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A Telecommunications Economics COST Network

cost

Autonomic Management of Mobile Networks

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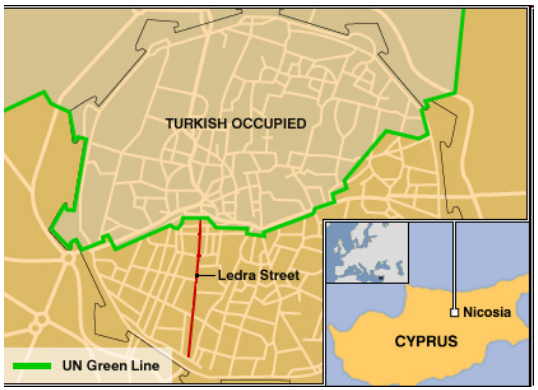
About

- KIOS (www.kios.org.cy)
  - Research Center for Intelligent Systems and Networks, UCY
    - Monitoring, control and management of large-scale complex systems
    - Development of advanced engineering tools for the management and protections of critical infrastructures
- University of Cyprus (UCY)
  - First and largest public university
  - Based in Nicosia
    - Capital of the Republic of Cyprus
    - "World's only divided capital"



Outline

- Introduction
- Network Management Basics
- Autonomics and Self-Management
- Policy-based Management (PBM)
- Self-Organisation in Mobile Networks
- Conclusions

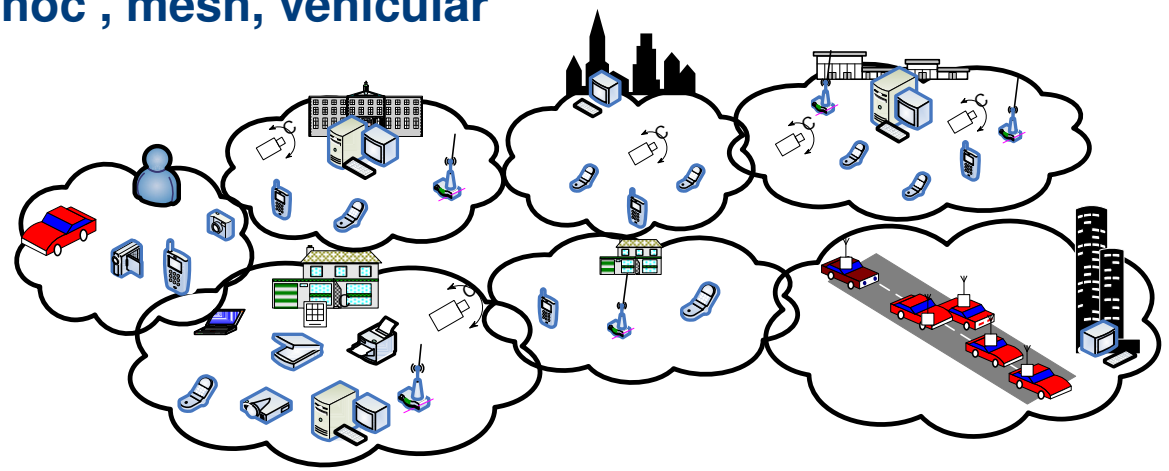
Introduction
Wireless and Mobile Networks

- Wireless Networks are **everywhere**!
  - WMAN: e.g. Mobile 2G/3G/LTE
  - WMAN: e.g. WiMax / Mobile WiMax
  - WLAN: e.g. WiFi
  - WPAN: e.g. Bluetooth, IR
  - WBAN: e.g. Zigbee, RFID

? → 4G

- Multihop Wireless Networks

  → **ad hoc , mesh, vehicular**



Introduction

Wireless Networks' Issues

- Multiple technologies → 4G
  - **Interoperability – Mobility – Scalability**
  - Multi-interface handsets
    - Today: 2G/3G, WLAN, Bluetooth, IR
    - Tomorrow: X, Y, Z, ?, ? , ?
  - New form factors
    - netbooks, MID, smartbooks, USB dongles etc …
  - Convergence of Fixed and Mobile Networks

→Increased scale

→Increased complexity →**Increased Cost**

→Increased heterogeneity

Introduction

Wireless Networks' Issues

- Typical OPEX Breakdown for a Mobile Operator
  - ~20% on Network Operations (source: Motorola-Yankee Group)
- Typical budget for IT
  - ~70% on Labor (source: IDC study
- Industrial initiatives to reduce cc

  → management automation →
- IBM: Self-Managing Autonomic
- 3GPP/NGMN: SON for LTE (20
  - Self-Organizing Networks (SON) L standards attempt to change the o paradigm
    - NGMN: Next Generation Mobile Netwo
    - 3GPP: 3rd Generation Partnership Pro,

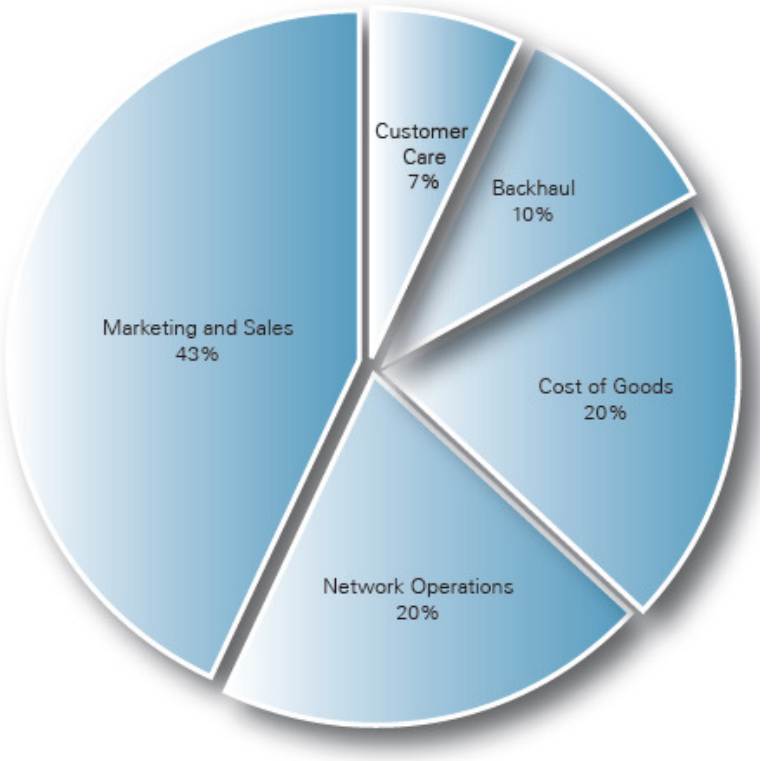


Figure 1: Typical OPEX Breakdown (source: Yankee Group)

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Network Management
Why should you care?

- Networks and systems management technologies and standards
  - As with most technologies and standards, they were, they are, and will be influenced by Techno-Economic factors!
  - But they can influence Techno-Economic factors!
  - We can learn from history
    - And history is repeated…
    - Better estimation/prediction of the Future

Network Management Basics
Functional areas of management

- Open Systems Interconnection (OSI) Systems Management (OSI-SM) [ITU-T Rec.X.700,]
  - Five generic functional areas of management

- FCAPS operations
  - Fault Management
  - Configuration Management
  - Accounting Management
  - Performance Management
  - Security Management

Network Management Basics
Taxonomy and Protocols

- Network and Systems Management Approaches
  - High-level Taxonomy and Protocols
- Remote Invocation (RI)
  - Manager-Agent
    - SNMP, COPS, NETCONF
  - Distributed Object/Service Interfaces
    - CORBA, Web Services
- Management by Delegation (MbD)
  - Code mobility
    - ScriptMIB, Mobile Agents

Network Management Basics
Organisational Paradigms

- Taxonomy Criterion: the organisational model
  - m as the total number of managers
  - a as the total number of agents
  - n = m + a as the total number of elements in the management system

- Four paradigm classes of organisational models:
  - centralised management (1 = m)
  - weakly distributed management (1 < m << n)
  - strongly distributed management (1 << m < n)
  - cooperative management (m ≈ n)

Network Management Basics
Evolution of Protocols & Technologies

- Milestone for network and systems management
  - The standardisation of two open protocols (1980's)
    - Common Management Information Protocol (CMIP)
    - Simple Network Management Protocol (SNMP)

- CMIP
  - used by OSI-SM framework, targeting OSI intermediate and end systems.
  - first object-oriented management approach
  - adopted by ITU-T as the basis for its Telecommunications Management Network (TMN)
  - established in the Telecommunications (Telco) community

Network Management Basics
Evolution of Protocols & Technologies

- SNMP
  - SNMPv1 completed around 1990 by IETF
    - final version: SNMPv3 (2002)
  - efficient and simple: “variable-based” information model and limited set of operations
  - adopted by the Internet (IP, Internet Protocol) community to manage local area networks, wide area networks and intranets
  - storming adoption and deployment on the majority of IP-capable devices
  - IETF shifted interest to new Internet management technologies
  - IETF: Internet Engineering Task Force
    - *“rough consensus and running code” D.D.Clark*

Network Management Basics
Evolution of Protocols & Technologies

- Common Object Request Broker Architecture (CORBA)
  - Outcome of research on the use of distributed object technologies (1990s) by OMG
    - OMG : Object Management Group
  - Employed for network and systems management
  - Fully object-oriented information model
    - Objects defined through their interfaces in IDL
    - Interface Definition Language (IDL)
  - Internet Inter-Operability Protocol (IIOP)
    - Remote call protocol mapping over TCP/IP
  - Gradually phased out OSI-SM/CMIP in Telco
    - ITU-T translating original specifications to CORBA's IDL

Network Management Basics
Evolution of Protocols & Technologies

- CORBA
  - Benefits: application interoperability independent of platform, operating system, programming language.
  - Drawbacks: relatively heavyweight nature and expensive deployment
    - Critical requirements of network management were not satisfied – not widely adopted
  - Established for service and application management in Telco industry
    - Continued use given the prior investment in this area
- Service management
  - Business process reengineering and automation
    - CORBA technology well suited
  - Trend towards Web Services (SOAP-based) solutions
    - Emerging importance of Policy-Based Management

Network Management Basics
Evolution of Protocols & Technologies

- The future of Internet management technologies
  - *J. Schoenwaelder, A. Pras, J-P. Martin-Flatin, "On the future of Internet management technologies", IEEE Commun. Mag., Vol.41, Iss.10, pp.90-97, Oct 2003.*
  - Authors identify the significant deficiencies and challenges of existing technologies.
  - Two approaches from the Internet community
- *Evolutionary* approaches
  - Aimed at solving problems by gradually improving the existing Internet management framework
  - Main problems of SNMP were targeted
    - elementary information model
    - use of unreliable UDP for transport
    - lack of transaction support
  - By 2003, "evolutionary" approaches abandoned
    - Admittedly had failed or had limited market acceptance

Network Management Basics
Evolution of Protocols & Technologies

- *Revolutionary* approaches
  - Since 2001, hardware vendors had been shipping products that offered XML-based interfaces
  - After 2003, the Internet management community focused its interest on “revolutionary” approaches
    - Aim: replace existing management-specific technologies with standard distributed systems technologies
  - Industry focus towards XML-based approaches was adopted by Internet community
  - IETF Network Configuration (NETCONF) working group was chartered May 2003
  - Trend towards standardised Web Services and XML/HTTP-based management
    - currently embraced and deployed by the network management community and industry

Network Management Basics
Evolution of Protocols & Technologies

- Web Services (WS)
  - an Internet-oriented technology, developed and standardised by the WWW Consortium (W3C)
  - WS were seen as the successor of distributed object technologies due to their strong analogies to CORBA
  - Candidate technology for network management, in spite of XML's verbosity leading to increased overheads compared to SNMP and CORBA
  - Main advantage: the use of XML, due to its universal adoption as an interoperable data interchange format
  - Open standards available
    - DMTF Web-Based Enterprise Management (WBEM)
    - OASIS Web Services Distributed Management (WSDM)

Network Management Basics
Evolution of Protocols & Technologies

- Web Services (WS) building blocks
  - WSDL (Web Services Description Language)
    - an XML-based language that provides a model for describing WS as collections of network endpoints, ports and messages. Provides an abstract definition of available services, thus separating them from their implementation
  - UDDI (Universal Description, Discovery & Integration)
    - a platform-independent, XML-based registry for Web Services, which service consumers can query to discover services' location of interest, mainly using SOAP
  - SOAP
    - an application protocol for message exchange between service providers and consumers, mostly used in RPC (Remote Procedure Call) mode of operation. The default mapping of SOAP over HTTP/TCP/IP is dominant

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Autonomics and Self-Management
Motivation

- In one sentence
  - Reduce complexity, increase automation, reduce OPEX
- Networks and Systems today
  - progressively more complex, interconnected networking infrastructure
    - explosive growth of the Internet
    - proliferation of mobile technologies
    - fixed-mobile convergence
  - difficulty in managing multi vendor environments
    - true for Telco operators and IT operators
    - current communications service offerings are inflexible

Autonomics and Self-Management
Motivation

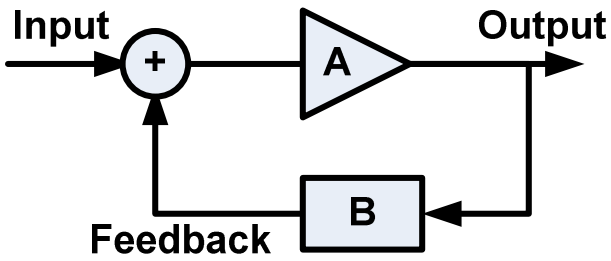
- Telco actors faced with difficulties
  - Direct impact on the OPEX and CAPEX
- Current communications service offerings are inflexible in nature:
  - rigidly defined and exhibit static functionality
  - closely coupled to specific network technology
  - Largely manually deployed and managed, requiring highly labor-intensive support structures,
    - consequent inflexibility & significant time to market constraints
- ***"Autonomic Computing and Networking, The operators' vision on technologies, opportunities, risks and adoption roadmap", (Eurescom P1855 D1) Editors: Bruno Dillenseger, Sven van der Meer, Stein Svaet***

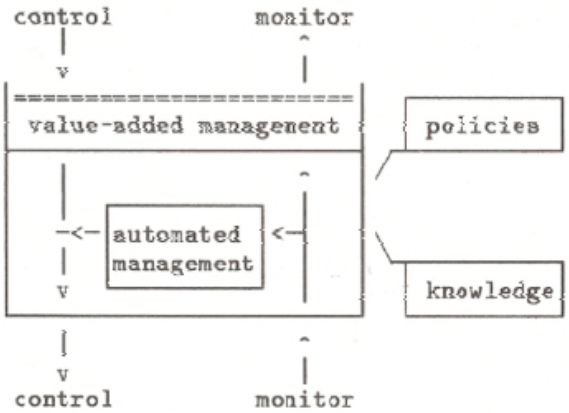
Autonomics and Self-Management
First steps and definitions

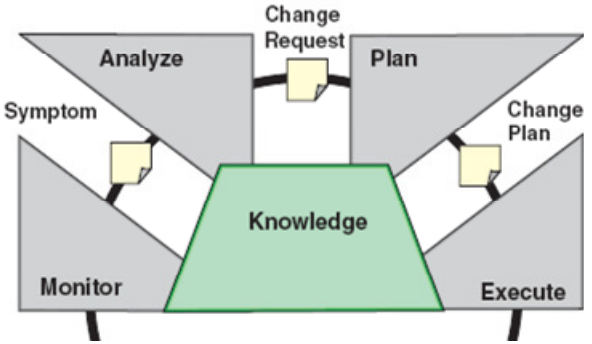
- **Autonomic Computing**:
  - a computing environment with the ability to manage itself and dynamically adapt to change in accordance with business policies and objectives [IBM2001]
  - "*Grand Challenge:* building and deploying computing systems that regulate themselves and remove complexity from the lives of administrators and users"
- **Self-management**:
  - the ability of independently achieving seamless operation and maintenance by being aware of the surroundings
  - Autonomic Management

Autonomics and Self-Management
First steps and definitions

- Basic underlying concept
  - Control Theory for Network/Systems Mgt.
    - ***Closing the management loop!***
    - L.Fehskens [IFIP/IM 1989]
    - IBM's Autonomic Vision [2000]
- Self-*
  - Configuration – Healing – Optimisation – Protection

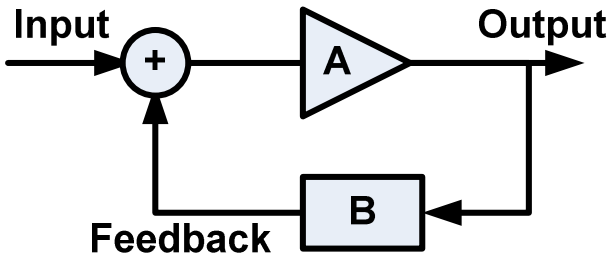


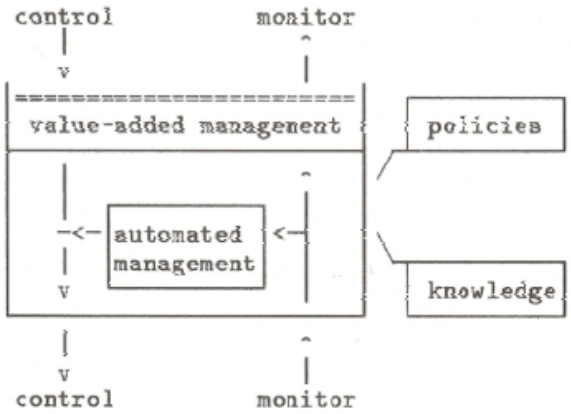




Autonomics and Self-Management
First steps and definitions

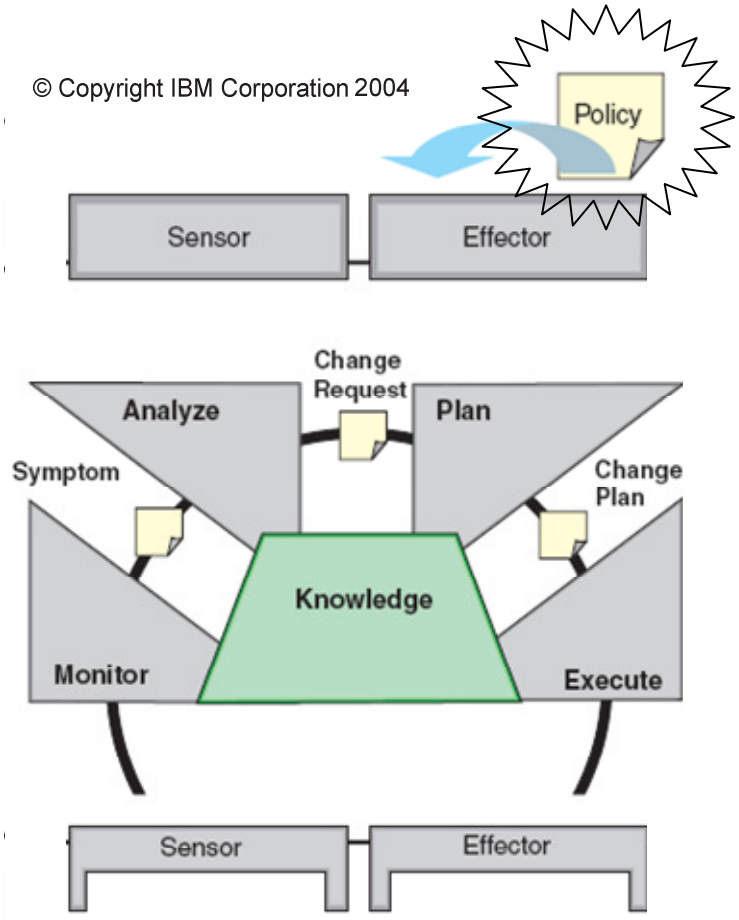
- Two main functions for self-management
  - A. Provide the logic and directives to achieve seamless operation and maintenance (→policies)
  - B. Provide the means to sense and evaluate their operating surrounding environment (→knowledge)
  - – interrelated and interdependent,
  - – forming a closed control loop with feedback





Autonomics and Self-Management
Architecture and Principles

- IBM's Autonomic Manager
  - building block of autonomic systems
- K-MAPE architecture
  - Knowledge
  - Monitor
  - Analyze
  - Plan
  - Execute



Autonomics and Self-Management
Architecture and Principles

- Use of a feedback loop
  - raises concerns about a system's stability
- "Valid operating region" of a feedback loop
  - Control theory: indicating the range of control inputs where the feedback loop is known to work well
- A major open issue, not adequately addressed

Autonomics and Self-Management
Roadmap

- The roadmap to autonomic management
  - Basic: manually operated management operations
  - Managed: management technologies used to collect and synthesise information
  - Predictive: correlation among management technologies provides the ability to recognise patterns, predict optimal configuration etc.
  - Adaptive: management framework can automatically take actions based on available knowledge, subject to the supervision of administrators
  - Autonomic: business policies and objectives govern infrastructure operation. Users monitor business proc.

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- Self-Organisation in Mobile Networks
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Policy-based Management (PBM)
Expectations and Potential

- PBM and policies
  - Envisioned as encapsulating business objectives which in turn are automatically applied to managed systems, requiring minimal human intervention
  - Initially overestimated expectations from policies
    - Practice has shown that what was initially conceived as the instant panacea of network management is in fact a long journey towards self-managing networks
  - Research on PBM has gradually verified its enormous potential and showed that it can simplify complex management tasks of large-scale systems.

Policy-based Management (PBM)
Overview

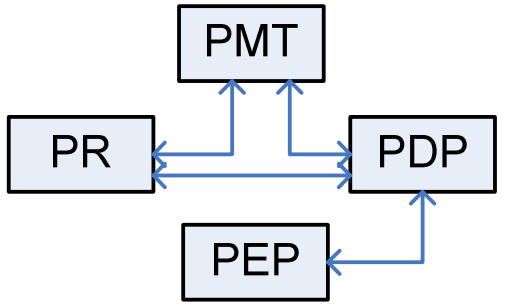
- Basic concept
  - high-level policies are translated to low-level element operations for monitoring the network and automatically enforcing appropriate actions
    - Intense interest, fuelled by IBM's vision in Autonomic Management
- The PBM paradigm
  - Policies capture high-level management objectives
  - Means to integrate self-management capabilities
  - PBM offers controlled programmability
- First steps on PBM from IETF
  - Policy Framework WG (POLICY) RFC3198,RFC3460
  - Resource Allocation Protocol WG (RAP) RFC2753
  - Reference framework, aimed for QoS provisioning

Policy-based Management (PBM)
Overview

- Main advantages of a policy-based system
  - Controlled programmability to the managed system, without compromising its overall security and integrity
  - Extends the functionality of a system dynamically in combination with its pre-existing management logic
    - re-programmable and adaptable management system, based on the supported general policy types.
  - Policies can be introduced to the system and parameterised on the fly, based on management goals and contextual information.
    - Policy decisions prescribe appropriate actions, to realise and enforce those goals.

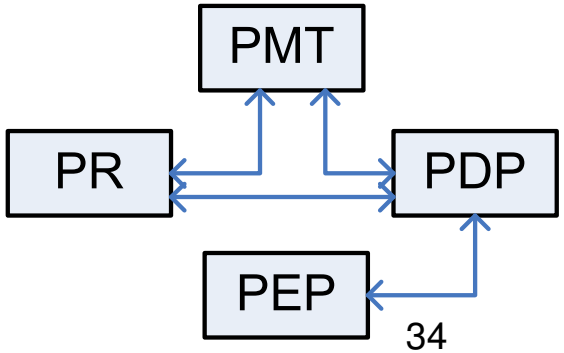
Policy-based Management (PBM)
IETF's Policy Framework

- IETF Definition of Policy
  - a set of rules to administer, manage and control access to network resources
- IETF's policy-based framework
  - Policy Information Model (PCIMe)
  - LDAP Data Model (PCELS)
  - Does not define a policy specification language
  - "Condition-Action" specification of policy rules
- Policy rules: building blocks of complex logic
  - Defined as Event-Condition-Action (ECA) clauses
  - on event(s) E, if condition(s) C true, then action(s) A is executed



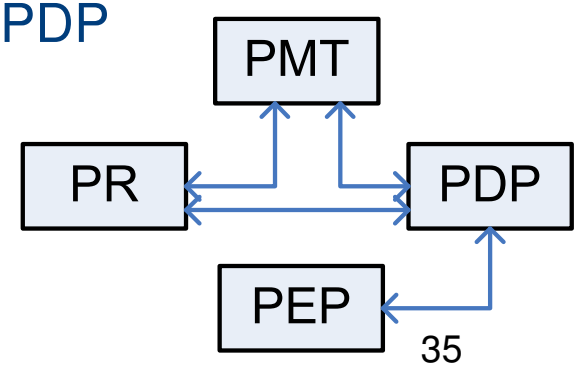
Policy-based Management (PBM)
IETF's Policy Framework

- Policy Management Tool (PMT)
  - the interface between the human manager (e.g. a consultant or network administrator) and the underlying PBM system
- Policy Repository (PR)
  - the blueprint of policies that a PBM system is complying with at any given moment
    - encapsulates the operational parameters of the network
    - one of the most critical elements



Policy-based Management (PBM)
IETF's Policy Framework

- Policy Decision Point (PDP)
  - a logical entity that makes policy decisions for itself or for other network elements
    - evaluation of policy rule's conditions
    - provisioning of actions' enforcement when conditions are met
- Policy Enforcement Point (PEP)
  - a logical entity that enforces policy decisions
    - Traditionally, the sole task of PEP is to execute policy decisions, as instructed by the controlling PDP
- *Policy provisioning*

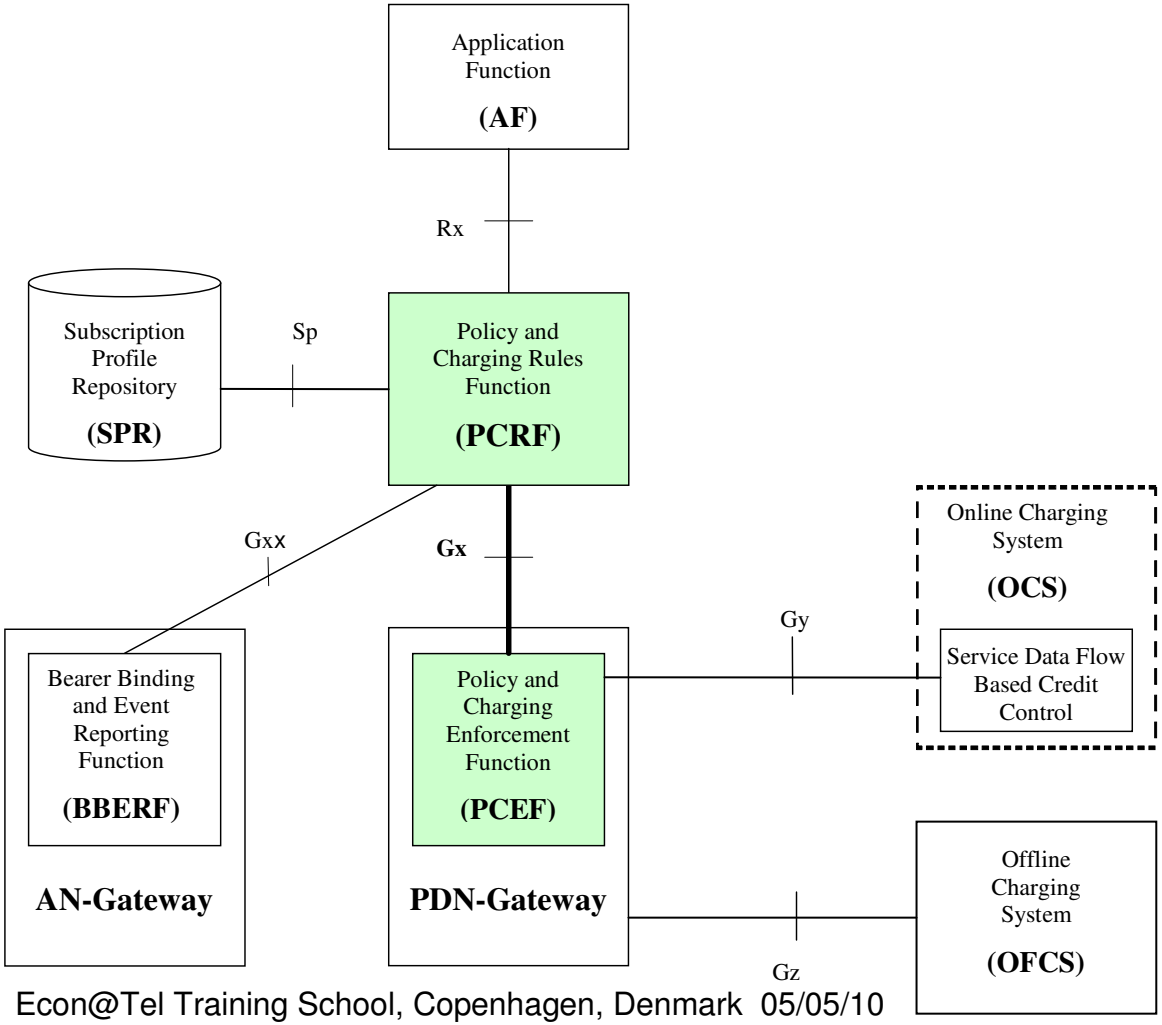


Policy-based Management (PBM)
Policy Support in Mobile Networks

- 3GPP (3rd Generation Partnership Project)
  - Adopted a Policy-based approach for QoS provisioning
  - Policy and Charging Control (PCC) architecture for IMS
  - Policy provisioning protocols (IETF protocols)
    - Initially based on COPS-PR (R5-R6) [RFC 3084]
      - Common Open Policy Service -Policy Provisioning
      - Failed to gain significant market acceptance because it failed to fully address SNMP deficiencies and introduced complexity
      - Maintenance costs and lack of backward compatibility further restricted its adoption.
    - Now based on Diameter (R7-R9) [RFC 3588]
      - Vendor specific extensions/implementations
      - AAA (authentication, authorization and accounting)

Policy-based Management (PBM)
Policy Support in Mobile Networks

- 3GPP Policy and Charging Control (PCC) architecture
  - PCRF
    - Policy and
    - Charging
    - Rules
    - Function
  - PCEF
    - Policy and
    - Charging
    - Enforcement
    - Function



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Self-organisation in Mobile Networks
Self-Management vs. Self-Organisation

- Different focus
  - Self-Managing Autonomic Networks (AN)
    - IT automation: Internet [e.g. Enterprise Network]
  - Self-Organising Networks (SON)
    - Telco automation: Mobile [e.g. 3GPP LTE RAN/EPC]
- Share the same self-* capabilities
  - *Share* ≡ “would benefit from” !

Self-Organisation in Mobile Networks

NGMN Use cases

- NGMN Alliance
  - Next Generation Mobile Networks Alliance
  - Vision: "to provide a platform for innovation by moving towards one integrated network for the seamless introduction of mobile broadband services."
  - Long Term Evolution (LTE)
- NGMN definitions:
  - Self-organising functionality
    - processes in a mobile network which require minimum manual intervention (taking place in the RAN and Core Network).
  - Automatic activity (→ autonomic)
    - A process where a significant part of the action is handled by a machine but some human interaction is required (e.g., verify results)

Self-Organisation in Mobile Networks

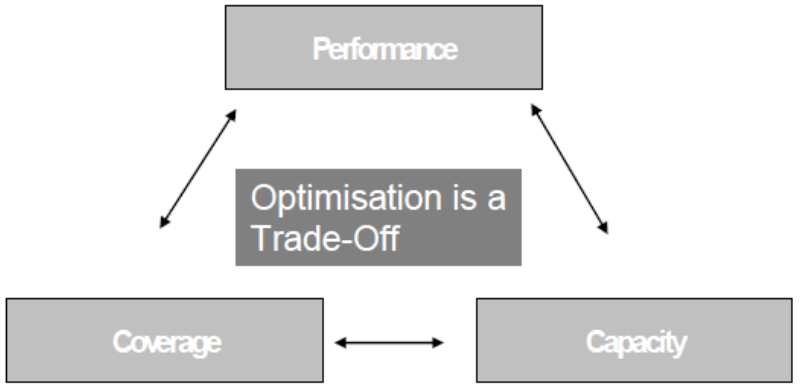
NGMN Use cases

- Planning
  - the process of preparing the parameters and settings of a network node (including site locations and HW configuration)
- Deployment
  - includes preparation, installation, authentication and delivering of a status report of a new Network Equipment
- Maintenance
  - the procedures to perform the routine actions which keep the network in working order or prevent trouble from arising
- Self-configuration
  - the process where newly deployed nodes are configured by automatic installation procedures with the necessary basic configuration for system operation (pre-operational state)
- Optimization (self-optimization)
  - the process where operational measurements are used to (auto-) tune the network (operational state)

Self-Organisation in Mobile Networks

NGMN Use cases

- Use Cases related to Self Organising Networks
  - http://www.ngmn.org/nc/downloads/techdownloads.html
  - Self-configuration Use Case (of a new eNB)
    - Planning Of Location, Capacity And Coverage
    - Planning Radio Parameters
    - Planning Transport Parameters
    - Transmission Setup
  - Self-optimisation Use Case
    - Interference Control
    - Handover Parameter Optimisation
    - QoS Related Parameter Optimisation
    - Load Balancing



Self-Organisation in Mobile Networks
Operator Top Ten Requirements

- Breaking news (Mar.2010)
- 3GPP, NGMN & TM Forum Workshop
  - *Operator Top Ten Requirements*
    - Quality and Quantity of Alarms
    - Automatic Software Management
    - Energy Saving
    - LTE Automatic Neighbour Relation (ANR) and SON Operation
    - Performance Management in Real-time
    - Substitution of Monitoring Probes (…)
    - eNodeB Plug & Play Self-Commissioning
    - OSS Standard Itf-N
    - LTE Parameter Optimization
    - Automatic Inventory

Self-Organisation in Mobile Networks

Autonomic Management

- Future Mobile Networks need to increase automation during all phases
  - Planning
  - Deployment
  - Optimization
  - Maintenance
- Extremely important in order to offer a competitive mobile broadband experience → 4G
  - Higher bitrates (more access & core network traffic)
  - Scalability (denser deployments, more devices)
  - OPEX reduction (heterogeneity, interoperability)

Self-Organisation in Mobile Networks

Autonomic Management

- Mobile networks automation can benefit from autonomic principles
  - Policy-based management
  - Self-awareness and context-awareness
  - Modular implementations of self-* capabilities
  - Control theory for closed-loop management
  - Distributed organisation and decision-making
- Future (mobile) networks automation
  - Researchers, SDOs, and Industry actively involved
  - Standards in place/progress → first market products

Self-Organisation in Mobile Networks
Policy-Based Management

- Future (mobile) networks automation
  - Product focus: PCRF or policy engine server
    - PCRF: Policy Charging and Rules Function
      - Latest: 3GPP Release 9
- Industry outlook
  - "Light Reading Mobile" Article on Policy Vendors at the Barcelona Mobile World Congress MWC2010
    - http://www.lightreading.com/document.asp?doc_id=187922
    - "**Policy control**, and its role in service and subscriber management, has emerged as one of the **key talking points** in the wireless industry in the past year or so…"
      - Several vendors and commercial products mentioned

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Conclusions
Industry quotes

- IBM on the growth versus cost dilemma
  - "IT complexity has to be simplified, or growth will begin to be hampered by the cost required to support it"
    - http://www.ibm.com/autonomic

- Motorola on LTE OPEX cost reduction
  - "A distributed architecture is better positioned to deliver a successful SON solution, (…) based on a policy-based management scheme"
    - http://www.motorola.com/Business/US-EN/Business+Product+and+Services/LTE/SON_US-EN

Conclusions

Summary

- Mobile Networks and Operators can benefit significantly from autonomic principles
- Autonomic Management promises solutions
  - Increase management automation
  - Decrease network operator costs
- Policy-Based Management important for automating mobile networks
  - Policy engine functionality aims at improving QoE
  - Critical issues remain open:
    - Scalability and interoperability
    - Centralised vs. distributed control
    - Conflicting policies and policy analysis

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- University of Surrey – University College London
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  - P1855 Autonomic Computing & Networking

SEISMYC-2010

- Workshop on Socio-Economics Inspiring Self-Managed Systems and Concepts
  - SEISMYC-2010
  - **CFP: deadline July 12, 2010**
    - **Short papers (4 pages)**
      - Published in IEEE Proceeding
  - September 27th, 2010, Budapest, Hungary
  - Located at SASO 2010
    - Fourth IEEE International Conference on Self-Adaptive and Self-Organizing Systems

Autonomic Management of Mobile Networks

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Thank you!
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