# Reliable Operation of Heterogeneous Wireless Networks with SON (Self-Organizing Networks) - Self-Healing

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**Nokia Siemens Networks**
**- Research**

**Tutorial** DRCN 9th International Conference on Design of Reliable Communication Networks

Nokia Siemens Networks

# Self-healing: background

- NGMN use case doc emphasizes „sleeping cell“ detection / recovery
- TMO/VDF „NGMN operations requirements“ doc 12/09:
  „quality and quantity of alarms“
  among Top 10 requirements
- Pain point (cf. Questionnaire on troubleshooting):
  missing detection & diagnosis functionality

**NGMN Operations Requirements**

*Top ten network operations requirements for multi-vendor, multi-technology environment*

Vodafone / T-Mobile

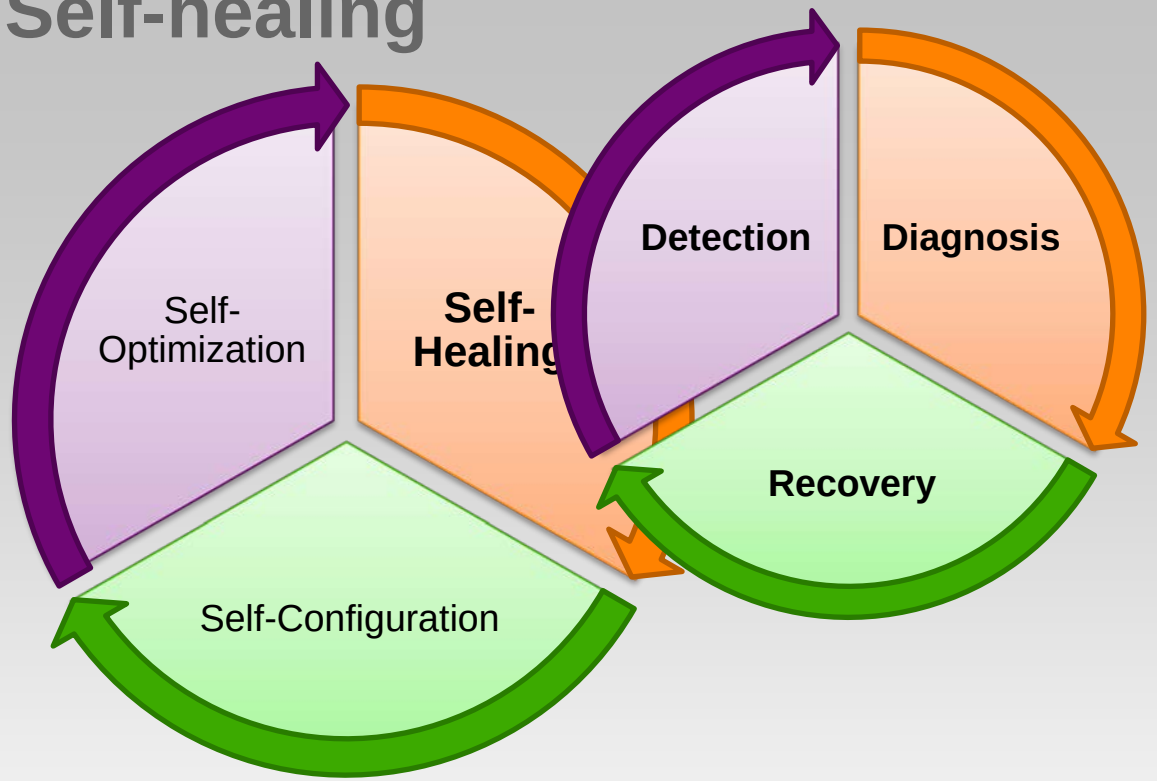
**Release 1.0**

*OPREQ-2009-01*

6. What are your most important pain points during your work?
   - Problems that cannot be directly solved through alarms (HW or SW failure?)
   - Problems that cannot be seen from the alarms

# Human operator work effort distribution: example

# Self-healing




**Cell Anomaly Detection:**
- profiles a cell
- monitors cell “health”
- triggers diagnosis in case of detection

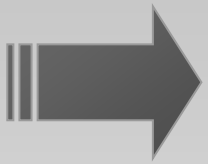
**Degradation Diagnosis:** identify root cause based on embedded operational knowledge and training (technologies: data mining, machine learning)

**Recovery:** choose action (e.g., cell reset, compensation) with best utility

# Self-healing: key requirements

**Realistic prerequisites**

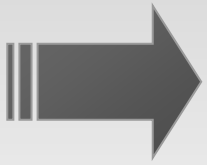
Take into account the information that is available from operators.



**Feasibility**

**Seamless integration**

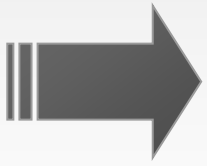
Integrate into the operator's current troubleshooting process.



**Acceptance**

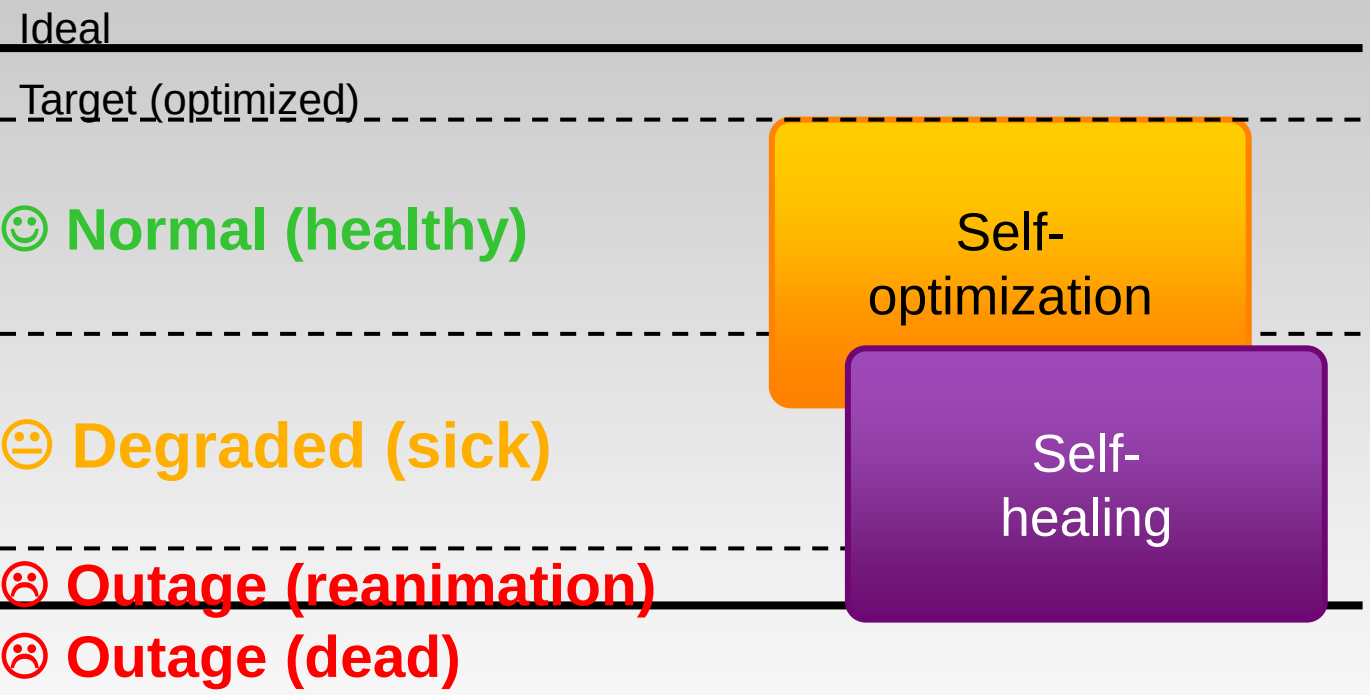
**Adaptation**

Adaptation to the operator's network (no universal expert knowledge).



**Flexibility**

# Self-healing: basics
## Operational status → actions



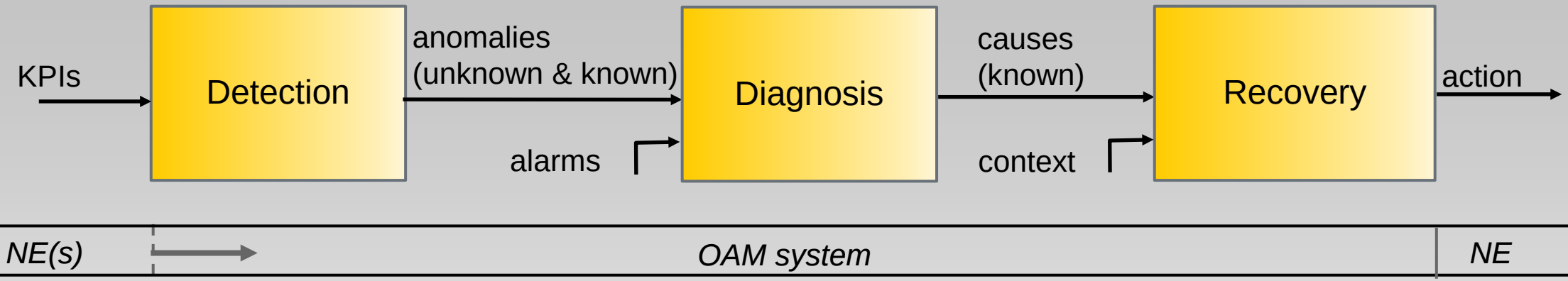

→ Config parameter change

→ Cell reset
→ Node reset (config / SW version / HW redundancy fallback)
→ Node update (config / SW version)
→ *Trouble ticket (replanning → add. HW)*

→ Compensation by other cell (COC)
→ *Trouble ticket (HW replacement)*

→ Requirement to determine the operational status (**detection** by analysis of (combinations of) KPIs & alarms), establish the cause (**diagnosis**) and decide / execute actions (**recovery**)

# Self-healing: basics

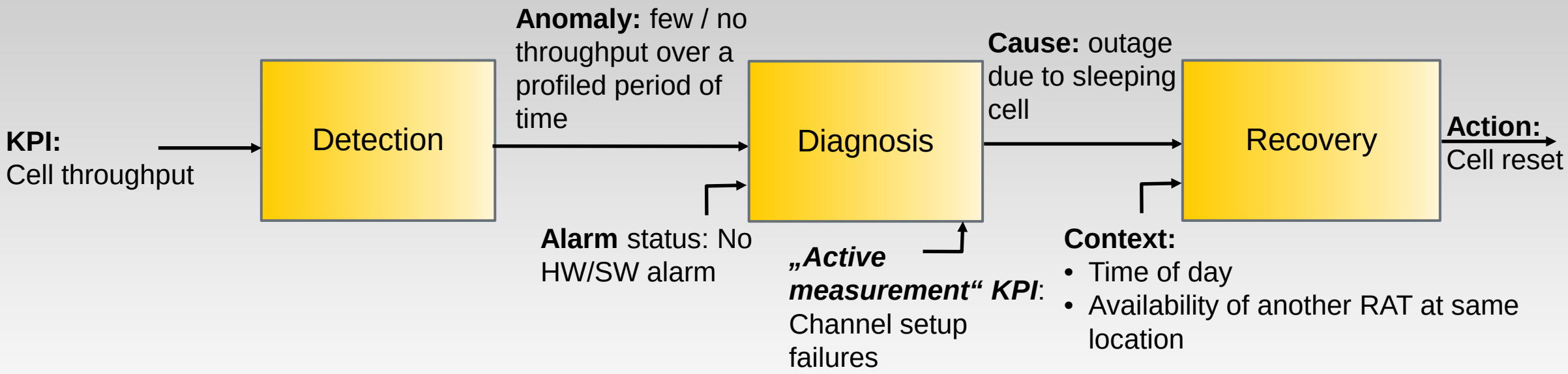



| Technologies | Time-series analysis / modelling → **profiling**<br>- prediction-based<br>- window-based (similarity measure) | Alarm correlation<br>Probabilistic Graph Models (Bayesian Networks)<br>Case Based Reasoning, Self-Organizing Maps<br>Neural Networks | Decision Theory<br>Policies |
|---|---|---|---|

Goals of **automatic** cell anomaly detection and diagnosis → OPEX saving

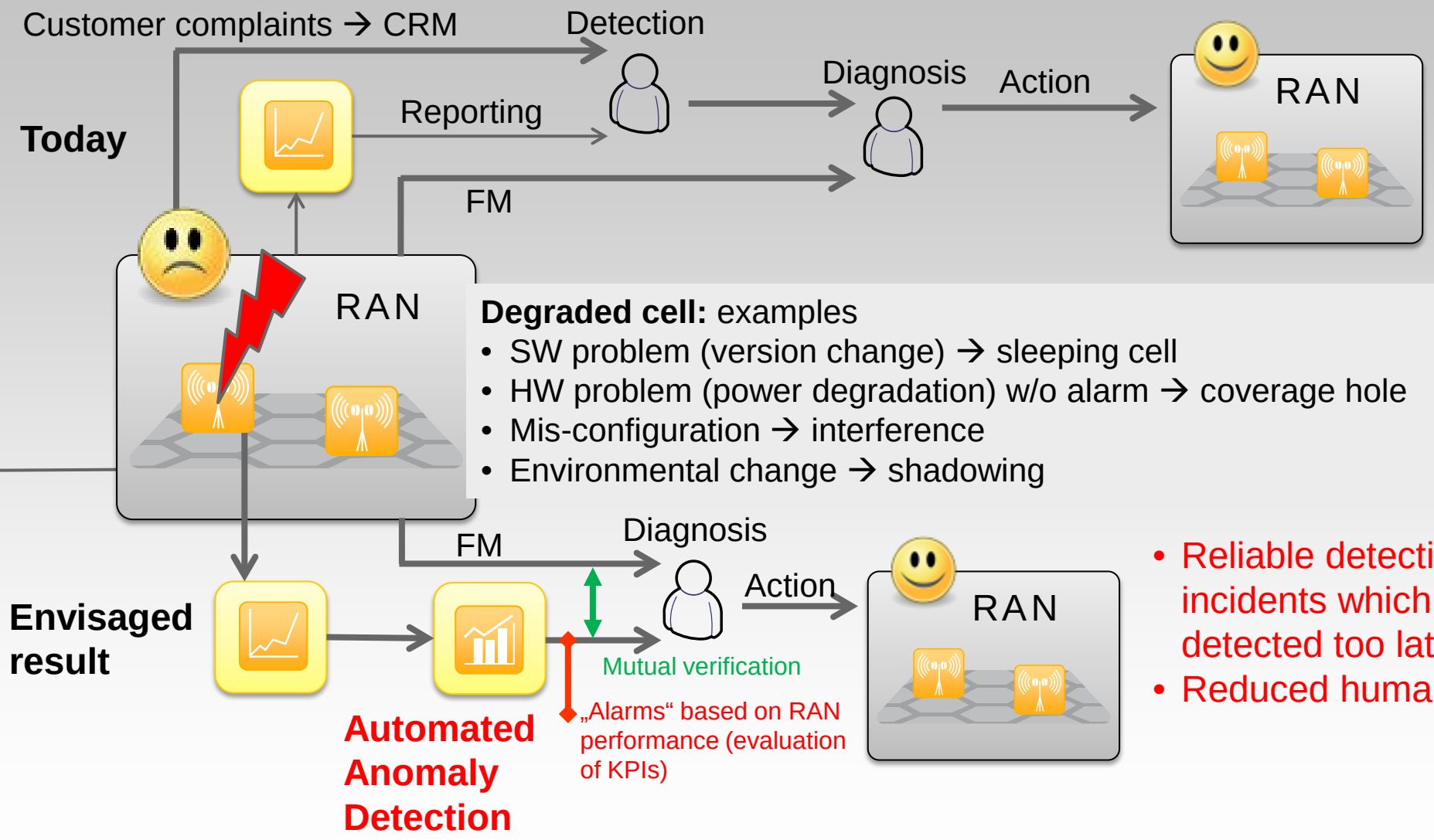
- Reduction of workload for human troubleshooting experts
  → free time for the really crucial problems
- Reduce time until a degradation / outage is detected and diagnosed
  → early trigger of actions

# Self-healing: basics
# Example: sleeping cell diagnosis and recovery




Research work: not technology research, but adaptation of technology to use case / domain

# Self-healing: cell anomaly detection




- Reliable detection (localization) of incidents which would otherwise be detected too late or missed entirely
- Reduced human work effort

# Self-healing: cell anomaly detection
# Problems with state-of-the-art

## Using thresholds and binary alarms

- to the operator, a KPI looks either 100% good (no alarm) or 100% bad (alarm); however, the state of the network is not black and white
- a small change in the state of the system results in a big step in detection (i.e., sending an alarm)

## Human operator is involved at an early stage

- has to calibrate thresholds separately for each KPI
- has to manually infer (i.e., diagnose) what is the problem based on the alarms

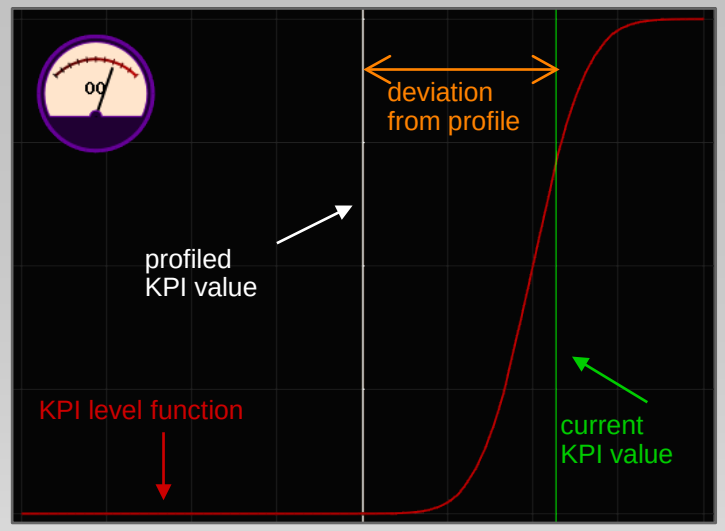
# Self-healing: cell anomaly detection KPI-level concept

## Detection is based on profiles

Detection should notice if the behavior of a KPI corresponds to or differs from its usual behavior, that is, the profiled value. However, there is no strict threshold and no alarm is sent.

## Unified KPI level concept

The level of each KPI is between 0 and 1, indicating the significance of deviation from the usual behavior. All KPIs can be leveled by the same concept, regardless of the specific type and semantics of the KPI.




KPI level as function of deviation

level → 0

behaves according to profile

level → 1

significant deviation from profile

# Self-healing: profiling for cell anomaly detection

Ideal

Target (optimized)

☺ Normal (healthy)

Profiling of **normal** state:
**cell anomaly detection**

*anomaly*

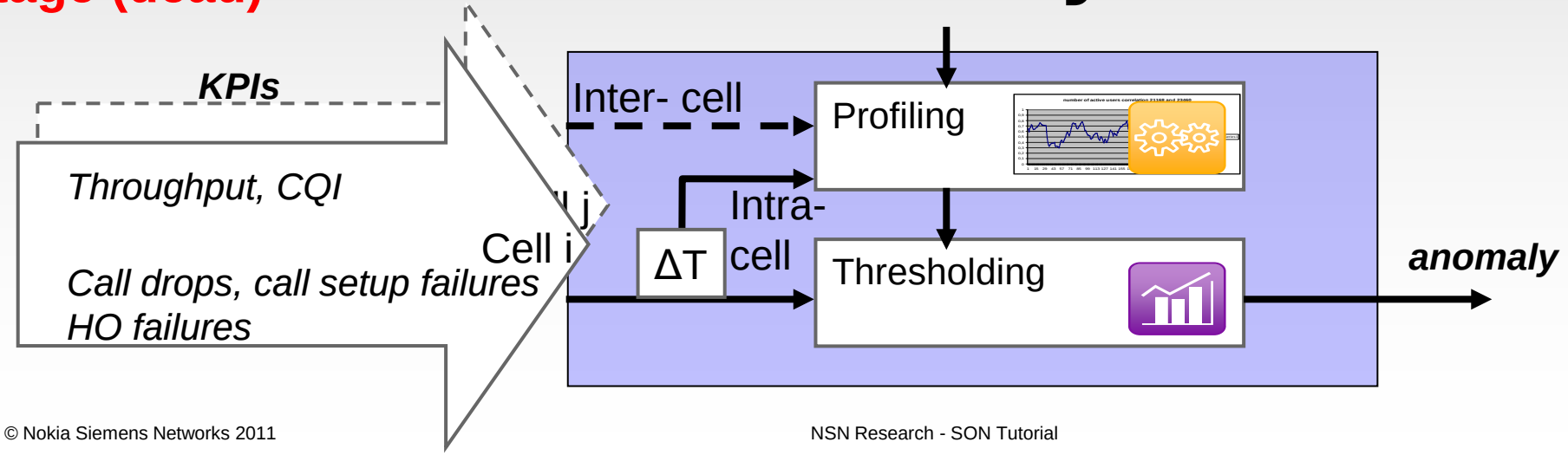
😐 Degraded (sick)

☹ Outage (reanimation)

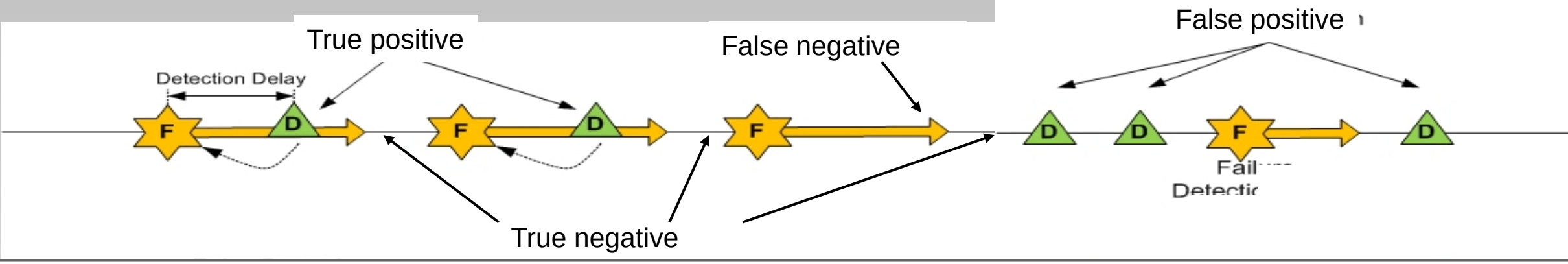
*outage*

☹ Outage (dead)

„Profiling“ of **outage** state:
**cell outage detection (COD)**



# Cell Anomaly Detection: performance metrics




- Detection **accuracy**: (→ reduce human workload)
  - False negatives, true positives: (un-)detected anomalies (for performance evaluation 100% knowledge of cases (symptom) required) → difficult to acquire data → simulation)
  - False positives (can be evaluated with available data known to be fault free)
- Detection **speed**: (→ reduce time until detection)

# Cell Degradation Diagnosis

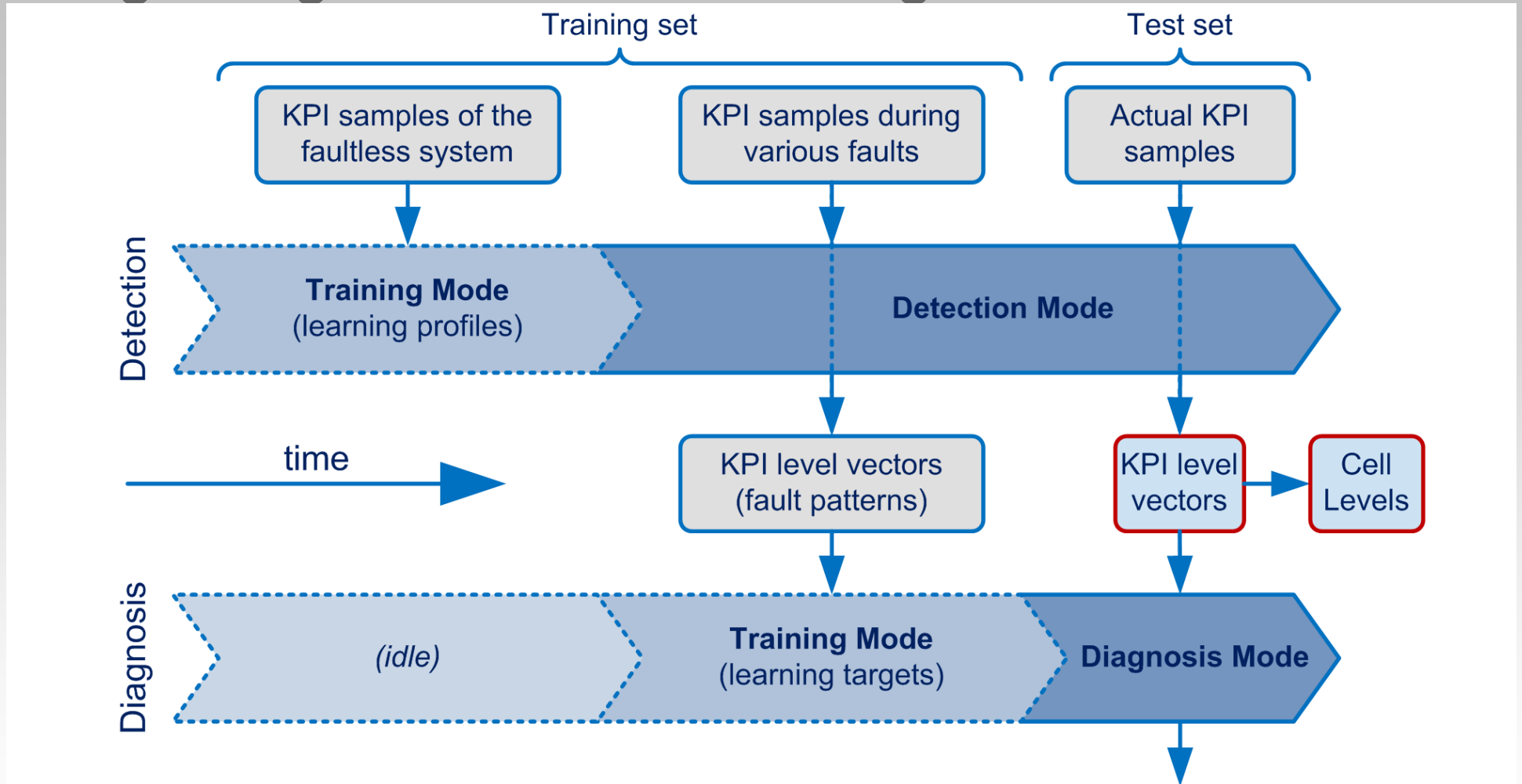
Challenge in linking symptoms to problem causes

- Problems can start in any part of the network; hardware, software, attached systems, or applications
- There is not always a direct indication (alarm, trap) of a problem (→ detection)
- A single problem often causes many symptoms in many related (or even not closely related) elements
- Different problems can cause overlapping symptoms
- Problems can escalate, symptoms can trigger further symptoms in related objects, making necessary to examine all symptoms across related elements to identify the root cause
- Network elements or software from different vendors have different bugs
- Even different software versions from the same vendor have different bugs
- Usually there is **no knowledge database (relating symptoms to problems),** which makes automation difficult

Problems with the state-of-the-art:

- Manual diagnosis, based on alarms
- Too many and too low level events/alarms
- Deduplication, filtering: no built-in intelligence, does not offer any root cause analysis

# Self-healing: Integrated Detection / Diagnosis Framework




→ DRCN paper: Szabolcs Nováczki „An Improved Anomaly Detection and Diagnosis Framework for Mobile Network Operators", session "Reliability of Wireless Access", Wednesday, 6.3., 15.20-16.40

# Cell Anomaly Detection and Degradation Diagnosis Demo

**An example application showcase:**

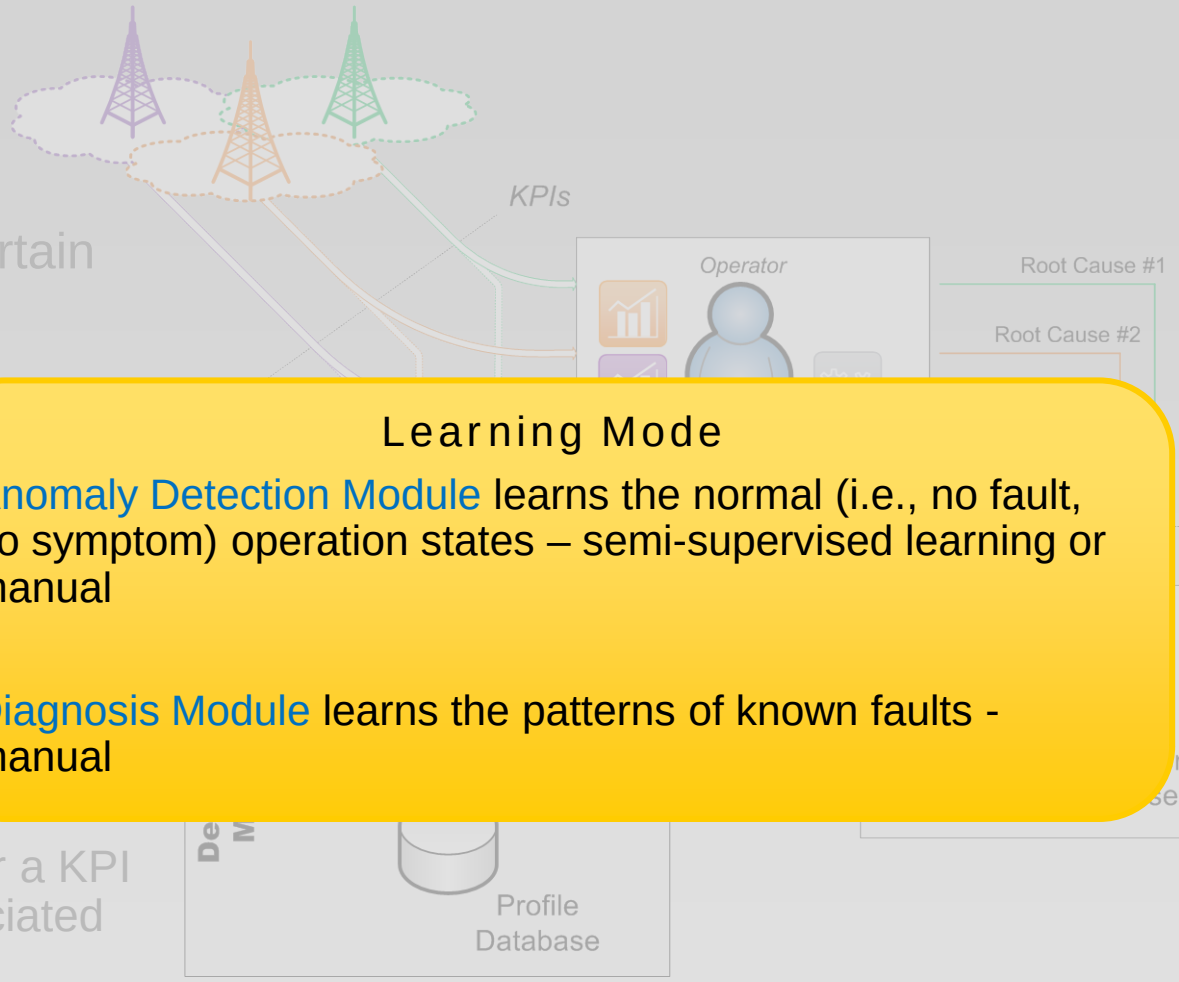
**- 70 3G cells of a live network**

**- 12 KPIs/cell**

**- 188 days data with hourly granularity**

# Learning Mode

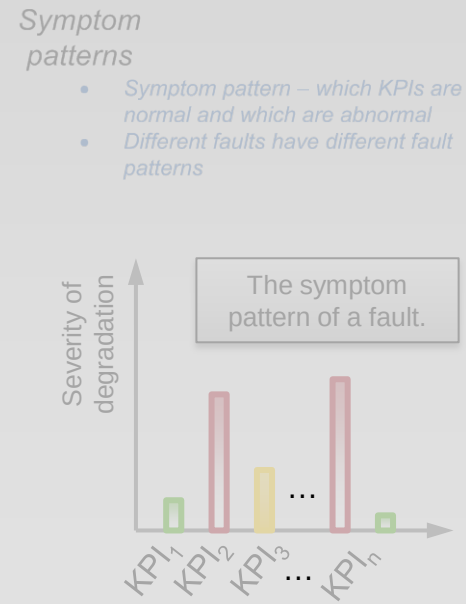
- KPIs are calculated at certain granularity.
- Manual troubleshooting process is triggered by alarm.
- The operator analyze (monitoring tools) and the root cause of the f
- The identified faults a in the fault pattern data
  - Each record tells whether a KPI was affected by the associated fault or not.
- In normal operation periods the profiles of the KPIs are learned




**Learning Mode**

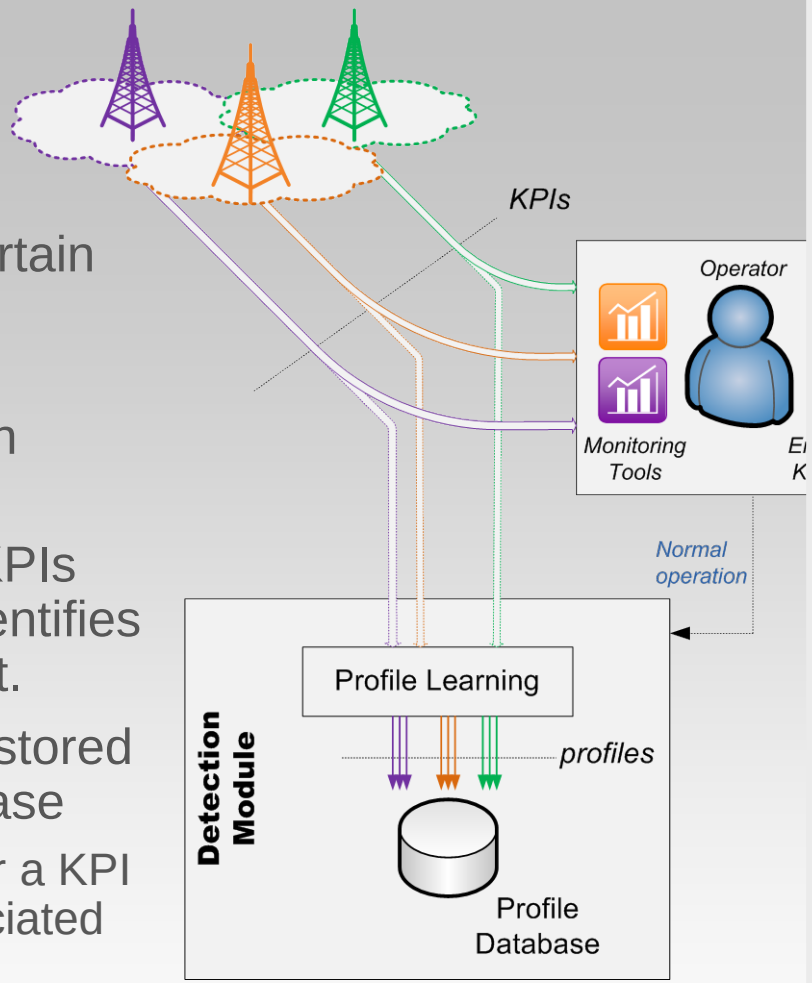
Anomaly Detection Module learns the normal (i.e., no fault, no symptom) operation states – semi-supervised learning or manual

Diagnosis Module learns the patterns of known faults - manual



# Learning Mode

- KPIs are calculated at certain granularity.
- Manual troubleshooting process is triggered by an alarm.
- The operator analyzes KPIs (monitoring tools) and identifies the root cause of the fault.
- The identified faults are stored in the fault pattern database
  - Each record tells whether a KPI was affected by the associated fault or not.
- In normal operation periods the profiles of the KPIs are learned




- *Multiple profiles for each KPI*
- *Only normal samples are used to create the profiles*

Anomaly Detection

# Monitoring Mode

- The KPI-level vector is the actual symptom pattern of the network element
  - Shows which KPIs are close to the profile and which are far
  - During normal operation all KPI-level is close to zero
- The actual symptom pattern is compared to the
- e most plausible
  nomaly
  ails:

- The anomaly detection analyzes each KPI; comparing them to the associated profiles.
- The detection result is a KI level assigned to each KPI
  - The KPI-level is a normalized [0,1] measure distance of the actual KPI value form the profiles.
- KPI-level vector (level value of each KPI) is passed to the diagnosis module
- Read attached paper for more details:

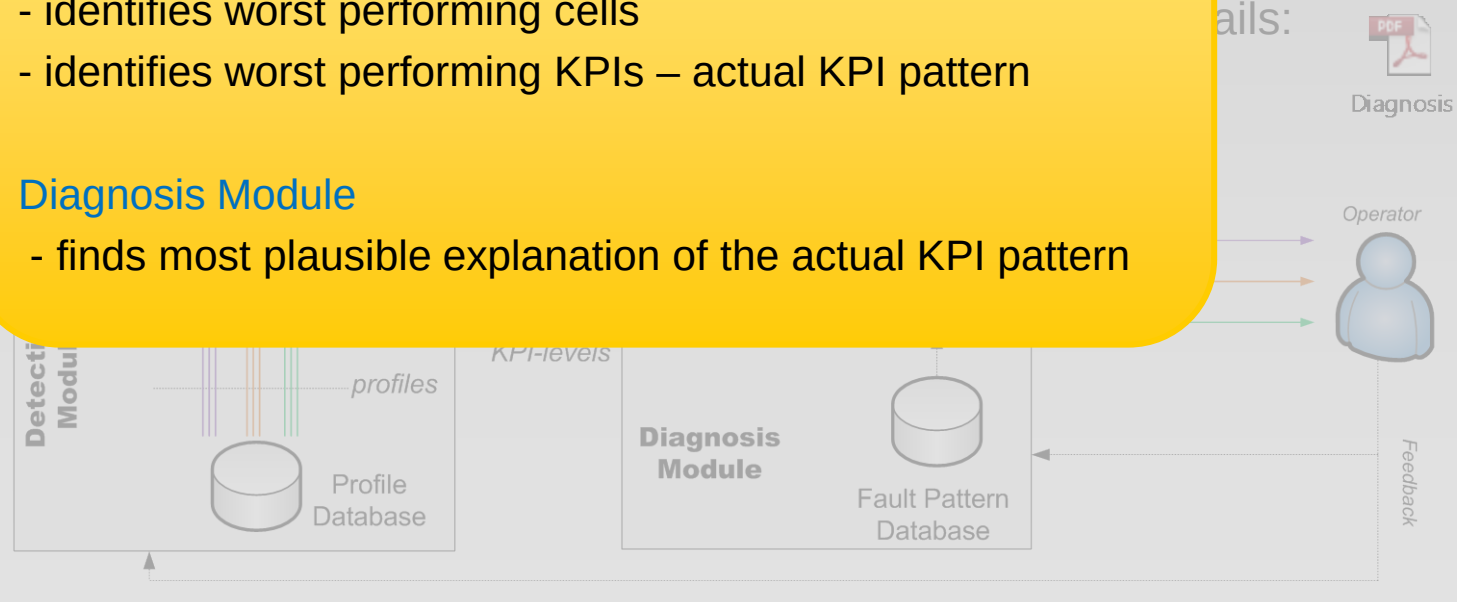
**Monitoring Mode**

Anomaly Detection Module

- identifies worst performing cells
- identifies worst performing KPIs – actual KPI pattern

Diagnosis Module

- finds most plausible explanation of the actual KPI pattern




*The FEEDBACK of the operator helps to improve anomaly detection and diagnosis performance by converging results to operator expectations*

# Monitoring Mode

- The anomaly detection analyzes each KPI; comparing them to the associated profiles.
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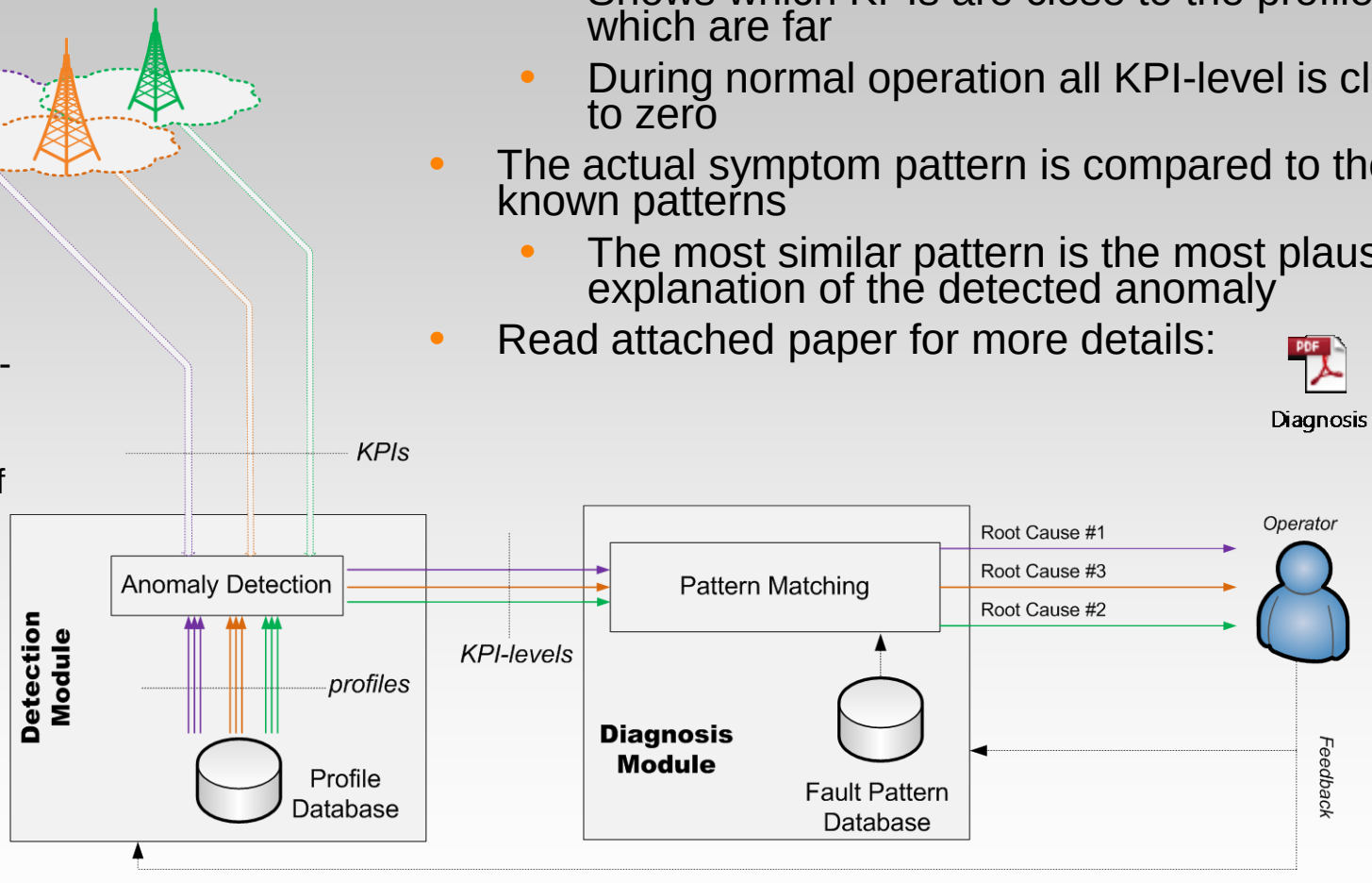
Anomaly Detection




- The KPI-level vector is the actual symptom pattern of the network element
  - Shows which KPIs are close to the profile and which are far
  - During normal operation all KPI-level is close to zero
- The actual symptom pattern is compared to the known patterns
  - The most similar pattern is the most plausible explanation of the detected anomaly
- Read attached paper for more details:

Diagnosis

*The FEEDBACK of the operator helps to improve anomaly detection and diagnosis performance by converging results to operator expectations*

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