Green ICT: Self-Organization Aided Network Sharing in LTEA

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Abstract

One of the targets of Green Information and Communication Technology (ICT) is to reduce the energy consumption of ICT itself. This paper provides a tutorial on a new energy reduction approach – self-organization aided network sharing, which exploits the concept of cooperation and adaptation in the cellular system level. Detail reviews from different perspectives including the academic literature, the existing standard, etc. are provided. Moreover, a simply example with simulation results is provided to demonstrate the energy efficiency of the proposed scheme.

Keywords: network sharing, self-organization, energy efficiency, LTEA.

1 Introduction

Energy efficiency and low carbon strategies have attracted a lot of concern. The goal for 20% energy efficiency and carbon reduction by 2020 drove the Information Communication Technologies (ICT) sector to strategies that incorporate modern designs for a low carbon and sustainable growth [1, 2]. The ICT sector is part of the 2020 goal and participates in three different ways. In a direct way, ICT are called to reduce their own energy demands (green

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networks, green IT), in an indirect way ICT are used for carbon displacements and in the systematic way ICT collaborate with other sectors of the economy to provide energy efficiency (smart-grids, smart buildings, intelligent transportations systems, etc.). As described in [3] green ICT is defined as: *Use of ICT for optimizing societal activities in order to improve environmental sustainability*.

This paper is focused on the direct way, which is to reduce the energy consumption of ICT itself, especially the energy consumption of wireless cellular network. Throughout the global community, wireless communications have had a profound social economic impact, enriching our daily lives with a plethora of services from media entertainment to more sensitive applications such as e-commerce. Looking towards the future, although voice and SMS are still major sources of revenue, mobile traffic will account for a large chunk of the internet highway. To cope with this increased demand, operators are required to invest more in core infrastructure, and deploy more advanced technologies. In fact, already in today's market operators are deploying over 120,000 new Base Stations (BSs) on a yearly basis across the world. Moreover, the mobile technologies is fast evolving from the 3rd Generation (3G) supporting 384 kb/s downlink in 2001 to the Long Term Evolution (LTE) supporting 300 Mb/s downlink in 2010. This development of wireless communication brings also the ever increasing energy consumption. For example, a medium sized cellular network uses as much energy as 170,000 homes. While the cost of powering the existing BSs accounts for a staggering 50% of a service provider's overall expenses. Therefore new solutions are required whereby operators can accommodate this additional traffic volume whilst reducing their investment in new infrastructure, and beyond that significantly reduce their energy bill.

In order to reduce the energy consumption, cooperation and adaptive optimization are two approaches often employed. A well-known cooperation example is that the cell-edge users transmit their information to the BS through relays located closer to the cell-center. Adaptive technology has been well studied in the link-level, which is specifically the adaptive modulation and coding scheme for optimizing the spectral efficiency so as to save energy. It has also been studied in the MAC-level such as the multi-user scheduling schemes so as to optimize the channels shared by multiple users. This paper is aimed at providing a tutorial on self-organization aided network sharing for energy efficiency, which extends the cooperation concept into network operators, and extends the adaptive optimization concept into the entire network resource management.

Network sharing is one of the most attractive solutions for energy and other costs reduction, in which operators cooperate with each other by sharing infrastructure, operational functions and even risks in a bid to reduce the capital and operational expenditure of the network. It is claimed that network sharing is able to achieve up to 65% saving in both roll-out capital expenditure (CAPEX) and network operations-plus-maintenance expenditure (OPEX) [4]. As a result, the regulators over the world are now encouraging this approach, although some restrictions still remain in order to avoid monopolies. Network sharing has already been implemented in various countries such as India, UK and USA. However, despite the recent efforts, the current state-of-the-art on network sharing is still in its infancy. In practice, the widely implemented network sharing is currently deployed in a very simple form of so-called passive sharing (e.g., sharing the towers), while active sharing and roaming-based sharing, which can provide more significant energy and cost saving, needs to be further investigated to support seamless and dynamic sharing. In addition, from a business point of view, the lack of clear cooperation strategies can hinder even passive network sharing among competing operators, which demonstrate the requirement of proper network sharing business models for providing incentives to the stakeholders. Hence, there is a need for further research to address all aspects of network sharing to achieve its full potential in cost and energy per bit reduction.

Once a sharing agreement is made among network operators, an effective management of the resultant network becomes crucial factor for the business success, and it is much more complex since it includes joint planning of the footprints, configuring the network parameter, etc. Self-Organizing Network (SON) techniques are capable of providing cost-effective network management for the complex shared network.

The rest of this tutorial paper is organized as follows. Section 2 provides a review on network sharing. Section 3 provides a review on self-organization network. Section 4 provides a simple example with simulation results, which demonstrated a significant gain in energy saving. A conclusion is presented in Section 5.

2 Network Sharing

From technical perspective, several architecture-level approaches have been proposed by vendors (e.g. Ericsson [5] and Nokia [6]), as well as the EU competition Directorate [7]. Although the proposed approaches from differ-

ent organizations are not identical, they can be generally categorized into three clusters:

- *Passive network sharing* in which operators share network assets that are not considered to be an "active" part of providing services, such as the sites and civil engineering elements (towers, shelters, air conditioning and cooling systems, AC and DC power supply, diesel generators).
- *Active network sharing* where operators share BS elements like the Radio Frequency (RF) chains, antennas or even Radio Network Controllers (RNC).
- *Roaming-based network sharing* where one operator relies on another operator's coverage on a permanent basis.

Figure 1 illustrates a general architecture of a wireless system and six different network sharing approaches. In general, the more network assets and operational functions are shared, the more cost savings are obtained accompanied by the loss of control of the entire network [8]. For example, in the case of full sharing, operator A relies on the operator B's network assets and operation functions to provide service to customers in operator B's coverage area. Both investment and operational cost are shared between A and B, while operator A has no control of the service quality at all. Apart from these architecture-level approaches, studies considering lower-layer technologies [9], such as Medium Access Control (MAC)/Physical (PHY) layer, in network sharing are very limited.

From the business perspective, the analysis results from both the academia and industry have demonstrated the benefits of network sharing in terms of meeting the increasing data demand and reducing the network cost [10]. Moreover, network sharing will probably further break down the value-chain, cultivate new business specialize in a certain area such as building tower, and create mobile virtual network operators who own no other physical assets except their home location resistor and billing system. In addition, the adoption of the aforementioned technical approaches depends on the business situation. For example, a high-degree network sharing would not be successful if two operators cannot agree with the technology updating plan because of different business strategies.

The benefits shown in technical and business analysis change the regulators' attitude from resistant to welcoming network sharing, although the tension still exists, and some resource sharing such as frequency pool are still not allowed. A summary of the policies in some EU countries are listed in [8]. In practice, the starting point is usually the sharing of sites, includ-

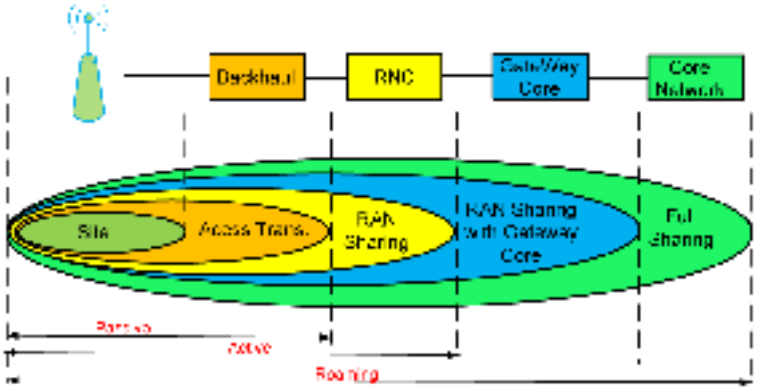

Figure 1 General illustration of wireless network architecture and different degrees of the network sharing.

ing passive infrastructure, as is the case of the recently announced joint venture Indus Towers, into which Indian operators Vodafone Essar, Bharti Infratel, and Idea Cellular are planning to merge their approximately 70,000 existing sites, and which should be responsible for the further network roll-out. Where emerging/developing market operators are looking at economic option for coverage and capacity growth, operators in mature markets are seeking cost optimization and technology refresh, like UK operators Orange and Vodafone, where active sharing are taken into consideration. Besides these successful examples, many Network Sharing deals have failed (despite considerable efforts from the operators' side). According to Ericson's analysis , common reasons for failed partnerships are: (1) the lack of confidentiality, trust and asset valuation; and (2) the complexity in RAN Sharing (Decision/Execution) often offsets savings.

2.1 Network Sharing in LTE-A Standard

3GPP has specified network sharing architectures shown in Figures 2 and 3, which allow a singular physical Universal Terrestrial Radio Access Network (UTRAN)[1] deployment to be shared between multiple Core Network (CN) operators, each with their own separate CN infrastructure deployments. Two architectural variations of Network Sharing are defined:

[1] UTRAN is the RAN employed in LTE system. Its evolution version E-UTRAN is employed in LTE-A system.

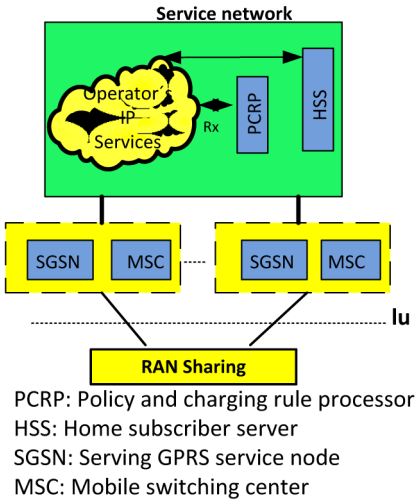

Figure 2 MOCN: Multiple Operator Core Network.

- MOCN: Multiple Operator Core Network.
- GWCN: Gateway Core Network.

This architecture applies to UTRAN and E-UTRAN (i.e. not GERAN: GSM/EDGE Radio Access Network). While Release 6 UE devices are required to fully exploit this Release 6 network capability, pre-Release 6 UEs are also supported by this architecture. MOCN allows a single UTRAN to be directly connected to up to five separate CN operators, thereby offering the opportunity for a new CN Operator to avoid RAN deployment. A separate Iu interface (PS and CS) is deployed for each CN operator. GWCN also allows a single UTRAN to be used by multiple operators

3 Self-Optimization Network

The appearance of SON algorithms represents a continuation of the natural evolution of wireless networks, where automated processes are simply extending their scope from just frequency planning to overall network resource management. The rationale for SON automation can be grouped into two broad categories:

1. Previously manual processes that are automated primarily to reduce the manual intervention in network operations in order to obtain operational and/or deployment savings. Automating repetitive processes clearly

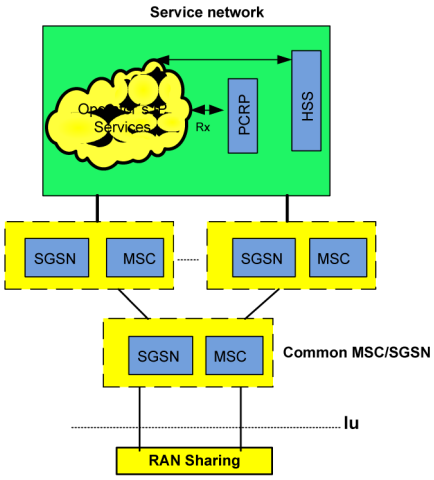

Figure 3 GWCN: Gateway Core Network.

saves time and reduces effort. Auto-configuration and self-configuration fall into this category.

2. Processes that require automation because they are too fast, too granular (per-user, per-application, per-flow, as a function of time or loading), and/or too complex for manual intervention. Automatically collected measurements from multiple sources (e.g., from user devices, individual network elements, and on an end-to-end basis from advanced monitoring tools) will provide accurate real-time and near real-time data upon which these algorithms can operate thus providing performance, quality, and/or operational benefits.

Consequently, substantial opportunities exist for cross-layer, end-to-end, and per-user/per-application/per-flow optimizations for extracting additional performance benefits and management flexibility.

In one of Next Generation Mobile Network (NGMN) white papers high-level requirements for Self-Optimization network strategy were included with set of use cases defined, covering multiple aspects of the network operations including planning, deployment, optimization and maintenance. More explicitly, some of the use cases were:

1. Plug & Play Installation.
2. Automatic Neighbour Relation Configuration.
3. OSS Integration.

4. Handover Optimization.
5. Minimization of Drive Tests.
6. Cell Outage Compensation.
7. Load Balancing.
8. Energy Savings.
9. Interaction Home/Macro BTS.
10. QoS Optimization.

Most of the use cases are addressed in 3GPP. 3GPP initiated the work towards standardizing self-optimizing and self-organizing capabilities for LTE, in Release 8 and 9. The standards provide network intelligence, automation and network management features in order to automate the configuration and optimization of wireless networks to adapt to varying radio channel conditions, thereby lowering costs, improving network performance and flexibility. This effort has continued in Release 10 with additional enhancements in each of the above areas and new areas allowing for inter-radio access technology operation, enhanced Inter-Cell Interference Coordination (eICIC) [14], coverage and capacity optimization, energy efficiency and minimization of operational expenses through Minimization of Drive Tests (MDT) [14].

4 Simulation Results and Discussion

4.1 Simulation Scenario

As shown in Figure 4, we considered a common area covered by *operator_1* (red) and *operator_2* (green). Assuming that *operator_1* has more subscribers in this area than *operator_2*, this area is covered by two small cells – *cell_1* and *cell_2* – of *operator_1*, and covered by one large cell named *cell_3* of *operator_2*. Without any sharing, users are only able to communicate to the BSs belonging to the operator they subscribed to. Hence, the edge-user *user_1* and *user_2* shown in Figure 4 suffer a relatively large path-loss, which results in high transmit power requirement and low cell-edge throughput.

The situation of employing network sharing is illustrated in Figure 5. The same geographic area shown in Figure 4 is considered. We assumed that *operator_1* and *operator_2* have service-level agreement. Moreover, we assumed that every user is capable of working on both operators' frequency bands. Therefore, the users are allowed to connect to BSs belonging to any operator. As a result, *user_1* and *user_2* will be able to connect to the nearest BS so as to save energy. Referring to the network sharing categories described in Section 2, the scenario we considered is *an active RAN sharing*, whose energy

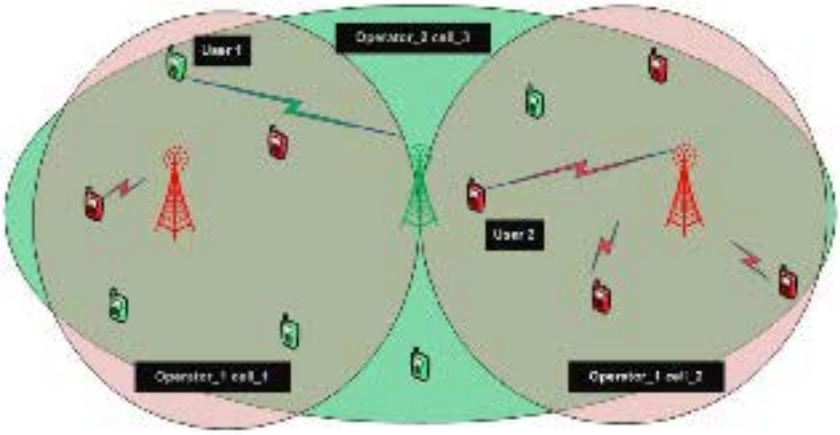

Figure 4 A common area covered by two independent operators: operator_1 (red) with cell_1 and cell_2; operator_2 (green) cell_3.

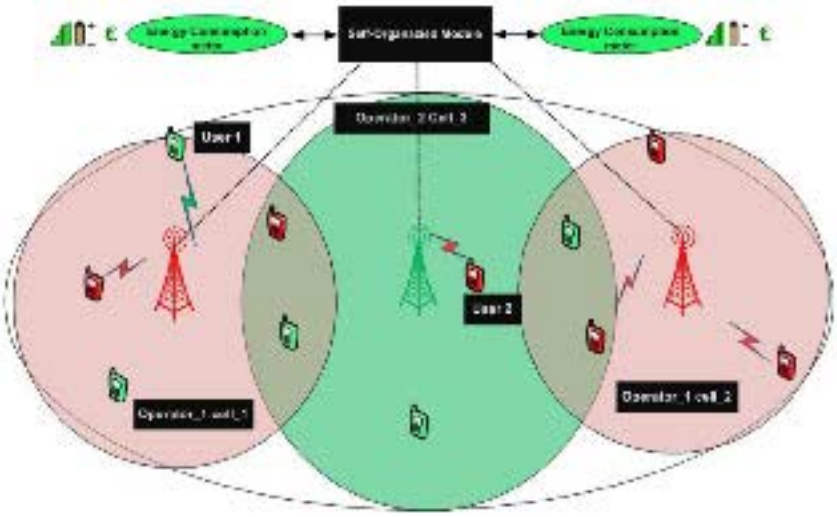

Figure 5 A common area covered by two service-share operators aided by self-organization.

saving will be investigated in this section. Moreover, the two operators could either further share or not share their MSC, core network, etc., depending on their policies.

Furthermore, a self-organizing optimization module is employed at every BS, which is capable of collecting reference signal received power (RSRP)

Table 1 Simulation parameters

Parameters	Downlink LTEA (FDD) System
Carrier frequency f_c	Operator_1: 2 GHz Operator_2: 1.9 GHz
Bandwidth	10 MHz
Fast fading model	Rayleigh fading using Pedestrian B model (6 taps, SISO) Urban
Number of cells	Hexagonal grid, 19 three-sectored cells
Number of users	100 per cell
User speed	3 & 30 km/h
Users power	23 dBm
BS transmit power	43 dBm
Inter-site distance	500 m
Time transmission interval (T_{ti})	1 ms (sub-frame)
Number of resource block	50 RB in each slot, 7 symbol, number of subcarriers per RB=12, total subcarrier=600
Link adaptation	EESM (Exp Effective SINR Mapping)
Traffic model	Mix Traffic Option (VoIP & NRTV), Cell Arrival Rate: 10 user/cell/sec
Radio resource management	RR, PF, Max C/I
Number of MCS	12 (from QPSK 113 to 64-QAM 3/4)

and Signal-to-Noise-plus-Interference-Ratio (SINR) from every user, monitoring the traffic load at the BS, so as to accordingly adjust the downlink transmit power at the BSs, with the purpose of finding the optimal coverage range, enhancing the throughput, and minimizing the energy consumption.

Throughout this section, we assume that LTEA-FDD technologies are deployed by all operators and cells. A hundred users are uniformly distributed over the area of interest. Other simulation parameters are shown in Table 1.

4.2 Definition of Some Parameters

In this subsection, we define the following parameters mostly related to self-organizing algorithm.

- *Coverage area of each operator*
  We assumed that the coverage area has a hexagonal shape, and this symbol r_{opi} represents the edge length of the hexagonal area covered by *operator_i*. As a result, the area covered by *operator_i* is calculated as

$$\varphi(op_i) = \frac{3\sqrt{3}}{2} r_{opi}^2.$$

Moreover, the length of the hexagon changes depending on the transmission power P_c .

- *Traffic load*
  The traffic load is a metric that represents the entire traffic load in the area covered by r_{opi}. That is:

$$T_{opi} = \sum_{x=1}^{n} \sum_{y=1}^{m} p(x, y) \cdot \delta_{opi}(x, y), \tag{1}$$

  where the symbol $p_{poi}(x, y)$ is the traffic load at point (x, y), and $\delta(x, y) \in \{0, 1\}$ is the function that indicates where that point (x, y) is covered ($\delta(x, y) = 1$) or not ($\delta(x, y) = 0$) by operator i.
- *Operators sharing area*
  This metric represents the ratio of the sharing area between *operator_i* and other operators. That is:

$$SA_{opi} = \frac{\sum_{j \neq i}^{N} \varphi(op_i, op_j)}{\varphi(op_i)}, \tag{2}$$

  where $\varphi(op_i, op_j)$ is the area value of sharing region between op_i and op_j. The symbol SA_{opi} represents the sharing ratio. Large SA means large sharing area. Index j is the operator index, $N$is total number of operators, and $\varphi(op_i) = \frac{3\sqrt{3}}{2} r_{opi}^2$ is the area value of the region covered by *operator_i*.
- *Energy*
  Energy of each operator in sharing region is measured in Joule/Bit:

$$\text{Energy Efficiency} \sim \frac{\text{Joule}}{\text{bit}} \tag{3}$$

- *Reference Signal Received Power (RSRP)*
  Supposed that transmit power of the BS in *cell_i* is P_i in dBm, the path-loss from this BS to a user ue equal to $L_{i,ue}^{p}$ (dBm), the corresponding shadow fading $L_{i,us}^{s}$ (dBm) having a log-normal distribution with standard deviation of 3 dB, and the fast fading is represented as $L_{i,ue}^{f}$ (dBm), the RSPR in dBm between this user and the BS in *cell_i* is formulated as

$$\text{RSRP}_{i,ue} = P_i - L_{i,ue}^{p} - L_{i,ue}^{s} - L_{i,ue}^{f}.$$

- *Signal-to-Interference-and-Noise-Ratio (SINR)*
  Supposed that the user ue is connected to the BS in *cell_i*, and received

interference from other cells, the SINR is formulated as

$$\mathrm{SINR}_{ue} = \frac{\mathrm{RSPR}_{i,ue}\ (\mathrm{mW})}{\sum_{j\neq i}^{N} \mathrm{RSPR}_{j,ue}\ (\mathrm{mW})} + N_0\ (\mathrm{mW}),$$

where all values are converted from dBm into mW, N is the total number of cells, and the symbol N_0 represents the noise power.

4.3 Simulation Results

In this section, several performance metrics including throughput, SINR distribution, and energy consumption of the *operator_1 cell_1* are measured in three situations:

1. without network sharing as shown in Figure 4;
2. with network sharing and constant transmit power as shown in Figure 5;
3. with network sharing and SON aided transmit power adaption as shown in Figure 5.

4.3.1 Network Sharing

Scenario definition is shown in Figure 5. Figure 6 shows the simulation results of average cell-edge user throughput versus the entire cell load of *operator_1 cell_1*. Traffic load and sharing region of each operator is calculated according to equations (1) and (2). A user is defined as cell-edge user if the distance between this user and its served BS larger than 2/3 radius of cell. Proportional fair scheduling is employed. It is demonstrated that the achievable average throughput of cell-edge users with network sharing is significantly higher than the one without sharing strategies. For instance, cell-edge average user throughput gain in non-sharing scheme is 33% at the cell load of 12 Mb/s, while in multi-operator sharing scheme the average user throughput is increased approximately by about 22% on same cell load. This is because that aided with network sharing, the cell-edge users such as *user_1* shown in Figure 6 become able to communicate with a nearer BS. As a result, the channel quality as well as the achievable throughput experienced by the cell-edge user is improved.

4.3.2 SON-Based Network Sharing

As illustrated in Figure 7, the self-organizing module takes input parameter the RSRPs and SINRs from users' feedback, as well as the current traffic load from the BS counter. It adjust the transmit power according to these

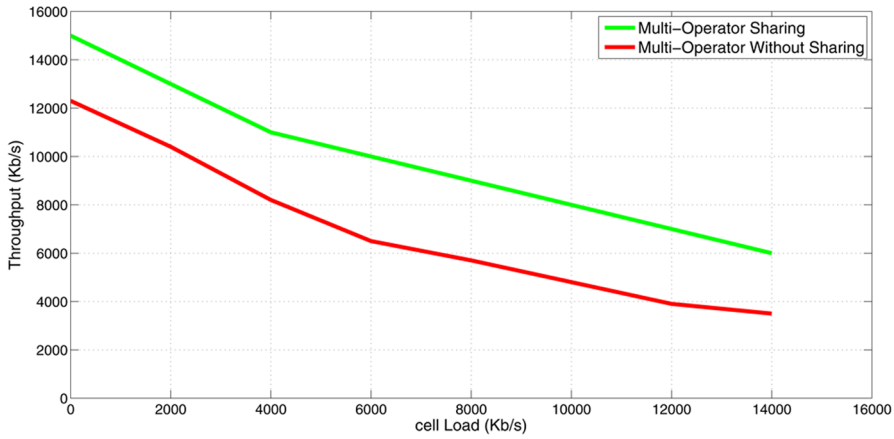

Figure 6 Averaged throughput of cell-edge op1 users versus the total cell load, when (1) op1 and op2 has sharing agreement, and (2) op1 and op2 has no sharing agreement.

parameters in order to maximizing the SINR values of the active users. For example, when the demanded traffic load increase in the *operator_1 cell_1* area, and is over the maximum affordable traffic load. Users who are in the coverage area of *operator_1 cell_1* cannot be served normally because of traffic overloading. The SON module detects this situation by observing a high ratio of admission denies in *cell_1*. As a consequence, the SON module adjust the transmit power at *cell_1* and *cell_3*. More explicitly, the BS transmit power at cell_1 is reduced, and the BS transmit power at *cell_3* is increased; in order to handover the cell-edge users' requirement from *cell_1* to *cell_3*.For simulation purposes, fixed number of users are deployed in each operator to see the performance of SON module.

Figure 8 show the Cumulative Density Function (CDF) of the users' SINR in cell_1. With SON based network sharing almost 85% of users achieve the required minimum SINR value 10dB. Without SON based network sharing, only 75% of users get required SINR value. This gain is achieved due to the optimal power allocation of SON module. SON module adapted its power according to traffic load in each operator cell.

4.3.3 Energy Efficiency

Energy efficiency is calculated according to equation (3). Figure 9 shows the energy consumption comparison of SON based Network sharing (SNS), simple network sharing and no sharing in term of energy per packet. Packet

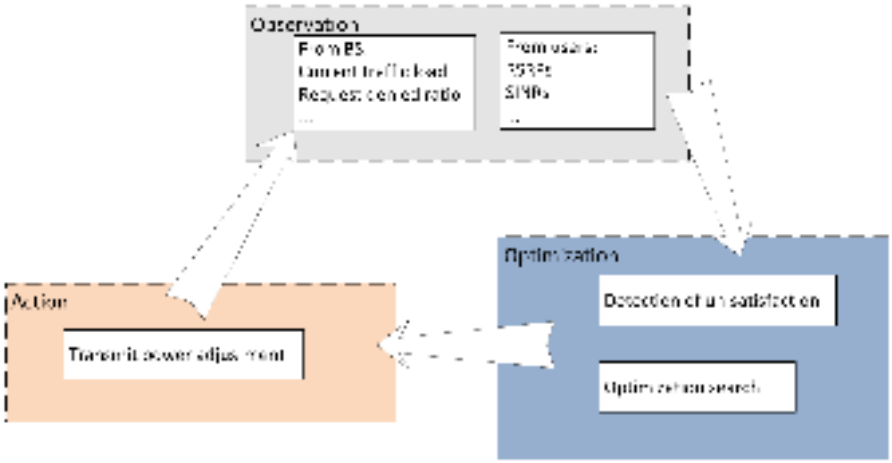

Figure 7 Flow chart illustration of the iterative optimization processing of SON module.

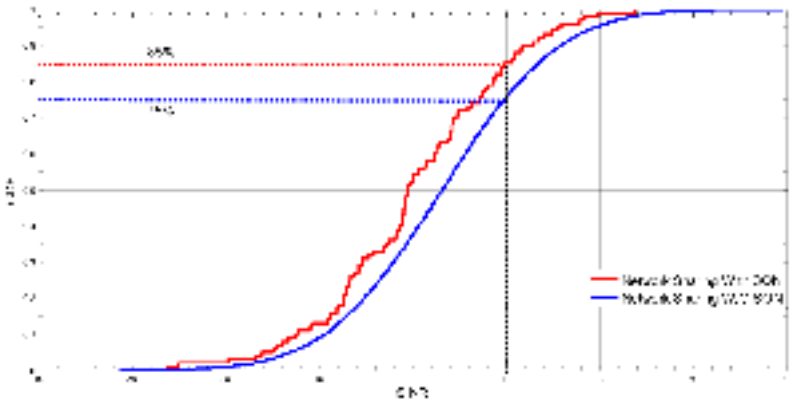

Figure 8 CDF of SON based network sharing.

size depends upon AMC scheme on each TTI. Mobile users are randomly distributed each operators site. We change the maximum allowed energy consumption per packet, and draw the overall energy consumption as shown in Figure 9, where we see clearly that compared with network sharing scheme, SNS achieves significant energy savings without network sharing yield minimum energy saving.

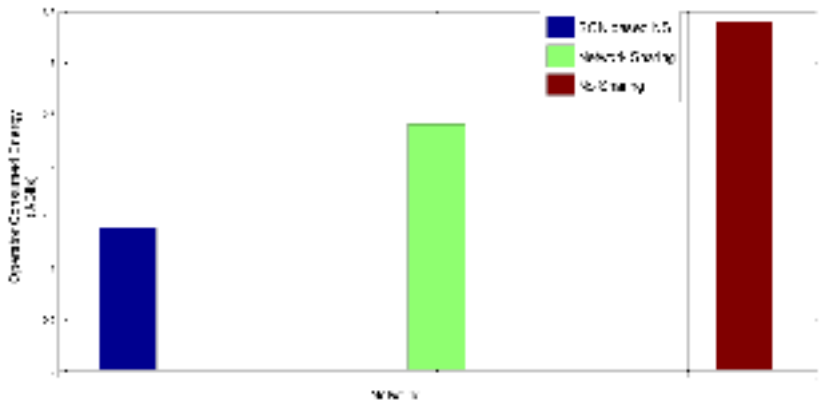

Figure 9 Energy efficiency comparisons.

5 Conclusions

ICT brings its intelligence to diverse networks and telecommunications industry. As these networks become more intelligent and complex, new solutions for network management are needed. ICT enables network optimization on multiple levels; energy consumption, throughput etc. SON has potential to self-configuring, self-optimizing and self-healing and minimizes the energy consumption in the network. In this paper we provided a tutorial on a new energy reduction approach – self-organization aided network sharing. We considered self-optimizing property of SON and showed from a simply example that SON based network sharing, optimized the system performance and minimized energy consumption in multi-operator scenario.

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Biographies

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Jonathan Rodriguez received his Masters degree in Electronic and Electrical Engineering and Ph.D from the University of Surrey (UK), in 1998 and 2004 respectively. In 2002, he became a Research Fellow at the Centre for Communication Systems Research at Surrey and responsible for managing the system level research component in the IST MATRICE,

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