COST 605

Econ@Tel
A Telecommunications Economics COST Network

Challenges and opportunities for LTE Network Management

Antonis M. Hadjiantonis

Research Fellow
Kios Research Center
University of Cyprus

antonish@ucy.ac.cy

Outline

- Introduction
- Network Management Basics
- Autonomics and Policy-based Management (PBM)
- Policy Management and Control for LTE/4G
- Conclusions

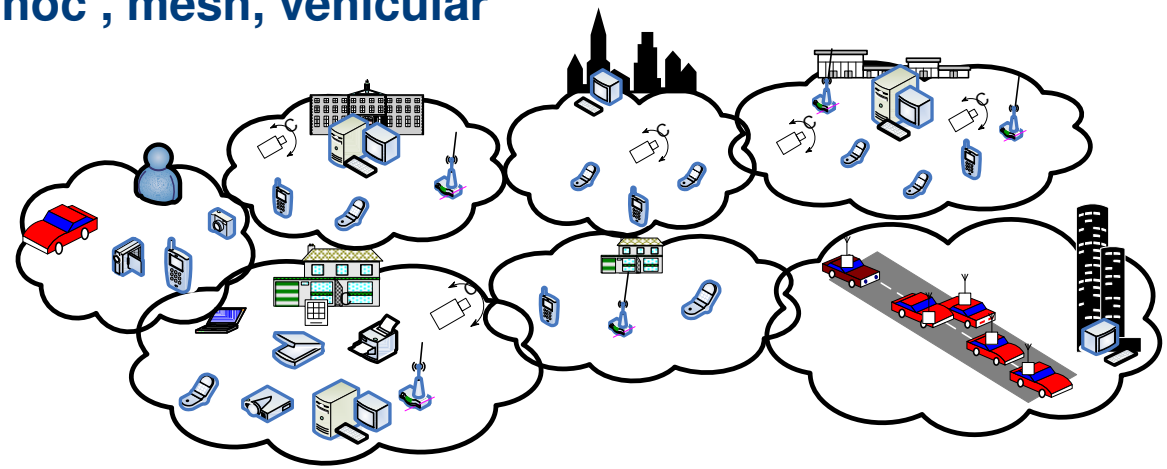
Introduction

Wireless and Mobile Networks

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

  → **ad hoc , mesh, vehicular**

? → 4G



Introduction and Background
Wireless Networks' Issues

- Multiple technologies → 4G → B4G
  - **Interoperability – Mobility – Scalability**
  - Multi-interface handsets
    - Today: 2G/2.5G/3G/3.5G/3.75G/3.9G, WLAN, Bluetooth, IR
    - Tomorrow: X, Y, Z, ?, ? , ?
  - New form factors
    - tablets, netbooks, MID, smartbooks, USB dongles etc …
  - Convergence of Fixed and Mobile Networks

→Increased scale

→Increased complexity →**<u>Increased Cost</u>**

→Increased heterogeneity

Introduction

Wireless/Mobile 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 for IBM)
- Industrial initiatives to reduce costs
  → management automation → ***Self-* Capabilities***
- IBM: Self-Managing Autonomic Technology (2001)
- 3GPP/NGMN: SON for LTE (2008)
  - Self-Organizing Networks (SON) Long Term Evolution (LTE) standards attempt to change the operations and maintenance paradigm
  - NGMN: Next Generation Mobile Networks Alliance
  - 3GPP: 3rd Generation Partnership Project

Introduction

Wireless/Mobile Networks' Issues

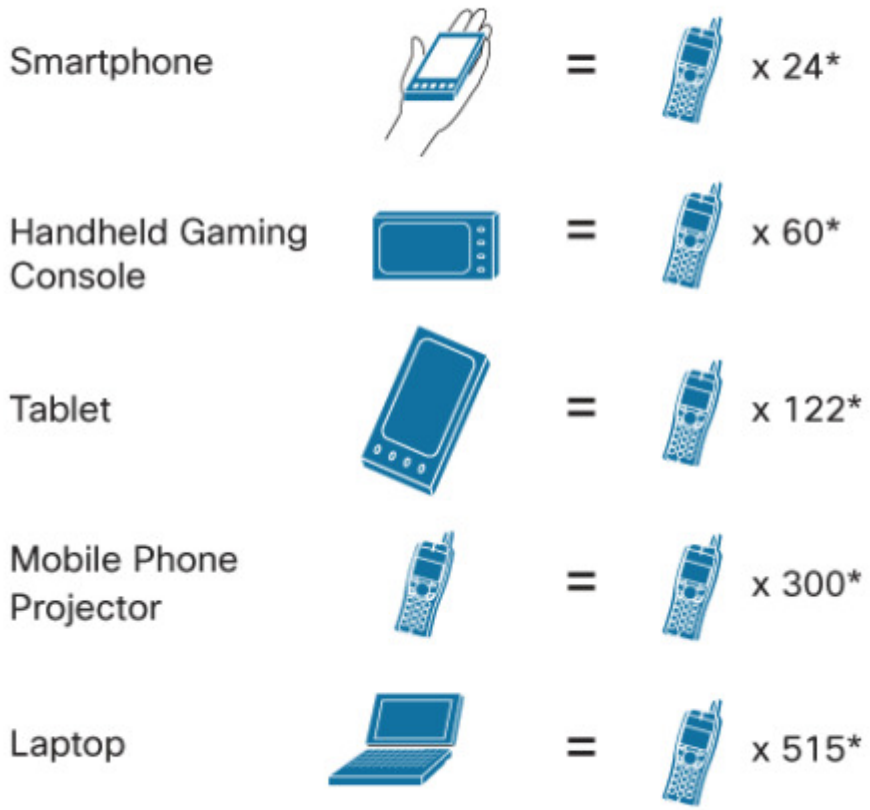
- Industry Whitepaper
  - about 17 % of wireless operator's CAPEX is spent on engineering and installation services
    - SON's self-configuring functions are expected to eliminate many on-site operations for the basic settings and subsequent updating of network equipments, and thus reduce CAPEX.
  - about 24 % of a typical wireless operator's revenue goes to network OPEX, which are the cost of network operation and maintenance, training and support, power, transmission, and site rental
    - SON's self-optimizing functions will reduce a workload for site survey and analysis of network performances, and thus reduce OPEX.
    - Moreover, SON's energy-saving functions reduce the costs of power consumed by the equipment.
  - "Self Organizing Network" "NEC's proposals for next-generation radio network management", NEC Corporation 2009

Introduction

Wireless and Mobile Networks

- Industry Whitepaper
  - Cisco VNI Mobile 2011
- Trend: Mobile Data usage explosion
- Smartphones represent only 13 % of total global handsets in use today, but they represent over 78 % of total global handset traffic.
- Mobile data traffic per month
  - Basic-feature cell phone 3.3 MB
  - Smartphone 79 MB

Figure 4. High-End Devices Can Multiply Traffic



* Monthly basic mobile phone data traffic

Source: Cisco VNI Mobile, 2011

COST 605

Introduction

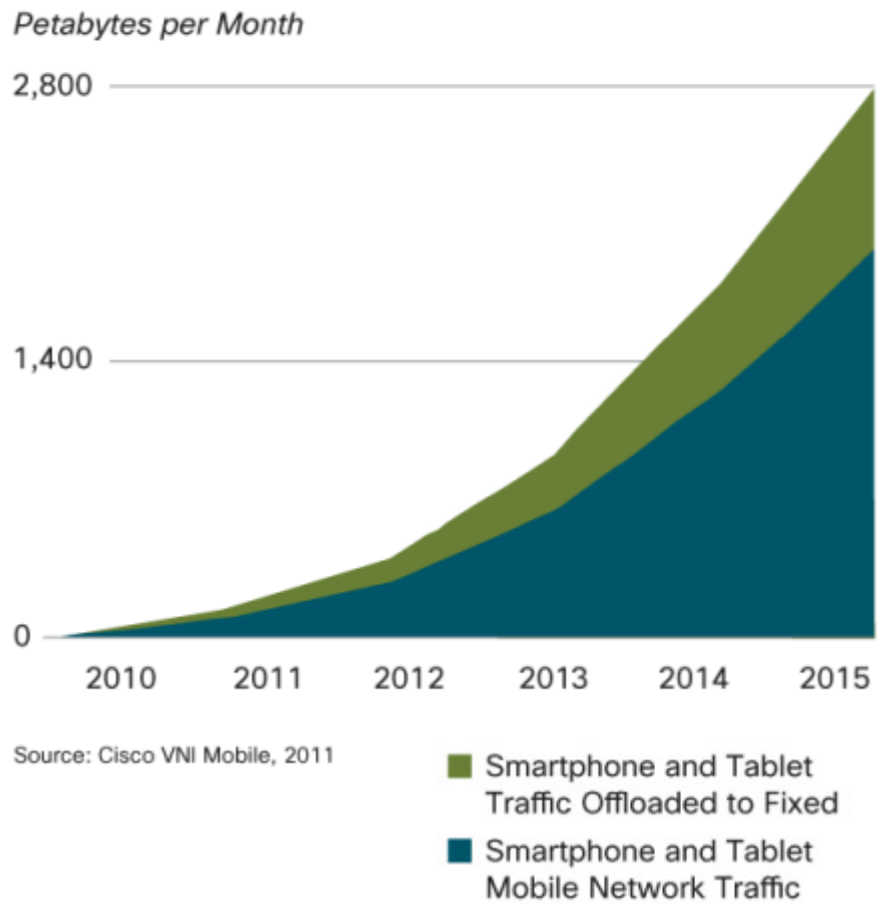
Wireless and Mobile Networks

- Industry Whitepaper
- Trend : Traffic Offload from Mobile Networks to Fixed Networks
- Cisco's survey: Much mobile data activity takes place at home
  - user's home 40 %
  - "on the move" 35 %
  - at work 25 %

- The relatively high percentage of home-based mobile data use suggests that operators may be able to offload traffic onto a fixed network

- Globally, 31 % of smartphone traffic was offloaded onto the fixed network through dual-mode or femtocell in 2010.

Figure 6. 39 Percent of Smartphone and Tablet Traffic will be Offloaded



Outline

- Introduction
- Network Management Basics
- Autonomics and Policy-based Management (PBM)
- Policy Management and Control for LTE/4G
- Conclusions

Network Management Basics
Why should you care?

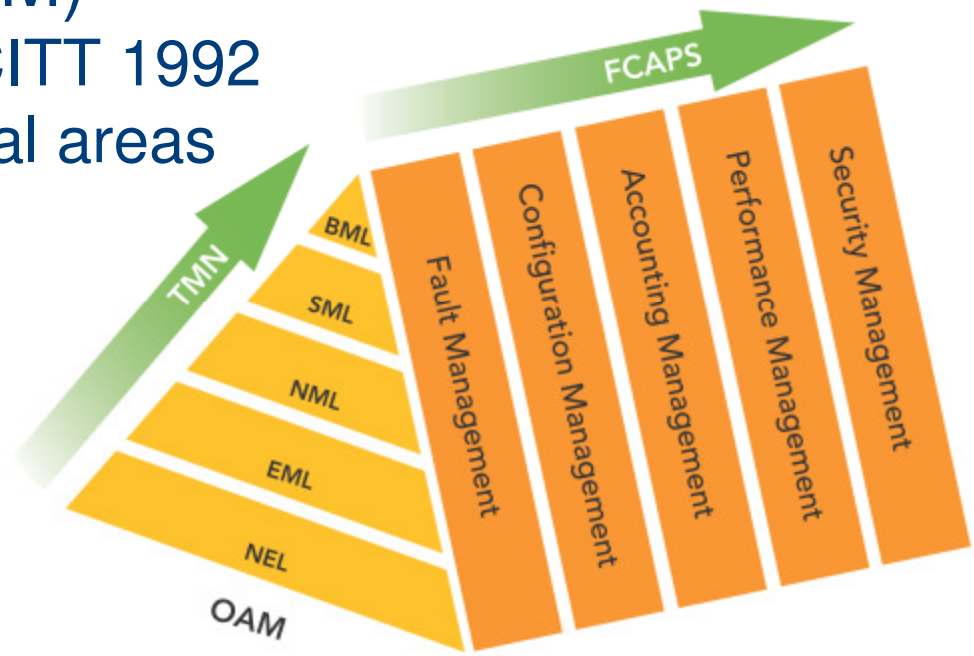
- Networks and systems management technologies and standards
  - As with most technologies and standards, they were, are, and will be influenced by non-technical factors!
  - We can learn from history
    - And history is repeated…
    - Better estimation/prediction of the Future

Network Management Basics

Functional areas of management

- Open Systems Interconnection (OSI) Systems Management (OSI-SM)
  - ITU-T Rec.X.700, CCITT 1992
  - Five generic functional areas

- FCAPS operations
  - **F**ault
  - **C**onfiguration
  - **A**ccounting
  - **P**erformance
  - **S**ecurity



Legend :
NEL: Network Element Layer (devices)
EML: Element Management Layer (device-level functions)
NML: Network Management Layer (topology management)
SML: Service Management Layer (Service Level Agreements (SLAs))
BML: Business Management Layer (budgeting and billing)

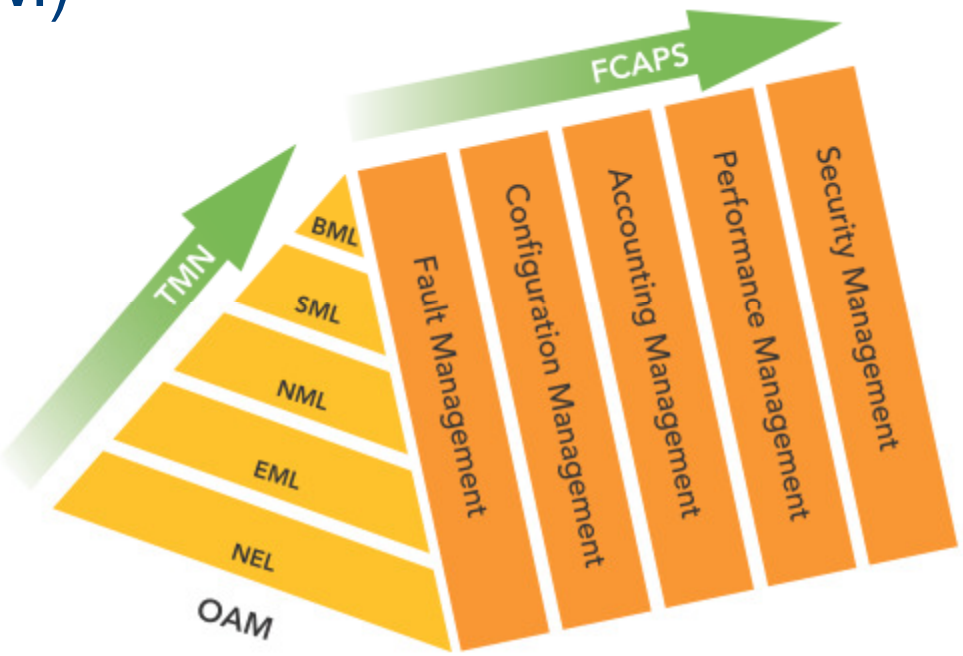
Figure 1. FCAPS model

Network Management Basics

Functional areas of management

- Open Systems Interconnection (OSI) Systems Management (OSI-SM)

New aspects
SLA Management
Event Management
Energy Management



Legend :
NEL: Network Element Layer (devices)
EML: Element Management Layer (device-level functions)
NML: Network Management Layer (topology management)
SML: Service Management Layer (Service Level Agreements (SLAs))
BML: Business Management Layer (budgeting and billing)

Figure 1. FCAPS model

Network Management Basics

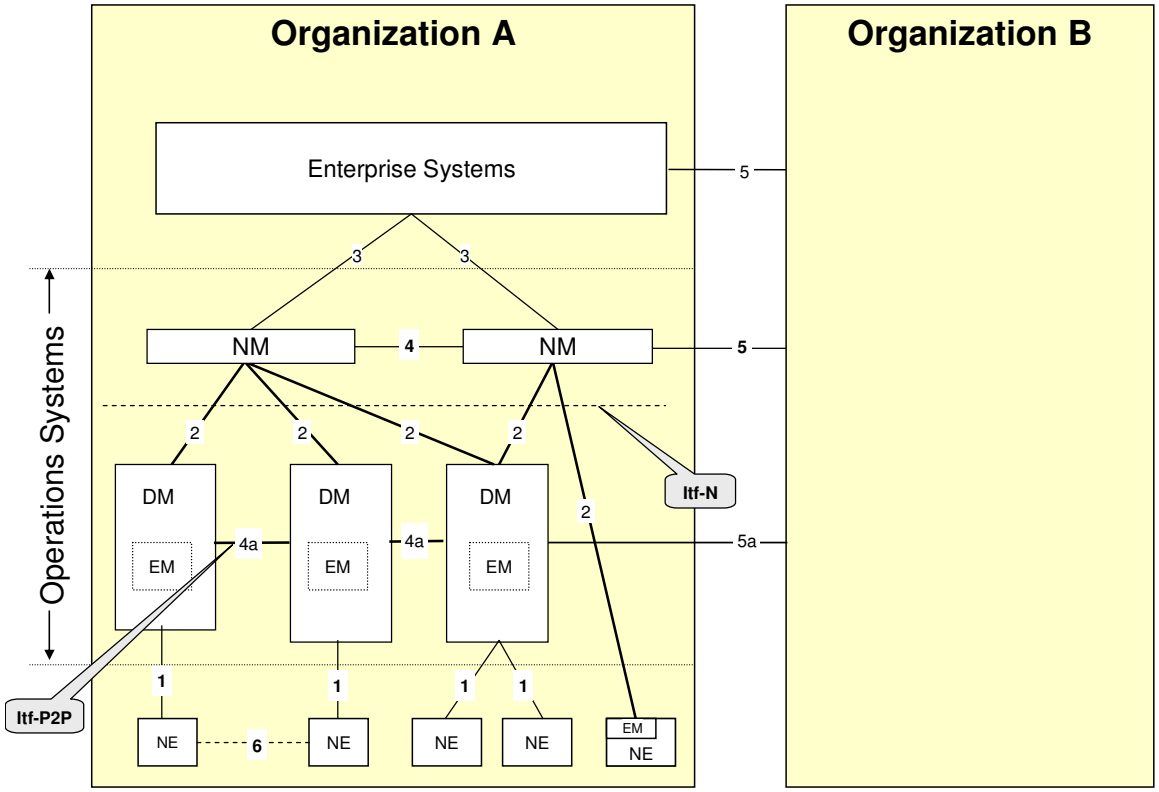
Functional areas of management

- Next Generation Networks (NGN)
  - *ITU-T Rec. Y.2011 (2004), "General principles and general reference model for Next Generation Networks".*
    - Next Generation Networks (NGN) are essentially about delivering new services that are available any place, any time, and on any device, through any customer-chosen access mechanism.
    - The decoupling is reflected in the NGN architecture as the separation of the **Transport and Service strata** and shown as two independent stratums.
- Management of Next Generation Networks
  - *ITU-T Rec. M.3060/Y.2401 (2006): "Principles for the Management of Next Generation Networks "*
    - NGN Management (NGNM) supports the aims of the NGN by decoupling and make independent, the service creation/deployment infrastructure from the transport infrastructure.
    - NGNM also introduces the **NGN management plane, union of the NGN service stratum management plane and the NGN transport stratum management plane** and may include joint management functions

Network Management Basics

Functional areas of management

- 3GPP Telecommunication management; Principles and high level requirements (TS 32.101, 32.102)
  - Management Infrastructure: the collection of systems (computers and telecommunications) a PLMN Organisation has in order to manage its network.



Network Management Basics

Functional areas of management

- 3GPP Telecommunication management; Principles and high level requirements (TS 32.101, 32.102)
  - The PLMN management architecture will facilitate the ITU-T NGN Management principles where necessary and suitable.

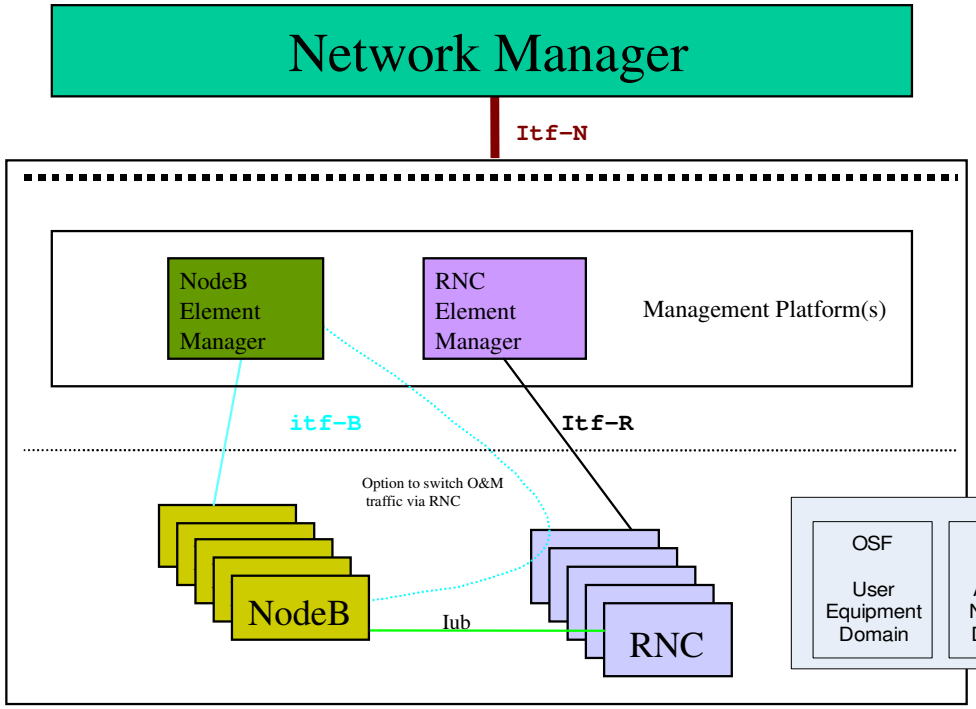


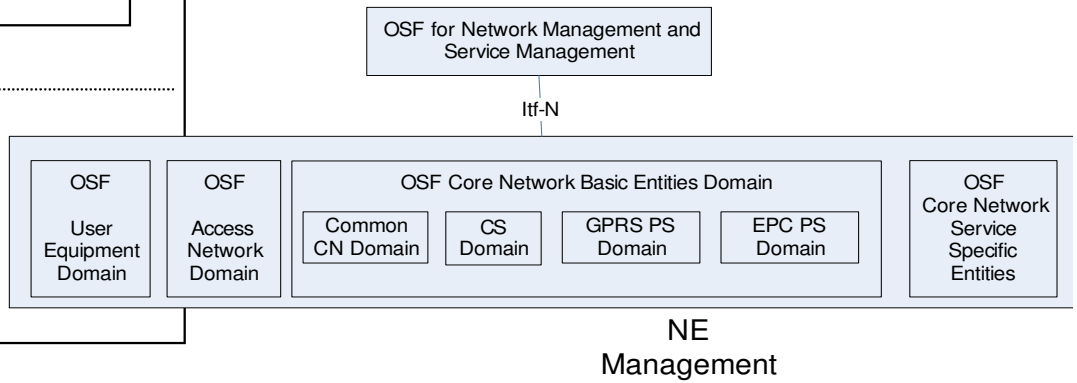
Figure 2: Radio Network management interfaces

3GPP Management application-layer protocols

SNMP

CORBA IIOP

SOAP



Overview of 3GPP Telecom Management Domains

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
Taxonomy and Protocols

- Remote Invocation (RI)
  - Established and dominant approach
    - Simple, efficient, predictable
    - Sometimes too simple
- Management by Delegation (MbD)
  - Failed to gain market acceptance
    - Reprogrammable but unpredictable with code mobility
- Is there a middle ground?
  - Policy-based Management
    - Controlled programmability

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”*

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
  - 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 for NM
  - 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

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 based on SOAP, WSDL
    - DMTF Web-Based Enterprise Management (WBEM)
    - OASIS Web Services Distributed Management (WSDM)

Network Management Basics

Evolution of Protocols & Technologies

- Network Configuration Protocol (NETCONF)
  - provides mechanisms to install, manipulate, and delete the configuration of network devices. It uses an Extensible Markup Language (XML)-based data encoding for the configuration data as well as the protocol messages. The NETCONF protocol operations are realized as remote procedure calls (RPCs).
  - RFC6241-6242 obsoletes RFC 4741-4742

NETCONF uses a simple RPC-based mechanism to facilitate communication between a client and a server. The client can be a script or application typically running as part of a network manager. The server is typically a network device.

```
RFC 6241                    NETCONF Protocol                    June 2011


                Layer                 Example
          +-------------+      +-----------------+      +----------------+
     (4)  |   Content   |      |  Configuration  |      |  Notification  |
          |             |      |      data       |      |      data      |
          +-------------+      +-----------------+      +----------------+
                 |                     |                         |
          +-------------+      +-----------------+               |
     (3)  | Operations  |      |  <edit-config>  |               |
          |             |      |                 |               |
          +-------------+      +-----------------+               |
                 |                     |                         |
          +-------------+      +-----------------+      +----------------+
     (2)  |  Messages   |      |     <rpc>,      |      | <notification> |
          |             |      |   <rpc-reply>   |      |                |
          +-------------+      +-----------------+      +----------------+
                 |                     |                         |
          +-------------+      +-------------------------------------------+
     (1)  |   Secure    |      |  SSH, TLS, BEEP/TLS, SOAP/HTTP/TLS, ...   |
          |  Transport  |      |                                           |
          +-------------+      +-------------------------------------------+

                    Figure 1: NETCONF Protocol Layers
```

Outline

- Introduction
- Network Management Basics
- Autonomics and Policy-based Management (PBM)
- Policy Management and Control for LTE/4G
- Conclusions

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
    - current communications service offerings are inflexible

Autonomics and Self-Management
Motivation

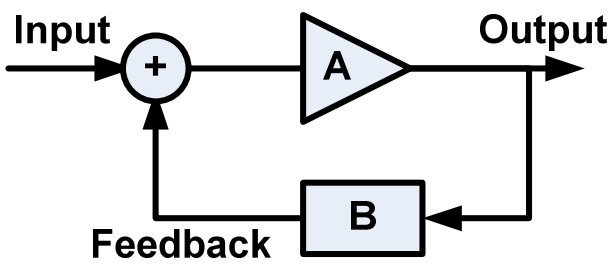
- Telecommunications actors faced with difficulties
  - Direct impact on the OPEX and CAPEX
- Current communications service offerings are inflexible in nature:
  - rigidly defined and exhibit static functionality
  - closely coupled to specific network technology
  - Largely manually deployed and managed, 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***

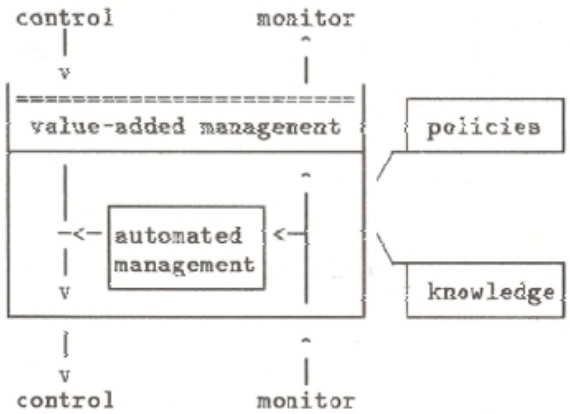
Autonomics and Self-Management
First steps and definitions

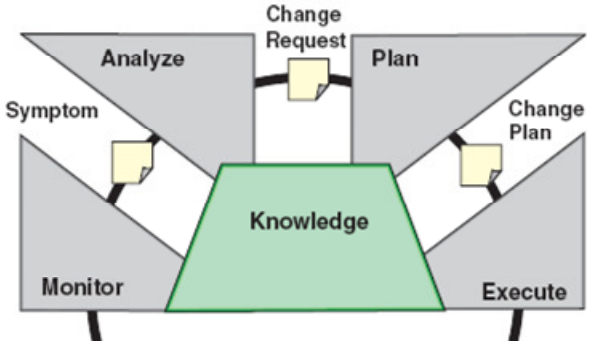
- **Autonomic Computing**:
  - a computing environment with the ability to manage itself and dynamically adapt to change in accordance with business policies and objectives [IBM2001]
  - "*Grand Challenge:* building and deploying computing systems that regulate themselves and remove complexity from the 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

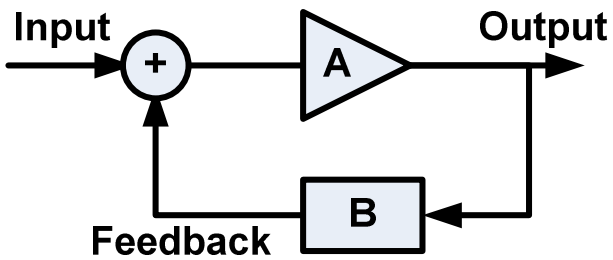


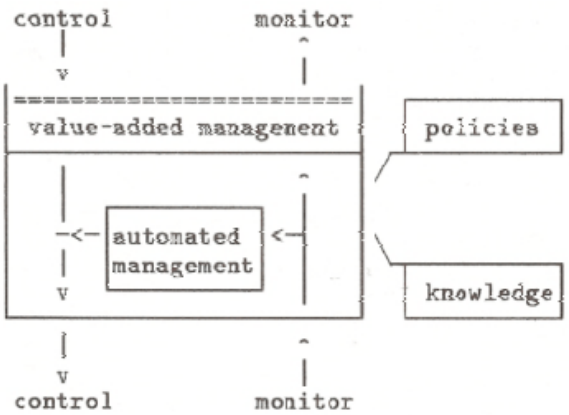




Autonomics and Self-Management
First steps and definitions

- 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

First steps and definitions

- Self Organizing Network and Self-configuration
  - deployment of new network elements should be automated to as large extent as possible and only require a single visit to the installation site

•The network elements shall automatically create the logical associations with the network
• DHCP for auto-configuration and EAP or SIM-card-based security parameter configurations
• initial configuration for the element. by using NETCONF protocol server
• self-test to determine that everything is working as intended.
• active service and self-optimization.

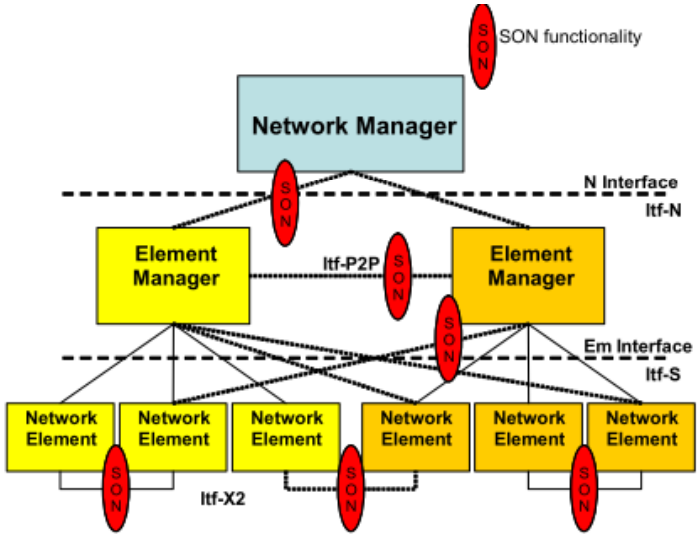


Figure 2. Simplified view of LTE network management structure.

•"Self Organizing Network" "NEC's proposals for next-generation radio network management", NEC Corporation 2009

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

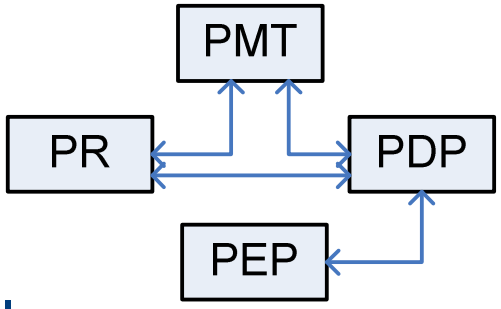
- Basic concept
  - high-level policies are translated to low-level element operations for monitoring the network and automatically enforcing appropriate actions
    - Intense interest, fuelled by IBM's vision in Autonomic Management
- The PBM paradigm
  - Policies capture high-level management objectives
  - 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.

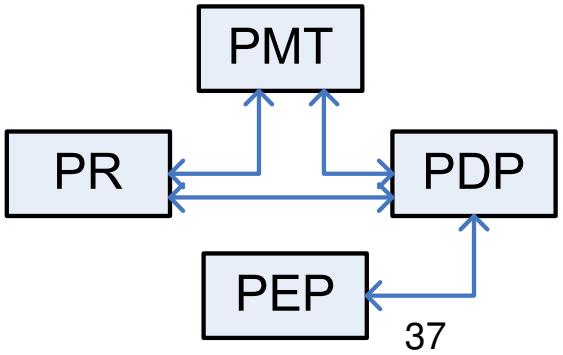
Policy-based Management (PBM)
IETF's Policy Framework

- IETF Definition of Policy
  - a set of rules to administer, manage and control access to network resources
- 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
- 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



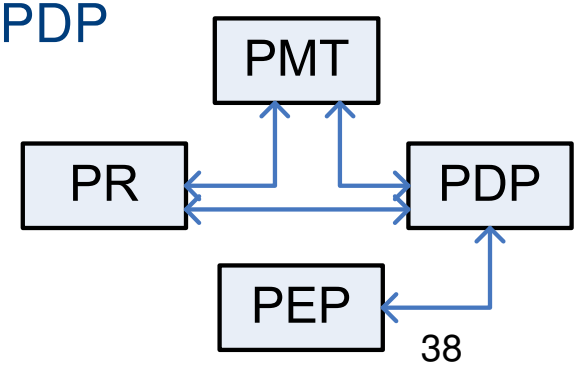
Policy-based Management (PBM)
IETF's Policy Framework

- 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



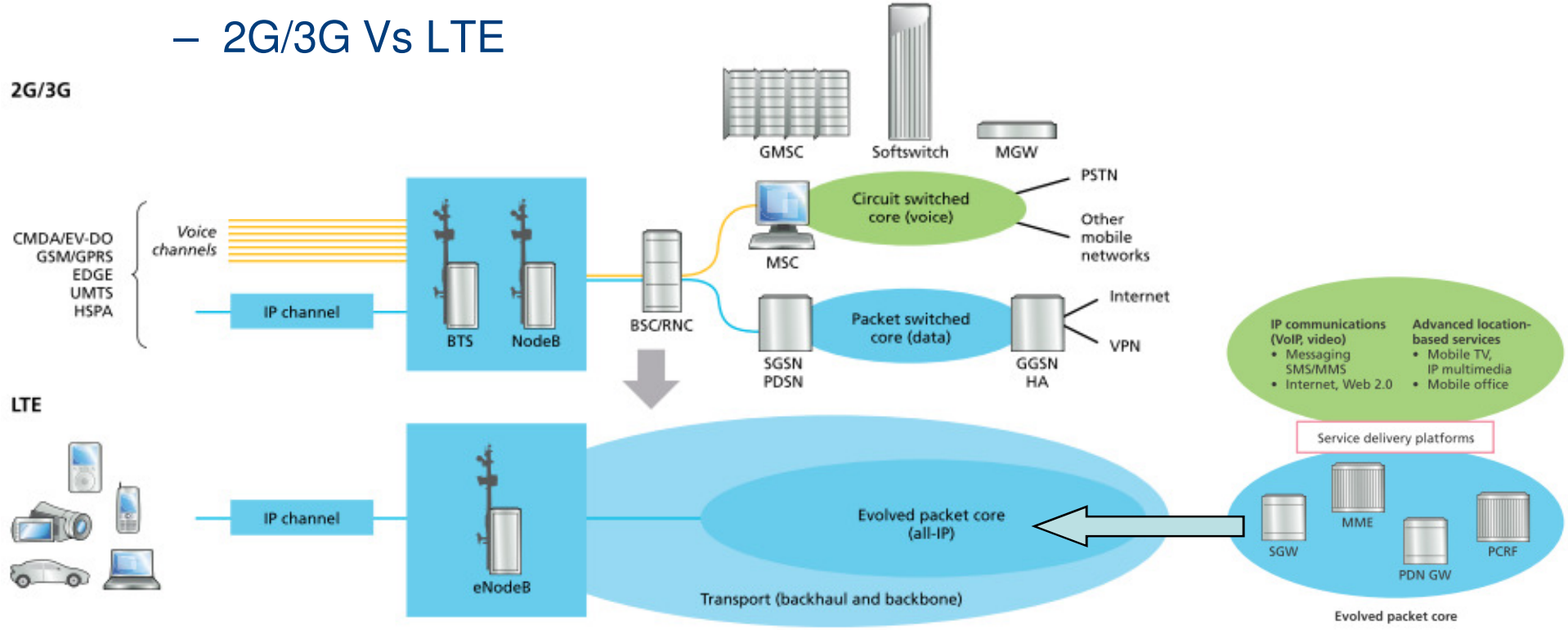
Outline

- Introduction
- Network Management Basics
- Autonomics and Policy-based Management (PBM)
- Policy Management and Control for LTE/4G
- Conclusions

Policy-based Management (PBM)

Policy Management and Control for LTE/4G

- Mobile Internet and Policies in Long Term Evolution (LTE)
  - LTE: Enhanced Packet Core (EPC) + LTE Radio Access Network
  - 2G/3G Vs LTE

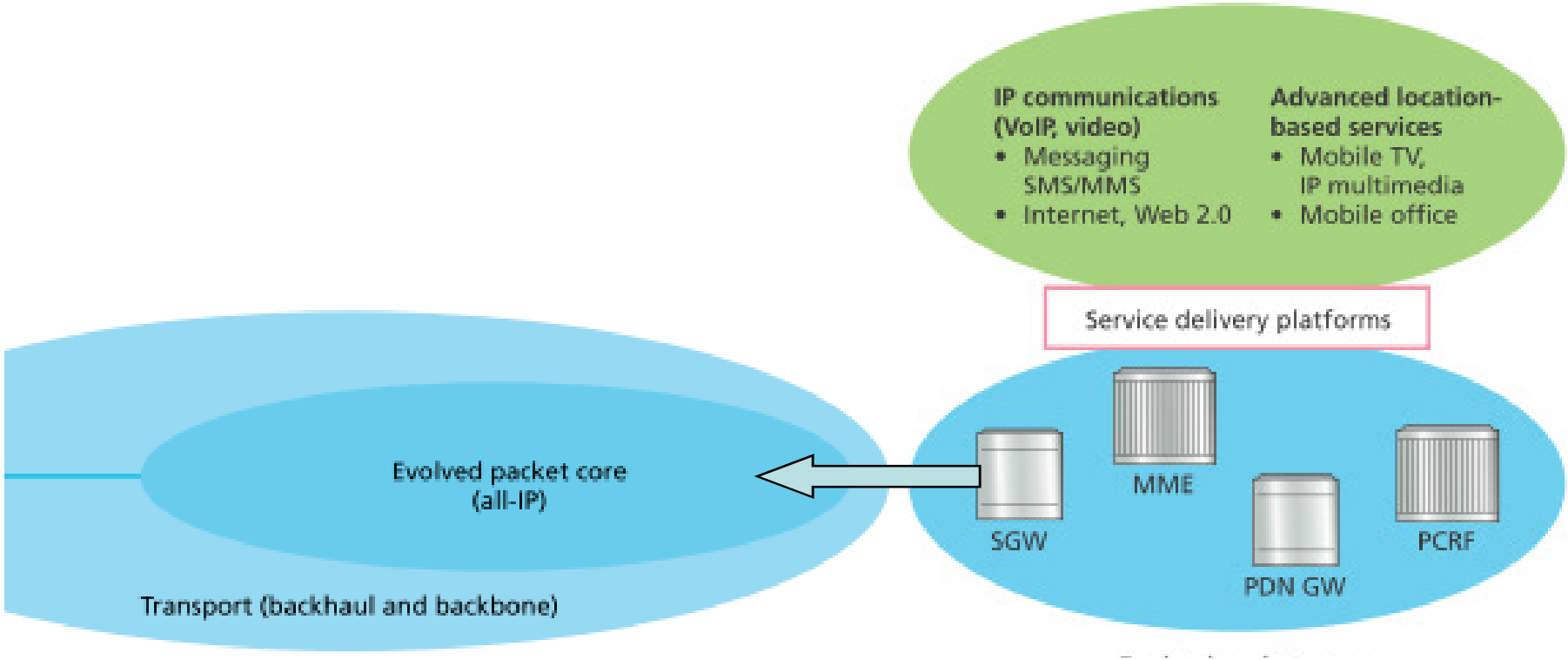


Alcatel-Lucent Evolved Packet Core Solution | Technology White

Policy-based Management (PBM)

Policy Management and Control for LTE/4G

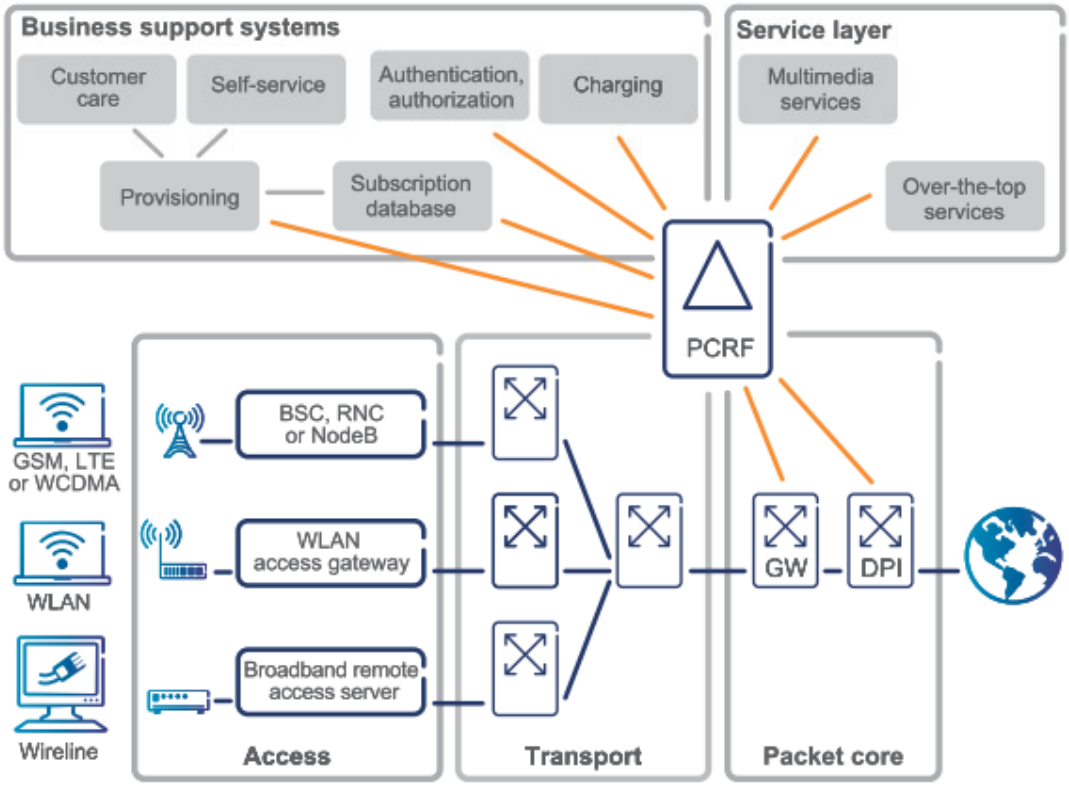
- Mobile Internet and Policies in Long Term Evolution (LTE)
  - LTE: Enhanced Packet Core (EPC) + LTE Radio Access Network



Policy-based Management (PBM)

Policy Support in Mobile Networks

- What do operators need?
  - intelligent policy decisions, e.g. prioritize delay-sensitive apps
  - ensure the delivery of a high-quality service to premium subscribers



ERICSSON WHITE PAPER
284 23-3158 Uen | May 2011
PERFECTING POLICY CONTROL – STRATEGIES FOR END-TO-END SUPPORT AND CONVERGENCE

COST 605

Policy-based Management (PBM)

Policy Support in Mobile Networks

Mobile Internet and Policies in Future Mobile Internet

- First generation of policy control solutions
  - designed for fixed broadband networks
  - only enforce policies in the core network
  - Not sufficient to manage congestion effectively

- Congestion in mobile networks typically occurs in the radio access or mobile backhaul networks
  - subscribers compete for a limited supply of shared capacity
  - data sessions use bursty applications

- Centralized solutions lack good, timely feedback mechanisms for their policy decisions
  - may result in instabilities

ERICSSON WHITE PAPER
284 23-3158 Uen | May 2011

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

- End-to-end versus centralised challenges
  - E2E requires integration of more network elements
  - E2E much more effective in managing traffic
- Ericsson study
  - Investigates how peak-hour traffic patterns and trends affect the need for investment in network capacity
    - Compares the impacts of applying centralized policy control and end-to-end policy control as the proportion of sites requiring upgrades
      - No traffic management: 20%
      - Centralized policy control: 14 %
      - End-to-end policy control: 9 %
    - The end-to-end approach is four times more profitable

ERICSSON WHITE PAPER
284 23-3158 Uen | May 2011

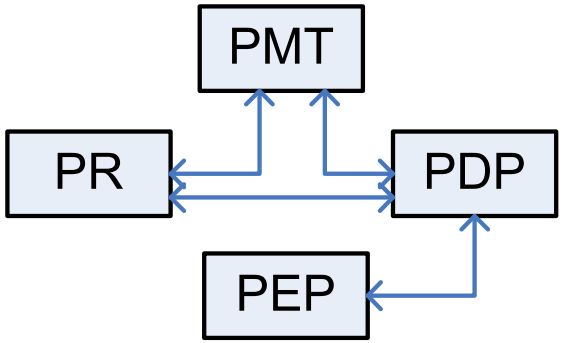
Policy-based Management (PBM)
Policy Support in Mobile Networks

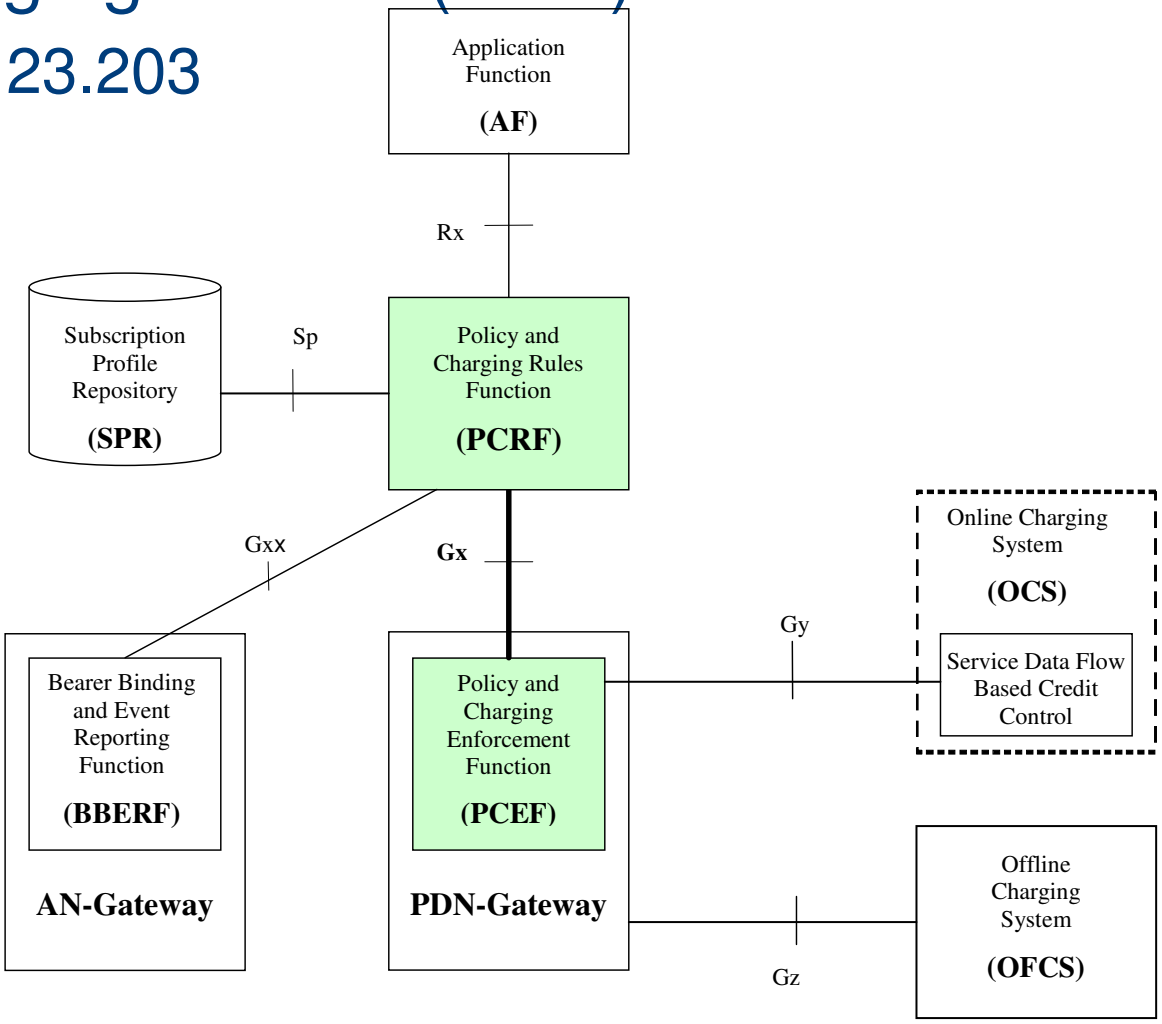
- 3GPP Policy and Charging Control (PCC)
  - encompasses high level functions for IP CANs
    - Flow Based Charging, including charging control and online credit control to allow for more granularity for end-user charging, accounting and online credit control
    - Policy Control (e.g. gating control, QoS control, etc.) to allow the operator to perform service based QoS policy control
      - (IP Connectivity Access Networks)
  - From Release 7 onwards PCC supersedes FBC and replaces the SBLP architecture and functionality.
    - An evolution of Flow Based Charging (FBC) and a replacement for Service Based Local Policies (SBLP) from Releases 5 and 6

Policy-based Management (PBM)

Policy Support in Mobile Networks

- Policy and Charging Control (PCC) architecture
  - 3GPP/ETSI TS 23.203





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

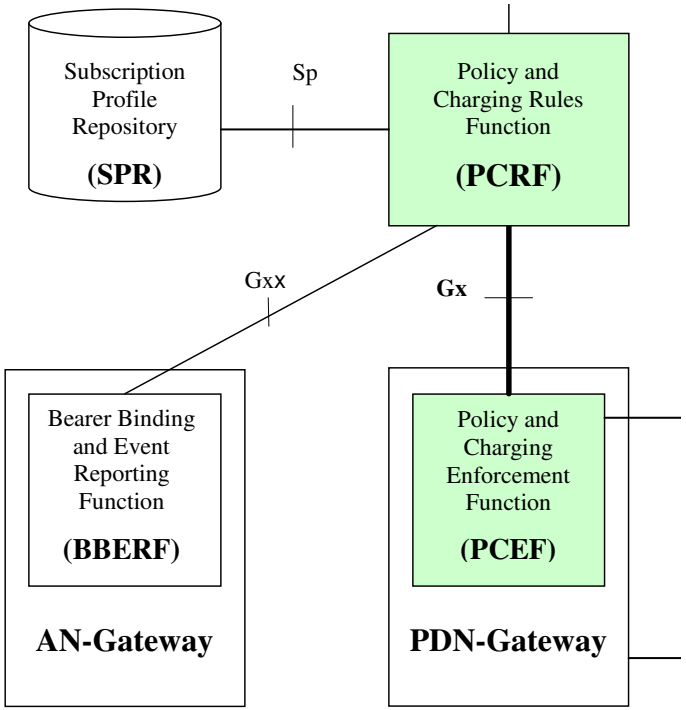
- Definitions
  - PCC rule: A set of information enabling the detection of a service data flow and providing parameters for policy control and/or charging control.
    - Pre-defined Vs Dynamic
  - PCC decision: A decision consists of PCC rules and IP CAN bearer attributes, which is provided by the PCRF to the PCEF for policy and charging control.

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

- Definitions
  - IP CAN bearer: An IP transmission path of defined capacity, delay and bit error rate, etc.
    - IP CAN session: The association between a UE and an IP network, (e.g. GPRS IP CAN)
  - service data flow (SDF): A set of packet flows that matches the set of service data flow filters in a PCC rule
    - service data flow filter: A set of packet flow header parameter values/ranges used to identify one or more of the packet flows constituting a service data flow

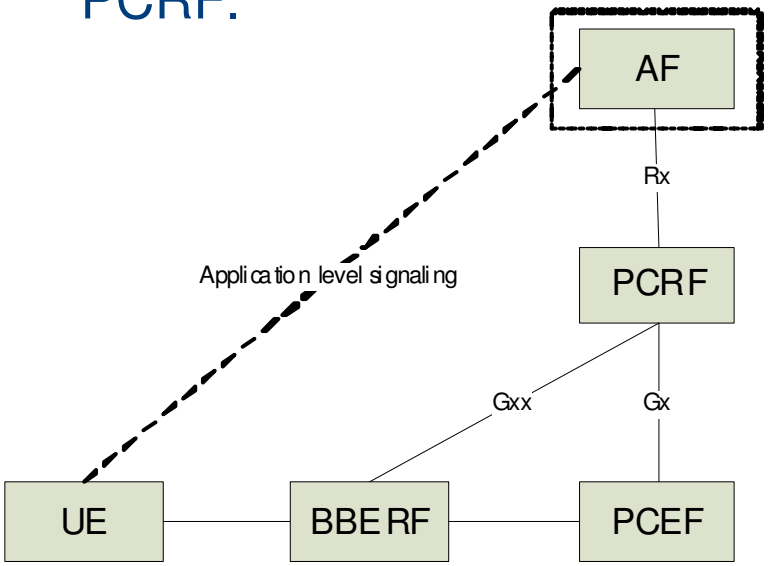
Policy-based Management (PBM)
Policy Support in Mobile Networks

- Policy control
  - The process whereby the PCRF indicates to the PCEF how to control the IP CAN bearer (QoS control and/or gating control)
  - the PCEF is a functional entity in the Gateway node implementing the IP access to the PDN. The allocation of the BBERF is specific to each IP CAN type.



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

- Gating control: The process of blocking or allowing packets, belonging to a service data flow, to pass through to the desired endpoint.
  - applied by the PCEF on a per service data flow basis.
  - To enable the PCRF gating control decisions, the AF shall report session events (e.g. session termination, modification) to the PCRF.



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

- QoS control
  - the authorisation and enforcement of the maximum QoS for a service data flow or an IP CAN bearer

- QoS Conflict Handling
  - It shall be possible for the PCC architecture to support conflict resolution in the PCRF when the authorized bandwidth associated with multiple PCC rules exceeds the Subscribed Guaranteed bandwidth QoS
  - KEY OPEN ISSUE!

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

- QoS control
  - on a per service data flow basis in the PCEF
    - Criteria such as the QoS subscription information may be used together with policy rules such as, service-based, subscription-based, or pre-defined PCRF internal policies to derive the authorized QoS to be enforced for a service data flow.
  - at IP CAN bearer level
    - support control of QoS reservation procedures (UE-initiated or network-initiated) for IP CAN bearers in the PCEF or the BBERF
    - Details of QoS reservation procedures are IP CAN specific

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

- Flow Based Charging
- Charging control
  - The process of associating packets, belonging to a service data flow, to a charging key and applying online charging and/or offline charging, as appropriate.
  - Examples of Service Data Flow Charging
    - An operator offers a zero rating for network provided DNS service. A PCC rule is established setting all DNS traffic to/from the operators DNS servers as offline charged. The data flow filter identifies the DNS port number, and the source/destination address within the subnet range allocated to the operators network nodes.

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

- Policy provisioning challenges
  - 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

- 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

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

"Traffic management is the No. 1 catalyst today for deploying policy tools – primarily PCRF-based policy servers and associated enforcement (PCEF) appliances and software – as operators struggle to control the torrents of new data traffic flowing through the network."

– *Heavy Reading*

"Operators aim to use their policy platforms to develop new charging models and develop tiers of services, so they can move away from the flat-rate mobile data models that currently prevail."

– *Heavy Reading*

Outline

- Introduction
- Network Management Basics
- Autonomics and Policy-based Management (PBM)
- Policy Management and Control for LTE/4G
- Conclusions

Conclusions

Summary

- 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)

Conclusions

Summary

- 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

Conclusions
Summary

- Mobile Network Operators can benefit significantly from policy control and policy-based management
  - Increase management automation
  - Decrease network operator costs
  - Policy engine functionality aims at improving QoE

- Critical issues remain open:
  - Scalability and interoperability
  - Centralised vs. distributed control
  - Conflicting policies and policy analysis
  - Net Neutrality/Transparency controversy

Further Reading Bibliography

- 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.
- A. Pras et al., “Key research challenges in network management,” Communications Magazine, IEEE, vol. 45, no. 10, pp. 104-110, 2007.
- G. Pavlou, “On the Evolution of Management Approaches, Frameworks and Protocols: A Historical Perspective,” Journal of Network and Systems Management, vol.15,no.4, pp. 425-445, Oct. 2007.
- J.-P. Martin-Flatin, S. Znaty, and J.-P. Hubaux, “A Survey of Distributed Enterprise Network andSystems Management Paradigms,” J. Netw. Syst. Manage., vol. 7, no. 1, pp. 9–26, Mar. 1999.
- R. Boutaba and I. Aib, “Policy-based Management: A Historical Perspective,” Journal of Network and Systems Management, vol. 15, no. 4, pp. 447-480, Nov. 2007.
- “Perfecting policy control – strategies for end-to-end support and convergence - Ericsson.” Available Online
- An e-Guide to Policy Control , Light Reading Sponsored Whitepaper Available Online