SIXTH IFIP/IEEE INTERNATIONAL WORKSHOP ON
DISTRIBUTED AUTONOMOUS NETWORK MANAGEMENT SYSTEMS
CO-LOCATED WITH
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Managing Mobile Networks for Service Delivery: technology vs. use cases

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Nokia Siemens Networks - Research

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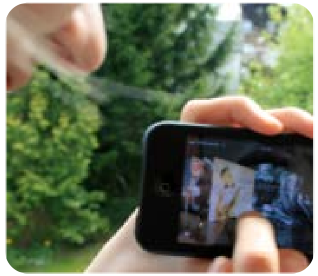
Key requirements for network infrastructure towards 2020

Support up to 1000 times more traffic

Manage up to 10 times more users

Enable Gbps peak speeds

Reduce latency to milliseconds



Improve energy efficiency

Make networks self-aware, self-adaptable, and intelligent

Deliver safe superior customer experience

We cannot predict all the use cases
so flexibility is a key requirement

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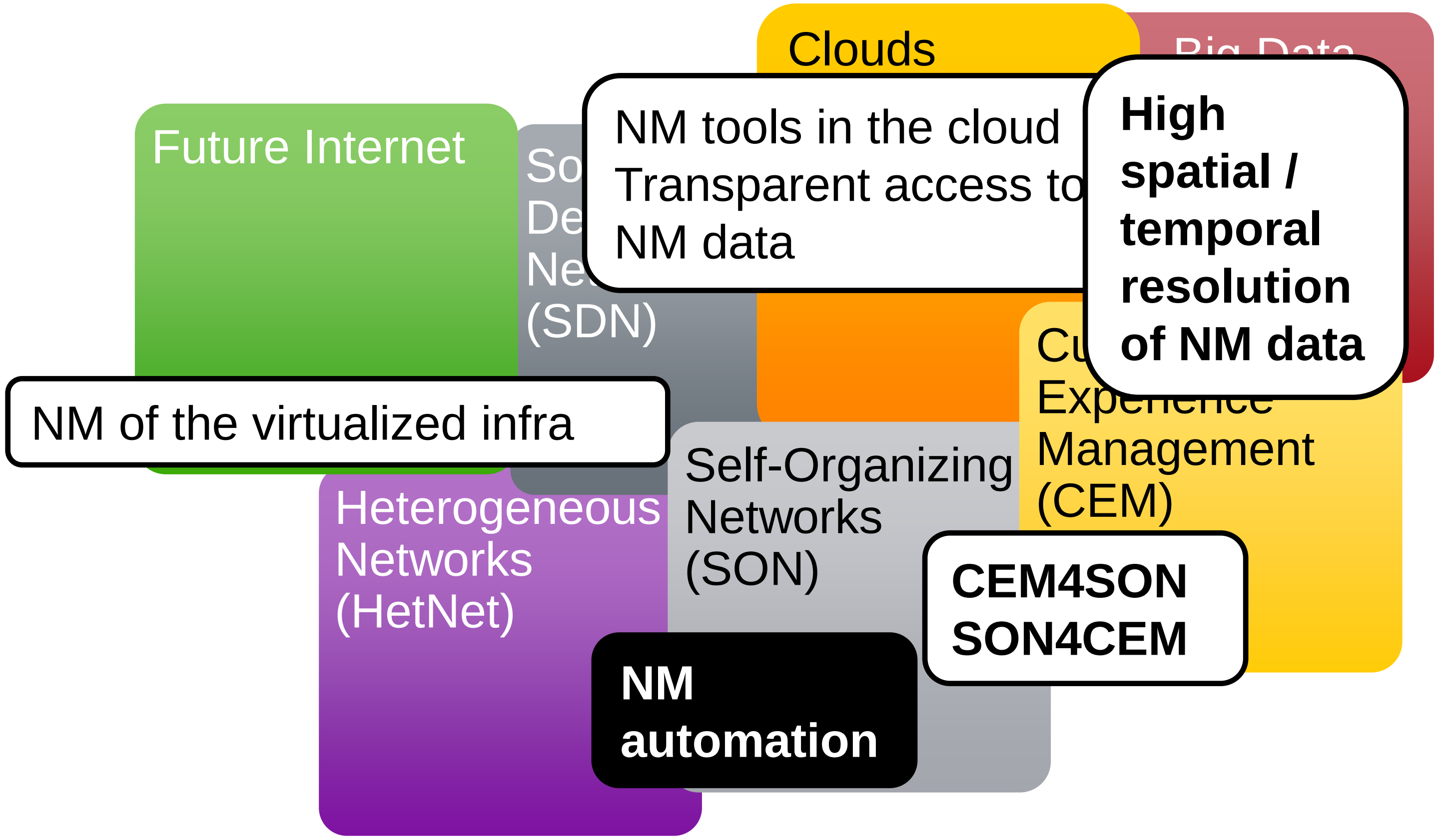
Technology areas: Network Management (NM) perspective



“Nobody knows what SDN is, nor does anyone know what the Cloud really is, so those topics have a strong affinity to each other”: JS, September 2012.

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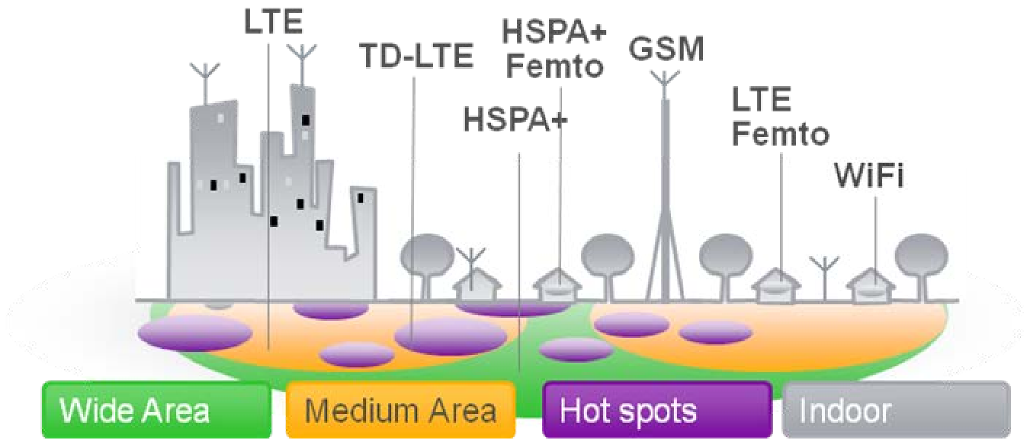
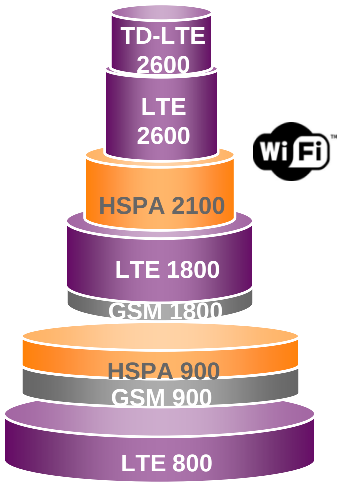
Heterogeneous Networks („HetNet“) providing “unlimited” capacity and “ubiquitous” coverage

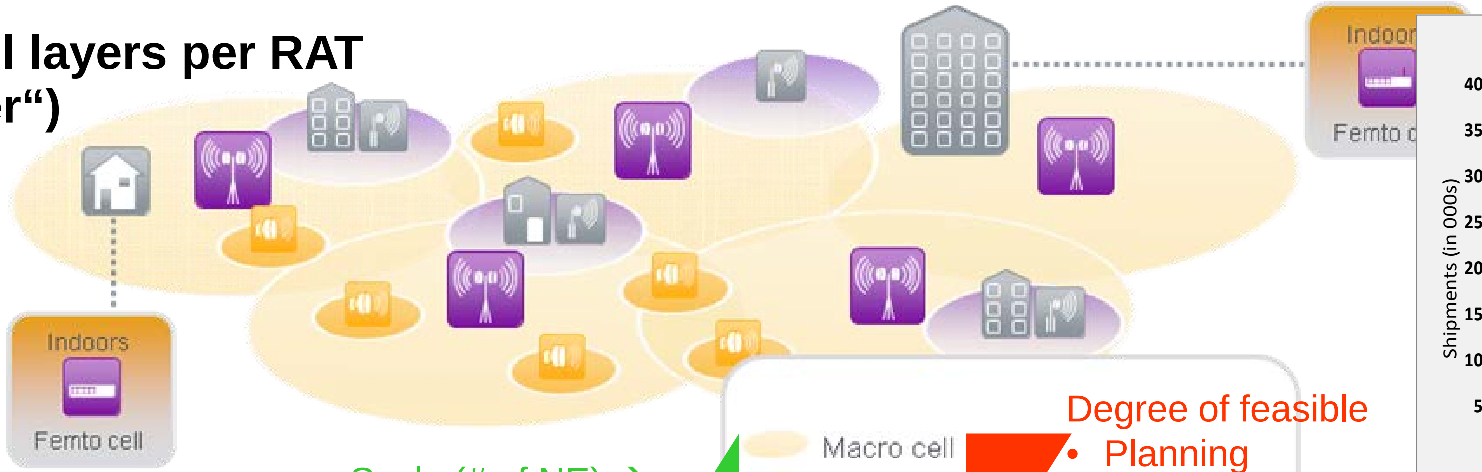
Multiple Radio Access Technologies („Multi-RAT“)

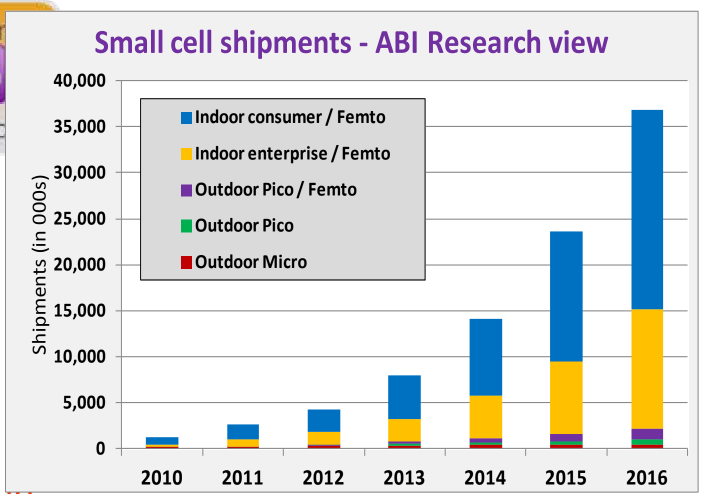




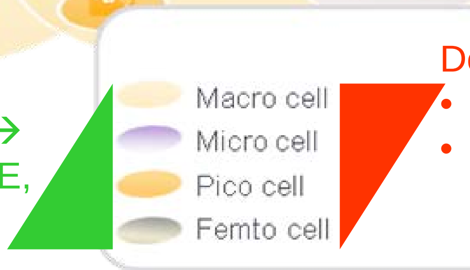
Spectrum & System options 2015

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





Scale (# of NE) → cost pressure (NE, backhaul, OAM)



Degree of feasible

- Planning
- Human interaction in deployment and operation

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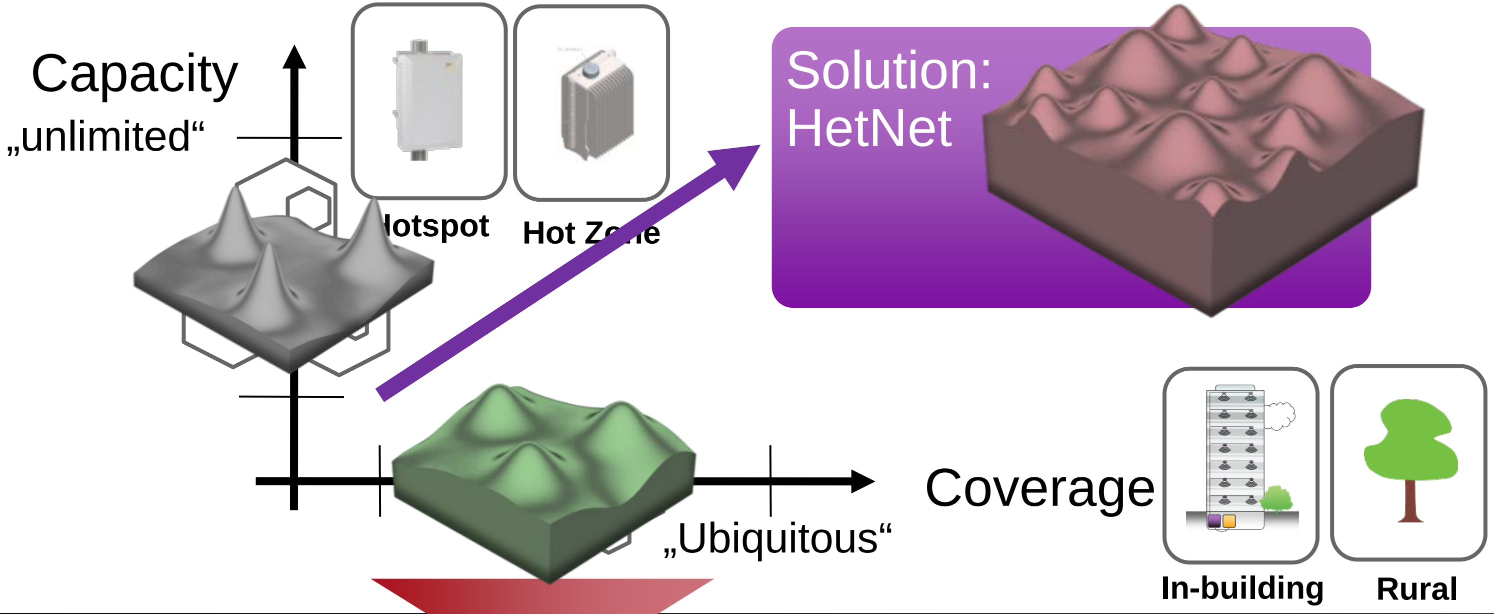
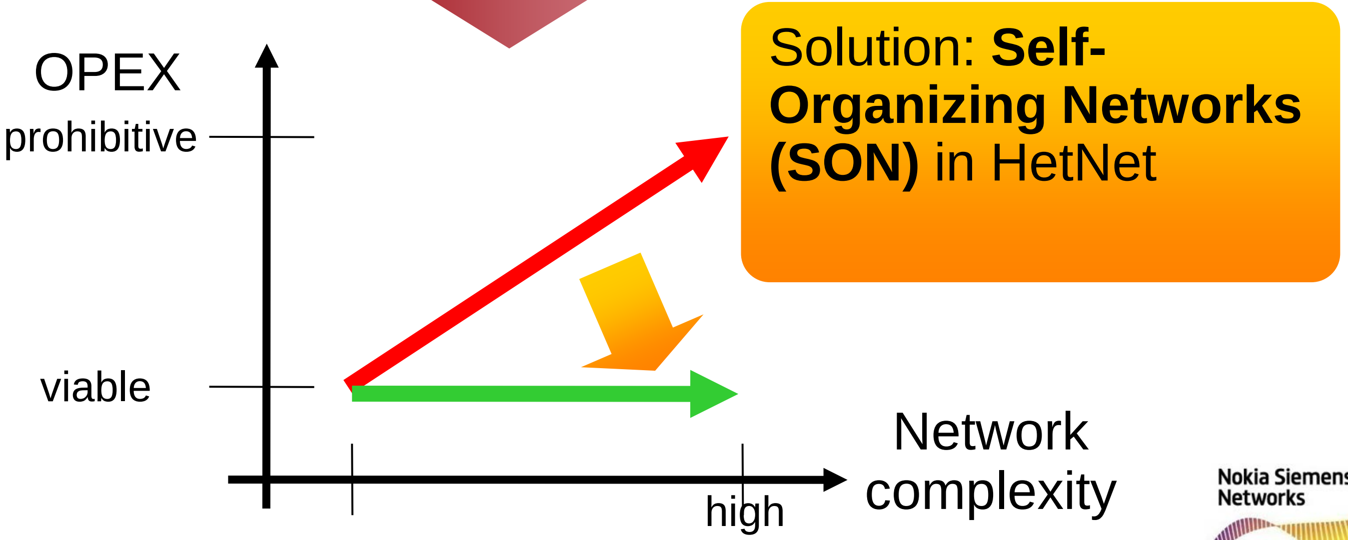
Densification and higher distribution brings complexity

Trend: exploding demand for ubiquitous mobile broadband



Problem: exploding OPEX to operate a complex (fragmented) network infrastructure



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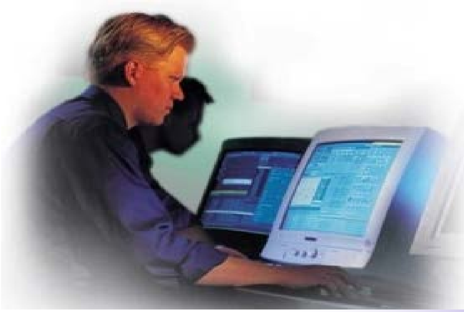
Self-Organization applied to infrastructure networks ?

Cellular macro network
- Tightly planned, automated operation
- Single operator
- Single vendor equipment per OAM domain

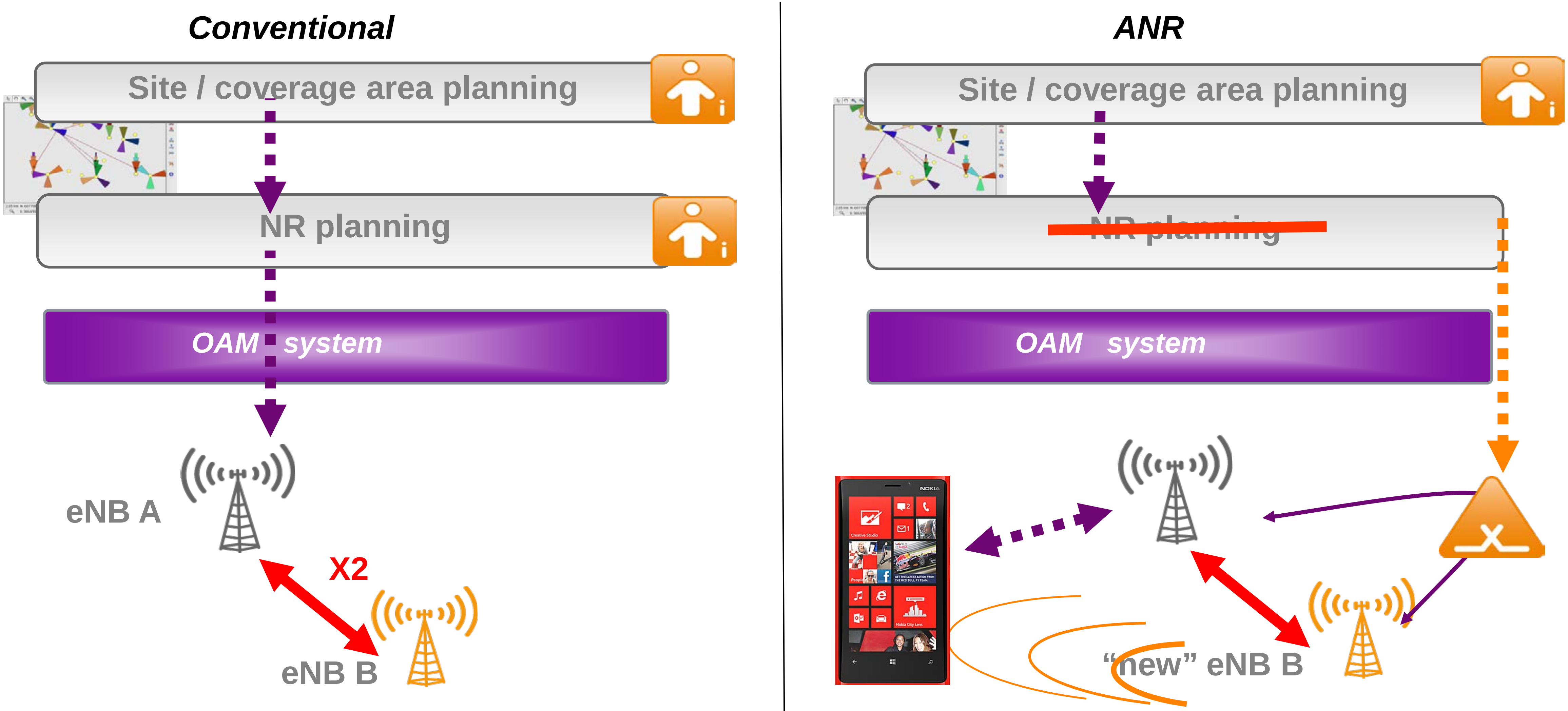
Cellular Heterogeneous Network
- Some parts only coarsely planned, highly automated operation
- Multi-operator (shared infra)
- Multi-vendor per domain



Ad-hoc / mesh network
- Uncoordinated deployment, autonomous operation
- Only node operator
- Open environment, standardized protocols between nodes

> “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)

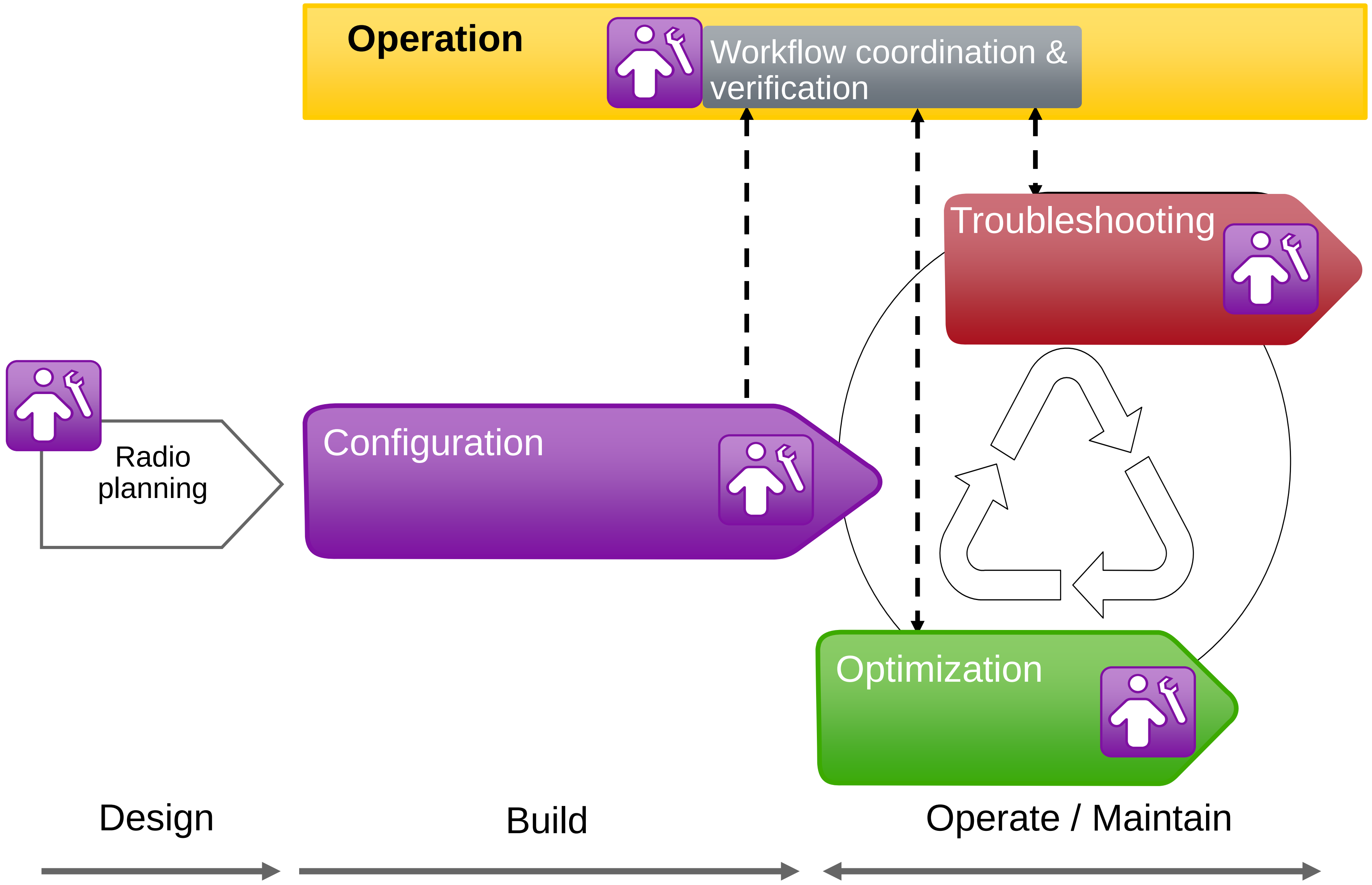
SON in LTE example: Automatic Neighbour Relations (ANR)



eNB A is pre-configured to know eNB B

UE relays info on eNB B to eNB A

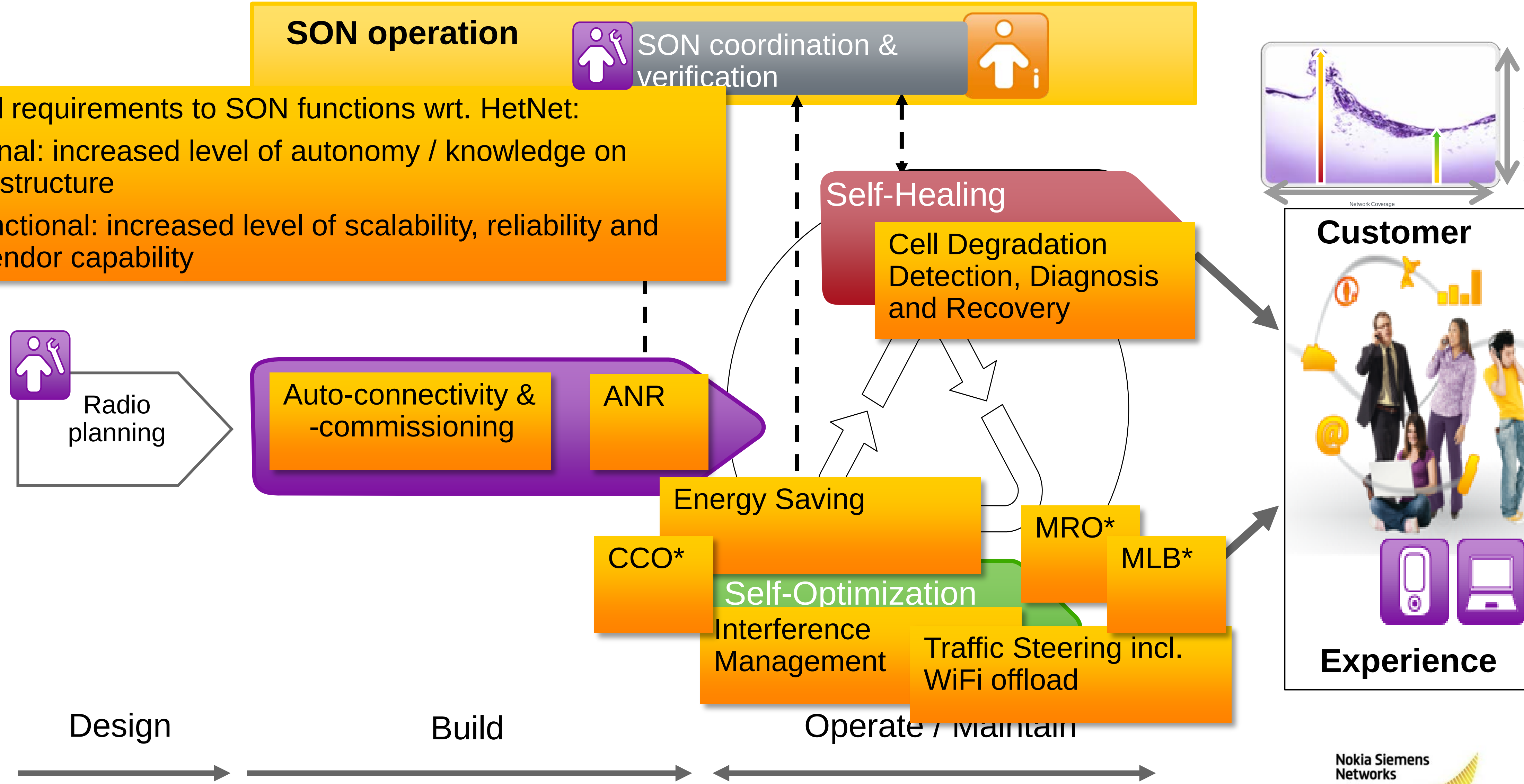
Network Operations use case areas



Self-Organizing Networks (SON)

Additional requirements to SON functions wrt. HetNet:

- Functional: increased level of autonomy / knowledge on HetNet structure
- Non-functional: increased level of scalability, reliability and multi-vendor capability



*MRO: Mobility Robustness Optimization MLB: Mobility Load Balancing CCO: Coverage & Capacity Optimization

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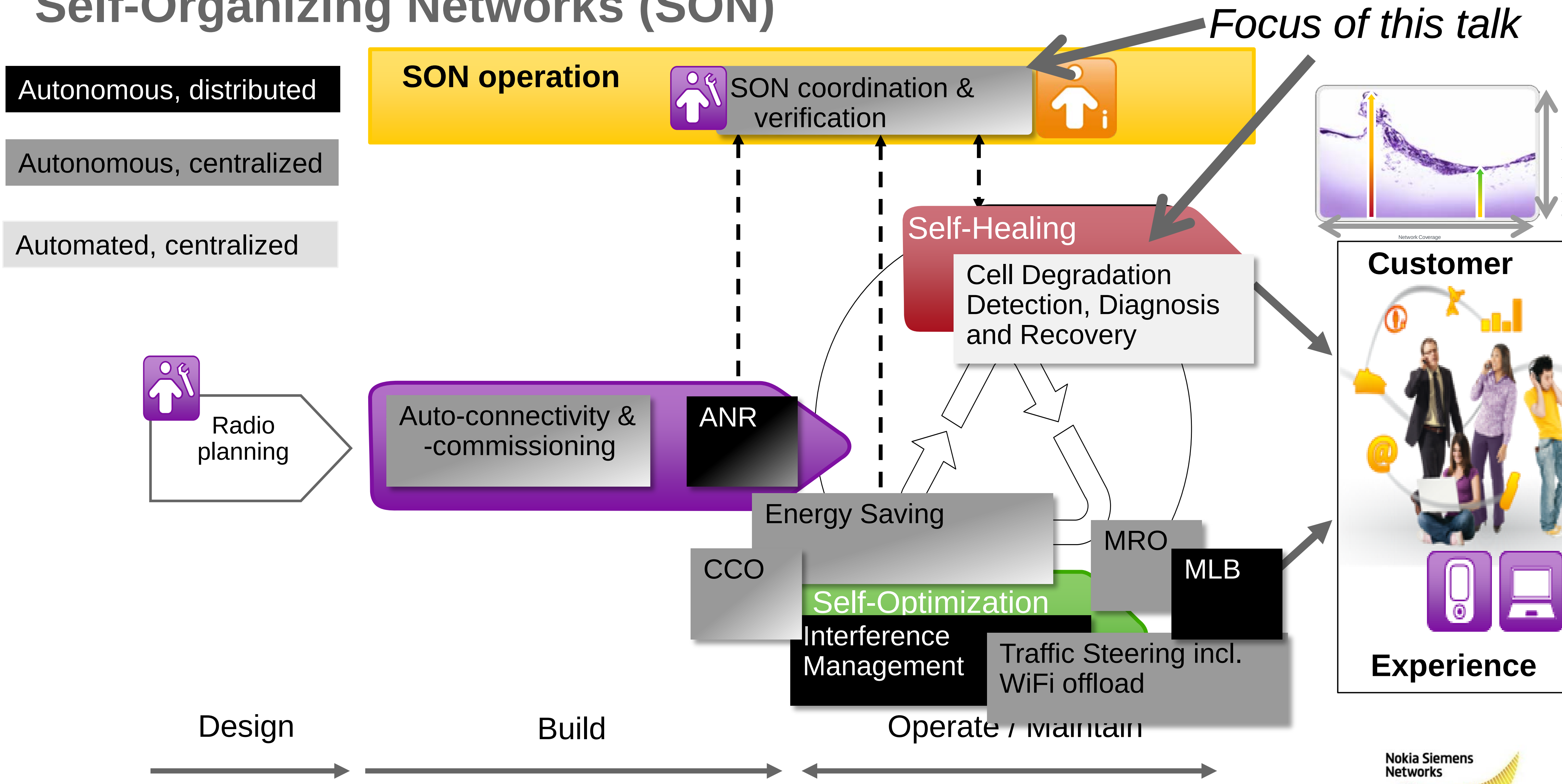
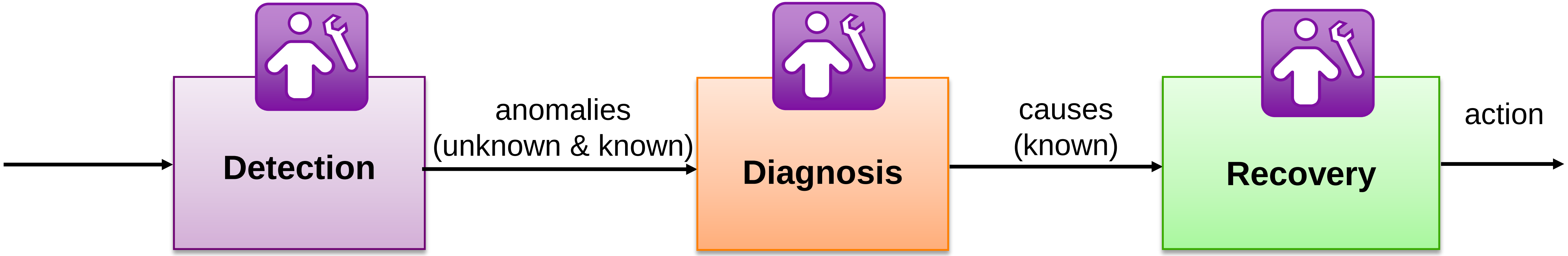
Self-Organizing Networks (SON)



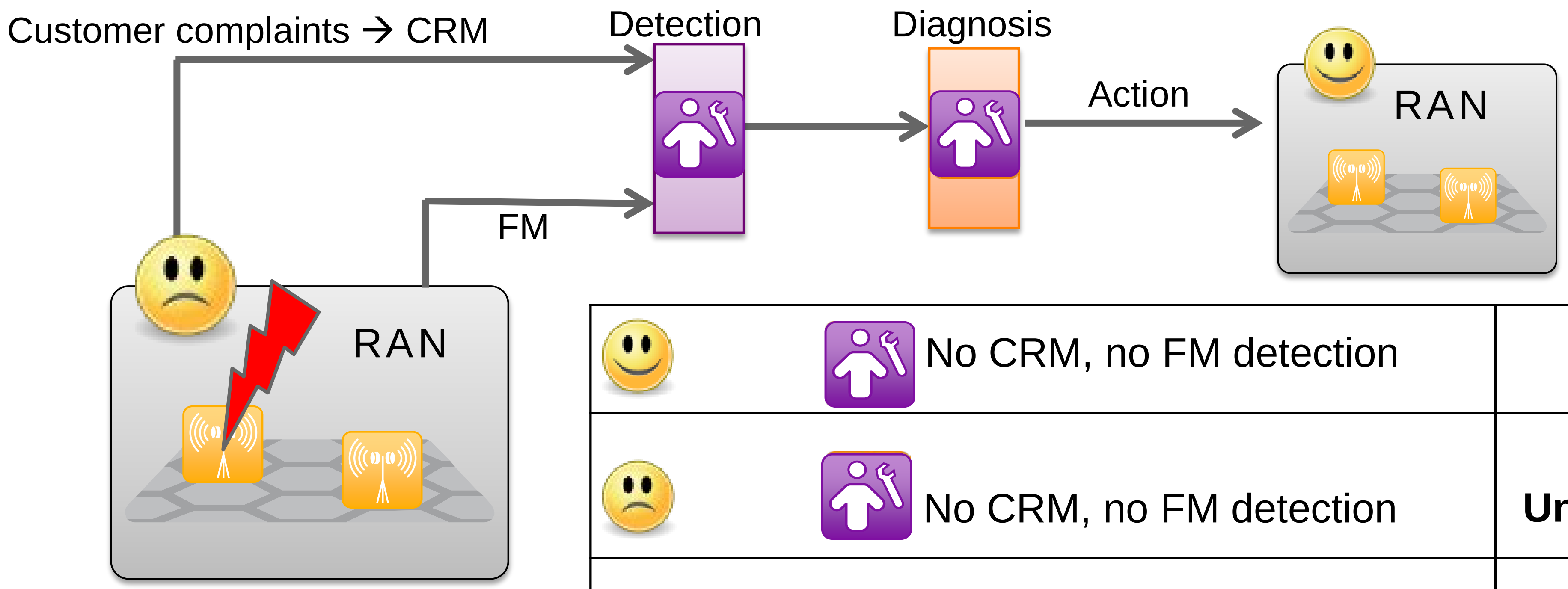
Network troubleshooting / Self-healing

Network troubleshooting



Anomaly Detection	Cause Diagnosis	Recovery Action Selection
Discover any anomalies in the monitored network	Determine plausible explanations for the detected anomalies and compute their likelihood	Determine possible recovery or observation actions and compute their alignment with the operational goals

Network troubleshooting: knowns and unknowns



No CRM, no FM detection	
No CRM, no FM detection	**Unknown, unknown**
CRM → No FM detection	**Unknown, known**
(CRM) → FM detection, diagnosis: ?	**Known, unknown**
(CRM) → FM detection, diagnosis: ok	**Known, known**

Network troubleshooting: knowns and unknowns

“There are **known knowns**; there are things we know that we know.
There are **known unknowns**; that is to say, there are things that we now know we don't know.
But there are also **unknown unknowns** – there are things we do not know we don’t know.”

Statement awarded „Foot in Mouth“ Award 2003
Linguist Geoffrey Pullum: “completely straightforward; impeccable (syntactically, semantically, logically, and rhetorically).“
Source: http://en.wikipedia.org/wiki/There_are_known_knowns

	Knowns	**Unknowns**
Known (we know that „something relevant“ is there → **automation)**	Labelled Diagnosis pattern (cause is known)	Detection / Unlabelled Diagnosis pattern (cause is not known)
Unknown (we don‘t know if „something relevant“ is there)	Problems (cause is known) without detection / diagnosis pattern	

Improve diagnosis: „ground truth“ (expert knowledge)

Improve detection

(Improve visibility of problems: CRM)

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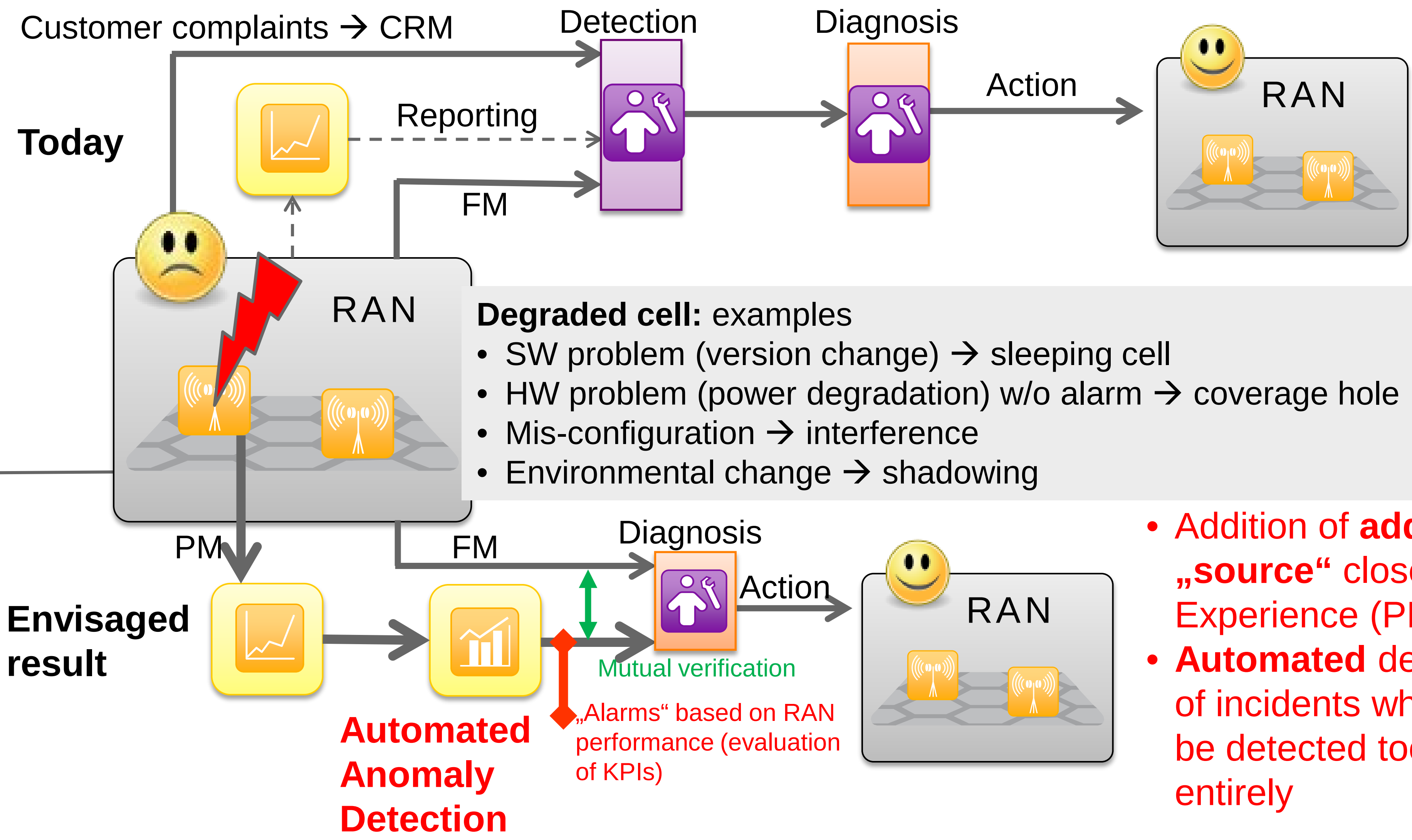
Self-healing: cell anomaly detection



Degraded cell: examples

- SW problem (version change) → sleeping cell
- HW problem (power degradation) w/o alarm → coverage hole
- Mis-configuration → interference
- Environmental change → shadowing

- Addition of **additional detection „source“** closer to Customer Experience (PM → CE metrics)
- **Automated** detection (localization) of incidents which would otherwise be detected too late or missed entirely

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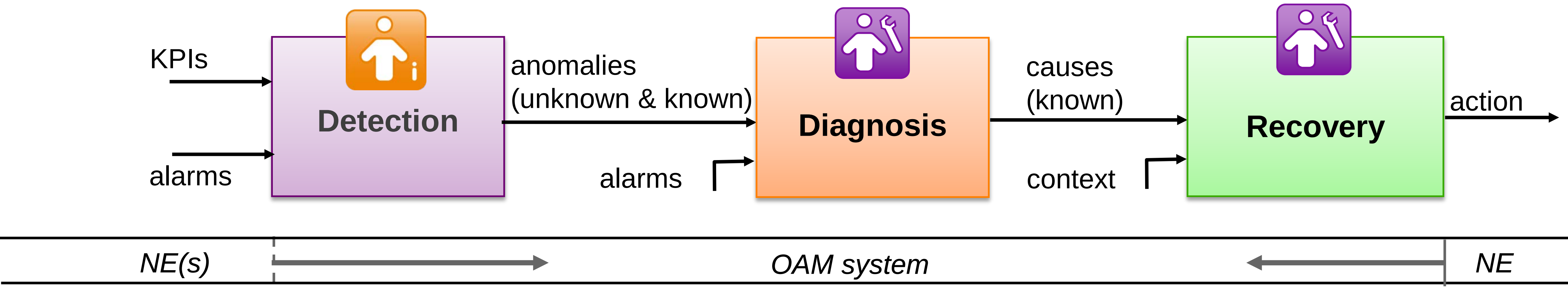
Self-healing: technology

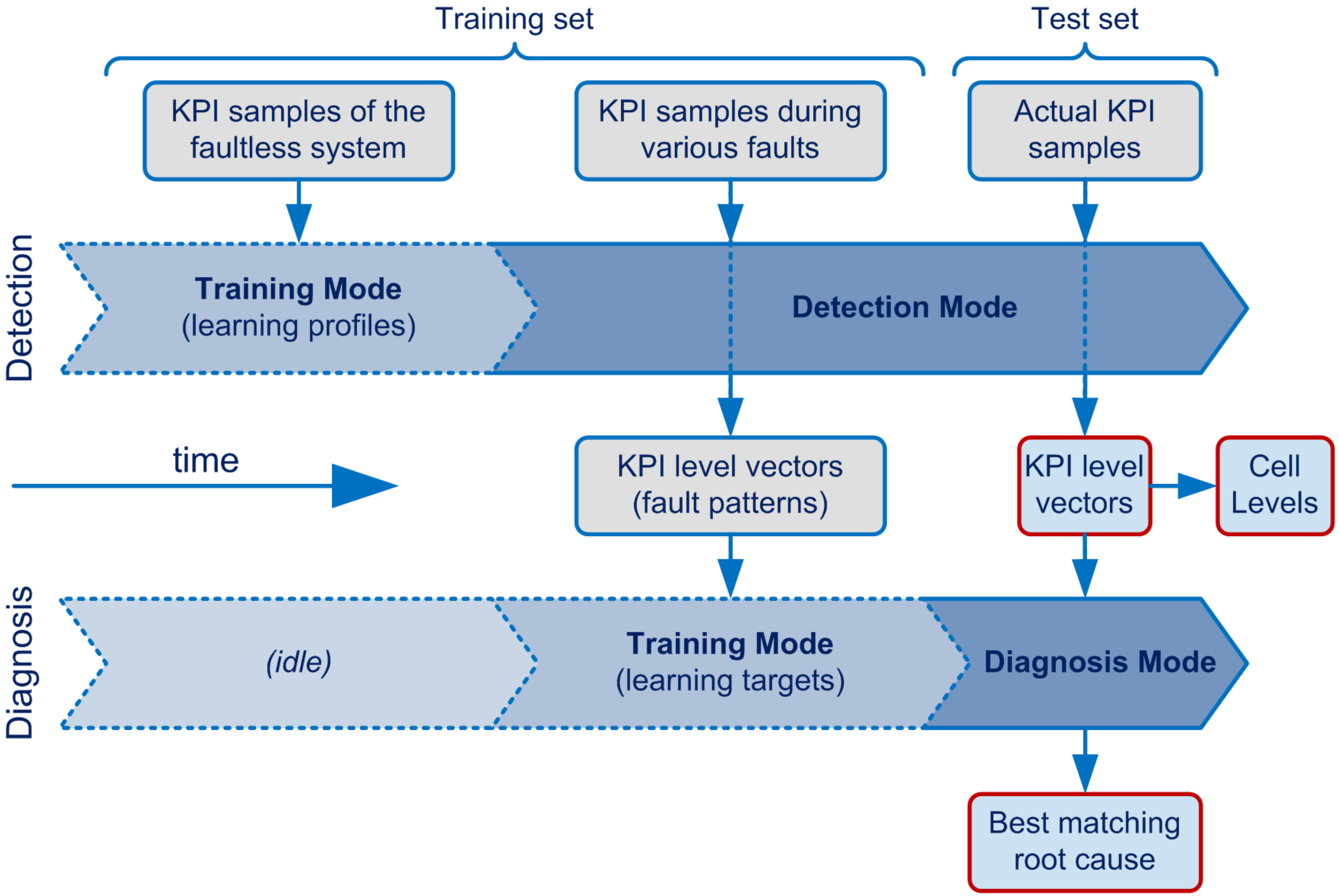


Technologies	Time-series analysis / modelling → **profiling** - prediction-based - window-based (similarity measure)	Alarm correlation Probabilistic Graph Models (Bayesian Networks) Case Based Reasoning	Decision Theory Policies

Goals of **automatic** cell anomaly 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

Self-healing: operation



SON operation

SON operation: SON management + SON coordination

- **SON management:**
  - Enabling the control of the SON system by the human operator (governing the behaviour of the SON functions (*target definition*) based on business-level requirements) in a uniform way → “design-time“
  - Configuration (*target setting*, on/off, time scheduling, stop points / approval of actions), Monitoring (results) of the individual SON functions → “run-time“
- **SON coordination:**
  - Assuring the stable operation of the SON system as a whole by *addressing the interactions (conflicts)* between the use cases → “run-time“
  - Key characteristic: relates to more than one single function instance
  - SON coordination itself should be *automated* (e.g., by rule-based decision making), yet it may be run under close human supervision (manual approval of coordination actions) as well

→ both SON management and SON coordination need a proper interface (GUI, tool chain) to the human operator

SON operation: time-scale

– Potential conflicts depend on the respective timing, e.g., a „slow“ CCO has impact on a „fast“ MRO with lower probability

– SON is not only about reducing OPEX as it is today, but doing network operations

- **Faster**
- More **adaptively**, cf. variable user demand over the course of a day (NSN‘s LiquidNet)

→ more frequent executions

– Centralized SON: lower bound on data availability
(granularity period GP: 15mins – 1h)
→ lower bound on the execution interval

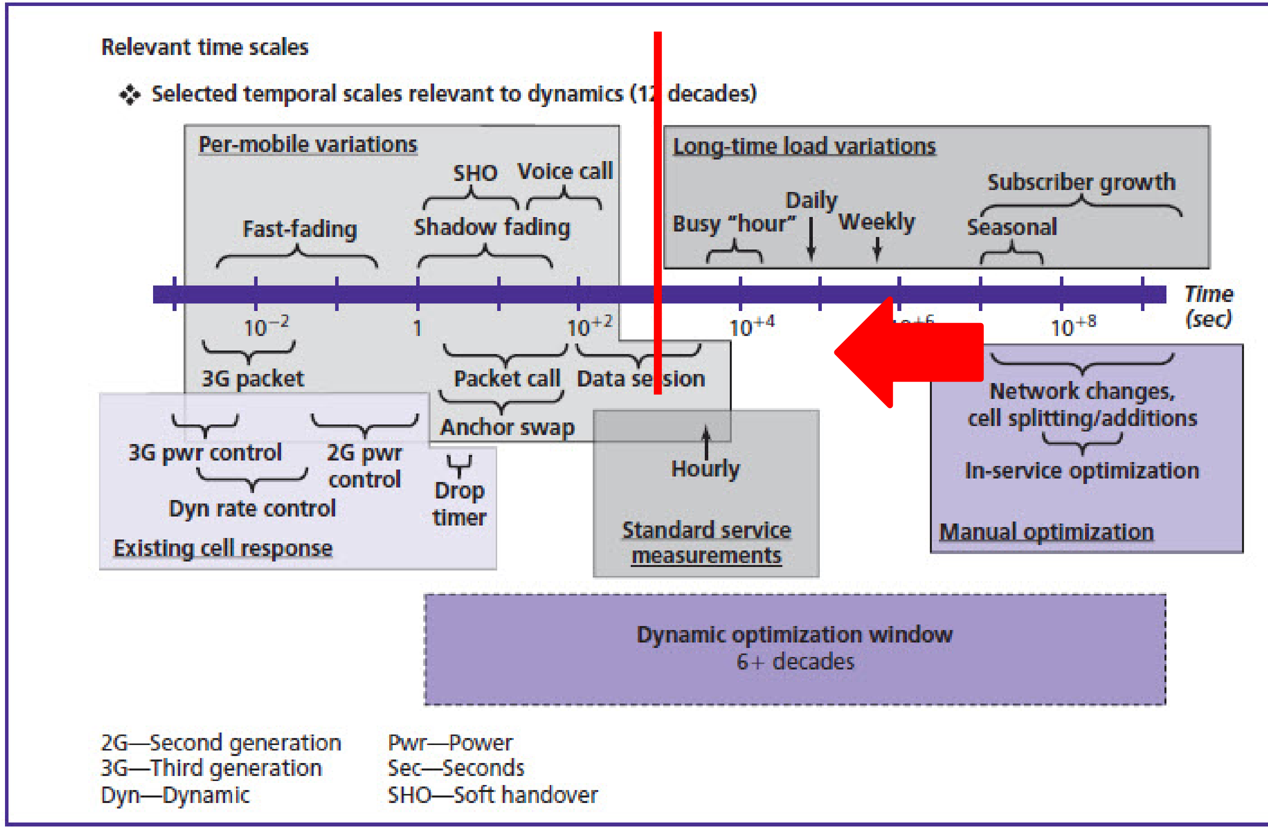


Figure 2.
A Bell Laboratories slide from 2003 showing relevant time scales for dynamic optimization.

10 Bell Labs Technical Journal DOI: 10.1002/bltj

→ C-SON function instances will have *sync‘ed execution intervals*

→ Batches of change requests with *overlapping impact times*

→ **Concurrency issues**

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SON concurrency control („SON coordination“)

- Input-related („race condition“) http://en.wikipedia.org/wiki/Race_condition#Example
  - both function instances („threads“) read system state (here: KPIs, CM data) corresponding to a certain time t. Instance 1 changes that state without Instance 2 being aware of it → potentially wrong / bad result
  - Solution: mutual exclusion (mutex)
- Output-related („lost update problem“) http://en.wikipedia.org/wiki/Concurrency_control
  - Both function instances write system state (here: CM data, change cell characteristic). Instance 2 overwrites the change of Instance 1 (without Instance 1 having taken effect)
  - Solution: locking
- Specifics in SON domain:
  - Problem: system state which needs to be protected
    - are both KPIs (*statistics on KPIs !*) and CM parameters
    - is physically distributed (cells on different basestations, RNCs)
  - Solution: pre-action coordination
    - **Impact area and time** definition related to both Instance 1 and 2
    - **„Virtual“ locking** at OSS (not NE) level

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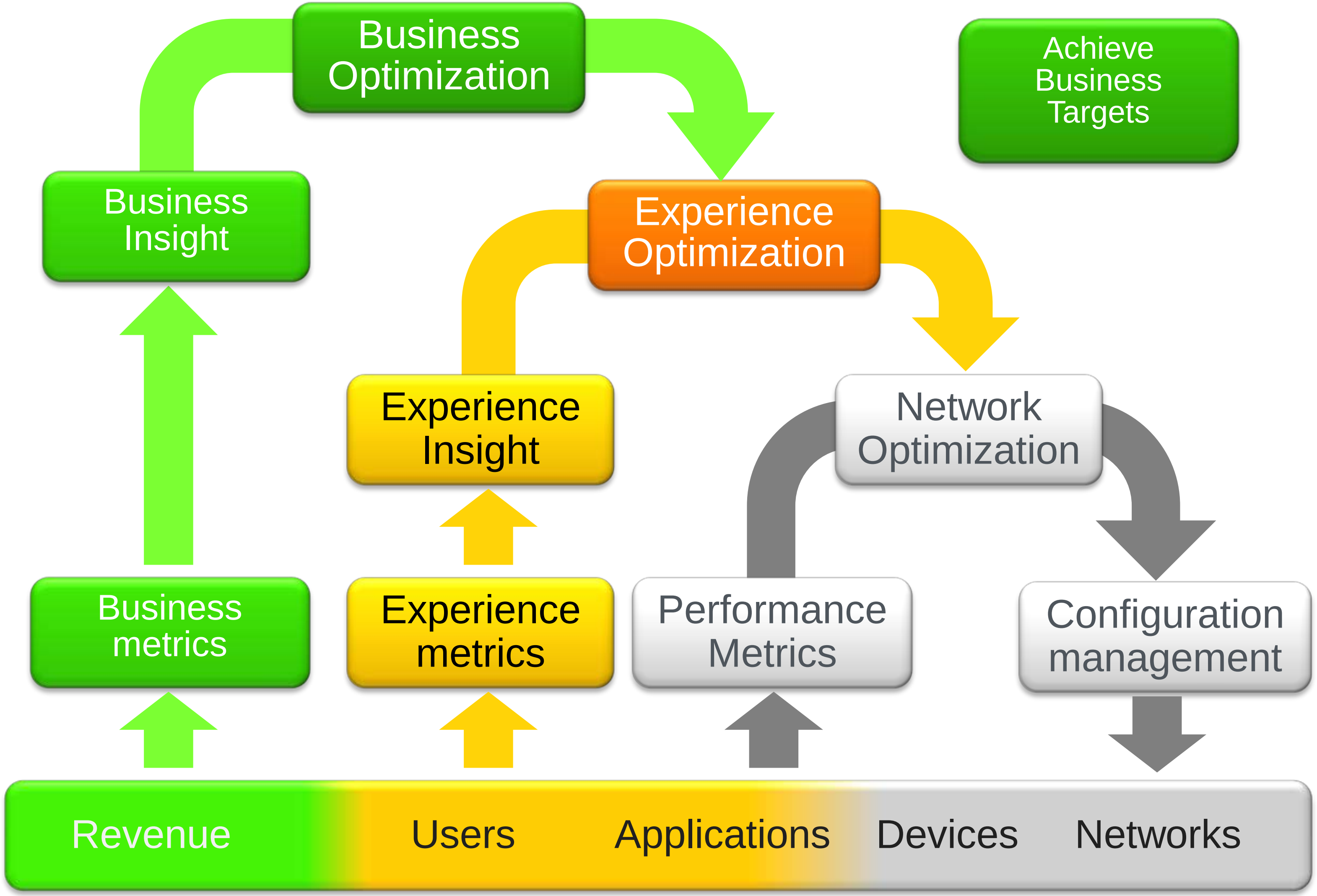
“Cognitive Networks” – Capability to Optimize User Experience and Network



Define business metrics and analyze business insight for business optimization

Drive experience optimization with business goals

Use your network as a tool for reaching business potentials

Implement Machine Intelligence

Source: Ossi Pöllanen, NSN

Conclusions

Mobile data traffic explosion → operators must „densify“ their network, increasing capacity and assuring coverage → **Heterogeneous Networks (HetNets)**

Decreasing revenue per user → operators must reduce costs to remain profitable; HetNets increase complexity and thus Operational Expenses (OPEX), however
→ **dilemma**

Manage complexity → apply **“Self-Organizing”** concepts to drive down costs for **infrastructure** networks

- Crucial to recognize (detect / diagnose) **relevant events** in the network (examples: self-healing, SON verification) → requirement to instrument the network (**data**) and run **automatic, online analysis** on the data (to gain “intelligence”, moving from “unknown” to “known”)
- Faster network operation time cycles (“Liquid Network”) → requirement to **control concurrency** in the automated network operation

Automated management driven by network data → management driven by **customer experience** data → management driven directly by **business objectives**
→ Challenge is to find the right **balance between automation and human interaction**

Innovation at the heart of our business

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