Reducing Energy Consumption in Mobile Networks

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Abstract

Operators face growing energy consumption with an associated increase in OPEX, arising from the introduction of 5G and massive MIMO technology combined with the need to add capacity and densify networks to address the continuous growth in mobile network traffic. Added to this, many operators have set global sustainability goals to reduce carbon emissions in part achieved through managing energy consumption.

Data provided to GSMA from 7 Operators with 31 networks in 28 countries highlighted that 73% of network energy consumption is in the RAN with the Core Network, Data centers and Operations accounting for the remainder.

NEC has developed a fully automated software-based solution to address RAN energy consumption at cell and site level, through advanced algorithms and traffic prediction, enabling safe shutdown of excess site capacity during periods with low levels of user and data traffic, thereby reducing energy consumption. The solution incorporates intelligent continuous customer experience feedback enabling fast reactivation should traffic levels increase unexpectedly. It is applicable to both legacy and Open RAN based deployments.

Keywords

Energy saving, Traffic and service aware, AI/ML, Cell traffic prediction, Carrier shutdown, Closed loop automation, Self Organizing Networks, RAN Intelligent Controller, 5G, mMIMO

1. Introduction

Reducing energy consumption and associated Operational Expenditure (OPEX) in mobile networks is a key objective for network operators, especially in the Radio Access Network (RAN) which accounts for over 70% of mobile network energy consumption according to a 2021 GSMA survey[1)].

As capacity in mobile networks increases with the addition of new spectrum and new technologies such as 5G and Massive MIMO (mMIMO), energy consumption also increases due to this additional network capacity. However, utilization of network capacity varies considerably based on time of day, day of week and site location, resulting in unused network capacity unnecessarily contributing to increased energy consumption.

This paper describes how NEC is working to manage and reduce energy consumption in the RAN using advanced automation and artificial intelligence techniques to dynamically adapt mobile network capacity based on variations in traffic demand thereby optimizing energy consumption on a per cell level across the network. Case study results are presented based on live commercial deployments which demonstrate the energy savings and overall performance achieved through the NEC energy saving solution. In addition, specific enhancements targeting 5G and mMIMO deployments are discussed including how 3GPP and O-RAN ALLIANCE led standardization of energy saving features is leveraged by NEC to maximize energy efficiency in the RAN for both traditional and Open RAN based networks.

2. Energy Saving Solution: Orchestrating Vendor Features

It has been observed that many operators have network equipment vendor Cell Sleep Mode feature parameters set to generic default static values throughout the mobile network. These features allow the capacity layer to go into Sleep Mode while the coverage layer provides sufficient capacity to handle all traffic. Implementing a layer of intelligence that translates these static settings into a dynamically changing set of optimal parameters continuously tuned for each individual cell enables the operator to achieve significant gains in energy saving.

Since each site behaves differently, typically with a primary pattern during the week and a secondary pattern during the weekend (**Fig. 1**), static settings applied network wide do not address the unique characteristics of each cell, especially when seasonality and network changes are considered, hence energy savings are not maximized.

The solution described in this paper is a traffic and service aware software application that continuously fine tunes the Cell Sleep Mode feature parameters on a per cell basis in a way that each cell has its own optimal parameter configuration that triggers Cell Sleep Mode according to its unique traffic behavior without compromising service KPIs. The algorithm works in closed loop with no need for human intervention, optimizing cell sleep parameters daily to achieve savings of up to 4 to 6 times greater than those achieved by the default statically configured vendor feature.

The application is both traffic and service aware (**Fig. 2**), meaning the decision logic to determine configuration settings for cell sleep periods evaluates KPI data to maximize additional energy savings while prioritizing service quality. As an additional safety mechanism, service quality metrics are evaluated as input to rollback decisions on a per cell level, with monitoring of KPIs including Physical Resource Block (PRB) utilization, number of radio connections and data volume. An Artificial Intelligence and Machine Learning (AI/ML) based orchestrator helps to ensure the optimal balance between energy saving and cell performance. Advanced AI/ML algorithms are utilized to continuously predict cell traffic demand, enabling the AI/ML based orchestrator to calculate on a per cell basis where and when to apply energy saving configuration changes. All this happens in closed loop without the need for human intervention.

To provide a level of control to the operator, the application can be set to work within configurable boundaries for sleep windows and sleep/wake thresholds which can be configured differently for weekdays and weekends.

All this is complimentary to vendor Cell Sleep Mode features, orchestrating such vendor features through the provision of traffic and service aware intelligence to create and push directly to the network the most optimal feature parameters for each cell in the network. Therefore, the application does not interfere with the internal near-real-time mechanisms supported by the vendor feature for traffic management, nor the associated sleep and wake mechanisms.

The differentiation between weekdays and weekends relates to the fact that almost all cells have significant changes in traffic behavior and the solution takes advantage of that to determine additional periods in which savings can be achieved without customer impact. In some cases, this includes up to 24 hours sleep time for capacity layers.

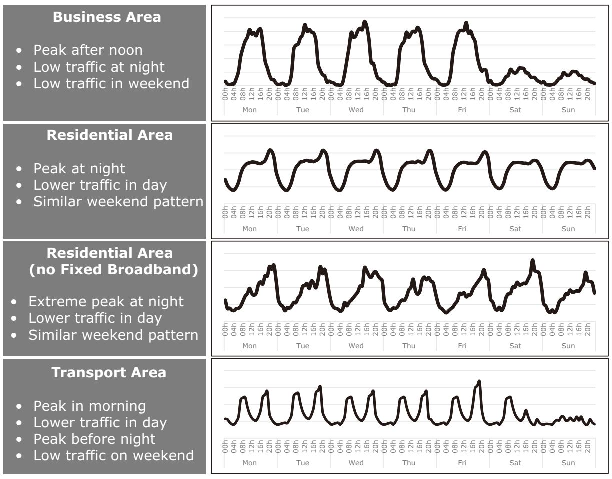

Fig. 1 Typical traffic pattern variations.

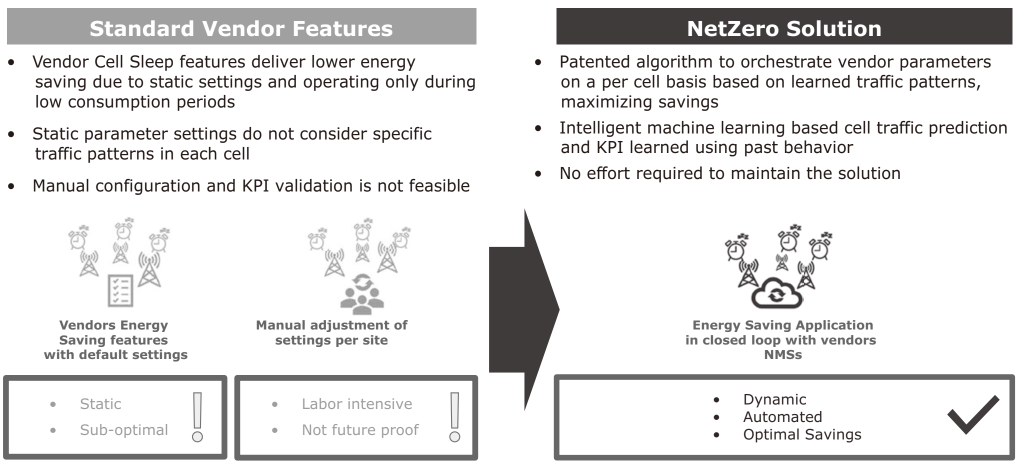

Fig. 2 Traffic & service aware cell sleep.

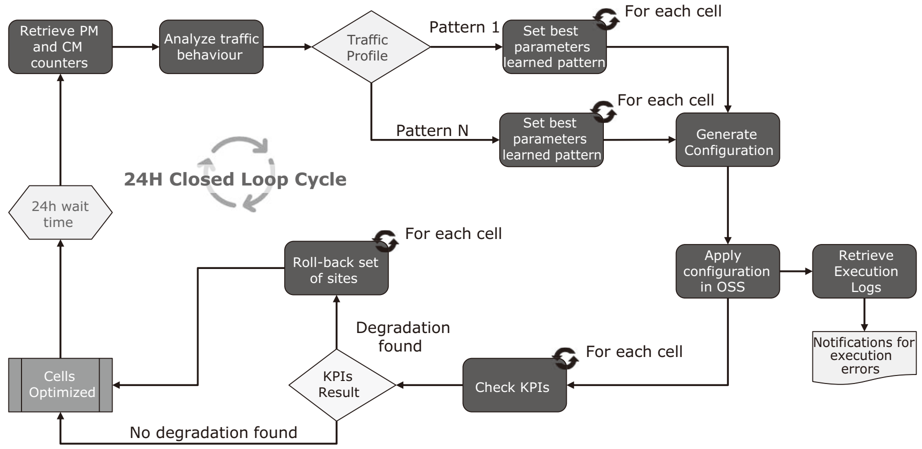

Fig. 3 Solution high-level flowchart.

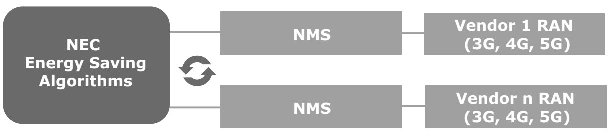

Fig. 4 Integration with vendor NMS.

The solution is multi-vendor, multi-technology (3G, 4G and 5G) and supports both traditional and Open RAN deployments.

It operates as an intelligent automation layer on top of vendor energy saving features (**Fig. 3**), via integration into vendor Network Management Systems (**Fig. 4**). By interworking with vendor features, the application has a network wide view to maximize energy gains while at the same time taking advantage of the real time response time provided by vendor features.

3. Vendor Agnostic Energy Saving for 5G

The solution described above orchestrates vendor energy saving features to provide a fully automated dynamic configuration capability. Support for such features, while varying from vendor to vendor, is less mature in 5G, in particular Cell Sleep Mode features. Hence the solution described above adapts to consider this scenario, based on the level of vendor feature support available.

In the scenario where 5G energy features are not yet supported by vendor(s), Operators with such vendors in their network can avail of a vendor agnostic solution mode to reduce 5G energy consumption based on traffic-based or time schedule-based cell shutdown (retaining the 5G logo on display on users' phone screen) and/or traffic-based reduction of bandwidth. This solution mode delivers significant energy savings in such networks where intelligent orchestration of vendor energy saving features is not possible. The use of advanced AI/ML based algorithms for cell traffic prediction enables dynamic shutdown of unused capacity without the need for the vendor to support Cell Sleep Mode energy features.

4. Deployment Model

The deployment model follows the typical introduction of a Self-Optimizing Network (SON), or non-Real Time RAN Intelligent Controller (Non-RT RIC) application, with initial cluster deployment taking between 4 and 6 weeks:

- Installation (1 to 2 weeks): Server preparation, software installation
- Integration (1 to 2 weeks): Integration of CM/PM with vendor's OSS
- Dry-Run (1 week): Execution of application in which changes are displayed but not applied to the network
- Cluster Deployment (1 week): First production cluster
- Phased Network Rollout: As per agreement with operator
- Reporting and Acceptance (2 weeks): Reporting of KPIs, savings and acceptance

To provide information for solution operational reporting and solution acceptance, power consumption measurements, using PM counters from the vendors network management system, are collected, and evaluated during solution implementation. These allows savings achieved to be determined as compared to savings directly attributable to the vendor Cell Sleep Mode features.

5. Typical Energy Savings Case Study

The typical energy savings achieved as illustrated in the example case study, are multiples of those achieved by the vendor feature, in the range of 4 to 6 times (**Fig. 5**) that of the vendor feature, depending on the traffic patterns and network configuration. The example below shows the implementation and results in US dollar savings compared to the default vendor feature.

An example case study that attests to the success of this solution is with a multi-vendor, multi-market operator in the Americas where the solution is implemented across three network equipment vendors in multiple geographical markets with resulting energy savings which were higher than initially forecast and increasing as more capacity is added to the network.

The results after one full year of deployment (**Table 1**) are described below for the implementation across almost 1,000 radio sites. The initial cost savings expected for one full year was USD425,000, however due to utility price increases the actual cost savings achieved was USD474,000 for that same full year. The kWh savings was equivalent to 255 tons of CO_2. Note this one year case study comparison excludes sites added to the network during this one year to enable accurate before and after comparison.

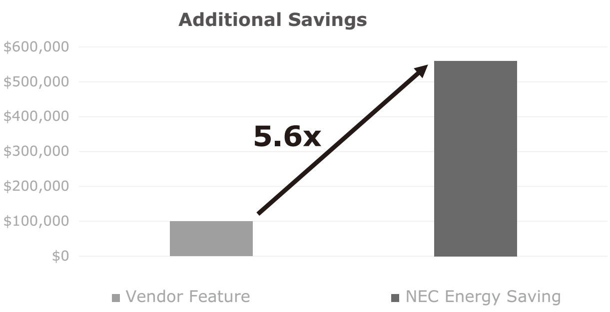

Fig. 5 Gains achieved with NEC Energy Saving.

Table 1 Case Study 1-year energy savings results.

Total Sites	970
KWh savings with default vendor feature (1 year)	265,538
Total KWh savings with NEC solution (1 year)	1,479,929
Additional KWh savings with NEC solution (1 year)	1,214,392
Additional KWh savings/site/day with NEC solution	3.43
Savings with default vendor feature USD (1 year)	$103,560
Total savings in USD with NEC solution (1 year)	$577,172
Additional savings in USD with NEC solution (1 year)	$473,613
Additional CO_2 Kg avoided (1 year)	255,022

6. Traditional & Open RAN

While the previously described energy saving solution are applicable to both traditional and Open RAN deployments, the question does arise as to whether Open RAN solutions are as energy efficient as their incumbent counterparts.

The O-RAN ALLIANCE is working to address energy efficiency in Open RAN networks, including publication of the Energy Saving Use Case Technical Report[2] within its Working Group 1. This is further described in the subsequent section of this paper.

One initiative to address energy efficiency in Open RAN based networks is the migration of existing 3GPP defined energy saving features to be implemented as separate third party applications within the RIC, using both non-Real Time and near-Real Time and combined non/near real time solutions. The design of such third party RIC applications negates the need for Open RAN CU/DU vendors to directly implement such 3GPP defined energy saving features, broadening the ecosystem, and driving increased energy efficiency. Additional use cases are being developed which leverage the "cloudification" of network functions extending to the O-Cloud Software/Hardware.

What is clear is that Operators view energy efficiency as a high priority issue, with a GSMA report[3] indicating that 62% of all operators, by revenue, have committed to reducing carbon emissions. Regarding Open RAN the MoU[4] formed in Europe consisting of Deutsche Telekom, Vodafone, Orange, Telefonica, and TIM have demonstrated their commitment to energy efficiency and documented such in their Open RAN technical priorities focused on Energy Efficiency.

7. Future Developments

3GPP and the O-RAN ALLIANCE are working to define and standardize vendor energy saving features. The O-RAN ALLIANCE has published details of this work in its Network Energy Saving Use Case Technical Report[2]. Use cases or features include 'Carrier and Cell Switch On/Off', 'RF Channel Reconfiguration On/Off', 'Advanced Sleep Mode' and 'O-Cloud Resource Energy Saving Mode'. This builds on 3GPP standardization work including energy efficiency KPI definition[5].

The 'Carrier/Cell Switch On/Off' feature allows specific network resources to be powered down at low load while retaining the existing coverage footprint, as only capacity layers are targeted. Shutdown of carriers and cells is not trivial to achieve, as an assessment must be made prior to shutdown to ensure service quality is maintained and

KPIs will not degrade, ensuring that the feature operates in a manner that is transparent to subscribers. Crucial also to this feature is ensuring that carrier and/or cells can be reactivated with minimal latency should traffic demand increase, which is addressed by the near real time Radio Intelligent Controller (Near-RT RIC) E2 interface.

The ‘RF Channel Reconfiguration On/Off’ feature aims to enable mMIMO Radio Units to greatly improve energy efficiency under low load conditions. It allows for several RX/TX arrays to be powered down thus reducing the number of spatial layers and corresponding Synchronization Signal Block Beam (SSB) beams. For example, a 64T64R Radio Unit could be reconfigured to 32T32R, maintaining capacity whilst reducing the mMIMO panel’s carbon footprint.

The ‘Advanced Sleep Mode’ feature defines Sleep Mode “States” ranging from Micro Sleep through to Deep Sleep and Hibernation. Additionally, criteria for energy saving and time windows are to be included in 3GPP Release 19 specifications.

The ‘O-Cloud Resource Energy Saving Model’ feature outlines multiple use cases leveraging the “cloudification” of Radio Access Network Functions. The first use case addresses Node Shutdown, introducing the concept of movement and scaling of network functions to reduce energy and facilitate shutdown. The second use case addresses CPU energy saving functionality. These features describe scaling of CPU frequency and voltage to reduce power (P-State) and operational conditions for CPU execution (C-State)[6].

The next level of advancement, building on the above, is to leverage multiple vendor features to provide a more holistic solution, standardized via industry bodies, with coordination across all energy features. While each vendor energy saving feature acting alone can deliver a step reduction in energy consumption and associated carbon footprint, a greater gain can be achieved through all active energy saving features working together in a coordinated manner as one holistic solution across telecoms applications, cloud (both VNF and CNF), and the underlying hardware and software platform layer, leveraging advanced automation and AI/ML to maximize energy efficiency.

As an example, the CPU C-State (**Table 2**) can be optimized if a carrier or network function is locked, or virtualized resources can be scaled down if the number of active antennae ports is reduced.

Table 2 CPU C-States for energy management.

C-State	Description (power vs latency)	Core Voltage	NEC Profiled
C0	CPU Active state, executing instructions	Normal	Yes
C1	CPU Halt state, not executing instructions, minimal latency returning to C0	Lower than C0	Yes
C3	CPU Sleep state, all internal clocks stopped, higher latency than C1 returning to C0	Lower than C0	No
C6	CPU Deep power down state, L1/L2 cache flushed, higher latency than C3 returning to C0	Can reduce to 0	Yes

8. Conclusion

In this paper, we provided an overview of the NEC developed automation and AI/ML enabled RAN Energy Saving solution, which is multi-vendor and multi-technology capable and applicable to both traditional and Open RAN based networks.

We presented results achieved from live Operator deployments, which have provided energy savings of over 1.25 MWh per mobile site annually resulting in annual savings of USD474,000 and 255 tons of CO_2 for 970 mobile sites, 4 to 6 times that of vendor features.

We have outlined future improvements in RAN energy efficiency including those led by 3GPP and O-RAN ALLIANCE, and how these improvements can be combined to bring even greater energy savings and associated reduction in carbon footprint to 5G and Open RAN networks.

References

1) GSMA Intelligence: Going green: benchmarking the energy efficiency of mobile, June 2021
https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=60621137&file=300621-Going-Green-efficiency-mobile.pdf
2) O-RAN ALLIANCE O-RAN Work Group 1 (Use Cases and Overall Architecture): Network Energy Saving Use Cases Technical Report, O-RAN.WG1.NESUC-v00.02.04
3) GSMA Newsroom: GSMA Reports 62% of Mobile Sector to Cut Emissions This Decade, May 2022
https://www.gsma.com/newsroom/press-release/gsma-reports-62-of-mobile-sector-to-cut-emissions-this-decade
4) OPEN RAN TECHNICAL PRIORITIES Focus on Energy Efficiency UNDER THE OPEN RAN MOU by Deutsche Telekom, Orange, Telefónica, TIM and Vodafone
https://cdn.brandfolder.io/D8DI15S7/at/5r3qmrncfp565xjtkb3t7k8c/Open_RAN_Technical_Priorities_-_Energy_Efficiency_-_FV.pdf
5) 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Management and orchestration; Energy efficiency of 5G (Release 18) 3GPP TS 28.310 V18.0.0 (2022-12)
https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3550
6) UEFI Forum: Advanced Configuration and Power Interface (ACPI) Specification, Release 6.5, August 2022
https://uefi.org/sites/default/files/resources/ACPI_Spec_6_5_Aug29.pdf

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