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Energy Efficiency Led reduced CO_2 Emission in Green LTE Networks

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Abstract

The technological advancements in smart phones and their applications have rapidly raised the number of users and their data demands. To fulfil enlarged user's data requirements, Basestation (BS) engages their resources over prolong time intervals at the cost of increased power consumption. In parallel, operators are expanding network infrastructure by employing additional BSs which also adds in power consumption. This directly increases carbon emission (CO_2) thus results in to more global warming. Therefore, Information and Communication Technology (ICT) has become major contributor in global warming while mobile communication is one of the key contributors within ICT. This paper investigates reduced CO_2 emission through decreased power consumption in LTE networks. Proposed energy saving scheme is validated through the analysis of various performance related parameters in MATLAB. Results have proven that proposed scheme reduces CO_2 emission by 2.10 tonnes per BS.

Keywords: LTE Networks, Energy efficiency, Green Communication, Carbon Emission.

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1. Introduction

Mobile communication has gone through incredible enhancements to support Quality of Service (QoS) of various applications with enlarged mobile users. To handle with these necessities, many wireless technologies have been introduced which covers small area with fewer number of users to the lengthy coverage with thousands of users. One of these technologies is known as Long Term Evolution (LTE) which fulfils higher data rate requirements and provides ubiquitous network coverage with adequate QoS. LTE network has been deployed by numerous vendors to satisfy higher data requirements of growing users. Importantly, these requirements are fulfilled at the cost of increased power consumption by BSs which adds in increased global warming. According to research, global ICT systems consume approximately 1200 to 1800 Terawatts per hour of electricity annually [1]. Importantly mobile communication industry is accountable for more than one third of this power consumption in ICT due to the increased data requirements, number of users and coverage length. Applying these values to global warming, telecommunication is responsible for 0.3 to 0.4 percent of worldwide CO_2 emissions [2]. Additionally, user data volume is expected to increase by a factor of 10 every five years which results in 16 to 20 percent increase in associated energy consumption [3]. In this view, mobile industry faces a prodigious sustainable development problem in power consumption. Noteworthy, BSs are responsible for approximately 60% of total power consumption in LTE network [4]. To meet these challenges, green communication has become key research area in mobile industry. Several researchers have introduced various energy efficient schemes which help reduce power consumption and lessen CO_2 emissions. Said schemes offer reduced power consumption through employment of various methods, i.e. deactivation of BS operations during off peak time, load balancing, carrier aggregation and bandwidth expansion. Existing energy efficient proposals in literature proves that energy saving at the BS is one of the major research area in wireless networks, because it has excessive potential to improve energy efficiency. Dynamic power consumption can be reduced through discontinuing transmission during lightly loaded condition [5]. On the same lines resource blocks carrier aggregation can also help reduce power consumption [6]. Said methods aggregates two resource blocks and turn off idle resources during off peak time periods. Next to this distance ware schemes involve turning off BSs based on load information [7]. Centralized methods also help reduce dynamic power consumption through migration of users from heavily loaded cells to lightly loaded cells [8]. In the same context, another work in [9] employs cell sectorization to reduce power consumptions. Though existing proposals offer energy savings, however there is no significant work in literature which investigates the impact of energy saving on greener communication. Based on our previously proposed energy

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saving scheme in [10], this work further investigates REHO performance through the analysis of radio link failure, carbon emission reduction and energy saving. Rest of the paper is organized as follows.

Following introduction section in 1, section 2 presents physical layer aspects of LTE networks. Section 3 briefly highlights our proposed REHO scheme while performance analysis is discussed in section 4. Paper is finally concluded in section 5.

2. Physical layer in LTE

LTE physical layer uses various frames for data and control information transmission. Each frame of 10ms duration is further subdivided into 10 sub-frames, each being 1ms long. Further each sub-frame is divided into two slots, sized 0.5 ms which contains one resource block (RB) whereas total number of resources depends on transmission bandwidth. Each RB consists of a total 72 Resource Elements (RE) which is the smallest resource unit. REs aggregate into RB; there are 12 REs per symbol while there are 6 to 7 symbols in each RB as shown in Figure 1[11]. OFDMA uses large number of narrowband multi subcarriers instead of wideband. For example, in HSPA with 20 MHz the overall transmission bandwidth consists of 4 subcarriers each with 5 MHz, in contrast OFDMA transmission may employ hundreds of subcarriers which transmitted over same radio link to the receiver. The number of subcarriers could range from few hundreds to the several thousand with subcarrier spacing ranging from few kHz to a several hundred-kHz depending on type of environment. Due to the orthogonality; two subcarriers do not effect from any interference between each other after demodulation [12].

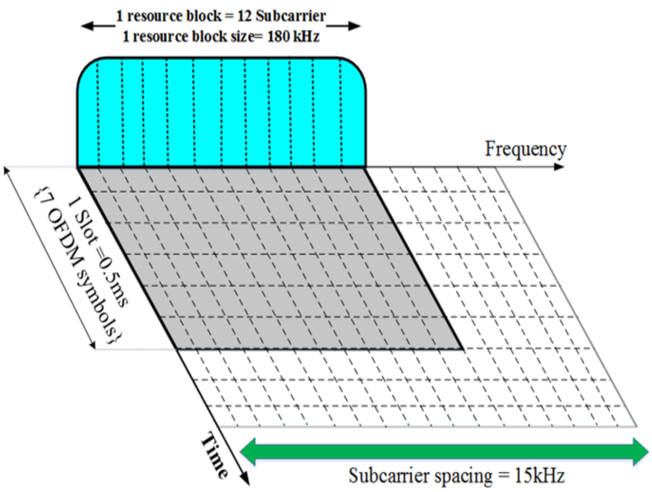


Figure 1. OFDMA Architecture

In LTE, overall bandwidth ranges from 1.4, 3, 5 10, 15, 20 MHz while these bandwidths allow 6, 15, 25, 50, 75 and 100 resource blocks respectively. The BS allocate resources to users for data and voice transmission at the cost of their power consumption. LTE PHY layer employee downlink physical channels which determines data processing and their mapping on resources blocks. Physical channels carry both data and control information and mapped to specific transport channel. There is fixed linkage between physical channels and transport channels as shown in Figure 2. In the same context, there are four transport channels at Downlink i.e. Broadcast channel (BCH), Downlink Shared Channel (DL-SCH), Paging Channel (PCH), Multicast Channel (MCH). Importantly LTE PHY consists of three physical data channels and three physical control channels. Since our proposed work also focus on physical downlink control channel (PDCCH) channel, therefore only PDCCH is discussed [13, 14]. The PDCCH used to support efficient data transmission. Therefore, PDCCH and PDSCH are the two key channels among rest of the four above discussed physical channels. Notably every subframe contains PDCCH signals as well as reference signals. The PDCCH channel carries control information about the data carried in PDSCH in the current subframe and contains information about the resource blocks which UEs required and use for uplink data. It also carries Downlink Scheduling Control Information (DCI) messages which contain information about the resource allocation, modulation and coding scheme thus allow UEs to decode data sent in PDSCH. Our proposed scheme targets PDCCH because it is the main contributor in overhead transmission. Point to be noted that one of the common drawbacks of all control signals is that they occupy capacity and consume power which causes signalling overhead, whereas PDCCH is one of the major signalling overhead's contributor is main disadvantage of this channel. Every subframe carry PDCCH signals, while these signals can be configured to occupy 1st, 2nd or 3rd OFDMA symbols in each time slot of each resource block. Accordingly, PDCCH's produces approximately 26 percent signalling overhead which contributes in additional energy consumption. However, energy consumption can be reduced by limiting these signalling overheads of PDCCH. Next to this, Medium Access Control (MAC) Layer consists of five logical control and two data channels as shown in Figure 2. It is responsible for logical channel's multiplexing and mapping them with appropriate transport channel, it also requests some services in the form of transport channels from Physical layer (Figure 2). Further downlink packet scheduling is also part of MAC layer, which control the allocation of shared channel transmission to the UEs depending on channel quality. Packet scheduling at BS occur at every Time to Transmit Interval (TTI) which allow utilization of information on the instantaneous channel quality for each UE [15]. Our proposed REHO scheme combines two resource blocks together and allocates to single user thus resulting into reduced PDCCH signalling overhead leads toward reduced power consumption in LTE networks. On the same line reduced power consumption helps vendors to decrease carbon emission CO_2 and stay greener.

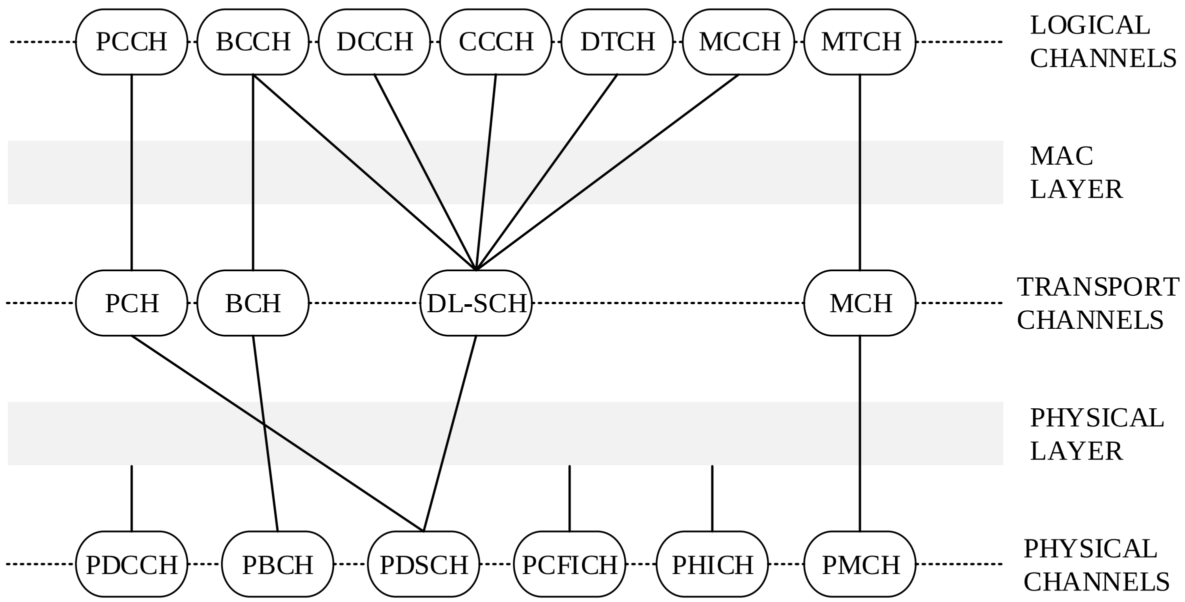


Figure 2. Physical and MAC Layers in LTE

3. REHO Scheme

REHO scheme employs the concept of early handover for energy saving purpose. In LTE networks, all BSs transmit cell specific reference signals (RSs), which are used to measure reference signal received power (RSRP) at receiver end. When user enters in coverage area of neighbour cell, it measures RSRP from both serving and neighbour cell. RSRP of neighbour cell becomes better then serving cell when user becomes closer to the neighbour cell thus triggering A3 event which results in to handover. There are three key parameters (Hysteresis, offset and Time to Trigger) involved in handover process, whereas REHO initiates early handover through appropriate tuning of hysteresis parameter. Early handover helps resources to become idle earlier which can be turned off for energy saving. REHO offers 35 percent energy saving as compared to standard LTE networks, which helps reduce 35 percent CO_2 emission [10]. Figure 3 presents working of our REHO in comparison with LTE standard LTE network. In our proposed REHO resources blocks are turned off right after early handover of users to target cell (Figure 3).

3.1 CO_2 Emission

The CO2 emission is measured in km^2 while its amount of emission purely relies on type of fuel used to produce electricity. Figure 4 presents different types of fuels currently used in electricity production and describes CO_2 emission (in grams) in line with fuel types. Importantly, gas and coal are main fuels used in electricity production which produces 960 and 443 Grams carbon per kWh respectively [16]. Accordingly, CO_2 emission can be calculated by multiplying total power consumption (kWh) with percentage of each fuel and associated CO_2 grams produced (Figure 4).

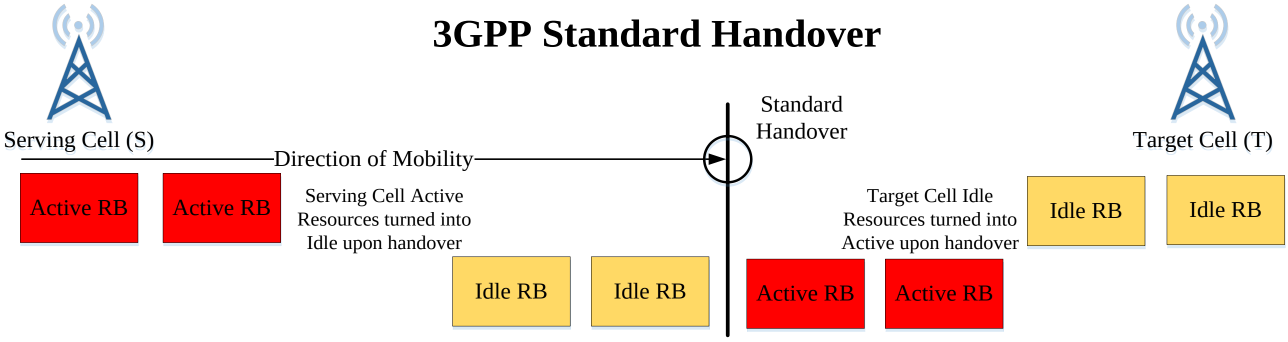
3.2 Power model

BS consists of Power Amplifier (PA), Radio Frequency (RF), Baseband (BB), DC to DC, AC to DC, Cooling system and Antennas Interface [17]. Power amplifier in BS is main power-hungry part, around 60 percent, while its power consumption is straightforwardly affected by data rate and resources utilization [17]. Figure 5 presents breakdown of power consumption by different sections inside the BS.

3.3 Mobility model

Proposed energy saving scheme is investigated and compared with typical LTE network using random way point mobility model (RWP), where each user firstly selects one random point, then starts moving towards selected point at fixed speed. Upon arrival of selected point, user waits for predefined time and then again selects another random point to complete mobility cycle as shown in Figure 6 [18, 19]. This process continues until random way point mobility model has completed predefined period. Said mobility model is employed to analyse REHO in realistic LTE scenario. Figure 6 clearly shows working of random way point mobility model in our system model. The key parameters used in RWP are presented in performance analysis section.

3GPP Standard Handover



Total Power = $P_{transmission} + P_{idle}$

- On the serving cell side, two UEs each having 1 active RB (shown in red) are heading towards target cell B.

Power consumed by active RBs before handover:

$P_{before\_handover} = P_{transmission} + 0$

- After handover, active RBs turn in to idle RBs (shown in amber above), thus accordingly $P_{transmission}$ becomes zero.

Power after handover:

$P_{after\_handover} = 0 + P_{idle}$

- On the target cell side, both RBs were in idle state before handover (shown in amber).

Power before handover: :

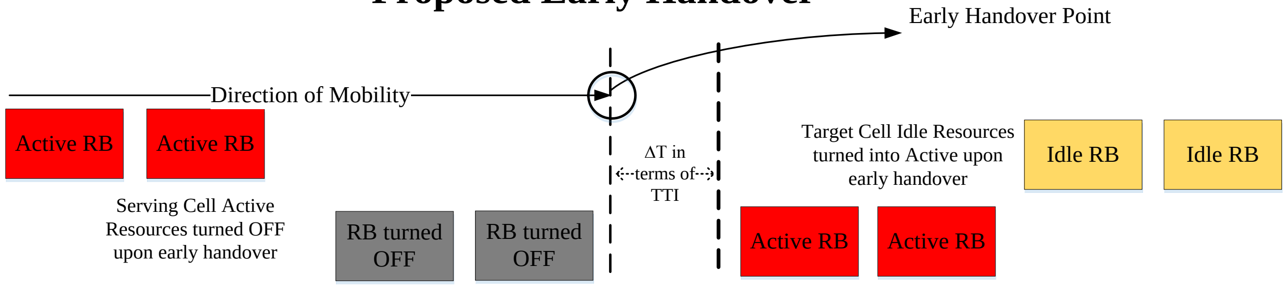
$P_{before\_handover} = 0 + P_{idle}$

- Power consumption after handover:

$P_{after\_handover} = P_{transmission} + 0$

Total power consumption of two BSs (Serving & Target) - Ptotal = $2^* P_{transmission} + 2^* P_{idle}$

Proposed Early Handover



- In proposed early handover scheme, freed RBs of serving cell are ***completely turned OFF*** (shown in grey) therefore these RBs do not consume any power at all, resulting into reduced overall power consumption.

$P_{before\_handover} = P_{transmission} + 0$

Power consumed after handover:

$P_{after\_handover} = 0 + 0$

- On the target cell side, both RBs were in idle state before early handover (shown in amber).

Power before handover:

$P_{before\_handover} = 0 + P_{idle}$

- Power consumption after handover:

$P_{after\_handover} = P_{transmission} + 0$

Total power consumption of two BSs (Serving & Target) - Ptotal = $2^* P_{transmission} + P_{idle}$

Figure 3. REHO Scheme vs Standard LTE

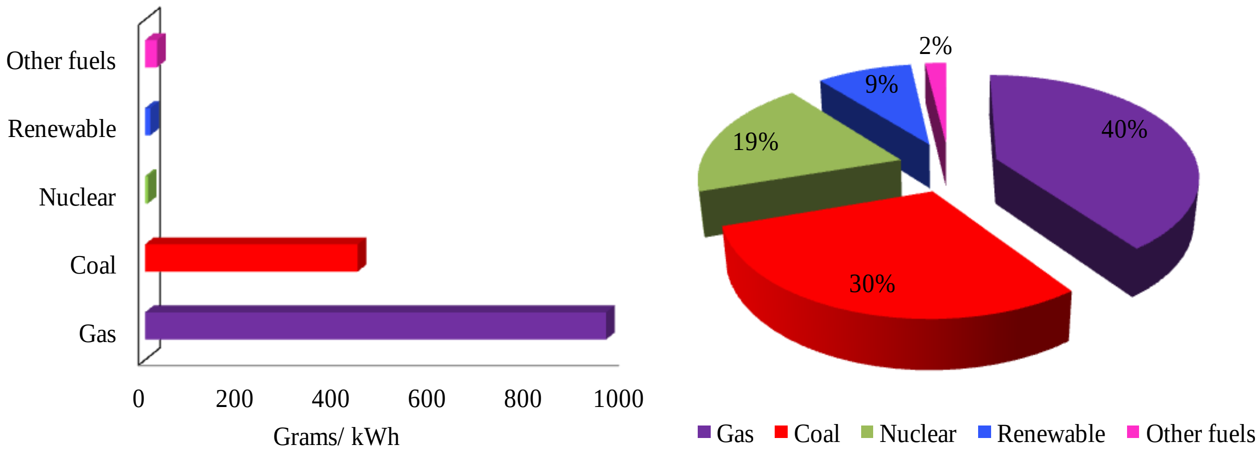


Figure 4. Fuels used in electricity production and associated CO_2 emission

4. Performance Analysis

Proposed scheme is validated though comparative analysis with typical LTE standard based on 3GPP in MATLAB. The system model consists of LTE network based on RAN and EPC configured in densely deployed scenario. Network consists of 7 cells, where 50 users randomly distributed per cell. Each BS covers up to 1000 meters with overlapping areas with neighbour cells. The total number of users is uniform in all cells. Table 1 presents detailed performance analysis related parameters based on 3GPP specifications [20, 21]. Various performance related parameters including dynamic power consumption, radio link failure and Carbon emission are investigated to validate proposed work. Importantly dynamic power consumption is calculated at Downlink BS.

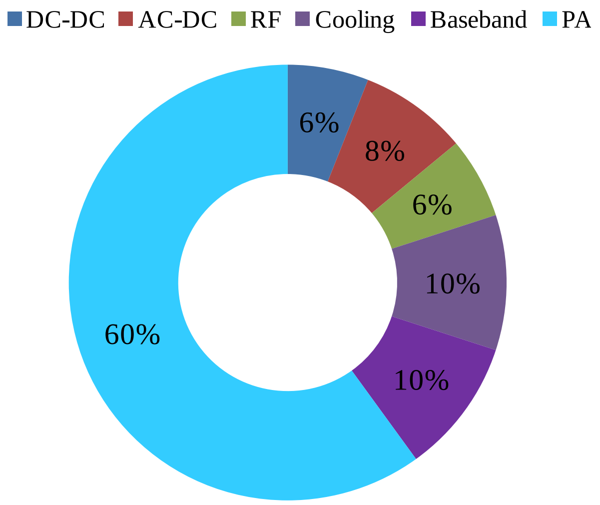


Figure 5. Breakdown of BS power consumption

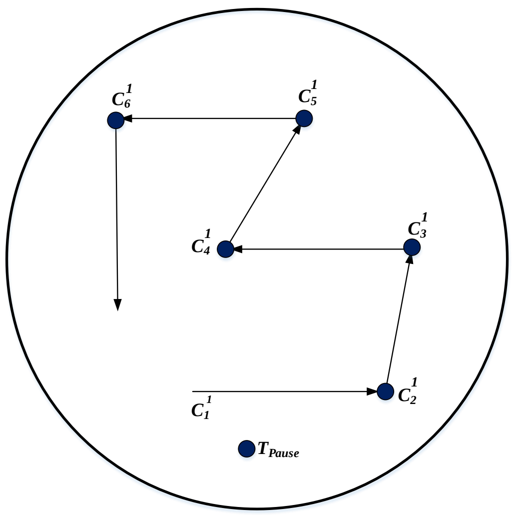


Figure 6. Random Way point model

Table 1. This is a legend. Caption to go above table

Parameters	Values	Parameters	Values
Frequency	2.14 GHz	Bandwidth	20MHz
No. PRBs	100	No. of cells	7
No. Users	50/cells	SINR	6.3 dB
BS coverage	1000m	Hysteresis	1, 4dBm
Max. Trans.	40W	User speed	40km/h
No. of RBs	100	Mobility model	RWP/SW
Run time	500sec	Time Pause	5sec
BS coverage	1000m	Hysteresis	1, 4dBm
No. of Antennas	4x4	Path loss	Log normal

4.1 Dynamic Power Consumption

REHO and LTE standard are compared for dynamic power consumption both for Straight Walking (SW) and RWP models in Figure 7. In standard LTE, resource blocks remain active both in idle and busy state. Therefore, it is evident that LTE standard results into same level of power consumption irrespective of the mobility models. However, it is found that SWM favours REHO scheme more (around 7.8 Watts consumption) compared to the realistic RWP mobility model (around 8.8 Watts consumption). Point to be noted that RWP is more realistic mobility model where user randomly changes direction while in SW model user only moves in one straight direction.

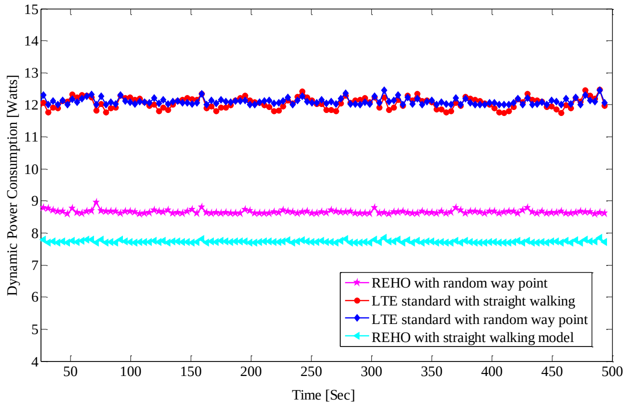


Figure 7. Dynamic power consumption

4.2 Radio Link Failure

Since proposed scheme achieves reduced power consumption, i.e. higher energy efficiency by reduced early handover, thus it is very important to investigate the effect of radio link failure. Figure 8 plots RLF both for proposed and benchmark systems for random way point mobility model. Clearly, RLF fluctuates considerably a lot due to increased mobility, however on average it remains around 8 percent for proposed scheme compared to 3 percent RLF for the benchmark systems.

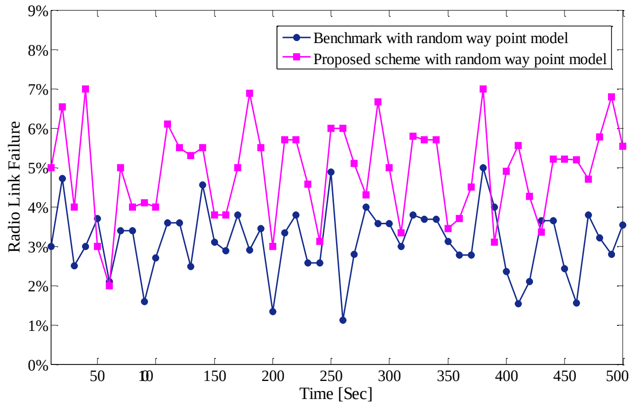


Figure 8. Radio link failure

4.3 Mean Energy Saving vs RLF and Hysteresis

Figure 9 plots mean relation between performance analysis parameters (i.e. energy saving and RLF) with varying hysteresis. Noteworthy the lowest limit of the hysteresis (1 dBm) offers highest energy saving with highest radio link failure up to approximately 5 percent, while on the other hand highest value of hysteresis (6 dBm) offers lowest energy saving with minimum radio link failure up to approximately 1.3 percent. Clearly the mean values of hysteresis offer fair balance between energy saving and RLF as shown in Figure 9.

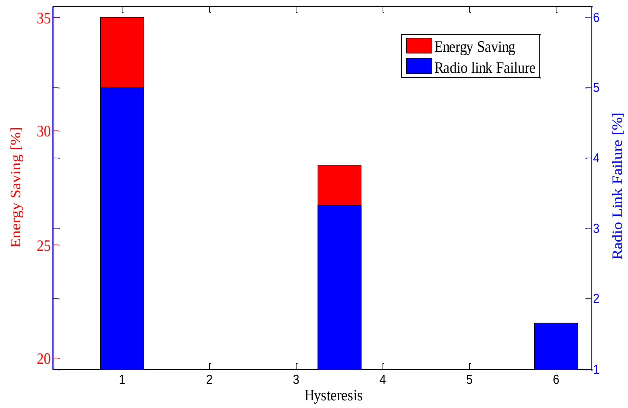


Figure 9. Mean of energy saving and RLF in REHO

4.4 Carbon Emission

Research has shown that average power consumption of one BS is approximately 1500W, which produces approximately 6 tonnes CO_2. However, the minimum 35 percent reduced power consumption through REHO helps operators cut down CO_2 emission by approximately 2.10 tonnes per BS as shown in Figure 10. Importantly the total amount of CO_2 reduction increases with enlarged number of BS (Figure 10). This helps operator to stay Green thorough reduced carbon emission.

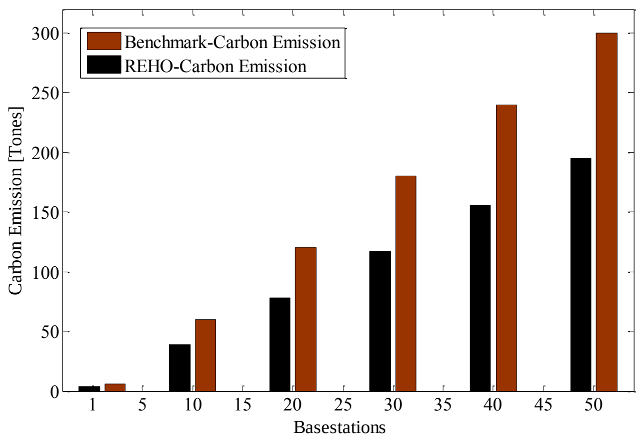


Figure 10. Carbon emission

Table 2 presents annual profit achieved through REHO and standard LTE. Notable annual expenses directly effects vendors profit. Initially data rate is allocated to each BS per km^2 which is further distributed over total number of users per km^2. Next to this, user's month tariff is calculated which is further used for annual revenue estimation. Annual expenses depend on various operational and capital expenditures. Table 2 present total annual expenses per km^2 [22]. Importantly Table 2 can be used as a ground for researchers to investigates vendors profits in relation to various reduced expenses per km^2.

Table 2. Annual Revenue and Expenses in REHO vs LTE Standard

Data Rate MB/s/km²	**UE/km²**	**MB/s/UE**	**GB/Month/UE**	**Equivalent tariff (GB)**	**Tariff cost /year**	**Tariff cost/year * Total No of UEs**	**Expense/km²**	**Profit/km²**
LTE standard network								
10	1000	0.01	25.92	unlimited	£360	£360 k	£193.01 k	£166.98 k
20	1000	0.02	51.84	unlimited	£360	£360 k	£193.06 k	£166.94 k
30	1000	0.03	77.76	unlimited	£360	£360 k	£193.09 k	£166.90 k
40	1000	0.04	103.68	unlimited	£360	£360 k	£193.12 k	£166.87 k
50	1000	0.05	129.6	unlimited	£360	£360 k	£193.15 k	£166.84 k
60	1000	0.06	155.52	unlimited	£360	£360 k	£193.17 k	£166.82 k
70	1000	0.07	181.44	unlimited	£360	£360 k	£193.19 k	£166.80 k
80	1000	0.08	207.36	unlimited	£360	£360 k	£193.21 k	£166.78 k
90	1000	0.09	233.28	unlimited	£360	£360 k	£193.23 k	£166.76 k
100	1000	0.1	259.2	unlimited	£360	£360 k	£193.25 k	£166.74 k
REHO								
Data Rate MB/s/km²	**UE/km²**	**MB/s/UE**	**GB/Month/UE**	**Equivalent tariff (GB)**	**Tariff cost /year**	**Tariff cost/year * Total No of UEs**	**Expense/km²**	**Profit/km²**
10	1000	0.01	25.92	unlimited	£360	£360 k	£192.71 k	£167.28 k
20	1000	0.02	51.84	unlimited	£360	£360 k	£192.75 k	£167.24 k
30	1000	0.03	77.76	unlimited	£360	£360 k	£192.78 k	£167.21 k
40	1000	0.04	103.68	unlimited	£360	£360 k	£192.80 k	£167.19 k
50	1000	0.05	129.6	unlimited	£360	£360 k	£192.82 k	£167.17 k
60	1000	0.06	155.52	unlimited	£360	£360 k	£192.84 k	£167.15 k
70	1000	0.07	181.44	unlimited	£360	£360 k	£192.86 k	£167.13 k
80	1000	0.08	207.36	unlimited	£360	£360 k	£192.88 k	£167.11 k
90	1000	0.09	233.28	unlimited	£360	£360 k	£192.89 k	£167.10 k
100	1000	0.1	259.2	unlimited	£360	£360 k	£192.91 k	£167.08 k

5. Conclusion

In modern mobile industry, there is rapid growth in number of mobile users and required data rate. Advancement in applications and smart phones demand higher data rates. Research has proven that these figures are going to be double after every five years. Increased data rate is provided at the cost of increased power consumption. Therefore, provision of such services at competitive prices has become major challenge for vendors. The increased data rate not only reduces operators profit but also results in to higher CO_2 emission which leads toward greater global warming. Importantly ICT has become major contributor in global warming and has been attracted by many researchers. In this context, this work has investigated our previously proposed REHO scheme considering energy saving impacts on CO_2 emission and offer insight by thoroughly analyzing performance analysis parameters. Various parameters i.e. dynamic power consumption, radio link failure and CO_2 emission etc have been analyzed to validates proposed work. Results demonstrates that 35 percent energy saving achieved through REHO significantly reduce CO_2 emission thus helps vendor to stay greener.

References

1. M. P. Mills, The Cloud Begins with Coal: Big Data, Big Networks, Big Infrastructure, and Big Power. Washington, DC, USA: National Mining Association, 2013.
2. R. Mahapatra, Y. Nijsure, G. Kaddoum, N. Ul Hassan and C. Yuen, "Energy Efficiency Tradeoff Mechanism Towards Wireless Green Communication: A Survey," in IEEE Communications Surveys & Tutorials, vol. 18, no. 1, pp. 686-705, First quarter 2016.
3. R. Tafazolli et al., "eMobility Mobile and Wireless Communications Technology Platform: Strategic Applications Research Agenda," NetWorks European Technology Platform, July 2010, http://www.networksetp. Eu.
4. T. Chen, Y. Yang, H. Zhang, H. Kim and K. Horneman, "Network energy saving technologies for green wireless access networks," in IEEE Wireless Communications, vol. 18, no. 5, pp. 30-38, October 2011.
5. P. Frenger, P. Moberg, J. Malmodin, Y. Jading, and I. Godor, "Reducing energy consumption in LTE with cell DTX," in Proc. IEEE 73rd Veh. Technol. Conf. (VTC Spring), May 2011, pp. 1-5.
6. F. Liu, K. Zheng, W. Xiang, and H. Zhao, "Design and performance analysis of an energy-efficient uplink carrier aggregation scheme," IEEE J. Sel. Areas Commun., vol. 32, no. 2, pp. 197-207, Feb. 2014.
7. A. Bousia, E. Kartsakli, L. Alonso, and C. Verikoukis, "Dynamic energy efficient distance-aware base station switch on/off scheme for LTE-advanced," in Proc. IEEE Global Commun. Conf. (GLOBECOM), Jun. 2012, pp. 1532-1537.
8. L. Li, Y. Zhang, B. Fan, and H. Tian, "Mobility-aware load balancing scheme in hybrid VLC-LTE networks," IEEE Commun. Lett., vol. 20, no. 11, pp. 2276-2279, Nov. 2016.
9. M. F. Hossain, K. S. Munasinghe, and A. Jamalipour, "Toward self-organizing sectorization of LTE eNBs for energy efficient network operation under QoS constraints," in Proc. IEEE Wireless Commun. Netw. Conf. (WCNC)0, Apr. 2013, pp. 1279-1284.
10. K. Kanwal and G. A. Safdar, "Reduced Early Handover for Energy Saving in LTE Networks," in IEEE Communications Letters, vol. 20, no. 1, pp. 153-156, Jan. 2016.
11. M. A. Seimeni, P. K. Gkonis, D. I. Kaklamani, I. S. Venieris and C. A. Papavasiliou, "Resource management in OFDMA heterogeneous network," 2016 Wireless Telecommunications Symposium (WTS), London, 2016, pp. 1-6.
12. M. Wang *et al.*, "The Evolution of LTE Physical Layer Control Channels," in *IEEE Communications Surveys & Tutorials*, vol. 18, no. 2, pp. 1336-1354, Secondquarter 2016.
13. 3GPP TS 25.814, "Physical Layer Aspects for Evolved Universal Terrestrial Radio-Access (UTRA)," Rel. 7.
14. http://www.ee.columbia.edu/~roger/LTE_PHY_fundamentals.pdf
15. 3GPP TS 36.321, "E-UTRA Medium Access Control (MAC) Protocol Specification," Rel. 8
16. K. Sovacool," Valuing the greenhouse gas emissions from nuclear power: A critical survey," in Elsevier Energy Policy, vol.36, pp. 2940-2953,. 2008
17. K. Liu, J. He, J. Ding, Y. Zhu and Z. Liu, "Base station power model and application for energy efficient LTE," Communication Technology (ICCT), 2013 15th IEEE International Conference on, Guilin, 2013, pp. 86-92.
18. L. Hanzo II, S. M. Mostafavi and R. Tafazolli, "Connectivity-Related Properties of Mobile Nodes Obeying the Random Walk and Random Waypoint Mobility Models," Vehicular Technology Conference, 2008. VTC Spring 2008. IEEE, Singapore, 2008, pp. 133-137
19. C. Bettstetter, G. Resta and P. Santi, "The node distribution of the random waypoint mobility model for wireless ad hoc networks," in IEEE Transactions on Mobile Computing, vol. 2, no. 3, pp. 257-269, July-Sept. 2003
20. 3GPP, "3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; Radio Frequency (RF) system scenarios", TR 25.942 V9.0.0
21. 3GPP, "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Networks (E UTRAN): Overall description", TS 36.300, V10.4.0.
22. T. M. Knoll, "A combined CAPEX and OPEX cost model for LTE networks," Telecommunications Network Strategy and Planning Symposium (Networks), 2014 16th International, Funchal, 2014, pp. 1-6.