Introduction to SON

Chapters 1 - 3

S. Hämäläinen

Outline

LTE principles, management architecture and radio access scenarios

SON Challenges – why SON?

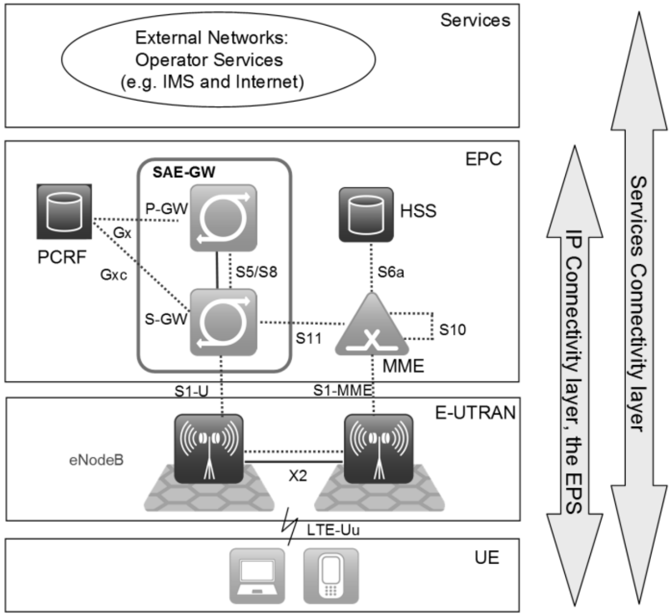
SON Vision

NGMN and 3GPP Use cases

LTE principles

System architecture

- Evolved Packet System (EPS) consists of
  - Evolved UTRAN
  - Evolved Packet Core
  - Connectivity to 3GPP and non-3GPP access systems
- In EPS only the radio access and core network are new
  - UE and services remain unchanged
- EPS is optimised for IP connectivity
- EPS key aspects are:
  - Reduced number of network elements on the data path
  - Streamlined RAN functionality provided with a single node
  - Separation of the control and user plane network elements (MME and S-GW)



TS23.402: Architecture enhancements for non-3GPP access

LTE principles

Evolved UTRAN

- LTE downlink is based on Orthogonal Frequency Division Multiplexing (OFDM) in which data are carried simultaneously by narrow-band subcarriers
- LTE uplink is based on Single Carrier FDMA to minimise UE power consumption
- The signal is organised into sub-frames of 1ms each
  - 1ms subframe and the flat network architecture enable very short latency for both data and signaling
- LTE is scalable with system bandwidth ranging from 1.4MHz up to 20MHz
- Both paired (FDD) and unpaired (TDD) spectrum allocation are supported with the same downlink subframe structure

LTE principles

Evolved UTRAN

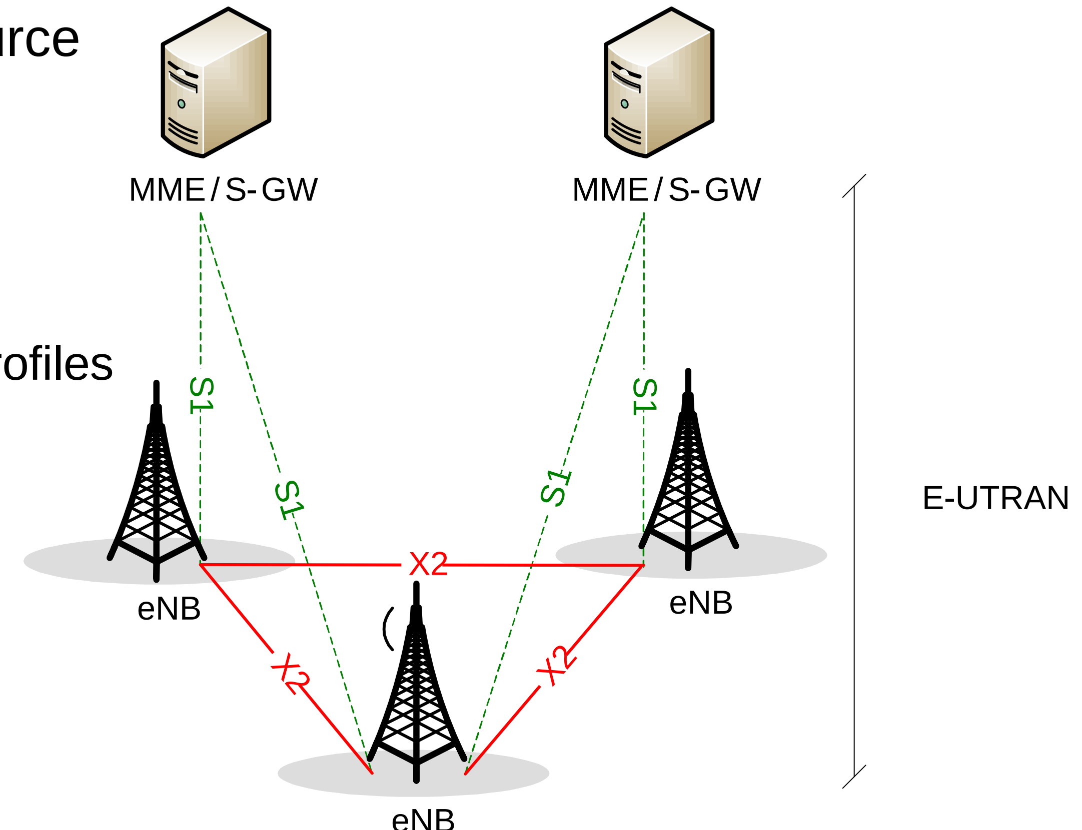
- All LTE UEs support at least two receive antennas, allowing downlink receive diversity
  - More advanced techniques, such as Transmit diversity, spatial multiplexing (Single-User and Multi-Users MIMO) and beam-forming are also supported
- LTE peak data rate increases by a factor of ~10x compared to HSPA+ . Spectral efficiency also increases significantly while there are no substantial improvements in coverage

Requirement	LTE	HSPA+
Peak transmission rate At 20MHz BW	DL: 150-300 Mb/s UL: 75 Mb/s	DL: 42-168 Mb/s UL: 11-54 Mb/s
Spectral efficiency (average) 4-rx mobile	1.7 – 2.7 bps/Hz/cell	1.21 - 1.9 bps/Hz/cell
Coverage	162dB	162dB

LTE principles

E-UTRAN functional elements

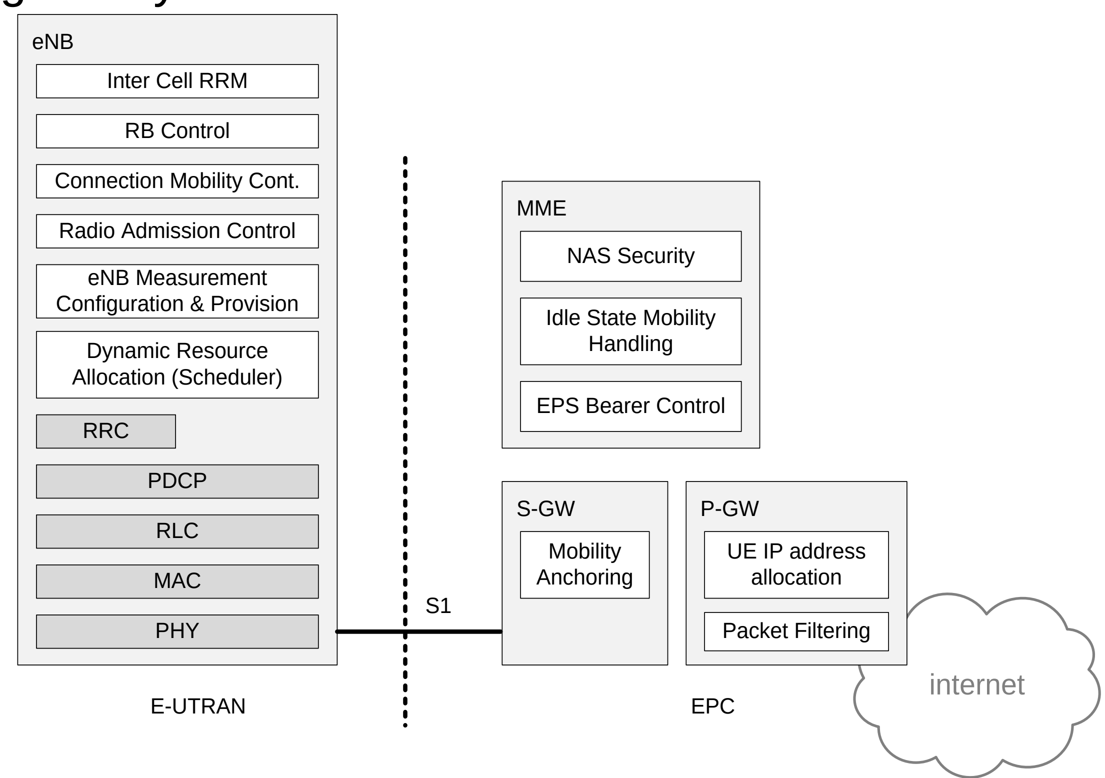
- eNB - Evolved NodeB. This is the only node in E-UTRAN
  - eNB forms a meshed network connecting each other through X2 interface
- All radio related functionality collapses to eNB
  - eNB is termination point for physical layer, MAC layer and PDCP layers
- In the control plane radio resource control (RRC) functionality involves
  - radio resource management
  - admission control
  - scheduling according to QoS profiles



LTE principles

Evolved Packet Core

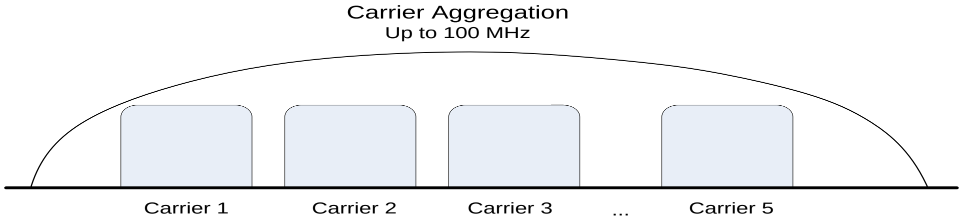
- EPC is optimised for packet data and does not support CS domain
- EPC contains the following functional elements
  - MME – Mobility management entity
  - S-GW – Serving gateway
  - P-GW – Packet data network gateway
  - SAE-GW – in case of co-located S-GW and P-GW
  - HSS – Home subscriber Service
  - PCRF – Policy control and charging rules function



LTE principles

LTE-Advanced

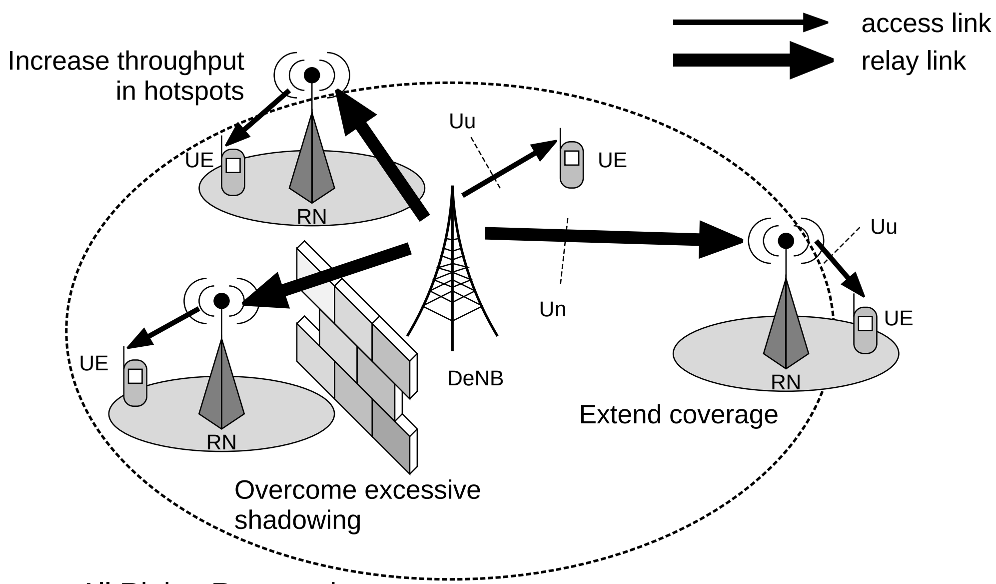
- LTE-A is defined in 3GPP Rel.10 and is targeting to requirements as defined by ITU-R
- LTE-A maintains backwards compatibility with previous LTE versions
- Technology components included in LTE-A are
  - Improved MIMO schemes
    - Rel. 10 extends downlink MIMO to support 8 RX/TX antennas in DL and 4 TX and 8 RX antennas in UL
  - Coordinated Multipoint Transmission and Reception (CoMP)
    - A number of geographically separated base station cooperate by providing joint scheduling and transmission in DL and joint processing of signal in UL
  - Carrier Aggregation (CA)
    - CA targets to data rates of 1Gpbs in DL and 500Mbps in UL by means of bandwidth extensions. Up to 5 component carriers can be used



LTE principles

LTE-Advanced

- Relay node (RN)
  - Demanding LTE-A targets require short distance between transmitters and receivers
  - In order to reach cell-edge users, multi-hop Relay Nodes (RN) have been introduced
  - RN's are served by Donor-eNB that allocates part of air-interface capacity to provide backhaul link for RN



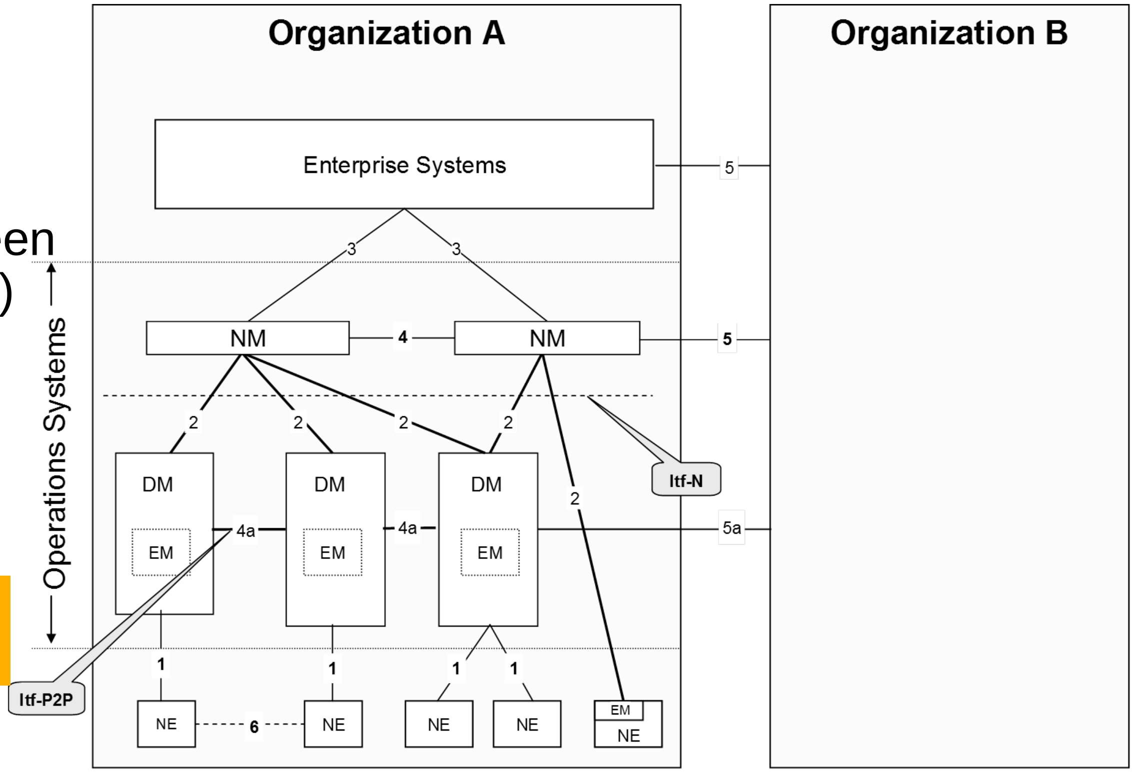
LTE principles

LTE-Advanced

- Heterogeneous Networks (HetNet)
  - In HetNets different types of base stations co-exist
    - macrocells provide wide area coverage
    - low powered base stations in small cells hotspot capacity
      - Small cells are micro, pico or femto (HeNB)
  - Micro, pico and Enterprise-femto cells are operated by operator, while residential-femto is operated by the end-user
  - HeNB operating modes are Open Subscriber Group, Closed Subscriber Group and hybrid
  - One of the key problems for SON to solve is inter-cell interference between macro and small cells. This is addressed by enhanced Inter Cell Interference Cancellation (eICIC)

LTE management architecture

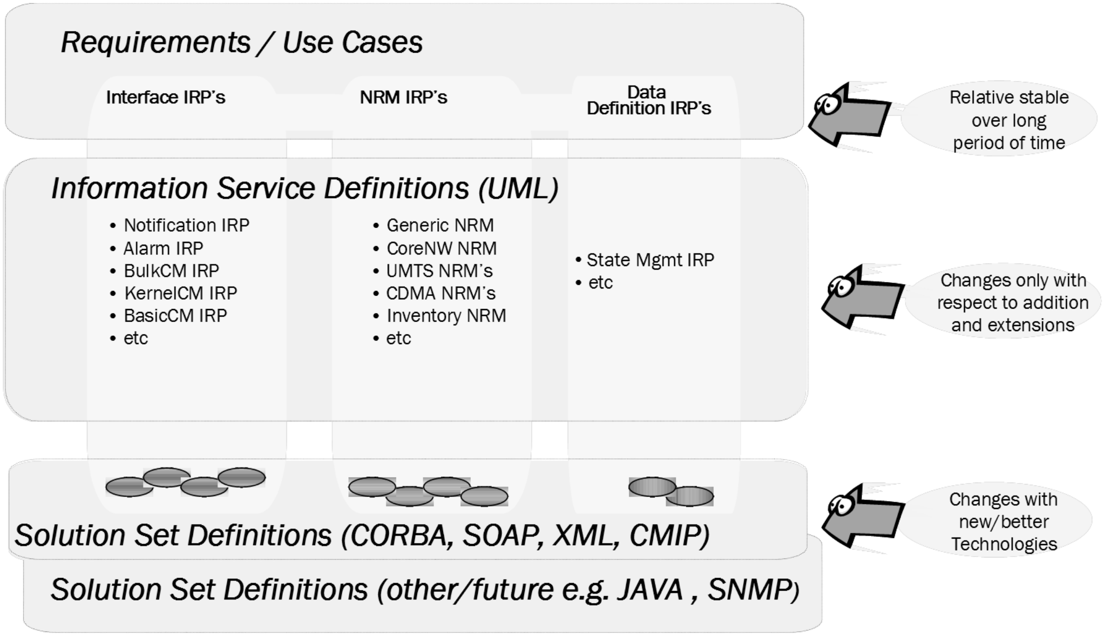
- LTE follows the same 3GPP management reference model as 3G as specified by 3GPP
- Several interfaces from operations systems to NEs are introduced
  - **Itf-S**: Interface between the Network Element (NE) and the Domain Manager (DM). This interface is vendor specific.
  - **Itf-N**: Interface between the Domain Manager (DM) and the Network Manager (NM). This is a standardised open interface and thus facilitates multi-vendor management
  - **The Itf-P2P:** interface between the Domain Managers (DMs) and the Element Manager (EM) embedded into the Network Element



TS32.101: Telecommunication management; Principles and high level requirements

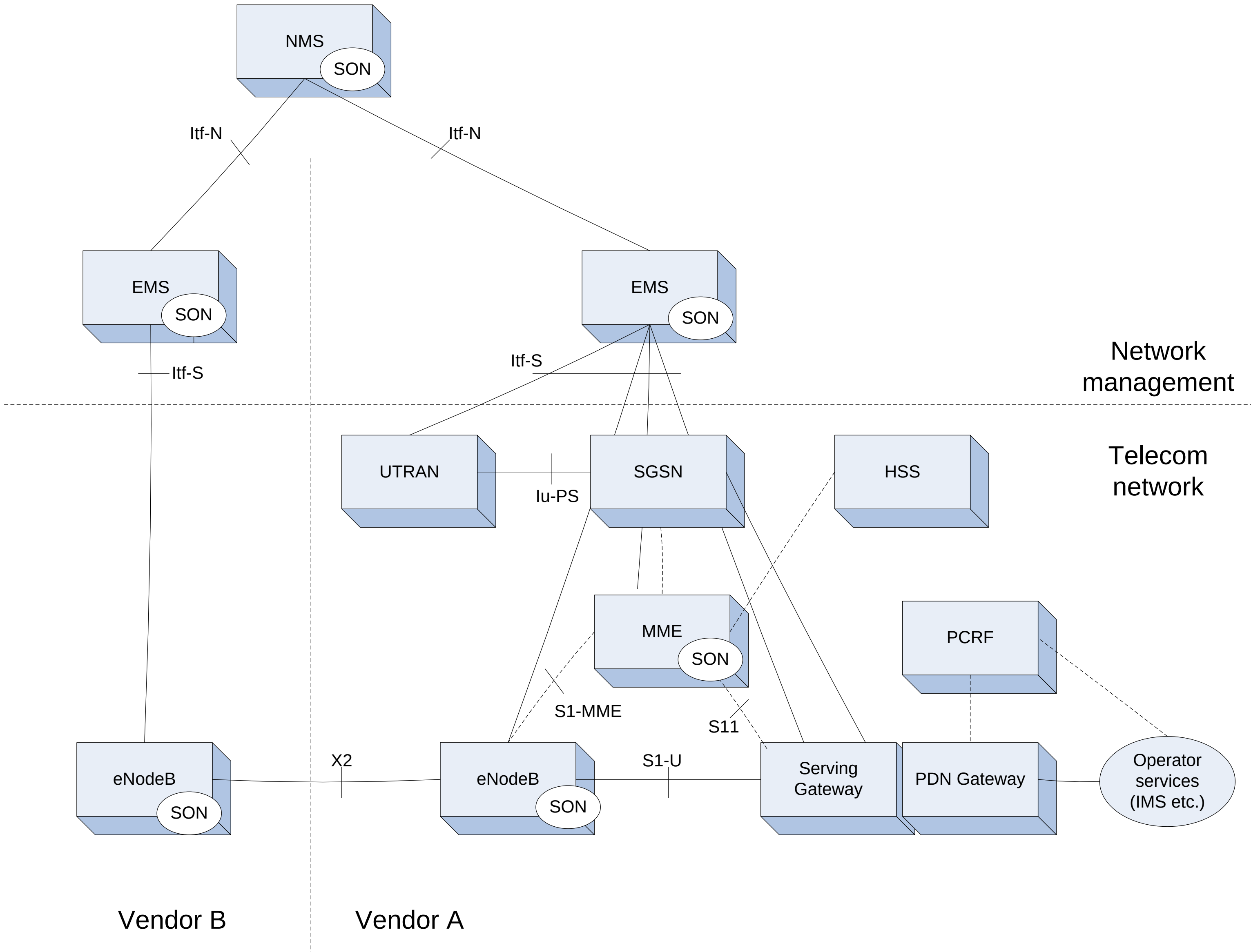
LTE management architecture

- 3GPP's management is based on an interface concept known as Integration Reference Point (IRP).
  - IRPs are defined with IRP Levels and IRP types
- IRP levels are
  - Requirements
  - Information Service (IS)
  - Protocol specific (CORBA, SOAP, XML) Solutions Sets (SS)
- IRP types are:
  - Interface IRPs define how information is shared (operations and notifications)
  - NRM (Network Resource Model) IRP defines what can be managed
  - Data Definition IRP – Abstract data definitions to be used in NRM IRPs
- Each IRP type is partitioned into Requirements, IS-level and SS-level Specifications



TS32.103: Telecommunication management; Integration Reference Point (IRP) overview and usage guide

Overall architecture

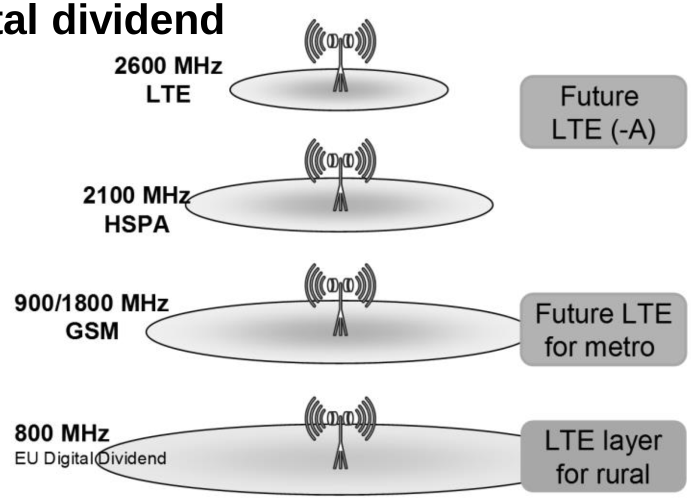


Radio access scenarios for SON

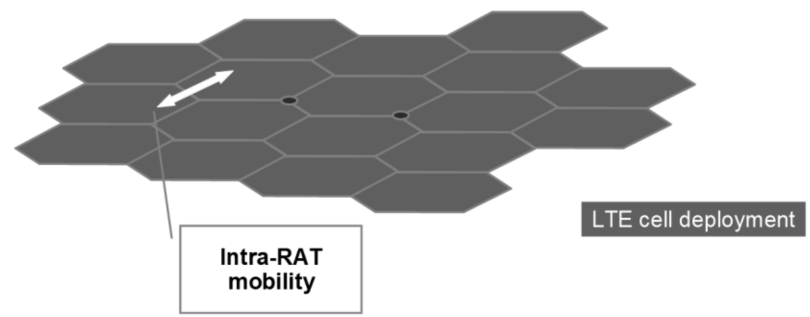
LTE Radio Coverage Scenario

- Digital Dividend in Europe. Switchover of TV signal to digital frees up frequencies at 800 MHz
- Public authorities requiring LTE license owners to first deploy rural coverage
- Greenfield operator with no previous mobile network in the area.
- Operator has another overlay network but there is no need to integrate it with LTE

Digital dividend



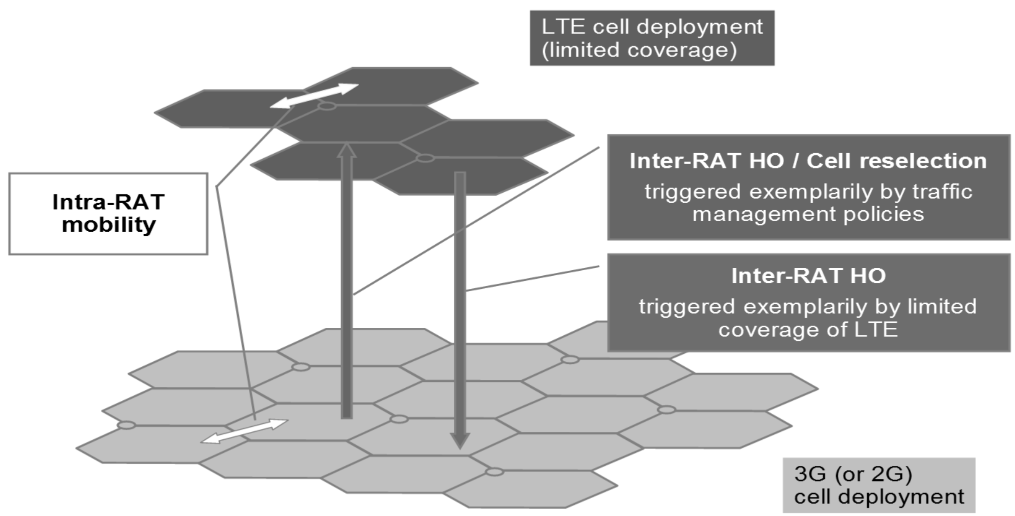
Standalone deployment



Radio access scenarios for SON

LTE for capacity enhancement in existing GERAN/UTRAN

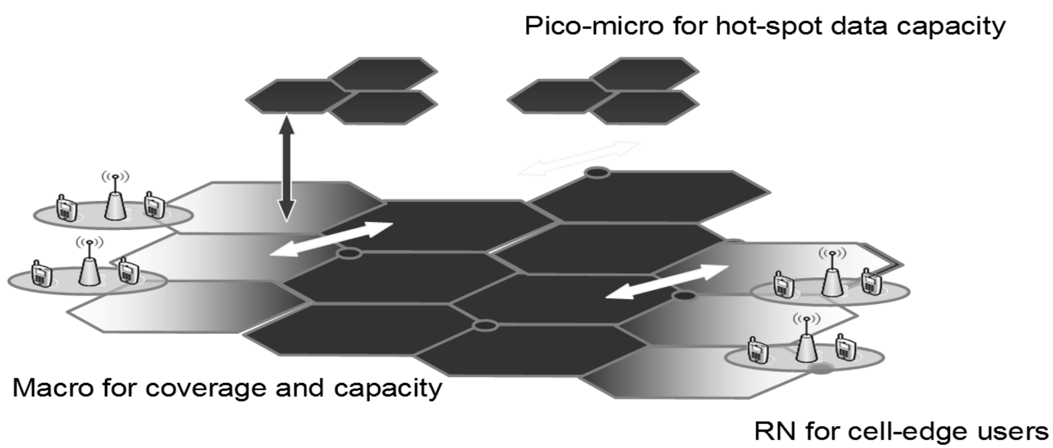
- This is incumbent operator's scenario to effectively integrate LTE with existing UTRAN and/or GERAN networks
- Typically a hot spot scenario, i.e. LTE coverage limited to high populated areas only
- LTE maybe cosited with 2G/3G
- SON impact comes from effective cooperation between LTE and legacy network through mobility robustness optimisation and traffic steering



Radio access scenarios for SON

Enhancing LTE Capacity, the Heterogeneous Network (HetNet)

- Network is made of multiple overlapping radio network layers different layers using the same or different frequencies
- In addition to multi-layer, network can be also multiRAT with 2G/3G base stations
- SON is important in this scenario due to complexity introduced
  - Large number of base stations and therefore parameters for configuration and optimisation
  - Interoperability between layers and RATs



Radio access scenarios for SON

Data Offloading, LIPA-SIPTO

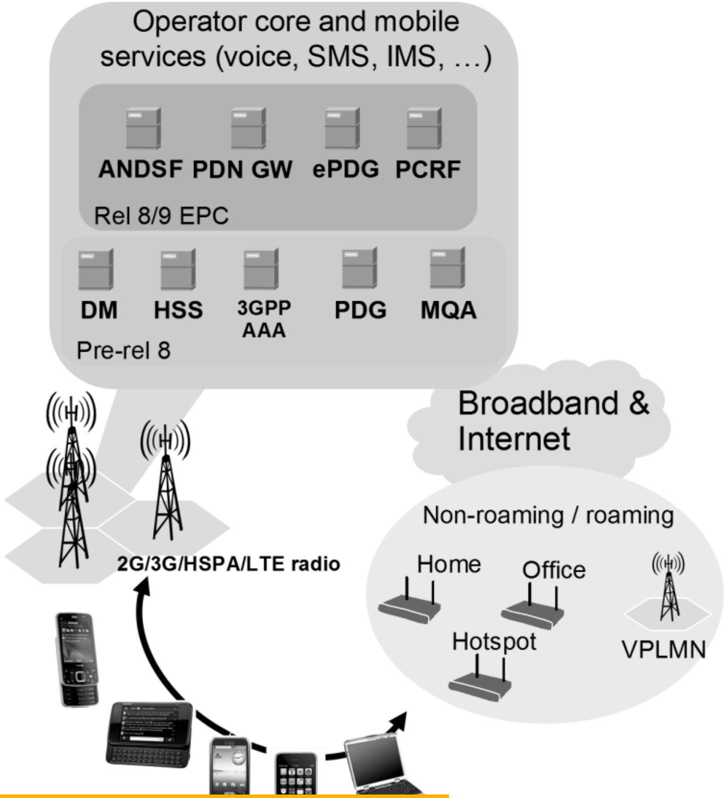
- 3GPP has set requirements to provide local IP breakout for H(e)NB subsystem and macro layer
  - LIPA is about local IP access to residential/corporate local network for H(e)NB
    - LIPA defines access to private network resources in the user premises using H(e)NB
  - SIPTO is about selective IP traffic offloading for H(e)NB and for macro network
    - SIPTO considers how internet traffic can be sent directly from local 3GPP access to internet

TR23.829: Local IP access and Selected traffic offload (LIPA-SIPTO)

Radio access scenarios for SON

Multi-Radio Access Network Scenarios or non-GPP

- 3GPP defines 3 different FMC (fixed mobile Convergence) architectures for data offloading utilising WLAN and IP access
  - UMA – Unlicensed Mobile Access
  - WLAN for packet based services
  - ANDSF – Access Network Discovery and Selection Function
- ANDSF defines
  - Mechanisms to transfer operator specific 3GPP/n3GPP access selection policies to device
  - Access for Non-3GPP network to EPC
  - Authentication and authorisation through 3GPP network before device starts to use WiFi
  - Selection of WiFi network for access based on ANDFS policies



TS23.234:3GPP system to wireless local are network (WLAN) interworking
TS43.318: Generic Access Networks (GAN); Stage 2
TS23.402: Architecture enhancements for non-3GPP access
TS24.302:Access to the 3GPP Evolved Packet Core (EPC) via non-3GPP access networks
TS24.312:Access network discovery and selection function (ANDSF) management object (MO)

Outline

LTE principles, management architecture and radio access scenarios

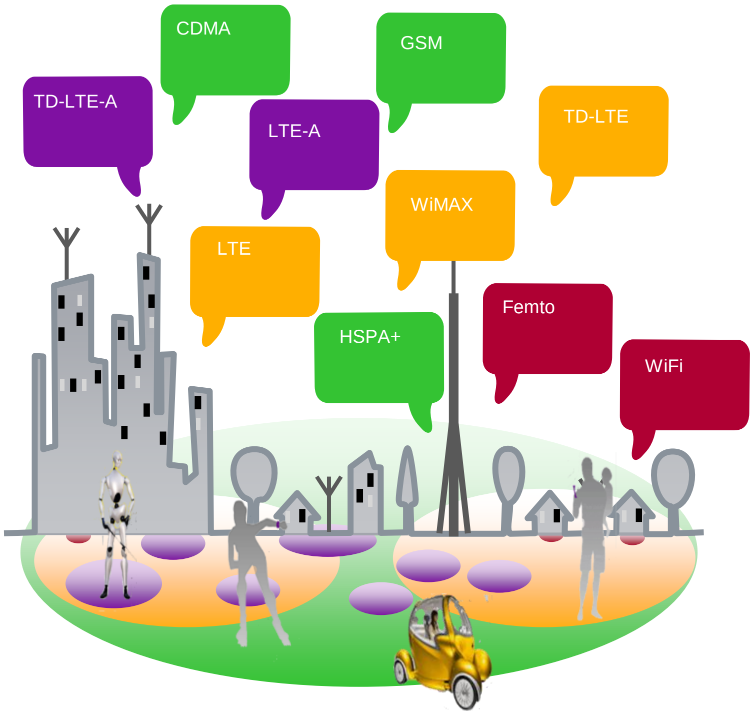
SON Challenges – why SON?

SON Vision

NGMN and 3GPP Use cases

Why is SON needed?

SON aims to address complexity and network management challenge through automation



Database entries grow exponentially with 3rd layer (interworking parameters). Manual checks are hardly possible anymore

Network systems are becoming more and more complex due to heterogeneity in the networks

45,000,000 parameters
37,000 transmission links

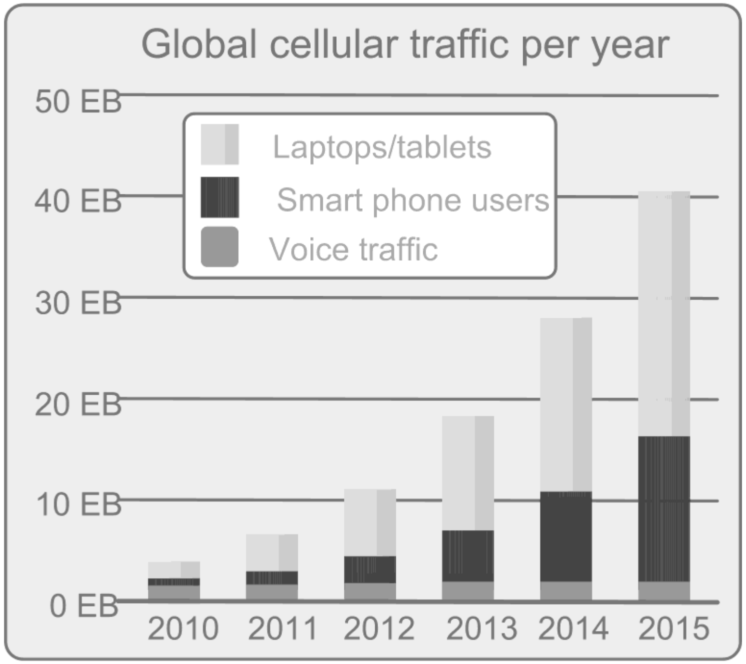
Moving from voice to data centric networks requires much faster network optimization cycles. This is not possible without more automation in SON

Drivers for complexity

Consumers
•Consumers demand access to high performance wireless networks reliably everywhere
•Consumers expecting service and data rates comparable to fixed line today
•Growing number of mobile subscribers also in developing countries

Applications
•Not only voice, but different kinds of data services with high data rate requirement and tight latency
•Data services putting high pressure on performance of network. Networks need to be well tuned

Terminals
•New terminals together with new network technologies enabling new applications and services demanding higher throughput and capacity



Drivers for complexity

Capacity needs

•Huge demand for increase capacity by new cannot be met by just adding more hardware

•New types of cells will emerge making network heterogeneous

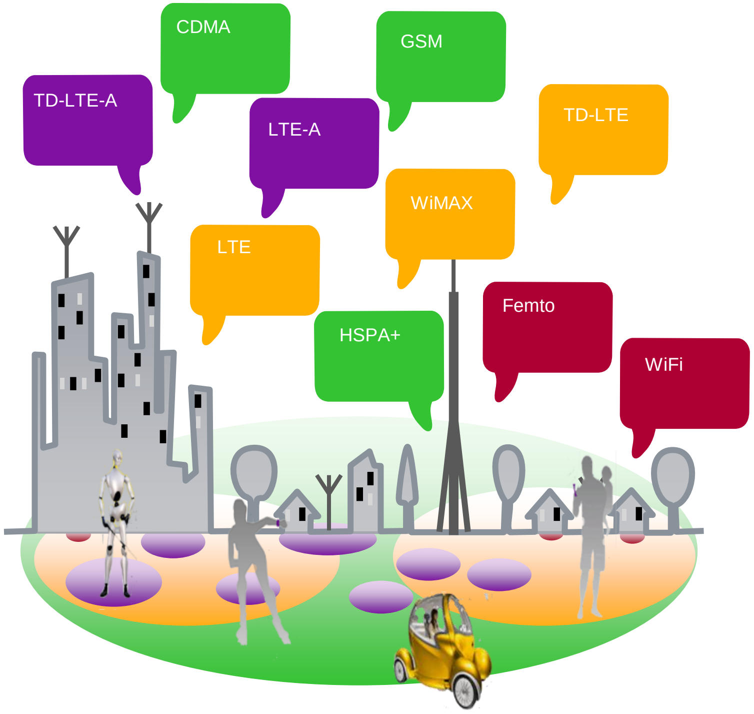
Legacy networks

•Operators will keep their existing 2G and 3G investments for years

•LTE and LTE-A networks are operated in parallel with GSM and HSPA networks next decade

Frequency variants

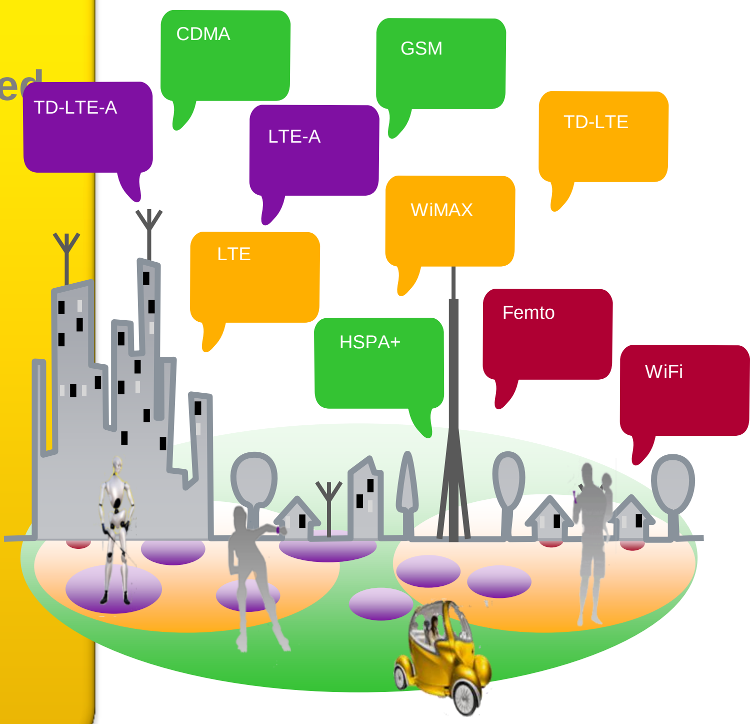
•Several frequency bands are utilized jointly for providing required capacity and coverage



Implications of complexity

Network implications

- Huge number of small base stations to be managed
- Huge amount of parameters to be operated due to inter-system operability need
- Huge amount of base stations and parameters leading increased human workload and cost
- Difficult to maintain all parameters and base stations in optimum
- Incorrect parameters lead to low network performance and poor quality of experience



Drivers for SON

- Operators face significant operational challenges in terms of work effort and thus cost
- Unfortunately, those costs will not be compensated by additional revenue due to the decreasing average revenue per user
  - caused by pricing schemes (flat rate) induced through fierce competition in the market
- Hence, the cost position as a vital interest of operators
  - CAPEX – optimum network settings leads to less investments. Less cost in network roll-out
  - OPEX – less manual effort in maintenance, troubleshooting and optimisation
  - Quality – Improved QoE leading to less churn and more revenue

Implications of complexity

End user implications

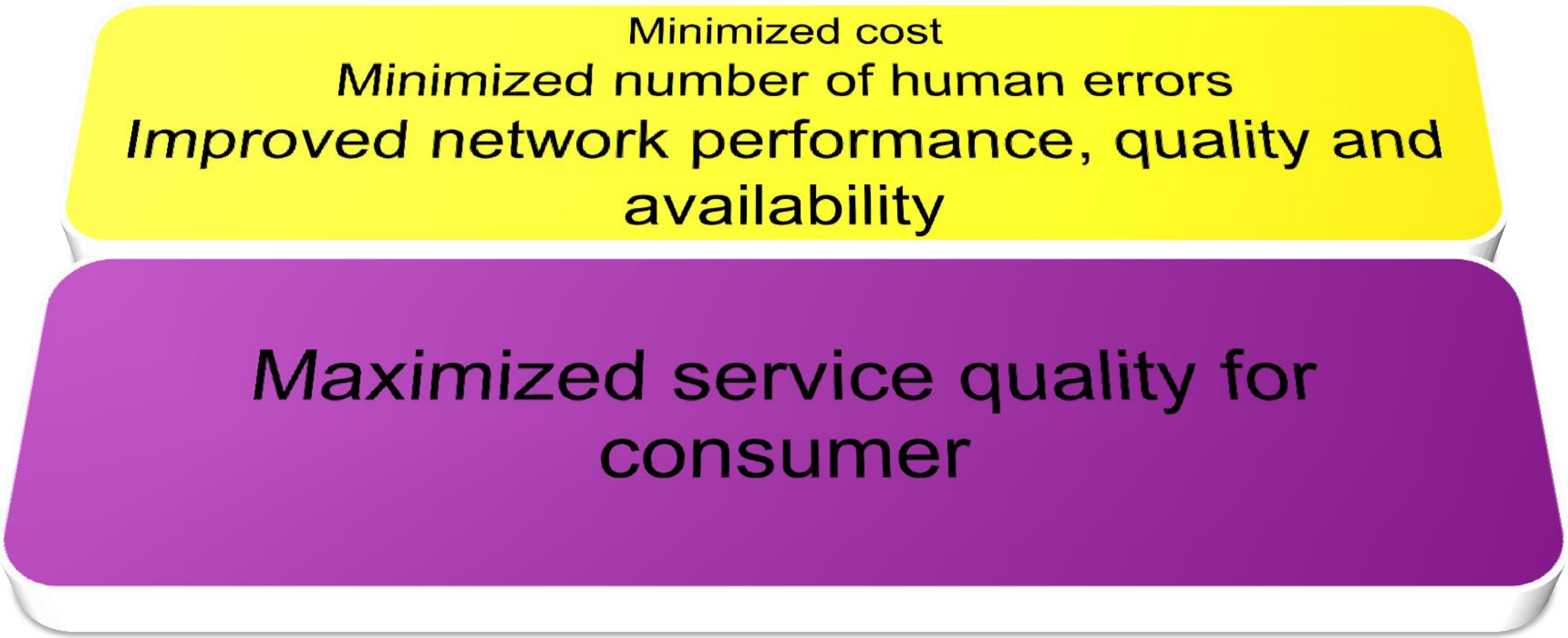
- Disappointed users lead to increased churn
- Satisfied customer uses more operator services and generate revenue

Management implications

- A completely new approach to network management is needed!
- Role of human operator on network management will change.

This leads to paradigm shift in network management

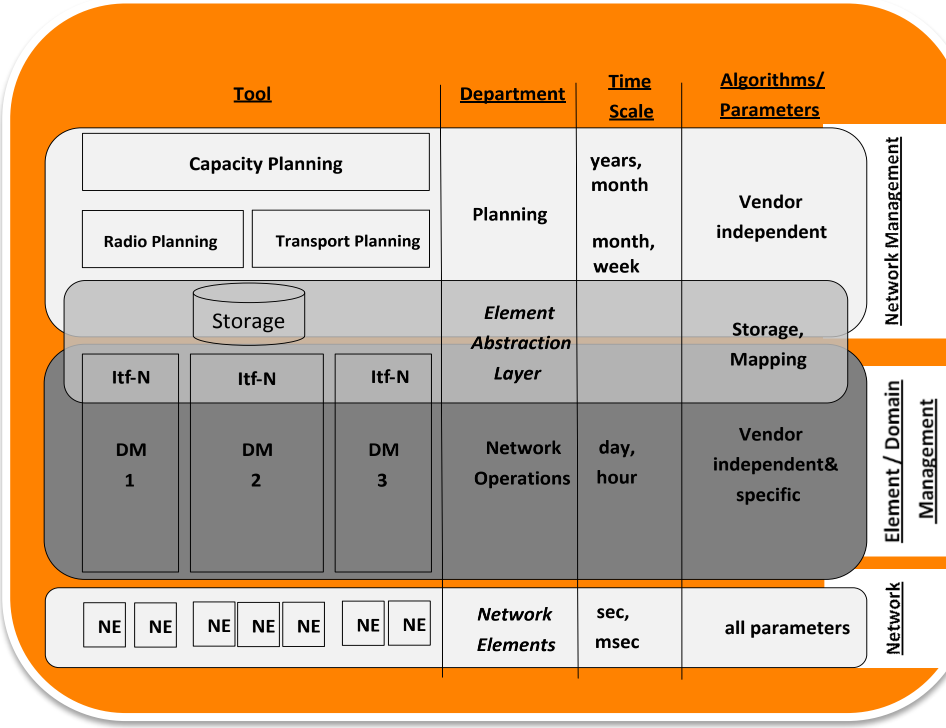
Benefits of SON



Transition from Conventional Network Operation to SON

‘Conventional network operation’

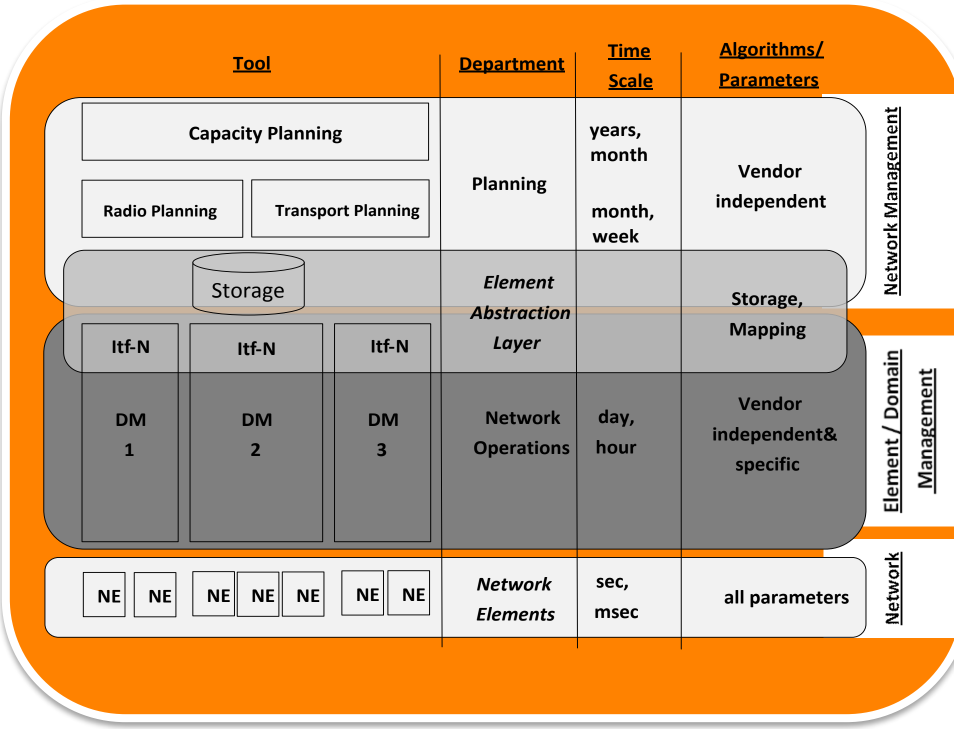
- Model of layered OAM tool chain
  - Planning and optimisation
    - Translate operators business targets to proper deployment of network elements
    - Usually as a part of vendor agnostic network management system
  - Network operation
    - Network operations separately for different vendors’ network elements
  - Element abstraction layer
    - Enables abstraction of vendor specific data from element management to vendor agnostic network management
    - Acts as a central repository for all standardised and many vendor specific parameters
    - Use usually standardised tools to exchange data



Transition from Conventional Network Operation to SON

‘Conventional network operation’

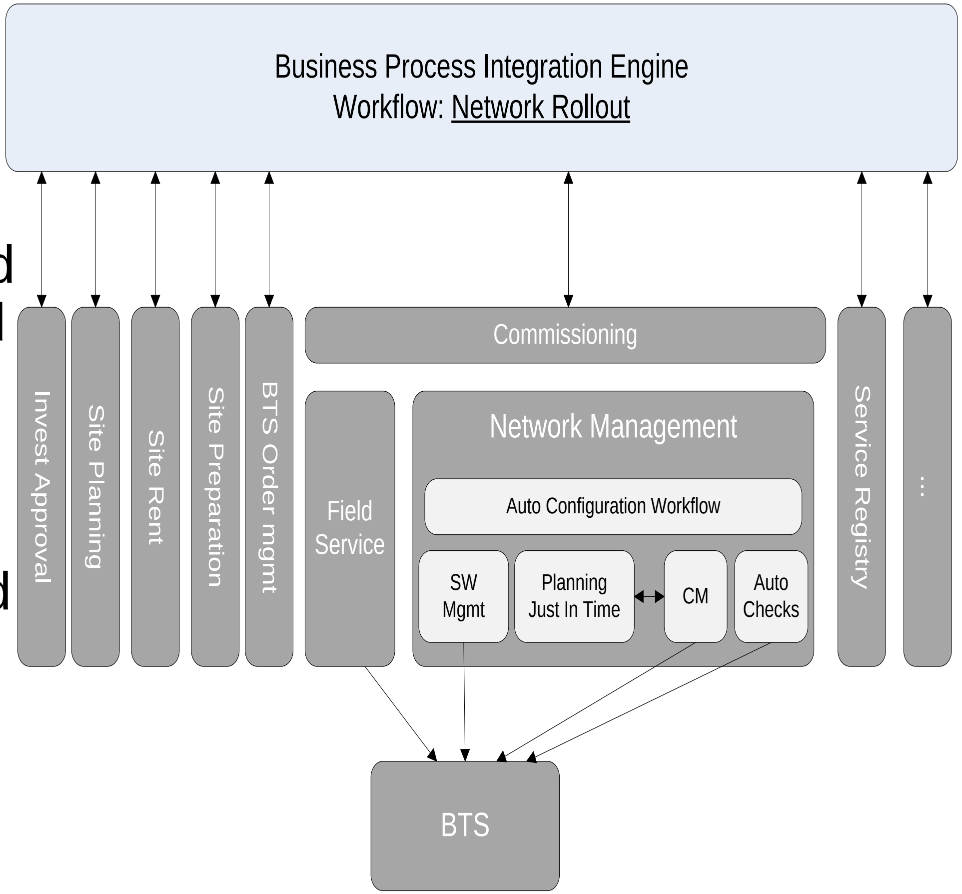
- Model of layered OAM tool chain
  - Northbound interface (Itf-n)
    - 3GPP specified
    - Interface between Domain/Element Management and Network Management
    - Mapping of vendor specific parameters to vendor agnostic parameters
    - Automated collection of alarms and performance management data and exchange of configuration management data
  - Network Element
    - Local maintenance terminals and site managers can be used with commissioning and installation of network element
    - Radio Resource Management



Transition from Conventional Network Operation to SON

Automation of the network rollout

- Network rollout business process contains several lower level workflows or processes
- Only installation, commissioning and registration of NE can be automated
- Installation and commissioning requires skilled engineers and at least two site visits
- Automation of network rollout would lead to less site visits, less manual work, faster time on-air, less errors, less workforce and therefore less costs



Transition from Conventional Network Operation to SON

Automation of the network optimization

- Ultimately optimisation targets to revenue optimisation
  - Revenue doesn’t depend only network, but also other instruments like marketing and sales
- A “super KPI” can be defined as optimisation target

*P = x * “Coverage” + y * “Capacity” + z * “Quality”*

- Where weights come from operators business targets
- Coverage: Service area created so that customers can use services in all relevant places
- Capacity: ability for network to carry traffic
- Quality: Good quality is needed to attract and keep customers

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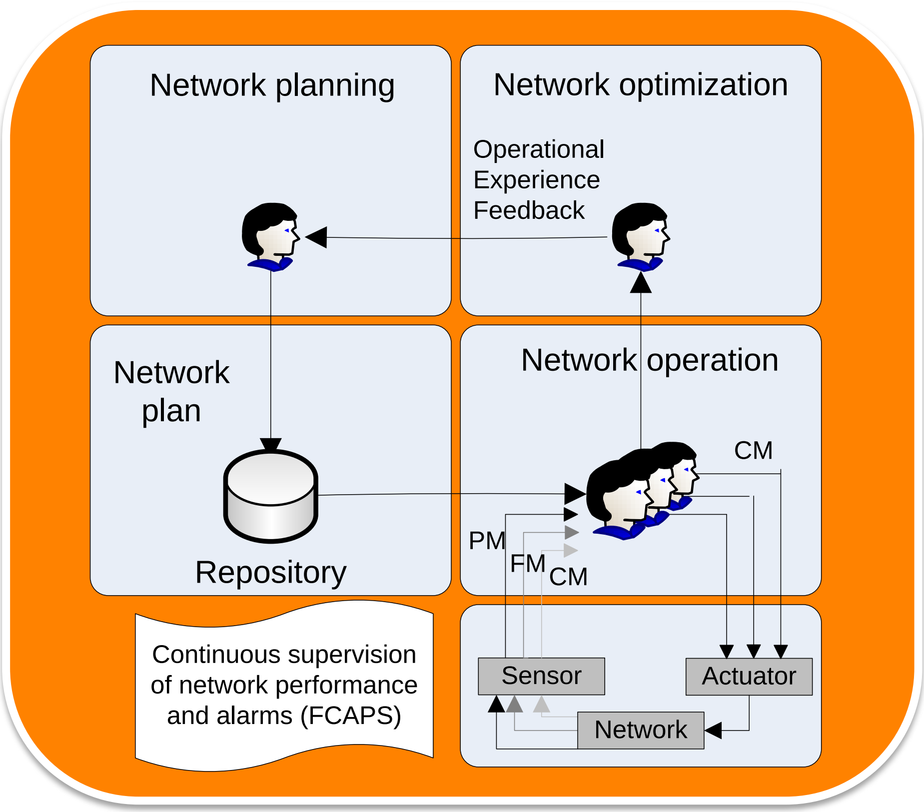
NGMN and 3GPP Use cases

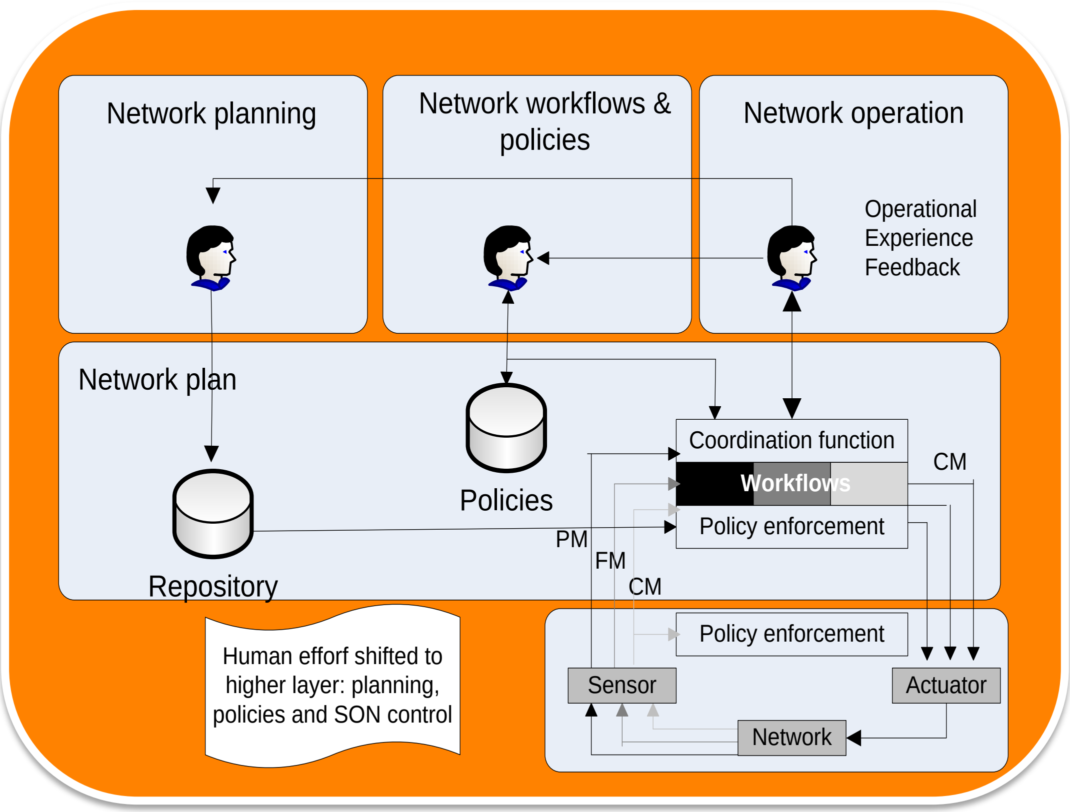
Management systems today – manually operated

- Today management of the network is based on traditional FCAPS model
  - Fault, configuration, accounting, performance, and security management
- In the FCAPS model functional tasks are carried out by human network operator manually
  - Human operator continuously supervises network performance and alarms, together with current network settings



SON Vision – closed loop automation

- Increased automation and reduced manual effort
- Human effort shifted to higher management layer
  - monitoring & policy design
- Policy based management
- Reduced OPEX and OPEX protection through minimizing human errors

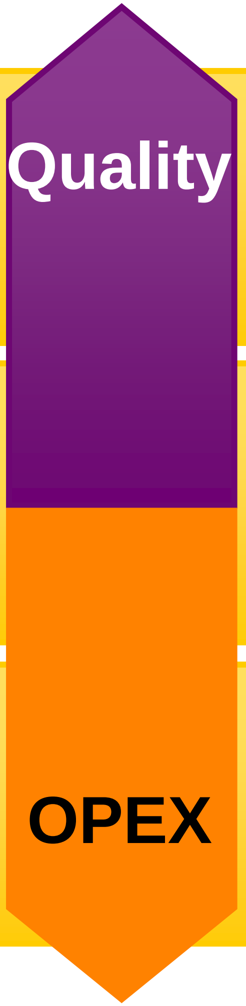


Main Categories of Self Organizing Networks

Self-Healing
- Automated preventive corrections
- Minimized revenue loss

Self-Optimization
- Optimal use of capacity
- Maximized revenue flow

Self-Configuration
- Automated BTS/eNB deployments
- Faster roll-out



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NGMN and 3GPP Use cases

NGMN and standardization

NGMN alliance listed operator SON use case 2007 and 2008 and recommendations for different use cases at 2010

NGMN use cases have had significant impact to development of SON both in 3GPP standardization and vendor specific proprietary algorithms

NGMN operator use cases were structurised according to a workflow model with the following categories: Planning, Deployment, Optimisation and Maintenance

Planning:
- Location
- Configuration
- Parameters
- Integration

Deployment:
- Installation
- Configuration
- Integration
- Testing

Optimisation
- Transport
- Radio

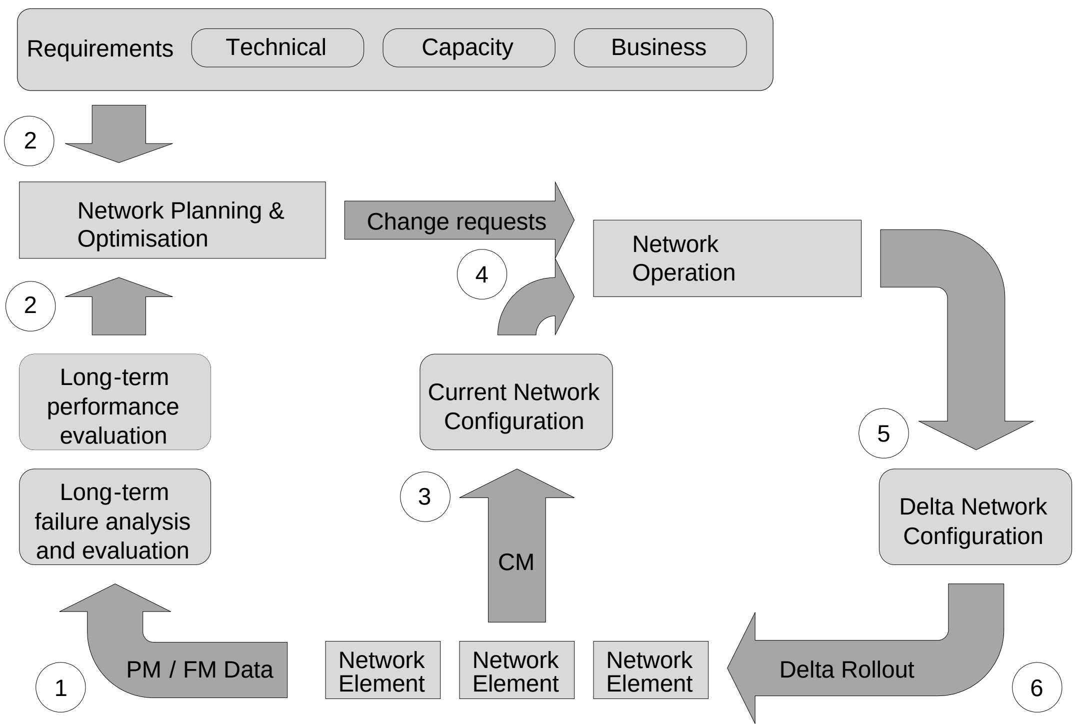
Maintenance
- HW + SW
- Monitoring
- Recovery

NGMN operational use cases Planning

Operator use cases for the planning category

- **Location planning**: The location shall fulfil the coverage and capacity requirements
- **Planning of the HW Configuration**: Based on the requirements the most suitable HW configuration is determined for an eNB or antennas
- **Planning of the radio parameters**: Typical examples are the power, tilt and handover settings
- **Transport parameters**: The configuration of the transport network, which is required to connect the new eNB with the neighbour nodes
- **Network Integration**: Selecting reasonable neighbour nodes, Security Gateways, Serving GWs, MMEs and O&M nodes

- NGMN goal is to substitute last three use cases by SON functionalities



NGMN operational use cases Deployment

Operator use cases for deployment category

- **Hardware Installation and initial configuration***:* Reduce the manual effort by Plug&Play behaviour of all the components like antenna, line, boards and cages
- **Network Authentication***:* The eNB needs to discover the EM and perform mutual node authentication
- **Software Installation, Transport and Radio parameters setup and Network Integration***:* The eNB gets equipped with the relevant software, retrieves a default data base, configuration data for transport and radio settings according to the planning phase
- **Testing**: The new eNB must accomplish a complete self test before it can be admitted to commercial operation.

- The goal is to achieve a high degree of automation in this operator use case category

NGMN operational use cases Optimisation

Operator use cases for optimisation category

- **Radio Parameter Optimization**, e.g.
  - neighbour cell list optimisation
  - interference control including HeNB deployments
  - handover parameter optimisation
  - RACH optimisation
  - QoS parameter related optimisation
- **Transport Parameter Optimisation**
  - provide means for optimising S1/X2 associations and the data routing in a meshed network

- The goal for SON functionalities is to achieve significant simplifications with respect to these optimization tasks
  - This implies to have less stringent requirements to define accurate default parameters for the operator use cases of the planning category

NGMN operational use cases Maintenance

Operator use cases for maintenance category

- **Hardware Extension/Replacement**, e.g.
  - Replacing of hardware with a minimum service outage
  - Performance or capacity extensions by providing additional hardware
  - Checking the hardware inventory and necessary hardware
- **Software Upgrade** with minimum operator attention and service impact
- **Network Monitoring**:
  - Retrieval of measurements and analyses of the RAN performance in order to recognise insufficiencies of the network
  - Seamless support of inter-vendor scenarios
  - Sophisticated trace functionality
- **Failure Recovery**: The recovery from network element outages shall not be a complex task that requires involving specially trained experts

- Concerning SON functionality the goal for the operator use cases of this category is to allow for a smarter operation and maintenance of the daily tasks

NGMN Use cases

NGMN described the most important operator use cases and also provided recommendations, solutions and proposals to standardisation bodies

The NGMN's overall objective is to enable multi-vendor networks with highest efficiency

NGMN TOP Operational Efficiency Recommendations for Self Organizing Networks

- Automatic Neighbor Relations
- QoS Optimization
- Minimization of Drive Test
- Handover Optimization
- Load Balancing
- Cell Outage Compensation
- Energy Saving
- Common Channel Optimization

SON in 3GPP standardisation

Standardisation for SON functions is needed when they depend on information exchange between network element provided by different vendors to guarantee interoperability

SON related standardisation is performed in three different 3GPP groups

RAN2: address only MDT case

RAN3 : Use cases needing radio network level functionality

SA5: Use cases needing network management involvement

SON in 3GPP standardisation

RAN2 and RAN3 activities

Self Conf.	R8	• Plug & Play, ANR: – Automatic PCI configuration, Detection of new neighbors and X2 setup
Self Optimization Intra-LTE	R9	• Mobility Robustness Optimization (MRO): – Detection of radio link failures (RLFs), Reporting RLFs and possibly UE measurements • Load Balancing (MLB): – Load and composite capacity reporting (including inter-RAT), HO negotiations • Energy Savings: – LTE cell status reporting and wake-up request • RACH Optimisation – Reporting RACH access statistics from UE, Exchanging PRACH configuration
Multi-RAT and MDT	R10	• Coverage and Capacity Optimization (CCO): – Current focus is on the detection of coverage problems • Enhancements to MRO and MLB: – Inter-RAT and load/capacity information enhancements – Support of unsuccessful re-establishment – Possibly including consideration of home/macro interactions • Energy Savings study – Inter-RAT energy savings – Enhancements to the intra-LTE solutions, e.g. in combination with coverage optimisation • Minimization of Drive Tests (MDT) – Main focus on coverage problems – Both, immediate and non-real time reporting – Based on RRC signaling and RRM events, with location information • ANR for 3G – Study on methods to enable updating neighbourhood relation tables in 3G (inter-RAT and intra-UTRAN)

SON in 3GPP standardisation

SA5 activities

R8	• ANR: – Object Model for ANR • Self-Configuration – Interfaces and data model for self-configuration – Possibility to stop&resume process at pre-defined points • Automatic Software Management – Download,installation, activation – based on same framework as Self-Configuration
R9	• Automatic Radio Configuration Function – Enables usage of both pre-planned or near real-time produced radio configuration data • Self optimization: Principle, HOO, LBO – object model for target&policy based management – targets defined for Hand-Over Optimization (HOO) – targets defined for Load Balancing Optimization (LBO) – measurements defined to monitor target achieval
R10	• Energy Savings Study Item: – TR 32,826 on principles about Energy Saving Management • Energy Savings Work Item – New object with attributes for energySavingState added to cell object – Configurable load thresholds in cell and neighborhood for leaving/entering the energySavingState – Possibility to define cells not to be changed by the functionality • RACH Optimization – Targets based on access probability or access delay probability • Cell outage compensation (COC) – possibility to define cells not to be changed by the functionality – object model to manage COC • SON Conflict resolution – Handling of competing self-X functionalities [still open} • Minimization of Drive Tests (MDT) – re-using trace functionality