Amdocs Open RAN Automation

Amdocs RAN Energy Savings Management

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Introduction

Reducing unnecessary energy consumption is a global environmental priority and is particularly pressing for mobile operators, who spend on average 20% of their RAN OPEX in energy.

This paper presents the Amdocs approach to the RAN Energy Savings Management (ESM) use case and, specifically, its implementation within Open Radio Access Networks (RAN).

Energy Savings Management has long been identified as a key use case since emerging during the first Self-Organizing Networks (SON) deployments. In recent years, with increasing cost pressures, operators have looked to accelerate the deployment of automated approaches to reduce energy without disruption to the quality of service offered. In this White Paper we concentrate on Energy Savings feature on Operation, Administration, and Maintenance (OAM) level.

First standardization attempts were made by 3GPP in their Release 10 in 2011 in 3GPP 25.927 and 3GPP 36.927. OAM Energy reduction approaches including switching off overlay cells and MIMO dimensionality reduction were outlined. These approaches used RAN analytics to identify off-peak when power consumption could safely be reduced and the setting of thresholds to trigger action. Two study items in Releases 10 and 11 (TR 32.826 on "Study on Energy Savings Management (ESM)" and TR 32.834 on "Study on Operations, Administration and Maintenance (OAM) aspects of inter-Radio-Access-Technology (RAT) energy saving") led to the first specification on OAM concepts, aspects, and functionality of RAN Energy Savings in 3GPP TS 32.551("Energy Savings Management. (ESM); Concepts and Requirements"). Here three new states for a RAN cell are introduced: The "notEnergySaving", the "energySaving", and the "compensatingForEnergySaving" state. We will later show how Amdocs implements these 3GPP concepts. Speaking further in this language, this White Paper is about the Amdocs' concepts and implementation of centralized Energy Savings Management.

Release 12 added the idea of dynamic/proactive traffic steering to redistribute UEs in off-peak time towards a favorable UE allocation for ESM. In release 15 Energy Efficiency and its Key Performance Indicators were defined in 3GPP 28.554, some of them being slice-aware. While Energy Savings specifications work is still going on in 3GPP, this further work and specified detailed ideas of 3GPP are beyond the scope of this White Paper.

In addition to the standardization activities within 3GPP, the Open RAN (O-RAN) Alliance focuses on specific requirements and open interfaces of RAN analytics and optimization use cases for Open RAN. As such, it discusses RAN Energy Savings Management in its Working Groups like many other use cases.

Specifically, O-RAN Working Group 1 (Use Cases and Overall Architecture Working Group – WG1) documented RAN Energy Savings as an O-RAN use case in O-RAN.WG1.TR.Use-Cases-Analysis-Report-R004-v15.00 (October 2024), O-RAN Use Cases Detailed Specification 15.0 (October 2024), and, especially, O-RAN Network Energy Saving Use Cases Technical Report 2.0 (June 2023).

In this White Paper we will demonstrate how Amdocs Energy Savings Management aligns with current industry specifications, enhances and implements them, leading to significant reductions in energy consumption in multi-layer cellular RANs.

Amdocs Energy Savings Management Objective & Architecture

Amdocs has adopted an architecture that can support both traditional and Open RAN and adaptable vendor capabilities, meaning a consistent approach to energy savings management can be taken.

Energy Savings Mode

The Energy Savings Mode of a cell is defined as an operation mode of a cell in which less power is consumed, so the cell is in a 3GPP "energySaving" state. Typically, the cell is then reconfigured or even shut down compared to its normal 3GPP "notEnergySaving" state. Such a reconfiguration can happen in times of less traffic load in the coverage area of a cell. Before a cell is put into the Energy Savings Mode, or, equivalently, the "energySaving" state, the remaining traffic might be steered and handed over into other cells covering the same area. In 3GPP language, these cells then go into the "compensatingForEnergySaving" state.

Network Architecture

The Amdocs ESM approach requires the cellular network to consist of multiple network layers per sites.

One network layer is the coverage layer, all cells in this layer are coverage cells. Coverage cells are never put into an Energy Savings Mode. Typically, the coverage layer is the network layer with the lowest carrier frequency.

There must be at least one further network layer, typically at a higher carrier frequency than the coverage layer. This or these network layer(s) is/are called capacity layer(s).

In a typical configuration each site has three sectors, where each sector needs to have one coverage cell (in the network coverage layer) and at least one capacity cell (in one of the network's capacity layers).

Each capacity cell needs to have the ability to go into an Energy Savings Mode, where less power is consumed compared to the normal working mode. The implementation of the Energy Savings Mode might be different to the cellular technology (4G/5G) and the vendor.

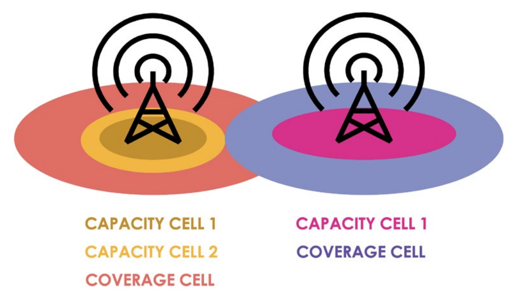


Figure 1: Network Architecture for ESM

The network example in Fig. 1 shows two sectors, each having a coverage cell, one of them having two capacity cells on top, while the right sector only has one capacity cell.

Amdocs High-Level ESM Architecture

As stated earlier, Amdocs implements a centralized Energy Savings Management strategy. So, there are centralized entities which oversee the situation of a complete cluster of cells, in terms of coverage, capacity, traffic load, power consumption, QoS, etc.

These centralized ESM entities are:

- ESM Policy (ESM-P).
- ESM Controller (ESM-C).
- ESM Analytics (ESM-A).

These three entities will be explained below:

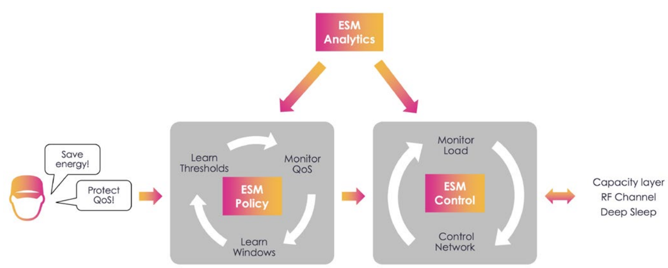


Figure 2: Amdocs overall ESM Architecture

Energy Savings Management Policy (ESM-P)

The **objective of ESM Policies (ESM-P)** is to set optimal parameters for ESM controllers in order to maintain a high level of QoS while saving as much energy as possible (i.e to put as many capacity cells for the maximum possible time periods into the "energySaving" state or the Energy Savings Mode.) Example policies can be time windows, in which the Energy Savings Mode for capacity cells is allowed or radio utilization load thresholds to maintain QoS SLAs while ESM is active. We will later explain our design and implementations.

Energy Savings Management Controller (ESM-C)

The **objective of the ESM controllers (ESM-C)** is to enable and disable various Energy Savings Mode implementations. According to O-RAN Network Energy Saving Use Cases Technical Report 2.0 (June 2023) possible ESM controller implementations are:

- **Cell on/off switching:** Once radio resource utilization thresholds are met, capacity cells are put into energy Savings mode, while the traffic is redirected to neighboring capacity cells or coverage cells. This mode is also referred to as overlay cell shutdown.
- **Component carrier on/off switching:** This controller is an extension of the capacity cells on/off switching. Here, a capacity component carrier is switched off for an entire cluster of cells, handing its remaining traffic over the other capacity layers or the coverage layer.
- **O-Cloud ESM:** IP resources in the O-Cloud can maybe switched off in times when not all computational resources are needed. This might be the case in low traffic times or in case the RF Channel Reconfiguration below switches the order the massive MIMO transmission regime down. In this case, energy can be saved on the O-Cloud hardware utilization.
- **RF Channel Reconfiguration:** In massive MIMO deployments energy can be saved in periods of low traffic, when a higher-order MIMO transmission regime (e.g., 64x64) is downgraded towards a lower-order MIMO transmission regime (e.g., 32x32, 16x16, or even 4x4). Then, Tx/Rs chains can be switched down. Note that for static/Grid-of-Beam type of beamforming (e.g., SSB beams or static CSI-RS beams), a reconfiguration of the O-RU is necessary then.

- **5G Deep Sleep Mode:** Several Deep sleep mode technologies could be enabled for the 5G cellular technology.
- In addition, the RF Channel reconfiguration controller works in cooperation with other Open RAN automation rApps, such as
  - SSB MIMO Optimization.
  - SU/MU MIMO mode switching.
  - CCO transmit power optimization.

  This cooperation of multiple Open RAN automation algorithms leads to an enhanced network configuration and improved energy saving type of operation.

Depending on the implementation and the controller strategy used, the southbound commands into the network might go directly via the O1 interface into the E2 nodes or will go as a policy into a near-real time RAN intelligent Controller via the A1-P interface. All O-Cloud ESM commands use the O2 interface directly into the O-Cloud, see Fig 3.

As shown later, Amdocs has implemented its algorithms as non-real time rApps and uses the O1 interface connection into the E2 nodes in its current implementations.

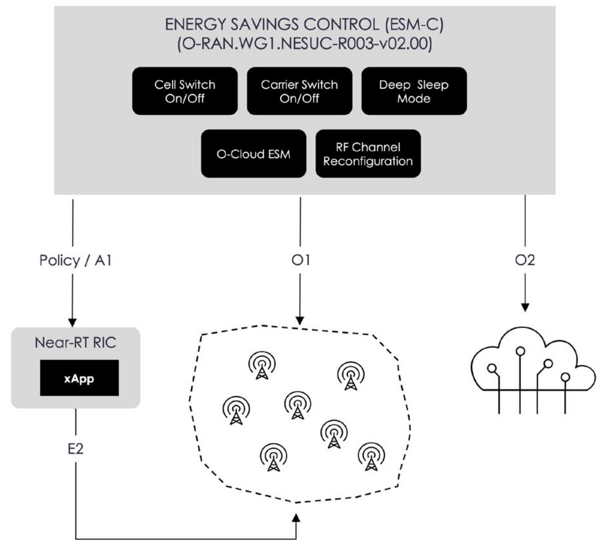


Figure 3: O-RAN Energy Savings Controller and interfaces

Energy Savings Management Analytics (ESM-A)

The **objective of the Amdocs Energy Savings Management Analytics (ESM-A)** is to analyze the potential and true amount of Energy Savings in the network. In addition, ESM-A can be used as a data producer for other rApps.

Energy Savings Management Policy

Amdocs has implemented two policy algorithms as a starting set of policies. Other policies are upcoming. This starting set of Energy Savings Policies consists of:

- ESM-P1: A Machine Learning (ML) based Sleep Windows Discovery Policy.
- ESM-P2: Radio Resource Utilization Thresholds Policy.

Both policy algorithms are explained below.

ESM-P1: A Machine Learning (ML) based Sleep Windows Discovery Policy

For capacity cells, network operators want to be able to configure a sleep window per day in which the Energy Savings Mode may be enabled. Thus, capacity cells would only be allowed to go to sleep within that time range. This feature can be seen as a psychological "safety" feature, as the radio resource utilization threshold-based mechanism of the Amdocs ESM-C Cell on/off Switching Controller already ensures that all that capacity cells are awake at moderate and high traffic loads. Amdocs has implemented a Machine Learning based Energy Savings (ES) Time Window Discovery Policy Algorithm. This algorithm uses these radio resource utilization KPI of capacity cells of at least four weeks into the past, all defined in 3GPP 28.552, section 5.1.1.2:

- DL Total PRB Usage
- UL Total PRB Usage
- Distribution of DL Total PRB usage
- Distribution of UL total PRB usage
- Peak DL PRB used for data traffic
- Peak UL PRB used for data traffic

Based on the provided radio resource utilization data, the Amdocs ML algorithm will learn and derive capacity cell states per time step and sector. These ML-detected states are:

- 'sleep' – low radio resource utilization, the capacity cell may sleep.
- 'tired' – intermediate radio resource utilization, is allowed within a sleep-window.
- 'awake' - high radio resource utilization, the capacity cell must not sleep.

A sleep-window must not contain an 'awake', and it must start and end with a 'sleep'. Inside the window there may be 'tired's.

In case there are multiple sleep window candidates detected by our ML algorithm, they are ranked by:

1. length.
2. number of inside 'tired' states.
3. distance to an assumed most likely sleeping time (e.g. 3am).

and the one with the highest rank is selected for each capacity cell as policy. We assume there must be only one such sleep window per day. Re-training with more current live data can go into the policy algorithm, updating the sleep window policies according to changes in the network behavior.

As a result, each capacity cell is associated with a sleep window start time and a sleep window end time as policy. This sleep window marks the time period, in which an ESM-C controller may put this capacity cell into the Energy Savings Mode.

ESM-P2: Radio Resource Utilization Thresholds Policy

The objective of the Radio Resource Utilization Policy algorithm is to optimize Energy Savings Policies which will then help an Energy Savings Controller (ESM-C) to maximize the energy savings potential while maintaining Quality-of-Service (QoS) Service Level Agreements (SLA). The policies can optionally be implemented with slice awareness. QoS SLA might include:

- For enhanced Mobile Broadband (eMBB) slices:
  - DL PDCP Throughput
  - UL PDCP Throughput
  - DL PDCP Data Volume
  - UL PDCP Data Volume
- For Ultra-reliable low latency (URLLC) slices:
  - UL Packet Loss Rate
  - DL Packet Loss Rate
  - DL Average Packet Delay

All above mentioned Key Performance Indicators (KPI) are cell-based Performance Management (PM) counters specified in 3GPP 28.552.

In order to better understand the reason the for Radio Resource Utilization Policy algorithm we illustrate the following example in Figure 4 below:

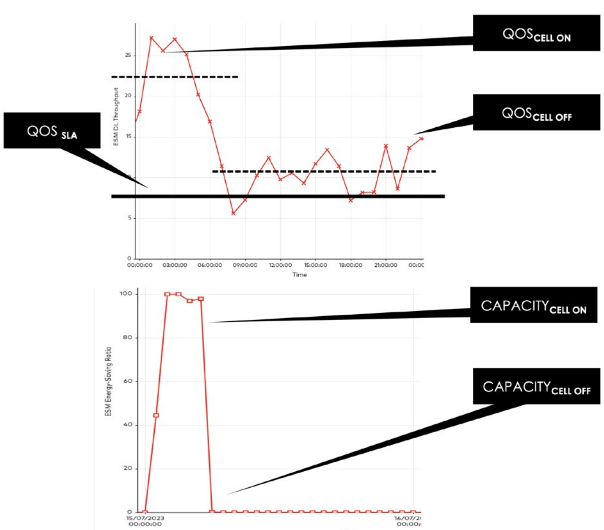


Figure 4: Amdocs Radio Resource Utilization Policy

Figure 4 shows the time progress on the x-axis. This entire time period shown there is assumed to be within an allowed sleep window period for the capacity cell discovered by the Amdocs ESM-P time window discovery. The ES state of the sector's capacity cell is shown in the lower figure. The graph on the top presents the QoS (see the list above, e.g., the DL PDCP throughput) of the entire sector on the y-axis. As can be seen there, this QoS value is mostly at any time above the agreed QoS SLA, even in the time period with the capacity cell being in the Energy Savings Mode ("cap_cell_off"). Consequently, the capacity cell could be in Energy Savings Mode in the entire discussed time period (no need to be "on" in the beginning as shown), hereby saving further energy. Thus, the Radio Resource Utilization Policy algorithm needs to adapt some thresholds for the ESM-C controller.

These radio resource utilization thresholds needed for the ESM-C controller are:

- For capacity cells: cap_cell_sleep_threshold: Once the current radio resource utilization of a capacity cell is lower than this threshold, the capacity cell can be put into the ES mode.
- For coverage cells: cov_cell_wakeup_threshold: Once the current radio resource utilization of the sector's coverage cell is higher than this threshold, the capacity cell(s) of this sector must be taken from the ES mode.

The radio resource utilization thresholds policy algorithm adapts the ESM-C radio resource utilization threshold(s) to QoS SLAs. So, it adapts the radio resource utilization thresholds to the level of QoS which needs to be maintained as a SLA, hereby trying to push these threshold to the limits – making them more "aggressive" to allow the ESM-C controller to switch more capacity cells to the Energy Saving Mode or to push longer time periods into this state – both in order to save more energy.

The radio resource utilization policy threshold algorithms learn from past data (training data) and is updated during run time with live data from the network. Thus, it implements the reinforcement Machine Learning technology.

This Radio Resource Utilization Thresholds policy algorithm is illustrated in Figure 5 below:

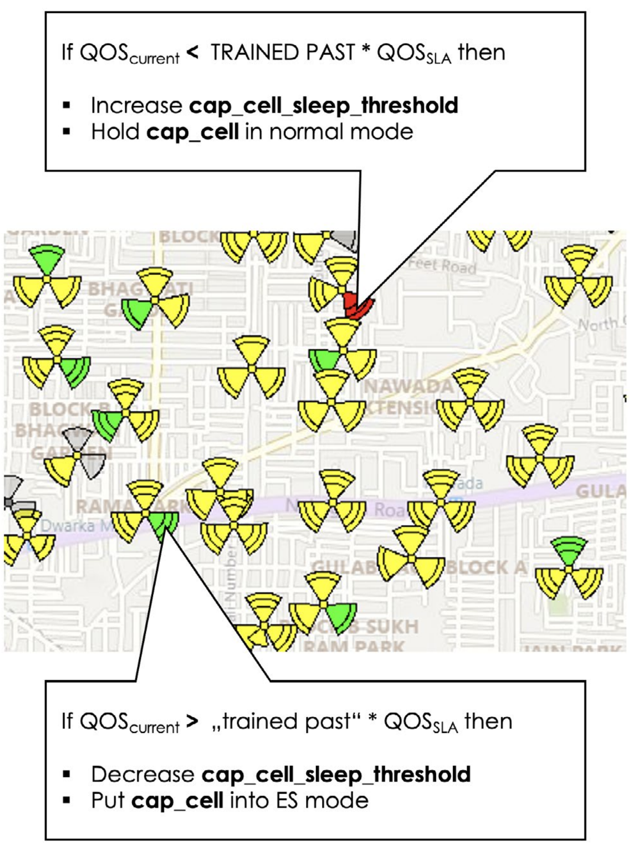


Figure 5: Amdocs Radio Resource Utilization Policy example

It is intended to run every couple of hours up to one time per day, so once every 24 hours.

Amdocs Advantages

Amdocs includes all cells in a cluster of cells into its algorithms. This, it does not solve problems of individual cells, but always oversees the joint situation in the entire cluster of cells in its algorithms. Both ESM-P algorithms are no exception from this rule.

Both ESM-P algorithms are ML-based implementations as described. So, they learn and get trained from past data with an ongoing adaptation (re-training) from live data during the runtime of the algorithm.

All ESM-P algorithms are independent of the Amdocs ESM-C implementation, so could work with Energy Savings Controller rApps from other rApp vendors as well.

Energy Savings Management Controller

ESM-C1: Amdocs ESM-C Cell on/off Switching or Cell Overlay Shutdown Controller

In this White Paper Amdocs uses overlay cell shutdown or cell on/off switching to illustrate the key concepts of automated Energy Savings Management Controllers.

As stated earlier, Overlay Cell Shutdown is supported in networks that with both coverage and capacity layers. During low demand periods capacity layer cells are shut and traffic moved to coverage layers. Coverage layer cells are never put into an Energy Savings Mode.

The Amdocs Cell on/off Switching controller implements this concept: Depending on a simple comparison of the radio resource utilization of the previous measurement period with the thresholds given by the Radio Resource Utilization Thresholds Policy to this algorithm it switches capability cells on or off.

The used cell KPI PM counter is 3GPP 28.552 5.1.1.2.1 "DL Total PRB Usage", which is measured for all coverage and capacity cells.

1. In case the current radio resource utilization of the capacity cell is lower than the respective capacity cell's sleep threshold (given as policy), this capacity cell can be put into the Energy Savings Mode, while all its remaining traffic is handed over to other capacity cells or the coverage cell.

cap_cell_radio_utilization

<

cap_cell_sleep_threshold

Then

cap_cell ES Mode On

Figure 6: Energy Savings Mode activation by Amdocs ESM-C

2. In case the current radio resource utilization of the sector's coverage cell is higher than the respective coverage cell's wakeup threshold (given as policy), then the Energy Savings Mode of all capacity cells of this sector must be disabled. Then, the capacity cell can carry traffic again.

cov_cell_radio_utilization

>

cov_cell_wakeup_threshold

Then

cap_cell ES Mode On

Figure 7: Energy Savings Mode activation by Amdocs ESM-C

This algorithm is illustrated in the below figure:

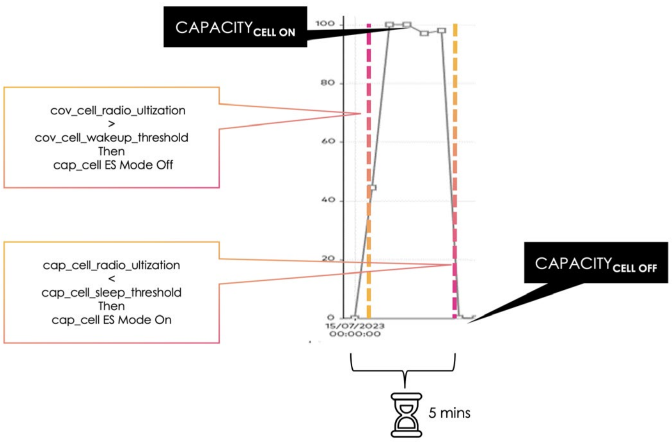


Figure 8: Amdocs ESM-C for Cell Overlay Shutdown or Cell on/off Switching

As shown above, the measurement period can be as short as only a few minutes, thus adapting the ES mode in the capacity cells as needed.

In case capacity cell(s) at a sector are identified for an enabling of the ES mode, then three different actions can be implemented:

- All capacity cells of the sector go into ES mode, the sector's coverage cell takes over their traffic.
- Only one or some capacity cells of the sector go into ES mode, the sector's coverage cell takes over their traffic.
- Only one or some capacity cells of the sector go into ES mode, the sector's coverage cell and the remaining capacity cells take over their traffic.

The applied strategy depends on the network topology and network operator operation policies.

All Amdocs ESM-C implementation mimic vendor controller behaviours but are implemented for Open RAN and are perfectly integrated with the Amdocs ESM-P rApps.

Energy Savings Management Analytics

Amdocs is able to show cell/sector KPI as well as use geo-location data an Enrichment Information (EI) to show all Energy Savings analytics as cell footprints. Some examples are shown below, one example per ESM algorithm introduced above.

ESM-P1 Sleep Window Size Analytics

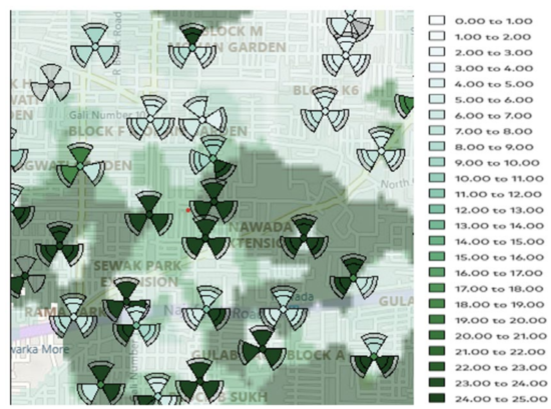


Figure 9: Amdocs ESM-A for Time Windows Discovery ESM-P

ESM-P2 Radio Resource Utilization Thresholds Analytics

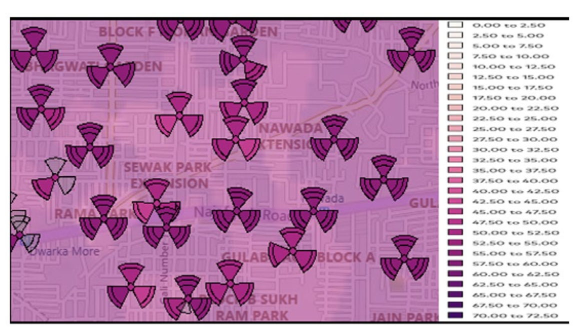


Figure 10: Amdocs ESM-A for Radio Resource Utilization ESM-P

In the above picture, the sector's capacity cells sleep window is shown as cell footprint in percent of the DL PDCP throughput QoS SLA.

ESM-C1: Cell Overlay Shutdown Analytics

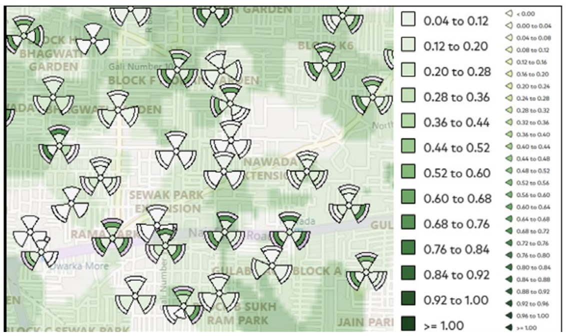


Figure 11: Amdocs ESM-A for Cell Overlay Shutdown/Cell on-off Switching ESM-C

The ESM-C controller puts capacity cells into the energy savings mode whenever possible. The above figure shows the ratio of times in energy savings mode per 24 hours, so a value of one reflects the rare situation that a capacity cell would be in energy savings mode all day.

Amdocs ESM-P and ESM-C Open RAN Case Study

Cloud-Native Implementation on O-RAN Architecture

All Amdocs Energy Savings algorithms are implemented as rApps in Docker containers. They can be attached to commercial or open source non-real time RIC platforms via their open RAN R1 interface. RAN telemetry data (CM, PM) are read via the Open RAN standardized O1 interface into the platform, while ESM-C commands to enable/disable the capacity cells Energy Savings Mode are sent via the O1 southbound interface directly into the E2 nodes, see the below Figure 12. This concept applies for all ESM-Px and ESM-Cx implementations.

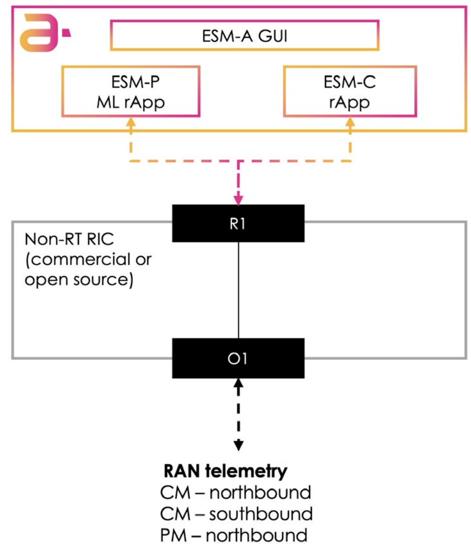


Figure 12: Amdocs ESM rApp Architecture on O-RAN

The ESM-A is implemented in a web-based Graphical User Interface (GUI).

Illustrative Optimization example

Network Architecture

We verified the various parts of our ESM algorithm implementation against a dynamic NR 5G SA cellular network simulator. In this simulator, a sample network with seven sites and two network layers, one coverage and one capacity layer, is created for an overall simulation area of ten square kilometers. The coverage layer is in 5G frequency band N12 at 700 MHz, while the overlaying capacity layer is in 5G frequency band N1 at 2100 MHz, both with a bandwidth of 20 MHz. There is only one network slice of type eMBB configured. Each site has three sectors with 0, 120, and 240 degrees of the antenna panel azimuth in each network layer. Altogether we have 7 (sites) x 2 (network layers) x 3 (cells per site and layer) = 42 cells in the network. All cells transmit with 49dBm transmission power and are equipped with a cosine sectorial antenna at 10m height over ground and with an e-tilt of 5 degree. This network was simulated in an area with geographically randomly distributed high-rise buildings at heights between 20m and 50m.

The RF propagation is simulated using the 3GPP 38.901 Urban Macro (UMa) with buildings propagation model. 200 mobile users were assigned at randomly chosen (x,y) coordinates at 1.5m height over ground to the network during the runtime of the simulation. 150 of these simulated mobile users are pedestrian outdoor UEs with a GBR conversational voice (5QI 1) service profile, while the remaining 50 users are indoor UEs with the same service profile identifier 5QI 1.

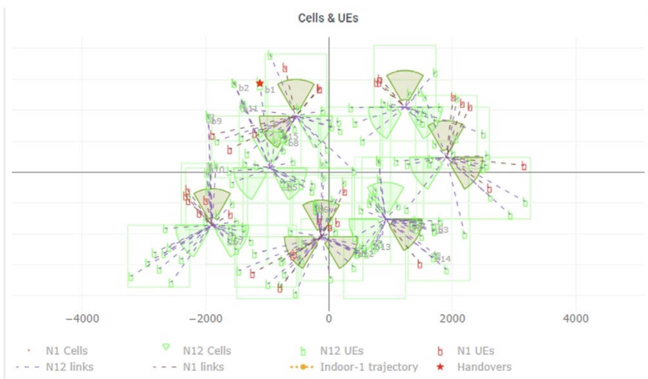


Figure 13: Simulation area setup.

The case study architecture is illustrated in the following Figure 15.

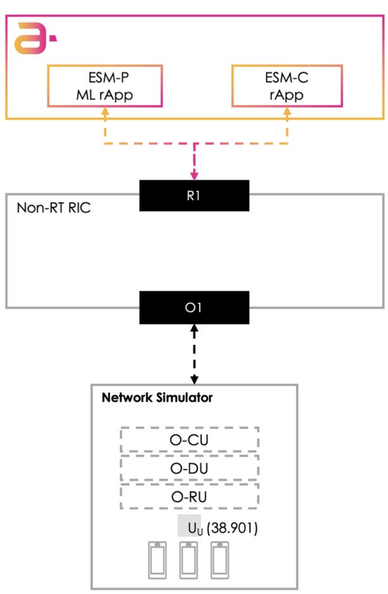


Figure 14: ESM Case Study Architecture

Case Study Sequence

The actual case study was performed as follows:

1. First, we collected four weeks of PM counters to train and feed the ML-based time window discovery policy algorithm.
2. Then this time window discovery policy algorithm detected time windows in which the energy savings mode could be enabled for the capacity cells in the network.
3. As the next step, the ESM-C controller was run with default threshold settings for cov_cell_wakeup_threshold and cap_cell_sleep_threshold and the first power savings could be observed.
4. After collecting further PM counters via the O1 interface, the ESM-P Radio Resource Utilization policy algorithm was run in order to update the above-mentioned thresholds for ESM-C while maintaining the QoS in the network. We used the DL PDCP Throughput per sector as the QoS marker in this exercise.
5. Finally, the ESM-C controller was run again to check, whether the updated thresholds would lead to further capacity cells, which could be put into the energy savings mode.

The overall sequence of this case study is shown below:

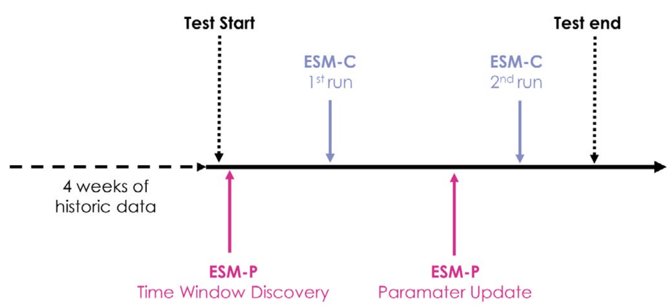
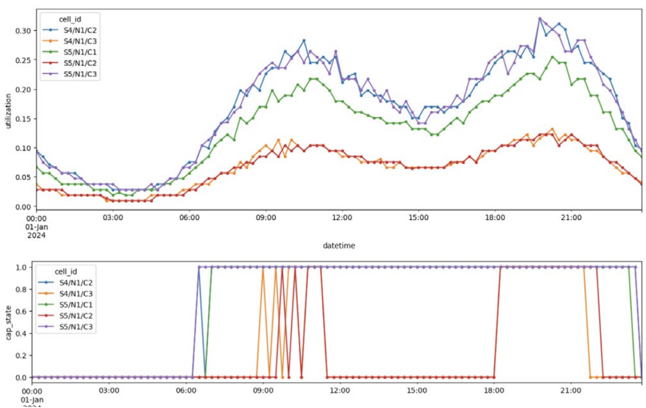


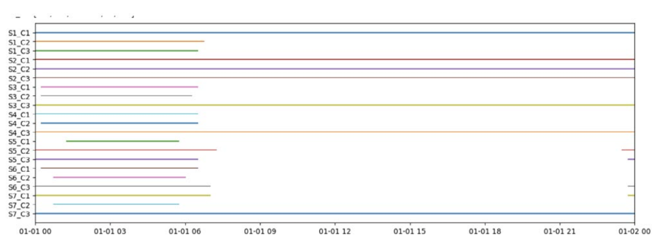
Figure 15: The overall case study sequence

Case Study Results

First, we illustrate the results of the ML-based time window discovery algorithm. As explained above, we collected load PM counters for all capacity cells for four weeks and used them to train the algorithm. The averaged traffic load over 24 hours as well as the ML-detected sleep, tired, and awake periods are shown below for some sample capacity cells of the overall simulated networks.



From these training data, the time window discovery detected one time window for each capacity cell, in which it could be put into the energy capacity cell, in which it could be put into the energy savings mode by the ESM-C controller. This time window could reach from a couple of hours per night up to the full 24 hours as depicted below:



The policy excerpt below demonstrates a detected sleep window between 12pm midnight and 6.45am in the morning:


```
{
    "change_type": "CELL_ATTRIBUTE",
    "new_value": "00:00:00",
    "cell_id": "S1/N1/C2",
    "attribute_name": "sleep_window_start_time",
    "utcdatetime": "2024-08-28T09:21:03.396761+00:00"
},
{
    "change_type": "CELL_ATTRIBUTE",
    "new_value": "06:45:00",
    "cell_id": "S1/N1/C2",
    "attribute_name": "sleep_window_end_time",
    "utcdatetime": "2024-08-28T09:21:03.396761+00:00"
},
```


As a result of the first ESM-C run (step 3) seven capacity cells could be put into the Energy savings mode, see the policy given into the E2 nodes via the O1 southbound interface:


```
{
    "change_type": "CELL_ACTIVE_STATE",
    "new_value": false,
    "cell_id": "S1/N1/C2",
    "utcdatetime": "2024-08-28T09:07:08.906459+00:00"
},
{
    "change_type": "CELL_ACTIVE_STATE",
    "new_value": false,
    "cell_id": "S2/N1/C2",
    "utcdatetime": "2024-08-28T09:07:08.906459+00:00"
},
{
    "change_type": "CELL_ACTIVE_STATE",
    "new_value": false,
    "cell_id": "S3/N1/C1",
    "utcdatetime": "2024-08-28T09:07:08.906459+00:00"
},
{
    "change_type": "CELL_ACTIVE_STATE",
    "new_value": false,
    "cell_id": "S3/N1/C2",
    "utcdatetime": "2024-08-28T09:07:08.906459+00:00"
},
{
    "change_type": "CELL_ACTIVE_STATE",
    "new_value": false,
    "cell_id": "S3/N1/C3",
    "utcdatetime": "2024-08-28T09:07:08.906459+00:00"
},
{
    "change_type": "CELL_ACTIVE_STATE",
    "new_value": false,
    "cell_id": "S4/N1/C3",
    "utcdatetime": "2024-08-28T09:07:08.906459+00:00"
},
{
    "change_type": "CELL_ACTIVE_STATE",
    "new_value": false,
    "cell_id": "S7/N1/C3",
    "utcdatetime": "2024-08-28T09:07:08.906459+00:00"
}
```

Then, the ESM-P radio resource utilization policy updated the ESM-C thresholds in step 4, see another policy excerpt for updates below:

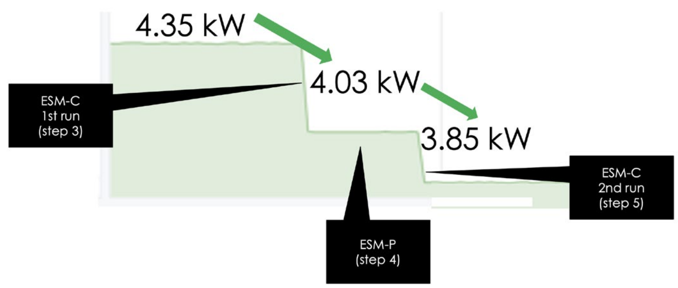

```
{
    "change_type": "CELL_ATTRIBUTE",
    "new_value": 65,
    "cell_id": "S4/N12/C3",
    "attribute_name": "cov_cell_ul_prb_utilization_wakeup_threshold",
    "utcdatetime": "2024-08-28T09:12:25.206847+00:00"
},
{
    "change_type": "CELL_ATTRIBUTE",
    "new_value": 15,
    "cell_id": "S2/N1/C3",
    "attribute_name": "cap_cell_dl_prb_utilization_sleep_threshold",
    "utcdatetime": "2024-08-28T09:12:25.206847+00:00"
},
```


Finally, ESM-C was run again (step 5), now being able to put four further cells into the energy savings mode:


```
{
    "change_type": "CELL_ACTIVE_STATE",
    "new_value": false,
    "cell_id": "S2/N1/C3",
    "utcdatetime": "2024-08-28T09:14:00.131738+00:00"
},
{
    "change_type": "CELL_ACTIVE_STATE",
    "new_value": false,
    "cell_id": "S5/N1/C2",
    "utcdatetime": "2024-08-28T09:14:00.131738+00:00"
},
{
    "change_type": "CELL_ACTIVE_STATE",
    "new_value": false,
    "cell_id": "S5/N1/C3",
    "utcdatetime": "2024-08-28T09:14:00.131738+00:00"
},
{
    "change_type": "CELL_ACTIVE_STATE",
    "new_value": false,
    "cell_id": "S7/N1/C1",
    "utcdatetime": "2024-08-28T09:14:00.131738+00:00"
}
```


The interested reader might want to compare the cell_ids of these four cells with the ones of step 3: They are different, we bring additional capacity cells into the energy savings mode in step 5, after the threshold were updated according to the current traffic conditions in the network. Compare the cell power savings after each step in the cell cluster as shown below:

Cluster Total Consumed Power [kW]



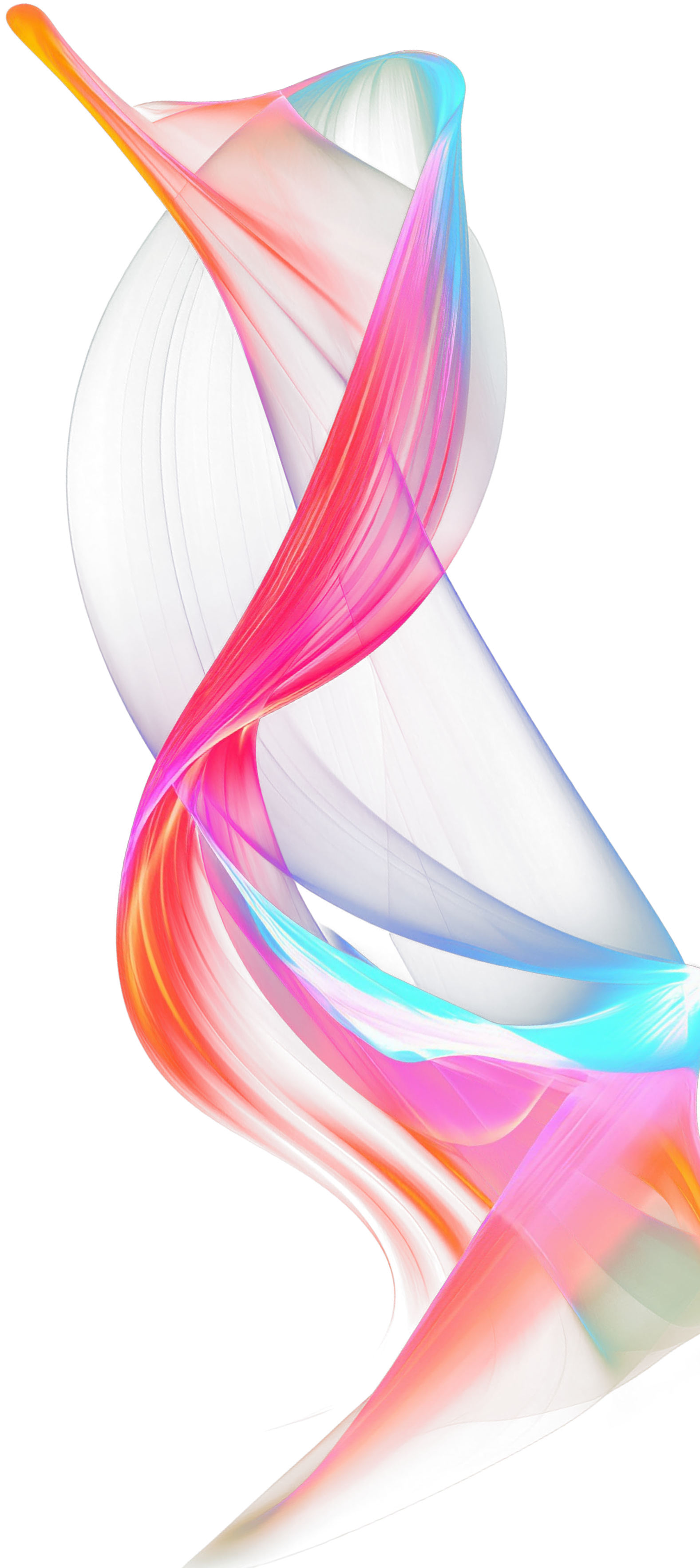
After the first ESM-C run seven out of 21 capacity cells could be put into the energy savings mode, causing the overall power consumption to go down from 4.35 kW to 4.03 kW, saving 8% of energy. After the second ESM-C run, we have eleven capacity cells in energy savings mode, bringing the power consumption of the cell cluster down to 3.85 kW and thus saving about 12% energy. The QoS SLA (here the DL PDCP Throughput) was maintained all the time.

Conclusions

Energy Savings Management (ESM) is a key technology of cellular networks and has a high demand in the society in order to bring the CO2 footprint of cellular networks down. ESM is a very complex task when executed for a cluster of cells, possible with multiple 5G network slices in the RAN, and a variety of service profiles with different QoS measures to be maintained while saving energy. Artificial intelligence (AI) is required to tackle this complexity.

This paper presents the Amdocs approach to ESM, which differentiates through:

- Robust ML based algorithms deliver double-digit energy savings whilst protecting QoS.
- Separation of policy and controller functions that provides the flexibility to support different network architectures.
- Cluster centered decision making for improved coordination across cells.
- Expanding controller and policy algorithms to support different energy savings mechanisms.
- O-RAN Alliance R1 compliance and compatibility with multiple RIC platforms.



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