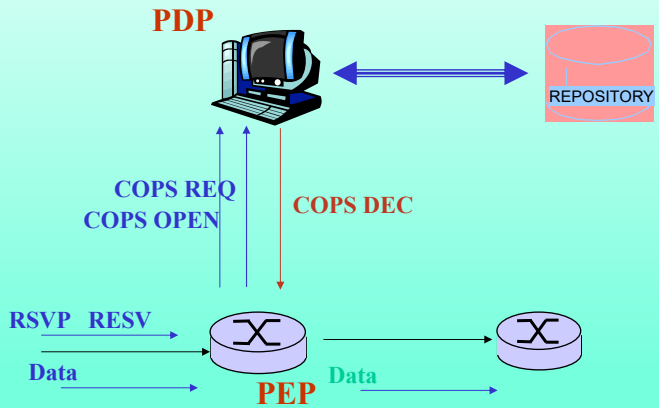
COPS with RSVP



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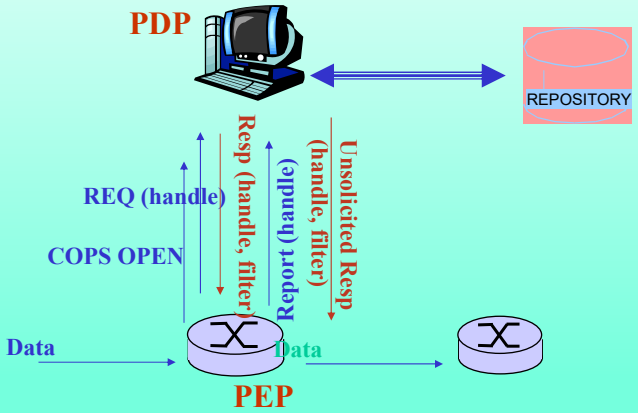
COPS with DiffServ



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

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SNMP

Simple Network Management Protocol

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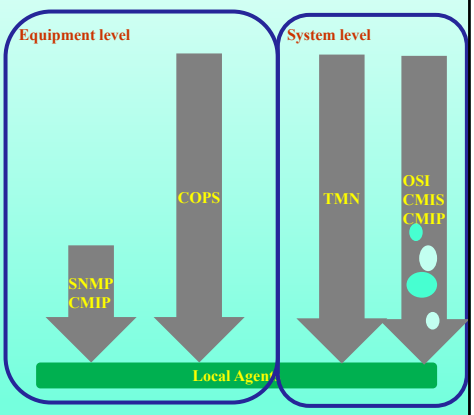
Gestão

1. Intention
2. Formalization
3. Storage
4. Implementation
5. Data transmission
6. Execution



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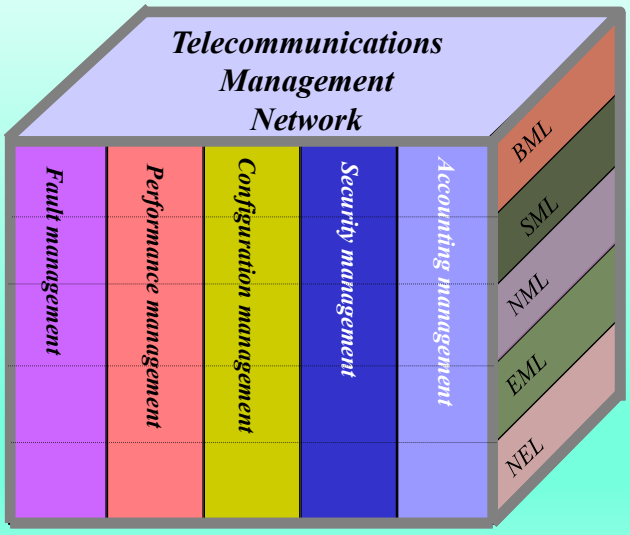
TMN Matrix



Depicts the FCAPS functionality along the TMN layers

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SNMP: Objectives and definition

- Ubiquity
  - All equipments
- SNMP inclusion in the network should be cheap
  - Small code with limited functionalities
- New extensions should be possible
  - "New MIBs"
- Management should be robust
  - Transport mechanism not connection oriented

- **A set of rules for describing management information**
- **An initial set of managed objects**
- **A protocol used to exchange management information**

- **SMI (RFC 1155)**
  - **Structure of the information management**
- **MIB-II (RFC 1213)**
  - **MANAGEMENT INFORMATION BASE**
  - **Many other MIBs exist**
- **SNMP (RFC 1157)**
  - **SIMPLE NETWORK MANAGEMENT PROTOCOL**
  - **Name refers to both the transport protocol and the reference architecture**
- **Other SNMP versions**
  - **SNMPv2 e SNMPv3**

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"immediate" SNMP evolutions

- **SNMPv2 extensions**
  - **Structure of management information (SMI)**
  - **Manager-Manager capacity**
  - **New protocol operations**
- **SNMPv3 extensions**
  - **New message format**
  - **Message security**
  - **Access control**

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SNMP System Management

- *de facto* standard for fault management
- Consists on an SNMP manager and a set of MIBs (Management Information Bases)
- Supports
  - Self-discovery of IP equipments in the network
  - Uses polling to recover from faults
  - Supports traps and events management
  - Can be implemented as proxy or gateway agents to support non-IP equipments
  - Integrates multiple applications

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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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Summary of System Management SNMP : 4 parts

- **Management information base (MIB):**
  - **Distributed storage of network information**
- **Structure of Management Information (SMI):**
  - **Data definition language for MIB objects**
- **SNMP protocol**
  - **Establishes relationships manager× managed to allow the exchange of information and commands**
- **Security and administration**
  - **Later developed, in versions SNMPv2 and SNMPv3**

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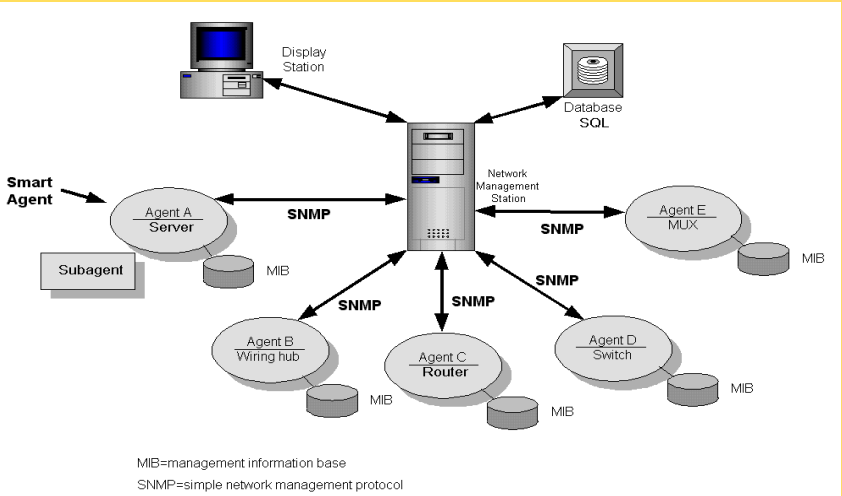
Structure of SNMP management



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SNMP services for managers

- **There are 3 SNMP services related with the managers control**
  - **Authentication service**
    - MIB access is limited to authorized managers
  - **Access policy**
    - MIB access can change according to the manager accessing
  - **Proxy service**
    - The agent can be proxy of other agents, which implies the support of authentication and policy services

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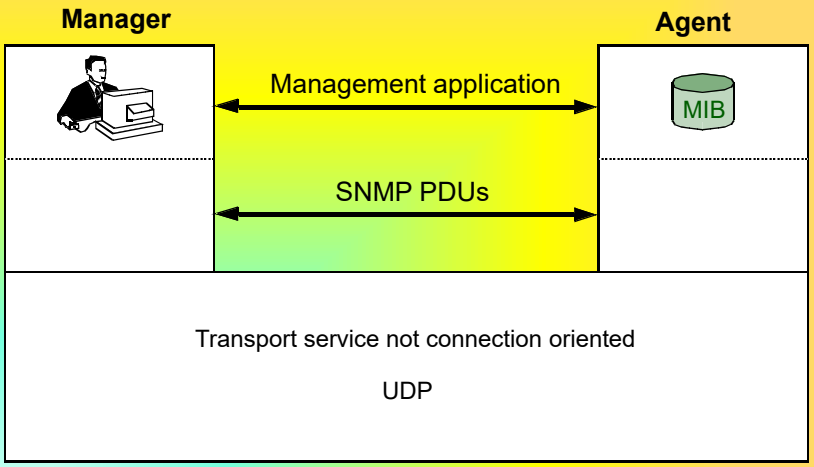
SNMP Structure



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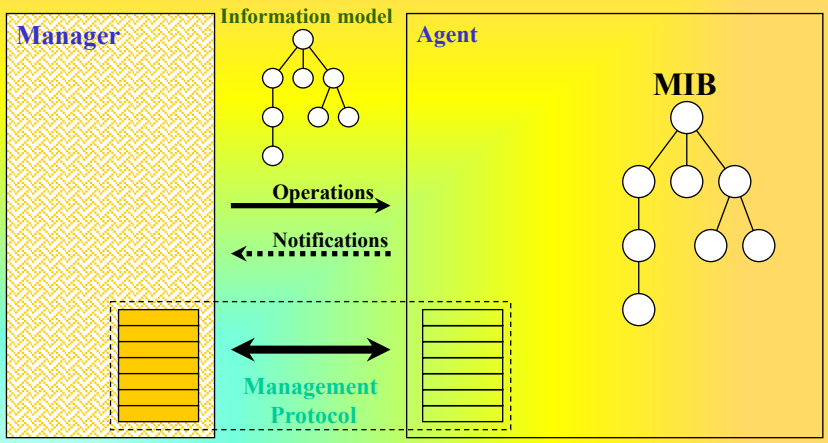
Manager/Agent model



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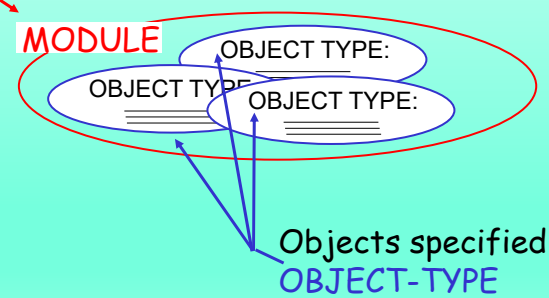
SNMP MIBs

MIBs are defined via SMI
(100+ standard MIBs, lot more for specific equipments)

MODULE-IDENTITY



Objects specified via SMI
OBJECT-TYPE

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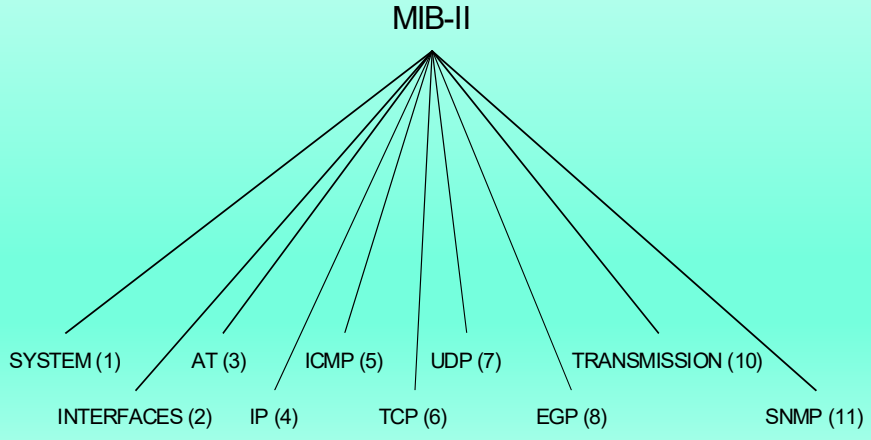
MIB-II

Defines TCP-IP management (170 variables)

- Defined in RFC 1213, associated to SMIv1
- Historically, evolution of MIB-I (RFC 1156)



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SMI: Data language definition

Objective: well-defined sintax and semantics of management information

- **Type of basic data**
  - **Traditional**
- **Type of object**
  - **Type of data, status, semantic of the managed object**
- **Module identification**
  - **Colection of objects inter-related in the MIB**

Type of basic data

INTEGER
Integer32
Unsigned32
OCTET STRING
OBJECT IDENTIFIED
IPaddress
Counter32
Counter64
Guage32
Tie Ticks
Opaque

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SMI: Examples of objects and modules

OBJECT-TYPE:
ipInDelivers

```
ipInDelivers OBJECT TYPE
  SYNTAX      Counter32
  MAX-ACCESS  read-only
  STATUS      current
  DESCRIPTION
    "The total number of input
     datagrams successfully
     delivered to IP user-
     protocols (including ICMP)"
::= { ip   9}
```

MODULE-IDENTITY:
ipMIB

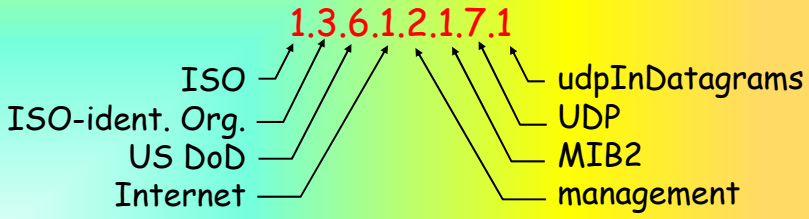
```
ipMIB MODULE-IDENTITY
  LAST-UPDATED "941101000Z"
  ORGANIZATION "IETF SNPv2
        Working Group"
  CONTACT-INFO
    " Keith McCloghrie
    ....."
  DESCRIPTION
    "The MIB module for managing IP
    and ICMP implementations, but
    excluding their management of
    IP routes."
  REVISION "019331000Z"
.........
::= {mib-2 48}
```


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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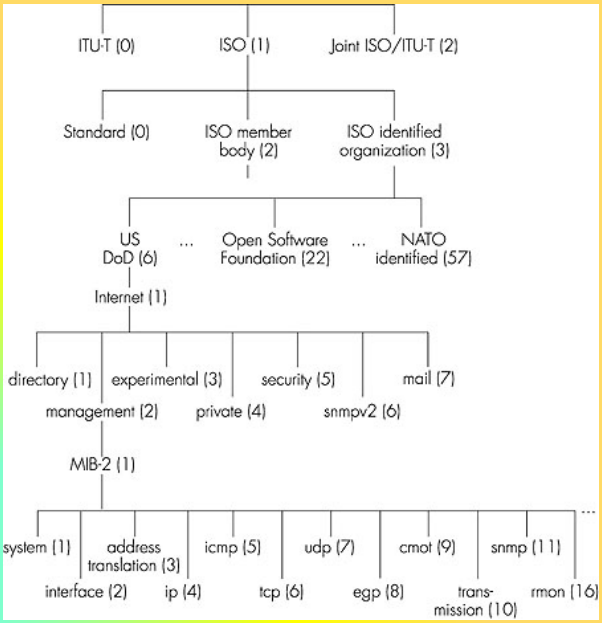
OSI Object Identifier Tree



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

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SNMP

The protocol

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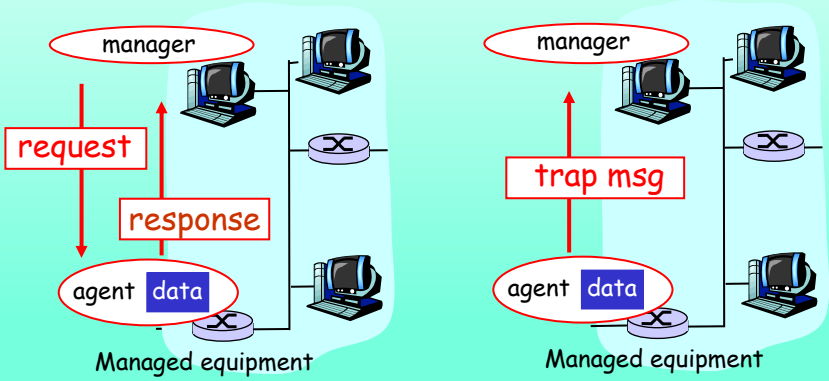
Information transfer in SNMP

Two mechanisms to transfer information



Request/response mode (polling)

Notification mode (trap)

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SNMP: Polling

- **Manager periodically asks the agent for new information**

☺ **Advantage: Manager completely controls the equipment, and knows all network details**

☹ **Disadvantage: delay between event and its entry in the system, and unnecessary communication overhead:**

  - **Slow polling, slow answer to the events**
  - **Quick polling, quick reaction, but large bandwidth wastage**

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SNMP: Traps

- There is an event ² trap is sent
- Trap contains appropriate information
  equipment name, time instant of event, type of event

☺ **Advantage**: information only generated when required

☹ **Disadvantage**:

- ☹ More resources required in the managed equipment
- ☹ Traps can be useless
  - If many events occur, bandwitdh can be wasted with all traps (thresholds can solve)
  - Since the agent has only a limited scope of the network, NMS may already know about the events.

- **Traps&Polling**
  - Event occurs ² trap is sent
  - Manager performs polling to obtain the rest of information
  - Manager also performs periodic polling, as backup

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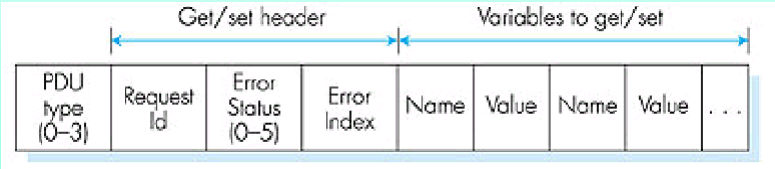
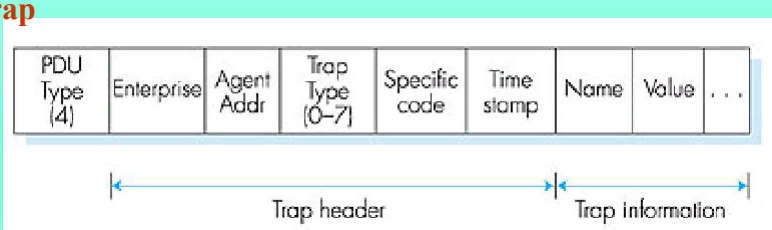
SNMP Protocol: messages format

Get, Set, Response



Trap



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SNMP Protocol: types of messages

Types of messages	Function
GetRequest GetNextRequest GetBulkRequest	Mgr ↴ agent: "get me data" (instantiates, next on the list, block of information)
InformRequest	Agent ↴ Mgr: informs the Manager of exception in a reliable way
SetRequest	Mgr ↴ agent: defines MIB value
Response	Agent ↴ mgr: answer value to Request
Trap	Agent ↴ mgr: informs the manager of an exception event

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SNMP: security and authentication

- In its initial version, the authorization and authentication were based in the notion of "SNMP community string"
- The "community words" identifying the permissions of the machine that access the agente: read-only ou read-write
- By default, all systems come configured with the strings:
  - public (read-only)
  - private (read-write)
- These strings are case sensitive.

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SNMP: security and administration

- Larger security in new versions
- Notion of "access control dependent on the user"
  - The agent mantains access rights information (policies) to different users in a data base
  - This data base is accessible as an object that can be managed
- Cipher support: SNMP message transported in DES
- Authentication: shared secret key
- Protection against replays: resort to *nounces*

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MIBs and SNMP access

MIB Access Category	SNMP Access Mode	
	Read-Only	Read-Write
Read-Only	get,trap	get,trap
Read-Write	get,trap	get, trap e set
Write-only	get, trap depends on implementation	get, trap e set depends on implementation
Not accessible	Not accessible	

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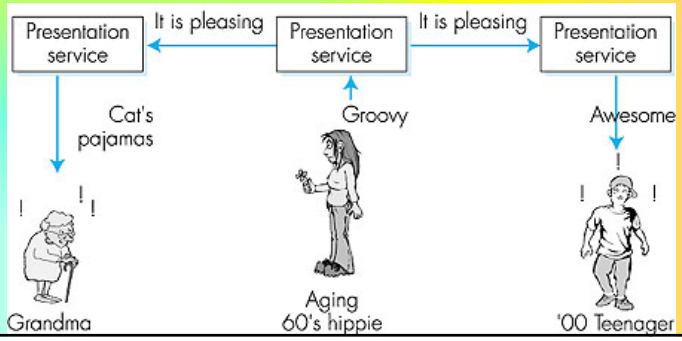
The presentation problem?

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.



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

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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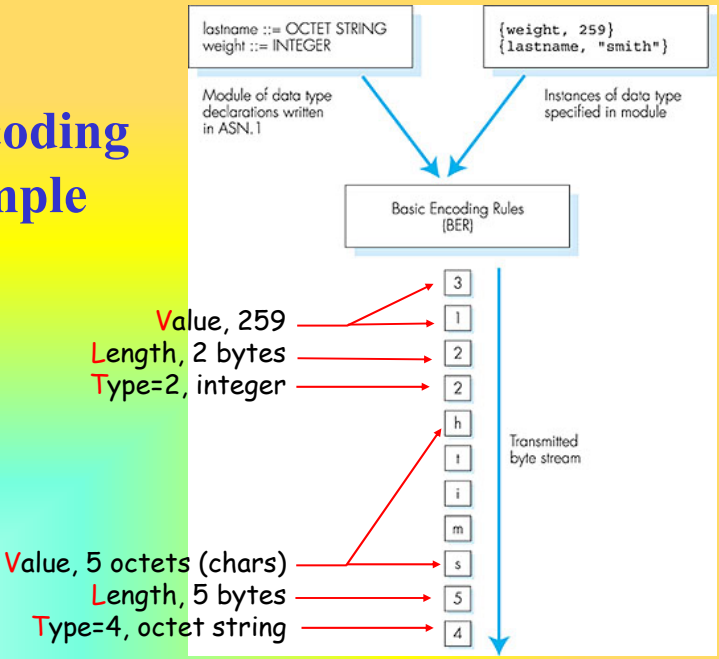
TLV coding example



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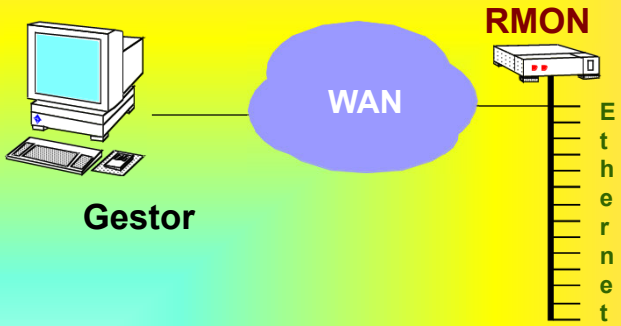
REMOTE MONITORING



- 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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RMON 2

- RMON is not enough!
- RMON 2 shows:
  - High level packets (applications)
  - Details of traffic flows

RMON ≠ RMON2

- RMON: used to analyse segments
- RMON 2: used in backbones

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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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Frameworks: SNMP versus 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