

White Paper

Green Radio

“NEC’s Approach towards Energy-efficient Radio Access Networks”

February 2010, NEC Corporation

Executive Summary

As part of the international efforts for energy conservation and CO₂ reduction, migration to an energy-efficient mobile infrastructure is of high importance to the mobile communications industry. For network operators, energy efficiency is much more than a corporate social responsibility topic — it will be one of the key factors for successful operation of large-scale mobile communication services.

In NEC’s Green Radio approach for next-generation mobile infrastructure solutions, energy-efficient operation is part of the overall design. The base station platform consists of energy-efficient key devices and enables operation without an air conditioner. It also provides intra- and inter-base station control mechanisms to adapt to changing demand for capacity at different locations and times in its resource usage, network coverage and energy consumption.

This whitepaper presents the benefits of the Green Radio approach and provides an overview of NEC’s development and standardization activities for ensuring a green future for mobile communications.

Operator Benefit

Due to the tremendous upswing of mobile Internet access demand, the cellular wireless system is currently transitioning to LTE. This next-generation mobile infrastructure provides broadband access and enables new classes of applications for mobile users.

With the emerging traffic demand, mobile operators are under pressure to enhance their infrastructure in a competitive time frame. However, the investment to enhance the infrastructure does not always pay off because the average revenue per connection continues to decrease, as shown in Figure 1. To overcome such a price-pressure trend, energy saving is one of the key subjects for mobile operators’ total cost of ownership reduction. Because the base station accounts for most of the energy consumption

by mobile operators, improving the energy efficiency of base station key components, such as power amplifiers and air conditioners, is of great importance, as shown in Figure 2 [2].

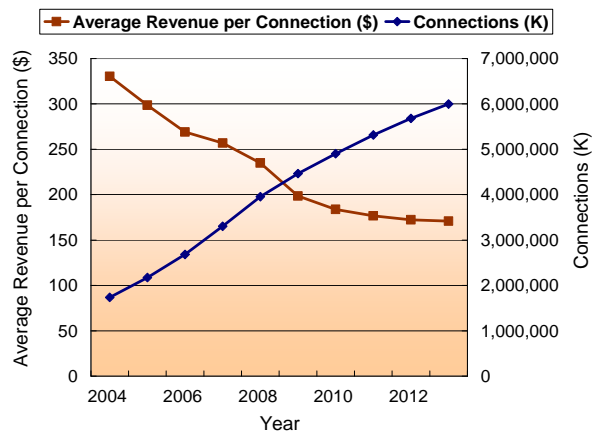


Figure 1: Mobile Service Price and Traffic Demand Forecast (Worldwide) [1]

Another driver for an energy-efficient mobile infrastructure is corporate social responsibility for international efforts against climate change [4]. By deploying energy-efficient base stations, operators can reduce the CO₂ emission from their network. Vendors can contribute to the efforts against climate change by providing technologies that lower network equipment’s power consumption. In the lifecycle of a base station, power consumption is more dominant in the deployment and operational phase than in the production phase. Therefore, ease of deployment and low-power operation are critical for an energy-efficient mobile infrastructure.

Independent of the actual energy source that is used for powering the access network achieving the highest possible energy efficiency is very important. This applies to conventional, grid-powered network elements in larger cities as well as (and often even more so) to, for example, solar-powered base stations in developing countries without reliable grid-based energy. Effective energy management is thus a key

requirement for successful and profitable operation of mobile communication networks.

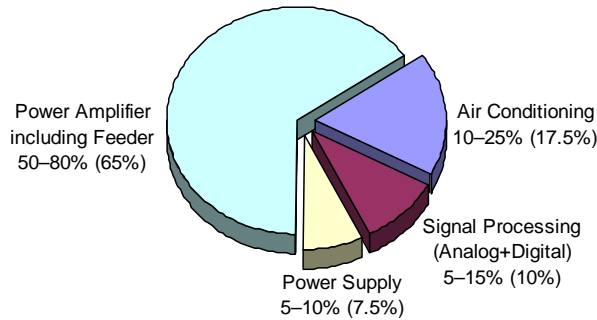


Figure 2: Breakdown of Conventional Base Station Power Consumption [2]

To address these requirements, we introduce the Green Radio solution for LTE, highlighting some NEC developments in this area, as well as standardization aspects in terms of future green technologies.

Key Technology Features

Energy saving for the mobile communication infrastructure requires a comprehensive approach. It incorporates both energy-efficient components and adaptable system platforms for base stations and other network elements, as well as a network-level architecture that supports coordination and full operator control.

1) Architecture for Green Radio

Energy saving can be viewed as an optimization function that reduces power consumption by adapting the provided network capacity to the actual demand at a given time. In accordance with other SON functions, such as for improving coverage and mobility robustness [4], energy saving should support autonomous operation, with the option of manual control where required.

Considering the tradeoff between network capacity and energy consumption, Green Radio functions must operate according to operators' objectives and policies. Configuring such objectives and policies, as well as ensuring their services is an important network management task. Energy saving in the access network has been shown to achieve optimal results when performed in a coordinated fashion, i.e., when there is a broader and collective view of load distribution, capacity requirement, and energy saving potential [5].

NEC's energy saving approach is thus based on corresponding coordination and management features, supporting different architecture alternatives.

- Distributed architecture, where base stations initiate the energy saving functions based on local knowledge and inter-coordination.
- Centralized architecture, where base stations propagate energy-saving-related information towards OAM, which initiates energy saving functions and executes the related algorithms for re-configuring base stations accordingly.
- Hybrid architecture, where the OAM can assist distributed energy saving by providing policies and enhanced information for local energy saving decisions.

The most suitable approach chosen depends on the specific deployment and operator strategies. For instance, the centralized approach enables the introduction of OAM-controlled energy saving features without requiring power-efficiency aware base station in an early deployment phase. The distributed and hybrid approach can enable optimized, self-organized energy saving, which will be beneficial in large-scale deployments. In a hybrid architecture, base stations would provide distributed energy saving functions, e.g., by exchanging load information for determining redundant cells that can be switched off. However, OAM would be enabled to steer this process by configuring certain policies such as preferable network areas, time periods and load thresholds.

To meet these different requirements, it is important to allow for a smooth migration from the initial centralized to more distributed and hybrid deployment forms. This is addressed by NEC's Green Radio, which leverages Green Radio hardware technologies as the basis for efficient and self-adaptable operation as well as self-organizing Green Radio technologies on the intra- and inter-base station level. We will describe these in the following subsections.

2) Green Radio Hardware Technologies

Energy-efficient hardware is essential for reducing the power consumption of base stations. To reduce RF signal attenuation inside base stations, the remote radio head (RRH) architecture is increasingly adopted in modern base stations. However, due to the dimension requirements, it is often hard to deploy RRHs near the base station antenna. NEC developed an all-in-one compact LTE base station, including RF, baseband, and a transmission unit, that can be mounted anywhere, such as antenna masts and building walls. Therefore NEC's compact LTE base stations can extend LTE broadband coverage compared to existing equipment architecture.

The key components that affect base station power consumptions are a transmitter power amplifier and a cooling fan for air conditioning [6]. In mid-to-high

traffic load conditions, the efficiency of the transmitter power amplifier is critical. In low traffic conditions, the power consumption of devices in standby mode and of cooling fans becomes dominant. Besides using state-of-the-art key devices, NEC employs fanless architecture to reduce power consumption.

Transmitter Power Amplifier

Transmitter power amplifiers are devices that increase the strength of RF signals transmitted from base stations to terminals. Generally, they consume considerable energy in mobile base stations [2].

NEC developed one of the world’s most efficient transmitter amplifiers for base stations: a 2.1-GHz model that produces 45 W of output power per 100 W of power consumption. NEC produced these latest amplifiers by adopting high-performance and highly reliable RF transistor technologies, in addition to independently optimizing Doherty RF circuitry. These innovations are accredited with NEC’s successful development of amplifiers with one of the world’s highest amplifier efficiency levels of 45%, corresponding to final stage efficiency of 60%. NEC further aims to achieve 55–60% amplifier efficiency by adopting digital amplifying technologies.

Fanless Base Station

In a conventional base station, a cooling fan consumes 10–20% of the overall energy [2]. Using efficient heat transfer packaging allowed NEC to move to fanless operation. Figure 3 depicts NEC’s compact and fanless outdoor LTE base stations.



Figure 3: Compact and Fanless LTE Base Stations

The heat is radiated through the forefront heat sink without use of a cooling fan. In addition to saving energy, the fanless architecture also reduces noise pollution and enhances reliability and maintainability by removing the mechanical moving parts from the base station.

3) Self-organizing Green Radio Technologies

Base station resources are commonly provisioned so that they can accommodate the traffic demand at peak times. NEC is researching mechanisms for actively exploiting the tradeoff between the capacity and the energy consumption for both intra- and inter-base station adaptations to capacity demand, which can lead to significant power saving.

Intra-Base Station Energy Saving

Conventional base stations are designed with a focus on spectrum efficiency rather than on energy conservation. Hence, base stations try to allocate radio resources while there is data to send, irrespective of the channel condition. To reduce the power consumption in low-traffic periods, the scheduler in a base station may queue the data in the packet buffer until the varying channel gain becomes good as depicted in Figure 4. Thus, the required amount of energy to send the same packet decreases as the channel gain increases. The scheduler also selects the appropriate modulation and coding schemes, and controls the power amplifier to switch off when there is no data to send to reduce energy without causing congestion.

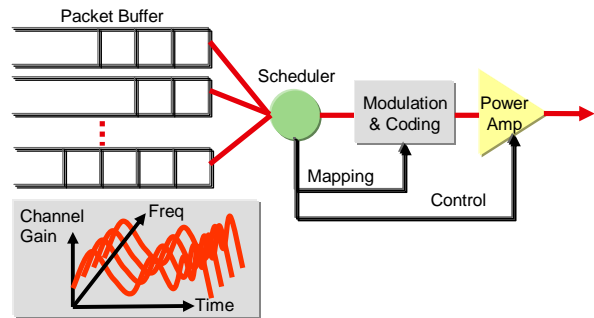


Figure 4: Energy-Efficient Packet Scheduler

Moreover, parts of the base station components can be turned off according to hourly traffic conditions. As shown in Figure 5, in off-peak hours, less processing capability is needed, and therefore parts of the unit can be transferred to sleep mode. Such fractional operation of base stations will further decrease power consumption.

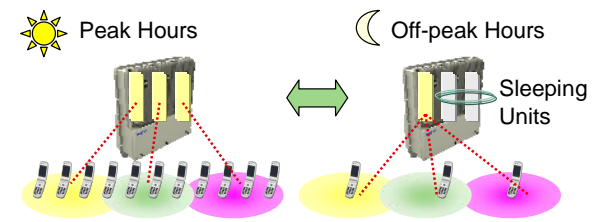


Figure 5: Fractional Operation of Base Stations

Inter-Base Station Energy Saving

While energy saving on the base station level is important to enable a base station to utilize its physical resources in the most efficient way, note that much higher energy savings can be achieved when relations between multiple base stations are considered appropriately. Such inter-base station energy saving could, for example, allow coordination of base stations to optimize energy saving decisions by leveraging actual knowledge of capacity and coverage demand. Such coordination involves the exchange of certain information among base stations, including load, coverage, and interference, and a collective decision for the energy saving state of particular network elements.

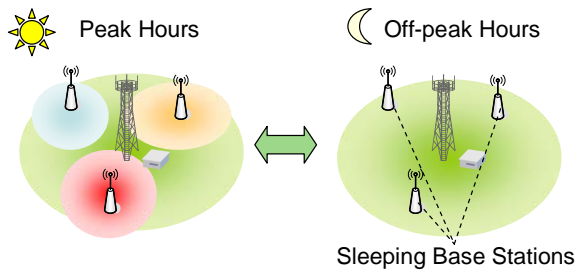


Figure 6: Energy State Control

A typical scenario is inter-base station energy saving in urban areas. Here, the network is designed to accommodate peak-hour traffic conditions by positioning cells relatively closely, forming dense arrangements for frequency reuse and capacity increase purposes. An example of establishing such an energy saving configuration is illustrated in Figure 6.

The objective is to match the capacity demand with the energy consumption at all times. This is ensured by a dynamic load and energy state arrangement, which balances extra load on a determined optimal set of base stations, thus maintaining minimum energy consumption. NEC’s LTE base station hardware is designed to minimize the power consumption in sleep mode. To ensure that the operators’ quality-of-service targets are always met, a complementary process can determine the optimal cell or site to wake-up to adapt to increasing load conditions, while introducing minimal additional energy consumption.

As an example, the energy consumption and coverage change due to base station sleep control were examined by simulation in an urban environment. In this case, 25 base stations were experimentally placed in a 6-km² area in central Yokohama, Japan. The traffic load was assumed to be uniform in the area. In the coverage- and traffic-based sleep control scheme, the sleeping base stations were selected according to

the traffic and the propagation prediction result. In the traffic-based sleep control scheme, the sleeping base stations are selected according to the increasing order of the traffic load. If the target spatial outage ratio is set to 1%, the coverage- and traffic-based sleep control scheme can select up to 13 base stations for sleeping, while the ordinary traffic-based sleep control scheme can select up to 9 base stations as depicted in Figure 7. The energy was confirmed to be reduced approximately 20–30% by the coverage- and traffic-based sleep control.

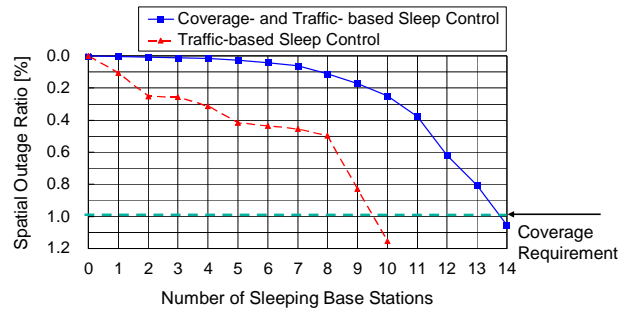


Figure 7: Coverage Change in Urban Environment according to Base Station Sleep Control

Standardization Status

To ensure effective and interoperable energy saving solutions, it is important to standardize fundamental mechanisms, e.g., for inter-base station coordination and energy saving management. NEC is actively contributing to the relevant standardization efforts in different bodies, namely 3GPP and IETF.

1) 3GPP

In 3GPP, NEC is supporting the energy saving work that has started in different areas to improve the energy efficiency of the UMTS and LTE mobile communication infrastructures. The objective is to create a solution that provides optimal energy saving with minimal operational cost while maintaining a constant quality of service. Such a solution would involve standardization of local coordination mechanisms for energy saving as well as OAM-based coordination and performance monitoring mechanisms.

3GPP’s TSG RAN WG3 is studying radio architecture aspects of energy saving for UMTS and LTE. The objective is to analyze energy saving potential and corresponding requirements for radio access networks. In addition, the first technologies for basic distributed energy saving functions are currently being developed.

3GPP's TSG SA WG5 is analyzing OAM aspects for energy saving in the TR 32.826 [7] study on Energy Saving Management by describing several use cases and corresponding requirements. The study shows what energy savings can be achieved in typical scenarios (e.g., with a day/night arrangement in urban networks) and what network management requirements result from approaches such as adapting power consumption to the actual load on network elements. The OAM aspects of energy saving are of particular importance for coordinated energy saving schemes that can help to minimize operational cost while maintaining network performance for users at all times. These topics will be specifically addressed by the corresponding normative work on energy saving management that 3GPP has added to its Release 10 work plan and that should be published around December 2010.

2) IETF

To manage energy consumption in mobile communications, fixed networks, data centers, and networked home environments effectively, it is important to base energy saving decisions on knowledge about actual power consumption. NEC is pioneering corresponding standardization efforts in the IETF and has specified energy consumption monitoring requirements [8] and managed object definitions [9] for creating interoperable monitoring standards based on Internet technologies.

Conclusion

Energy-efficient operation of next-generation mobile communication technologies is a key success factor for OPEX reduction and satisfying corporate social responsibility. By applying the Green Radio approach to all aspects of overall system development, NEC proposes a comprehensive approach. Green Radio includes efficient hardware and software platforms and careful integration into SON functions. To ensure maximum energy efficiency in different deployment scenarios, NEC is committed to supporting standardization of essential inter-working functions in different standardization bodies.

References

- [1] Gartner, "Forecast: Mobile Services, Worldwide, 2004–2013, 4Q09 Update," by Jessica Ekholm, et al., 2 Dec. 2009, Chart created by NEC based on Gartner's data.
- [2] Study on Energy Efficient Radio Access Network (EERAN) Technologies, 2009 Project Report of

- Technical University of Dresden, Vodafone Chair Mobile Communication Systems.
- [3] GSMA, "Mobile's Green Manifesto," November 2009.
- [4] NEC, White Paper: Self Organizing Network, <http://www.nec.com/lte/son/index.html>
- [5] M. Gupta and S. Singh, "Greening of the Internet," Proc. ACM SIGCOMM, August 2003.
- [6] H. Karl (Ed.), "An Overview of Energy-Efficiency Techniques for Mobile Communication Systems," Technical Report TKN-03-017, Telecommunication Networks Group, Technical University Berlin, 2003.
- [7] 3GPP TR 32.826, Telecommunication Management; Study on Energy Savings Management (ESM), (Release 9), December 2009.
- [8] J. Quittek (Ed.), "Requirements for Power Monitoring", Internet Draft draft-quittek-power-monitoring-requirements-00, Work in Progress, 2010.
- [9] J. Quittek (Ed.), "Definition of Managed Objects for Energy Management", Internet Draft draft-quittek-power-mib-00.txt, Work in Progress, February 2010.

Acronyms

3GPP	3 rd Generation Partnership Project
CO2	Carbon Dioxide
IETF	Internet Engineering Task Force
LTE	Long Term Evolution
OPEX	Operation Expenditures
OAM	Operation and Management
RAN	Radio Access Network
RF	Radio Frequency
RRH	Remote Radio Head
SA	Service and System Aspects
SON	Self Organizing Network
TR	Technical Report
TSG	Technical Specification Group
UMTS	Universal Mobile Telecommunications System
WG	Working Group

NEC Corporation

7-1, Shiba 5-chome, Minato-ku, Tokyo 108-8001 Japan
 tel: +81-(0)3- 3454-1111
www.nec.com/lte

Copyright (C) 2010 NEC Corporation. All rights reserved. All trademarks are the property of respective companies. Information in this document is subject to change without notice.