



**6th IFIP/IEEE International Workshop on Broadband  
Convergence Networks (BcN 2011), May 23, 2011.**

# **Self-Organising, Heterogeneous Wireless Networks**

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# Mobile data traffic explosion

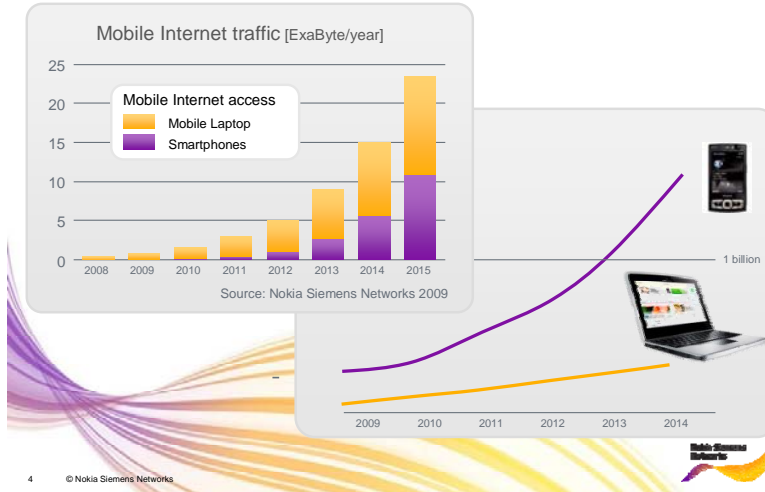
People use increasingly their smart phones, tablets and net books for daily tasks

- Browsing the Internet, email, music and video, navigation, communities, business on the move etc.

When accessing to services, people expect ease of use, speed and responsiveness



## Mobile broadband growth



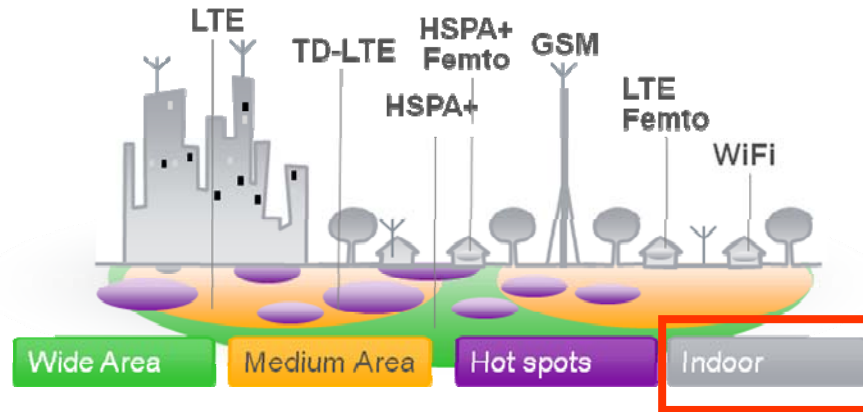
Flat rate subscriptions, adoption of data services and strongly growing market share of especially smart phones has lead to mobile data traffic explosion

- However, mobile data revenues are not expected to grow the same pace as mobile data traffic

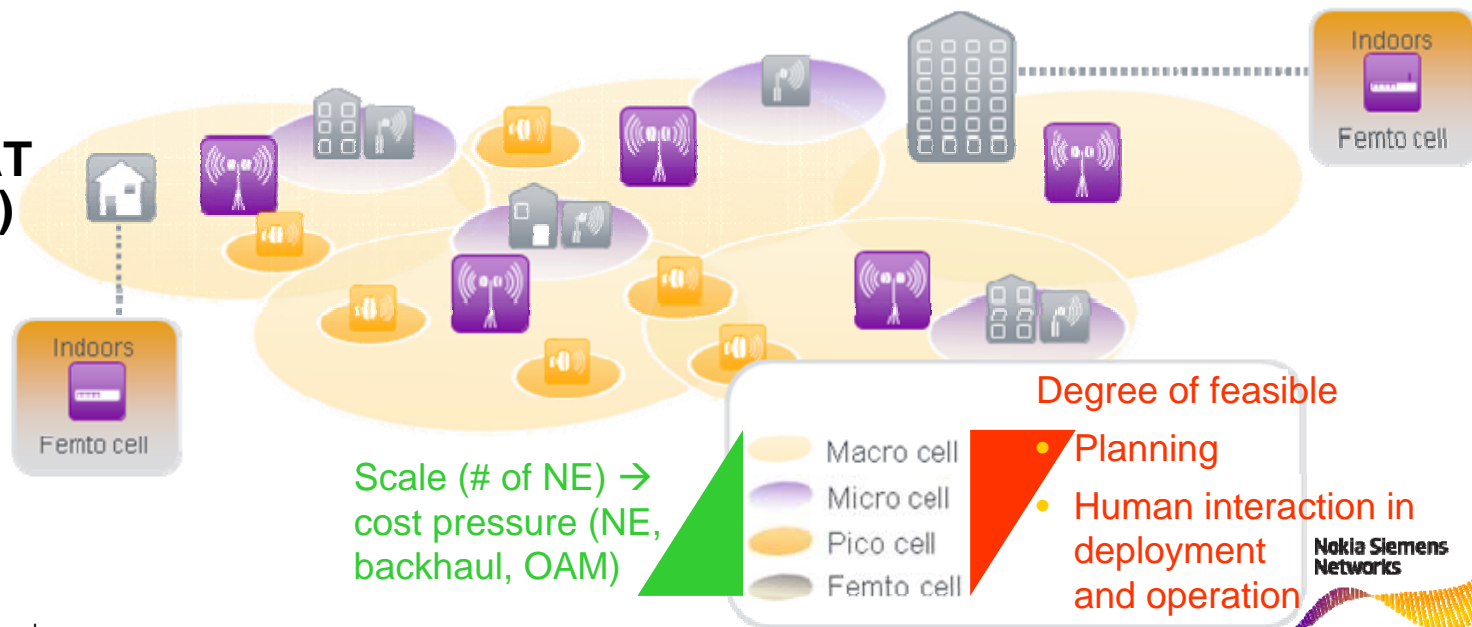
→ How can mobile network operators cope in terms of their infrastructure (CAPEX) and its operation (OPEX) ?

# Heterogeneous Networks providing “unlimited” capacity and “ubiquitous” coverage

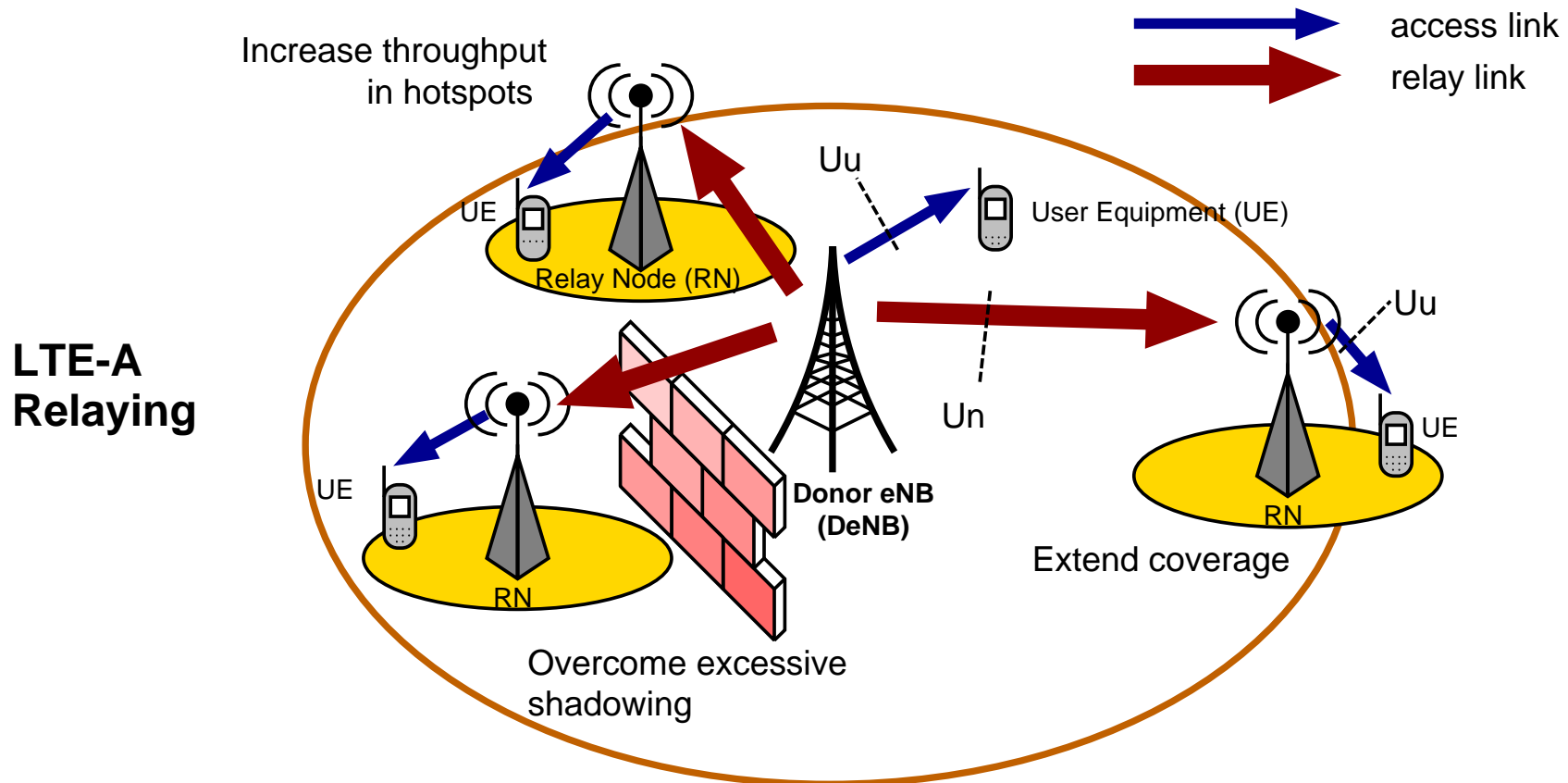
**Multiple Radio Access Technologies („Multi-RAT“)**



**Multiple cell layers per RAT („Multi-layer“)**

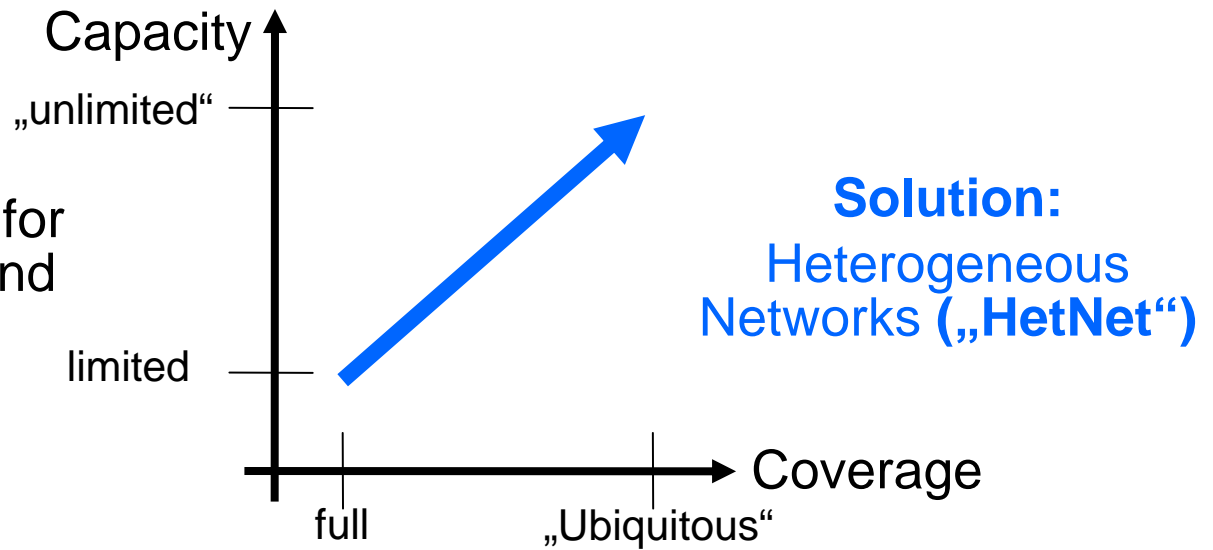


# Heterogeneous Networks providing “unlimited” capacity and “ubiquitous” coverage

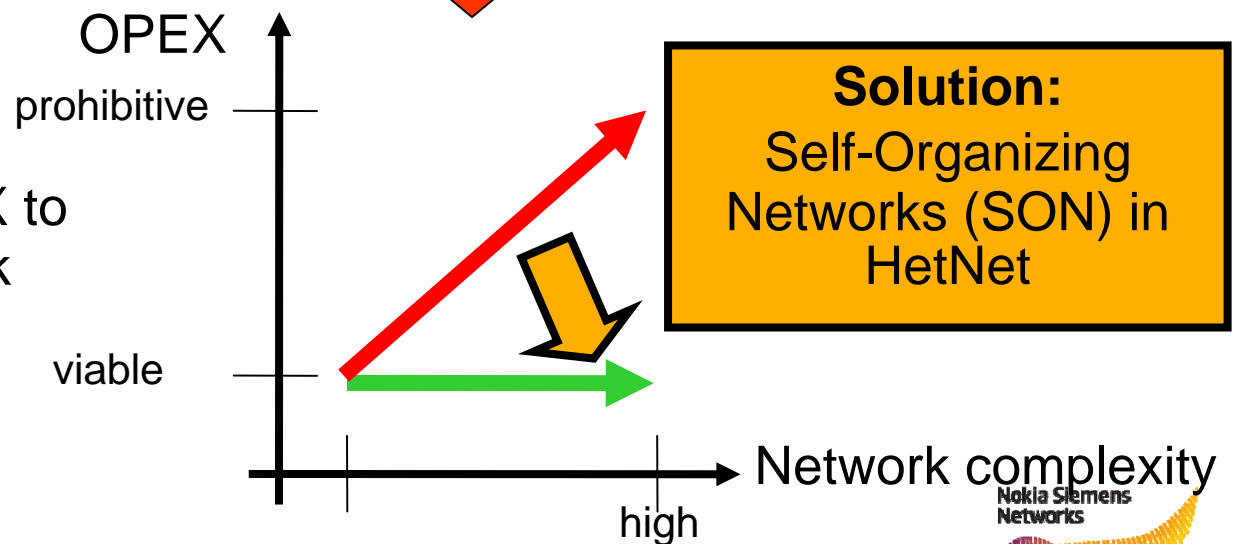


# Densification and higher distribution brings complexity

**Trend:** exploding demand for ubiquitous mobile broadband



**Problem:** exploding OPEX to operate a complex network infrastructure



# Infrastructure networks

## Cellular macro network

- **Tightly planned**
- **Single operator**
- **Single vendor equipment per OAM domain**



## Cellular HetNet

- **Some parts only coarsely planned**
- **Multiple operators (shared infra)**
- **Multiple vendor's equipment per domain (multi-layer)**



## Ad-hoc / mesh network

- **Not planned: uncoordinated deployment**
- **No network operator, only node operator**
- **Open environment, standardized protocols between nodes**

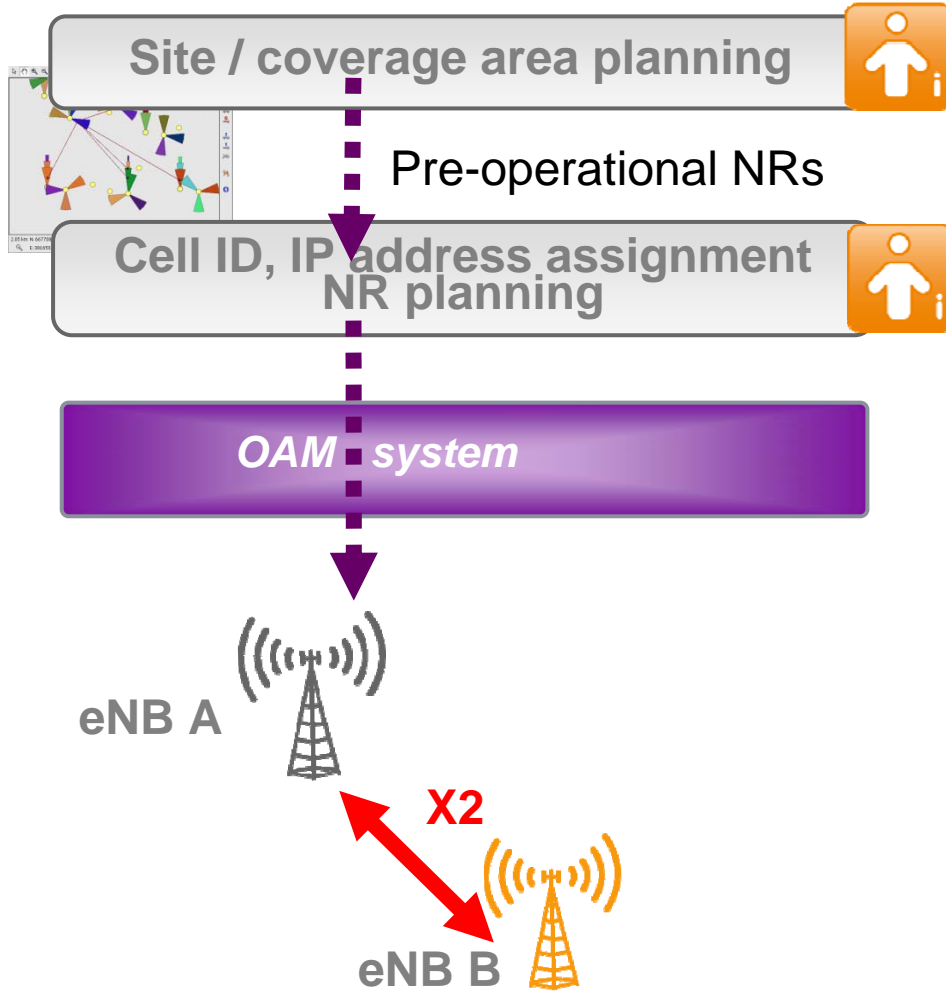
self-organized ?

“Self-organization is a process where the organization (constraint, redundancy) of a system spontaneously increases, i.e., without this increase being controlled by the environment or an encompassing or otherwise external system.”  
(F. Heylighen, Principia Cybernetica Web, 1997)

# Example: Automatic Neighbour Relations (ANR)

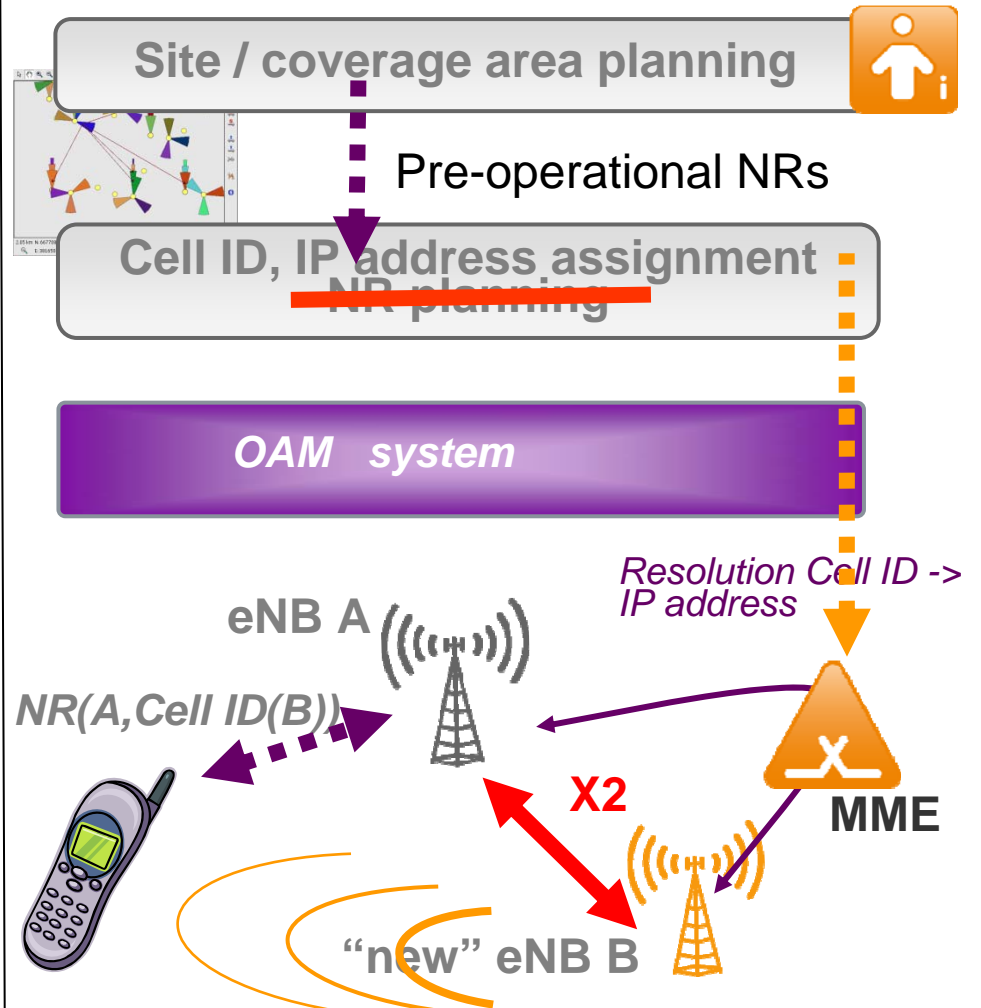
Handovers require (pre-)established Neighbour Relations (NRs) between cells

## Conventional

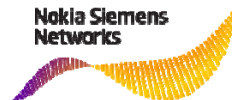


eNB A „knows“ eNB B (Cell ID, IP address)

## Fully UE-based ANR

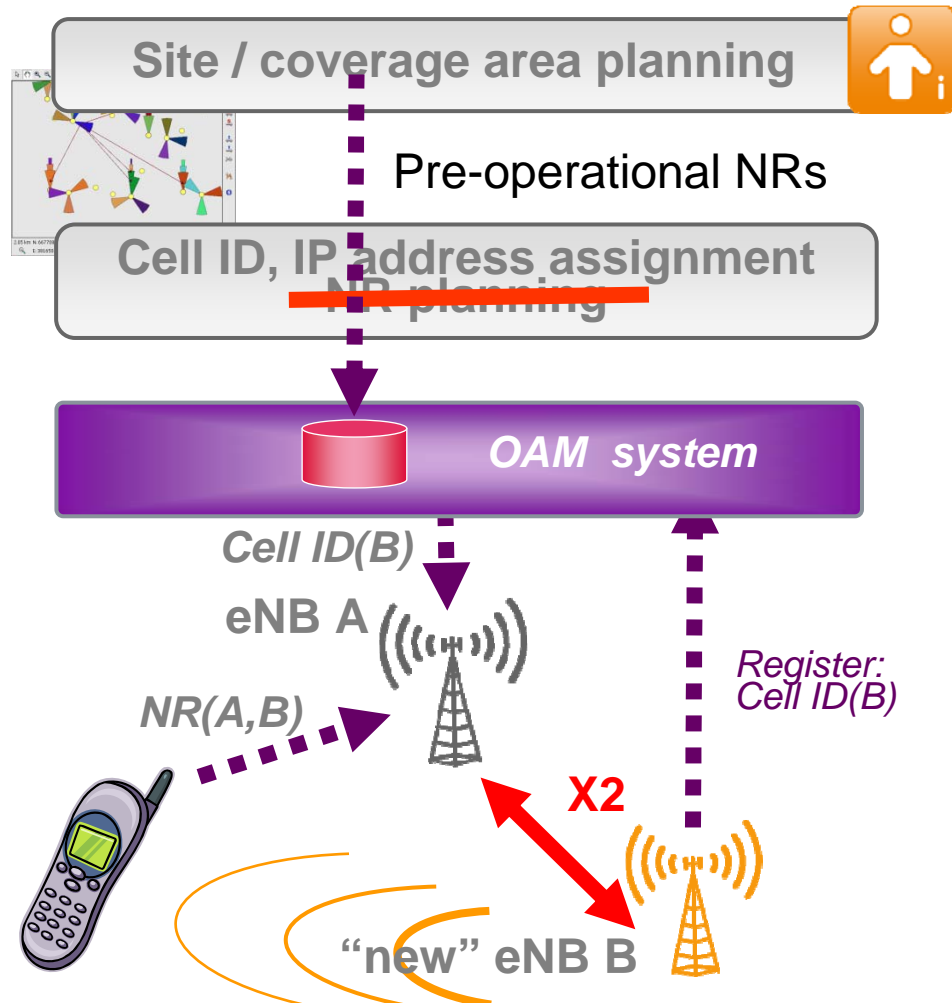


UE relays info (Cell ID) on eNB B to eNB A



# Example: Automatic Neighbour Relations (ANR)

## UE-based ANR (OAM supported)



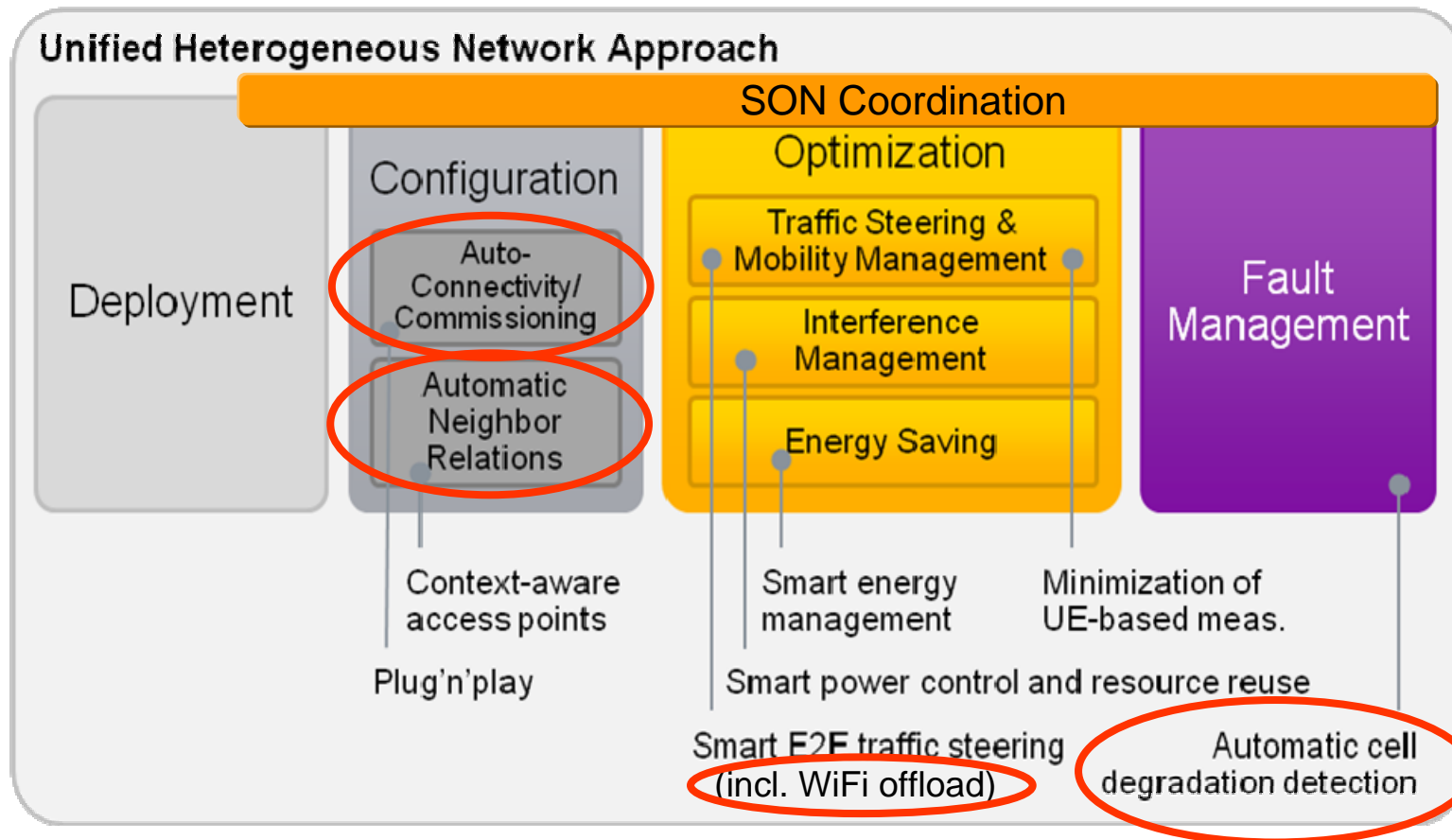
OAM system „learns“ and relays info (Cell ID) on eNB B to eNB A

**Infrastructure network:** key parameters already available in the system → no need to self-organize, but parameters need to be configured on the NEs (Configuration Management: CM) !

1. Fully UE-based ANR avoids that configuration (but requires **UE/eNB/MME** & protocols to be extended / standardized to do automatic, dynamic, distributed CM)

2. UE-based ANR with OAM support does automatic, dynamic, centralized CM in the OAM system (but is only partially standardized)

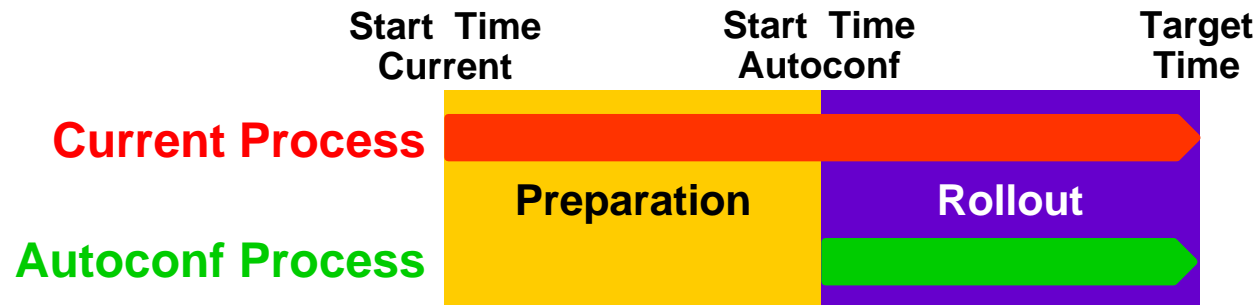
# Self-Organizing Networks in HetNet: Overview



Additional requirements to SON functions wrt. HetNet:

- Functional: increased level of autonomy
- Non-functional: increased level of scalability and reliability

# Auto-connectivity and -commissioning

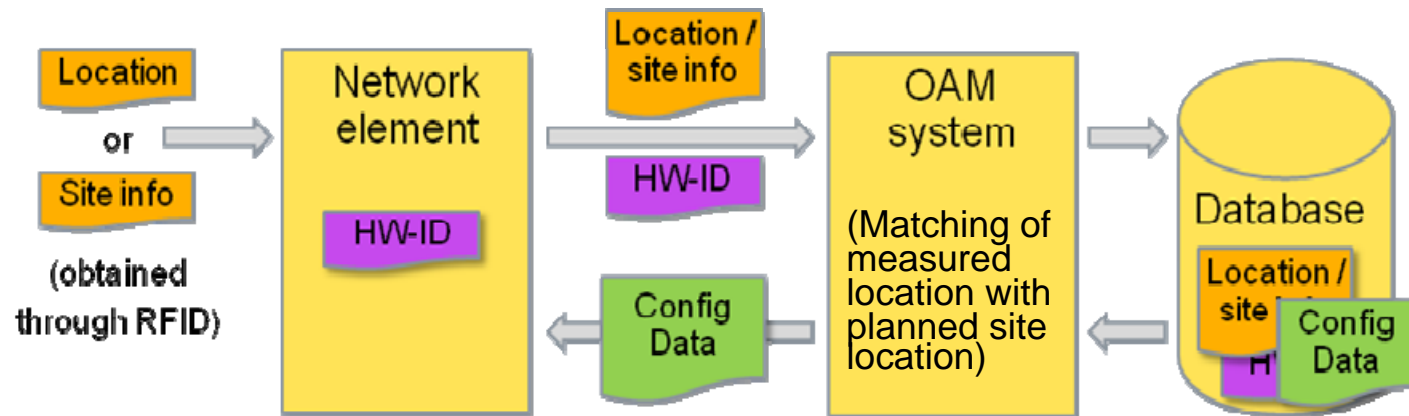


→ Gain of planning flexibility until roll-out / auto-configuration of “off-the-shelf” base stations starts

**Automatic, non-ambiguous identification of the site**  
 (against the network plan) on which an NE has been installed is crucial to allow for true “self-configuration“ in an infrastructure network

# Auto-connectivity and –commissioning

Satellite-based positioning (GPS)  
Radio network-based positioning



Technique	Macro (outdoor)	Pico (out/indoor)	HetNet (out/indoor, co-location)
Satellite positioning	+ (working well)	-	0
Radio NW pos.	0 (with limitations)	0	0
RFID	- (poorly)	+	0

All site identification methods relevant (dense deployment of small cells, large number of co-located sites, indoor deployments)

Full accuracy of positioning methods required & information available in the OAM system and acquired on-site by the NE to avoid ambiguities in the identification

# Auto-connectivity and –commissioning for Relay Nodes

## Preparations:

1. Creation of specific Access Point Number (APN), “APN-OAM”
2. PDN Gateway (PGW) configured to host the APN-OAM
3. PGW configured to perform DHCP relay functionality

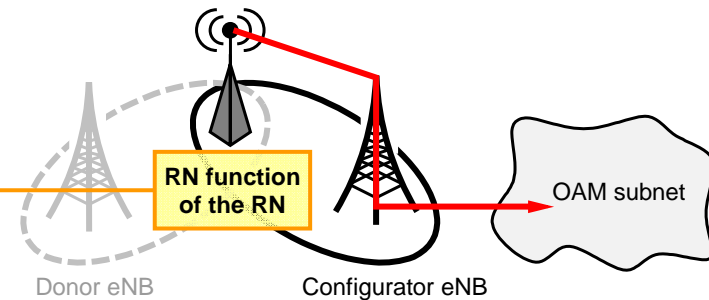
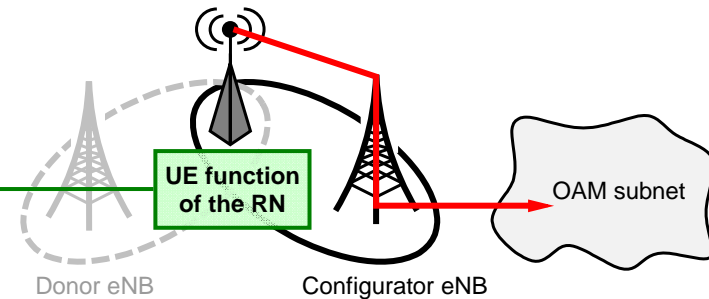
Off-line, before RN field deployment

## Initial connection as a UE (Layer 2)

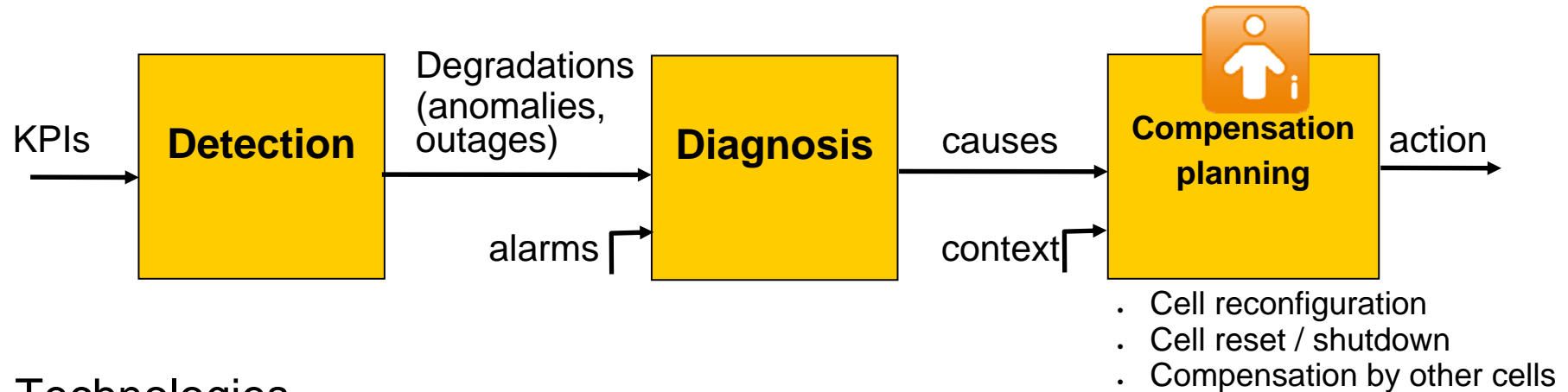
## IP connectivity establishment (Layer 3) to the OAM system

## Establishment of secure connectivity to the OAM system

- Authentication
- IPsec (optional), TLS (mandatory)



# Automatic cell degradation detection & diagnosis



## Technologies

Thresholding, Profiling - time-series analysis - <b>statistical</b> analysis - data mining	Alarm correlation <b>Probabilistic</b> Graph Models (Bayesian Networks) Case Based Reasoning	Decision Theory Policies
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## Goals of **automatic** cell degradation detection and diagnosis

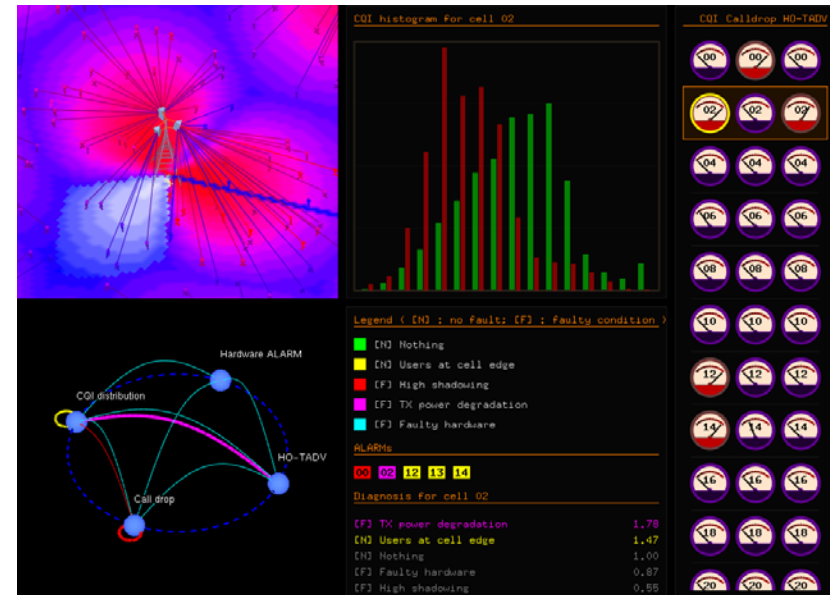
→ OPEX saving

- Reduction of workload for human troubleshooting experts
  - free time for the really crucial problems
- Reduce time until a degradation / outage is detected and diagnosed
  - early trigger of actions

# Cell degradation detection and diagnosis in HetNet

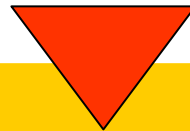
## Challenges:

- Faults „hidden“ to the OAM system but highly perceived by customers („sleeping cell“)  
→ detection
- Significant number of alarms  
→ diagnosis (alarm correlation)
- Low cost, rel. unsupervised NE (e.g., mis-configured / rogue femto impairing macro cell in co-channel deployment)  
→ compensation planning (shutdown femto)



## Advantage:

- Some inherent redundancy in multi-RAT, multi-layer (conventional macro scenario: complex compensation by adjusting adjacent cells required)



Knowledge on HetNet structure

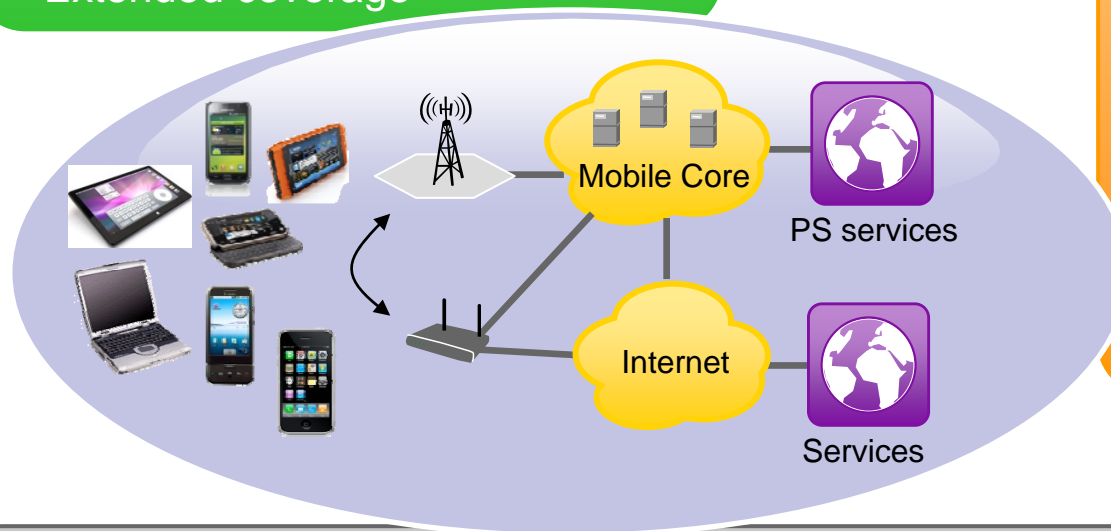
(multi-RAT, multi-layer) crucial as input to decision making („context“)

Quality of the detection, diagnosis and compensation planning more important than the quality of the actual compensation itself

# Traffic Steering: WiFi offload

## End user benefits

- Faster data connections
- Seamless access to services via mobile and Wi-Fi networks
- Extended coverage



## Operator benefits

- Selective traffic offload to Wi-Fi preserving mobile network capacity
- High performance indoor coverage and capacity by leveraging Wi-Fi
- Increased customer satisfaction
- Retain position in traffic value chain and control over user experience for Wi-Fi access



- 3GPP standards based solution ensuring compatibility to large number of devices and easier integration in multi-vendor networks
- Overlay solution compatible with 2G/3G/HSPA/LTE and existing Wi-Fi

# Traffic Steering: WiFi offload

## Device Management (SADM) & One-AAA

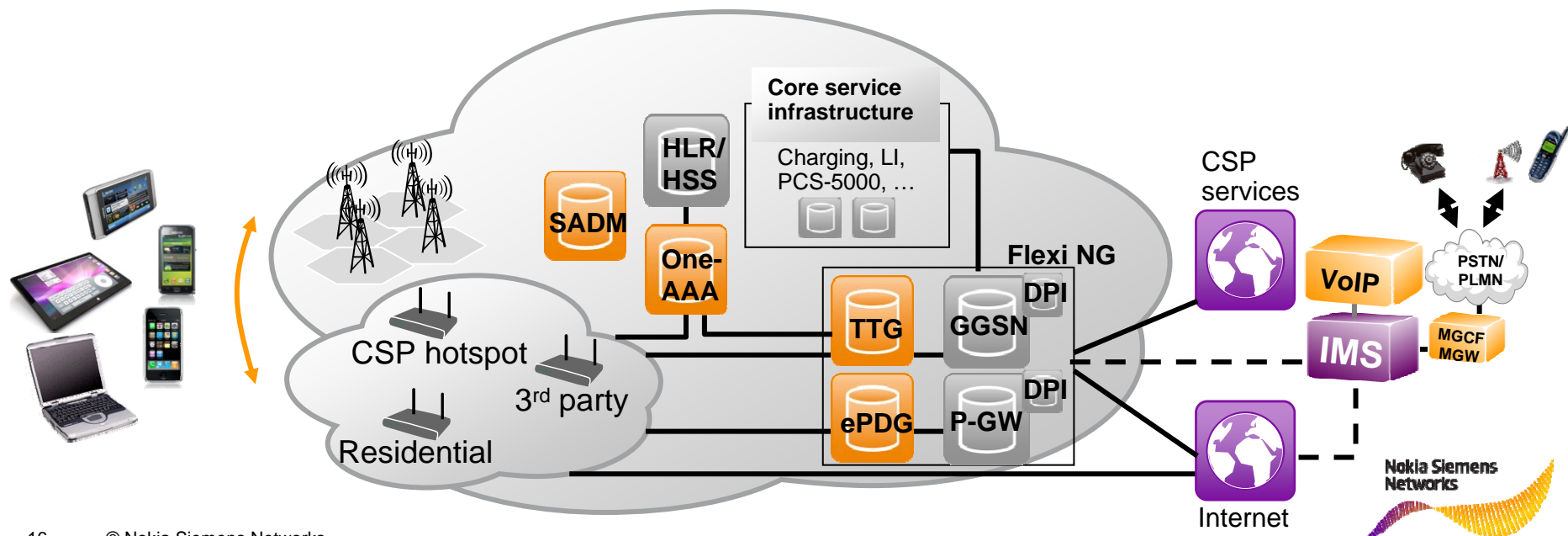
- Enhanced 3GPP/Wi-Fi interworking, for example ANDSF

## Flexi NG TTG & GGSN

- Supporting non-LTE devices ensuring smooth evolution towards LTE

## Flexi NG ePDG & P-GW

- Data encryption and integrity via IPsec tunnels over all Wi-Fi networks
- Robust application connections via service continuity support with for example option to steer selectively traffic between mobile and Wi-Fi networks
- Reusing existing packet core service infrastructure (charging, DPI, policy control etc.) for Wi-Fi provides CAPEX savings and harmonized traffic handling for both access types, enhanced policies with **PCS-5000** (PCRF) for Wi-Fi access



# Conclusions

- The strong user demand / mobile data traffic explosion requires that operators „densify“ their network increasing capacity and assuring coverage → **Heterogeneous Networks (HetNets)**
- The decreasing revenue per user forces operators to reduce costs to remain profitable; HetNets increase complexity and thus Operational Expenses (OPEX), however → **dilemma**
- **Self Organizing Networks (SON)** concepts aim at managing complexity and thus drive down costs for **infrastructure** networks
  - For infra networks, SON concepts have to be carefully evaluated (business value, legacy / standardization requirements, complexity)
  - Implementations exist already for 3GPP macro networks (3G, LTE)
- **For HetNets, SON becomes imperative**
  - Existing concepts need to be extended, new concepts are required to address Multi-layer, Multi-RAT requirements
  - Diverse technical competence required (radio technology, distributed systems, network management, policy, security, ...)
  - Time horizon: from combination of available features into a solution (cf. WiFi offload) to long-term research agenda (Cognitive Networks)

# Further reading on the topic

## Chapter 10: SON for Heterogeneous Networks

Hardback, 448 pages  
ISBN 978-1-119-97067-5

**Publication 01/2012**

