POWER OPTIMISATION IN HETEROGENEOUS CELLULAR NETWORKS USING BRANCH AND BOUND REDUCTION ALGORITHM

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Abstract : Recent years have seen a sharp increase in the demand for data rates from mobile customers, and efforts to lower the energy usage of cellular networks have focused on the idea of shutting down base stations during off-peak hours. Heterogeneous Cellular Networks (HCNs) in the 5G wireless communication system provide an anticipatory strategy to satisfy the increasing demand for cumulative data rates. However, the most significant utilization of the available radio resources at closely deployed small cells still needs to be solved. The new small base station has been turned into a sleep mode for time-varying traffic loads to reduce power consumption.

The sleeping mode control in HCN is described in this work to reduce power consumption while adjusting to the time-varying traffic load. The user association of low loads into sleep is solved using a typical 0/1 knapsack Branch and Bound (BnB) approach to find the answer to the sleep mode control issue. The suggested algorithm selectively turns off certain micro base stations that use the fewest associated users. Comparing the suggested method with the dynamic programming methodology, the simulation results demonstrate that the latter can't successfully lower the system's power usage during low traffic periods.

IndexTerms - Heterogeneous Cellular Network, Branch and Bound (BnB) method, Power Consumption.

1. Introduction

The need for mobile phones has grown significantly over the past few decades, thanks to the development of file applications, telecommunication services, and movie running. As a result of this advancement, wireless access networks have been widely positioned to increase their resilience and accessibility. When power reduction is considered, quick access to data rates and excellent service facilities are the primary constrictions in the system [1]. The base station's power requirement increases with an intense increase in devices like tablets, instruments for household applications, and wearable healthiness displays [2]. To perform these data transfers, around 50% of the base station power increases [3].

By 2020, seventy-five per cent of information and communications technology (ICT) production will be wireless. This trade alone accounts for five per cent of global carbon emissions [4]. 4G's coverage and capacity have expanded with the advent of tiny cells. Thus, a study on energy depletion per unit area for a heterogeneous chamber placement for fourth-generation systems [5]. As the number of base stations increases, so does the energy usage. The location of tiny cells shows excellent consideration for available resources. Thus, creating tiny cells improves the system's and the user equipment's energy efficiency.

The objective function has been developed to minimize energy consumption using natural sources and energy-responsive communication [6]. The present-day development focuses on base station power requirements that can be solved by the use of Renewable energy sources, regulating the coverage area of a base station dependent upon the load level, turning off the small base station with a low load into sleep mode and balancing the load by passing over the UE to the adjoining small cells over the UEs to the macro base station

The impact of this work is (i) reflecting the lowest number of the UEs and their related small cells into sleep mode to decrease the energy ingesting of the complete system and (ii) Dealing with the LTE-Advanced Standard [7]. The energy reduction in the base station is considered by turning off some small cells in low-movement circumstances. The paper describes the following sections: Section II describes the various energy reduction methods in mobile environments. Section III presents the system model. Section IV introduces the recommended Branch and Bound algorithm. The mathematical effects of energy saving are given in Section V, whereas Section VI determines the paper.

2. Review of literature

To satisfy consumer demands, the BSs are switched on at any time without considering the traffic level of each BS. It represents the BSs consuming the same power even when the number of users is deficient. The BS positioning is planned to provide perfect data services at a peak rate. Worldwide the average consumption rates of mobile systems were around 80% in 2019. Base stations are the power-consuming part of a mobile system that encourages research to reduce the power consumption of base stations by shutting down underutilized stations to achieve energy savings for spatial and temporal fluctuations in traffic [8] [9]. 3GPP Long Term Partnership Project (LTE) Standard Release 11 [10] specifies that BSs can be switched off during short periods of movement to save energy. For example, the authors of [9] investigated the possibility of reducing the number of dynamic BSs, allowing operators to work day and night on the go. In [11], the book describes the active control of the base station power for mobile systems and, consequently, the energy savings.

To satisfy consumer demands, the BSs.

The concept of cell height that is dynamically adjusted to account for traffic variances has been agreed upon in [12]. Cell enlargement concepts have been implemented to reduce BS energy depletion by reducing cell size when the BS has little traffic in its coverage. At the same time, the neighbouring cell has grown in size to offer users opportunities. This embodiment can be performed by changing physical parameters, such as the transmission power of the base station, or by supporting and retransmitting between base stations. The authors in [13] demonstrated an insufficient increase in the number of cells in some cases and discussed the possibility of specifying reduced but additional nodal sites to improve energy efficiency. Another comparable proposal for dynamic correction of cell size in cryptograms, called "cell respiration", was presented in [14]. Furthermore, a distributed BS idle method has been anticipated for the LTE system. As long as the data service level and maximum operational power are maintained, the BS can be shut off when its utility value is at its lowest [15]. The journalists in [16] spoke about the BS operation cycle and suggested a requirement for selecting an antenna.

3. System Model

The twin-tier downlink HCN in which a number of minor chambers are overlapped with a macro cell within a finite Euclidean plane, as illustrated in Fig. 1. There are N users and M small cells. Let $B_M = \{1\}$ denote the index of the macro cell BS. Both users and SBSs are arbitrarily and independently spread across the macro cell handling range [17].
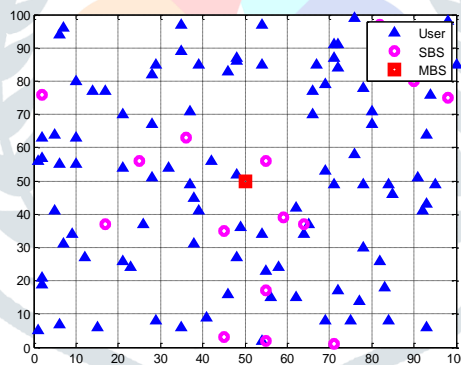

Fig. 1 Placement of BSs and Users

All SBS do not overlap and have the same extreme transfer power Pmax. The concentrated transfer power of MBS is Pmax. Inside the attention of MBS, there are total N users and MBS and SBSs are deployed with different transporter rates. To mark the complete coverage, the MBS would not be revolved into sleep mode. Hence, to satisfy users' needs, the SBS is selected to make it into sleep mode or active mode. The entire mechanism is revising at MBS; the subsequent conventions are to be deliberated [18]:

(1) The operator inside the exposure of SBS will possibly be functioned by either SBS or MBS. For a stream of traffic, the operators, who are committed and assisted by SBS, are called SBS user equipment (SUE).

(2) The user, who drops out of the exposure of SBS, can only be assisted by MBS and is called macro user equipment (MUE).

3.1 Path Loss Model

It is necessary to determine the route loss between a macro BS and user equipment before creating a mathematical model for predicting the SINR. By conferring to [19], the path loss model for the connection from MBS to MUE follows:

$$PL_M = 128.1 + 37.6\ log_{10}(D) \qquad (1)$$

Where PL_M designates lust for the load in dB for MBS and D designates the expanse between MBS and user in kilometres. The lust for the load from SBS to SUE follows:

$$PL_S = 140.7 + 37.6\ log_{10}(D) \qquad (2)$$

where PL_S represents path loss in dB for SBS and D denotes the space between SBS and user in kilometres.

3.2 Power Depletion Model

The power ingestion model of the MBS can be designated as follows according to EARTH:

$$P_{in} = N_{TRX} \cdot (P_o + \Delta_p P_{out}), \qquad (3)$$

N_{TRX} is the number of transmitting antennas in an MBS, P_0 is the linear model parameter to represent power consumption at zero RF output power, and Δ_p is the capacity gradient required by power consumption.

For SBS, the power depletion model is termed as follows:

$$P_{in} = \begin{cases} N_{TRX} \cdot (P_0 + \Delta_p P_{out}), & 0 < P_{out} \leq P_{max} \\ N_{TRX}, P_{sleep}, & P_{out} = 0 \end{cases} \qquad (4)$$

Where Pmax indicates the extreme RF output power at a given load, the power absorption modulus increases linearly with the ratio of animated backup blocks (RBs) used in a frame. This ratio is called the exploitation feature and is represented as c, where c can be calculated using the equation

$$\chi = \frac{R_B^{UE}}{R_B^{T}} \qquad (5)$$

where R_B^{UE} is the amount of RBs that are dynamically used in an LTE frame broadcast, and R_B^{T} is the total number of RBs in an LTE frame. The Macro BS is significantly affected with the increase of χ, micro cell is affected less significantly. χ can has a value between 0 and 1, when RBs are not used the exploitation feature is 0 and when all RBs are used then then the value of exploitation feature is 1.

3.3 Optimization Problem Creation

Let $x_{ij}=1$ represent that the ith user is committed to the jth BS and $x_{ij}=0$ indicate the opposed occasion. The state of BS is indicated by 1 and 0. If it is 1 the respective BS is active otherwise it is inactive mode. The occupied position of the jth SBS can be termed as follows:

$$v_j = \begin{cases} 1, & \sum_i x_{ij} \neq 0 \\ 0, & \sum_i x_{ij} = 0 \end{cases} \qquad (6)$$

LTE practices adaptive modulation and coding (AMC), which means that it can change among various modulation arrangements and station coding location dependent on the link signal to interference plus noise ratio (SINR). SINR can be found as,

$$\zeta_{ij} = \frac{P_j \, a_{ij}}{\sum_{k \neq 0} P_k \, a_{ik} b_k + N_0 B} \qquad (7)$$

where P_j is the transmit power of jth BS, a_{ij} is the channel gain from j^{th} base station to user together with path loss and shadowing effect, N_0 is the noise power spectral density, B is the bandwidth of one RB in an orthogonal multiple access system by frequency division, for example, at 180 kHz in the LTE system.

To satisfy i^{th} user QoS mechanism with minimal number of data needs for each operator (R_i^{min}), the lowest number of resource blocks are used then the data rate is described as

$$D_{ij} = \frac{R_i^{min}}{B. \log_2 (1 + \zeta_{ij})} \qquad (8)$$

The over-all power ingestion of the structure is the summation of MBS power (P_{macro}) and SBS power (P_{SBS}) which can be written as:

$$P_{total} = P_{macro} + \sum_{j=0}^{M} P_{SBS} \qquad (9)$$

Working in idle mode can be expressed in an optimization problem. Constraints include the QoS of each operator in the cell and the fact that the organization must function in a balanced state. Therefore, the optimization problem for the SBS suspend mechanism is formulated as follows:

$$\min P_{total}$$
$$\text{s.t}$$
$$\sum_{i=1}^{N} \zeta_{ij} x_{ij} \leq N_{RB}^{Total}, \forall j \qquad (10)$$

$$x_{ij} \in \{0,1\}, \quad \forall i \in \{1,2,.....N\}$$

It denotes that the capacity of each BS should be less than the whole number of resource block (N_{RB}^{Total}), where the QoS of lowest data rate condition for each user has been involved.

4.   Branch and Bound (BnB) Sleep Mode Control

Considering (3) to (10), the inactive mode control problem is, in fact, a combinatorial optimization problem. Ideally, this involves extraordinary difficulty calculating O (2 N + M) to complete the entire exam for optimal results. Assuming the UEs will not be connected to two different BSSs simultaneously; therefore, try to be a traditional 0/1 backpack problem. Here, a Branch and Bound algorithm to reduce power consumption (BnBMP). In this method, the state space tree can be used in any method, such as width search (BFS) and depth search (DFS). These searches start with the source node and create other nodes. The BnB process separates the set of all possible outputs in a reduced form, repeatedly performing the search process to get the optimal result [21].

The segregation, as it is called, that separates the subclasses from the results is also limited and complete. That is any reasonable explanation addresses exactly one subclass. For each segregation of the results, the upper bound of the extreme value of the objective function reached by the resolutions belonging to the subclass is calculated [22]. Taking into account the value of the upper limits and another phase of divergence is performed, new upper limits are calculated, and the process is repeated until the optimal result is found, which has an objective function rate more significant than the upper limits of all subclasses and also more remarkable than the objective load values for all previously obtained results. The upper limit indicates the upper limit associated with node n. If the branch cannot be taken from the previous node, it is called a dead node. The branch of the previous node with the highest upper bound rate can generate two additional new descendant nodes.

Table 1. Pseudo Code of BnB algorithm

Algorithm: BnB Algorithm
Input: Array of users, RBs,User threshold
Output: Maximum Value
Compute Upper Bound (UB)
If UB <0
Return
End;
For i = 1:N
Compute
$UB=RB+(U_{th}-u)*(RB_{(i+1)}/u_{(i+1)})$
Obtain matrix based on UB
End;

5.   Results & Discussion

As in Figure 1, the setup considered here is that only one Macro BS (MBS) is placed at the middle of the cell and 50 SBS are randomly situated in the cell and the exposure of SBS are not covered. Assume that the operators are randomly dispersed in the exposure area. The fraction of amount of active users to amount of all operators varies with time in one day, which is attained from [19, 20]. And this phenomenon is shown in Figure 2. The simulation results are illustrated in Figures 3, 4, 5, 6, and 7.
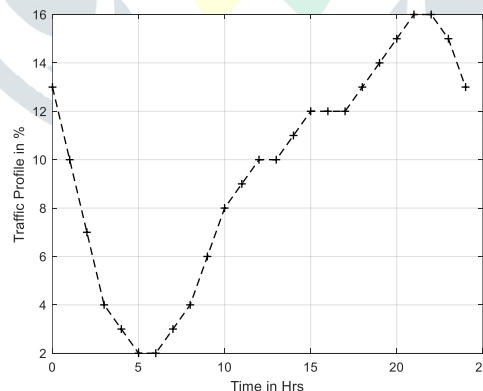

Fig. 2 Average data traffic profile in 1day

Figure 3 shows the path loss model for the MBS and SBS as in (2) and (3). Prototypes and simulation assumptions are designated according to the LTE – A calculation criteria précised in Table 2. During the simulation, path loss and shadow fading are only considered, lacking seeing the fast fading channel. The procedure of SBS sleep mode is shown in figure 4.
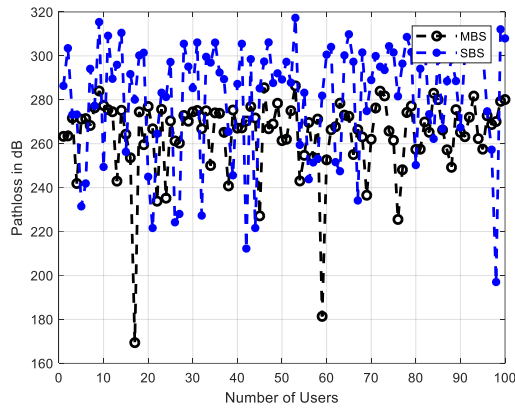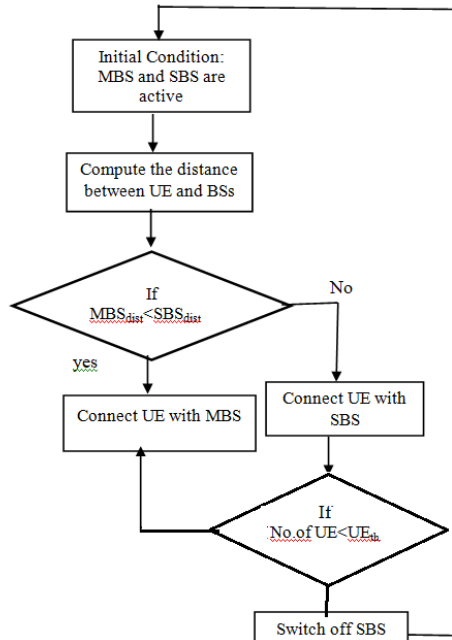
Fig. 3 Pathloss for MBS and SBS

Fig. 4 Flowchart for SBS sleep mode Algorithm

Table 2. Simulation Parameter

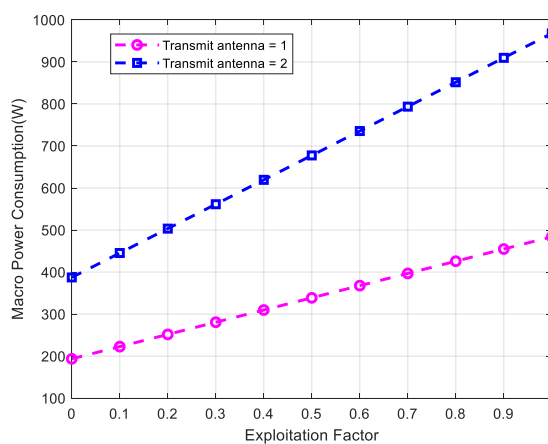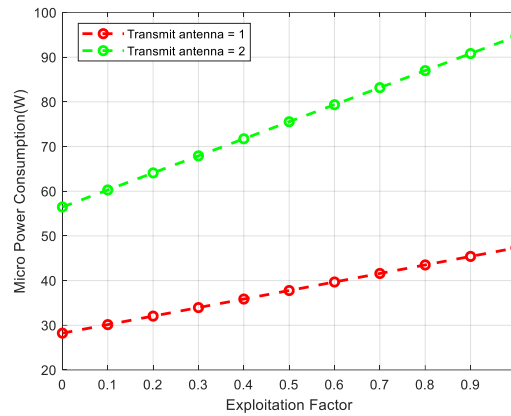| Parameter	Value
Number of RBs	50
Macro BS Power	46dBm
Micro BS Power	20dBm
Bandwidth	10MHz
Number of MBS	1
Number of SBS	50
White noise power density	-174 dBm/Hz

Fig. 5 The Effect of χ on MBS

Fig. 6 The Effect of χ on SBS

Figure 5 and 6 shows the total consumed power of an MBS and SBS for various transmitting antenna values. The power consumption value depends on the dynamic and constant power consumption at full load.

Figure 7 shows the SBS for various conditions like distance aware, load and all the SBS are active ON. When the distance is considered, 50% of the SBS are active, while considering load, only 36% of the SBS are active. Hence the proposed method of load-aware switching off SBS saves power consumption. The corresponding power consumption plot is shown in figure 8. If the SBS are active, it consumes more power compared with the switch-off mode.
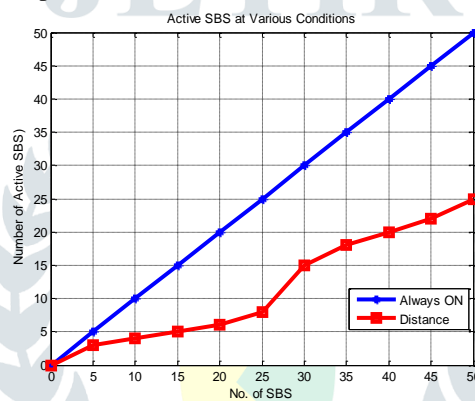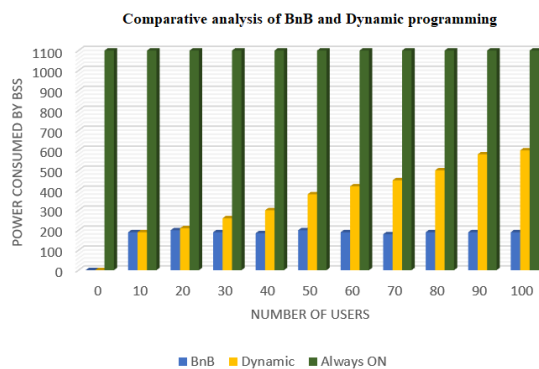

Fig. 7 Active SBS at various conditions

Fig. 8 Power Consumption with SBS are in sleep mode

6. Conclusion

This study discusses the inactive mode control strategy for the SBS process in heterogeneous networks. The recommended method is developed based on a typical 0/1 knapsack issue, and extremely low computer complexity is achieved by utilising the Branch and Bound technique. The numerical data show how much power base stations use under different conditions, including load, distance, and always-on mode. Compared to alternative solutions, turning off the SBS during a low traffic load results in superior power reduction. The next step that might come after this endeavour is to supply the electricity required for the SBS to realise a large decrease in fossil fuel depletion and the carbon footprint, which will achieve improved energy efficiency using renewable energy sources.

REFERENCES

1.Energy-efficient Strategies with Base Station Power Management for Green Wireless Networks Thesis[2016] by Hong Zhang, University of Manitoba Winnipeg.

2. A Survey on Recent Trends and Open Issues in Energy Efficiency of 5G, Muhammad Usama and Melike Erol-Kantarci School of Electrical Engineering and Computer Science, University of Ottawa, Ottawa, Canada.

3.Ge, X.; Yang, J.; Gharavi, H.; Sun, Y. Energy Efficiency Challenges of 5G Small Cell Networks. IEEE Commun.Mag. 2017, 55, 184–191.

4. Buzzi, S.; Li, C.; Klein, T.E.; Poor, H.V.; Yang, C.; Zappone, A. A Survey of Energy-Efficient Techniques for 5G Networks and Challenges Ahead. IEEE J. Sel. Areas Commun. 2016, 34, 697–709.

5. Lorincz, J.; Matijevic, T. Energy-efficiency analyses of heterogeneous macro and micro base station sites. Comput. Electr. Eng. 2014, 40, 330–349.

6. Zhang, Y.; Xu, Y.; Sun, Y.;Wu, Q.; Yao, K. Energy Efficiency of Small Cell Networks: Metrics, Methods and Market. IEEE Access 2017, 5, 5965–5971.

7. "Green" Distance-Aware Base Station Sleeping Algorithm in LTE-AdvancedAlexandra Bousia, Angelos Antonopoulos, IEEE ICC 2012 - Communication QoS, Reliability and Modeling Symposium.

8.K. J. Christensen, C. Gunaratne, B. Nordman, and A. D. George, "The nextfrontier for communications networks: power management," Computer Communications, vol. 27, no. 18, pp. 1758–1770, Dec. 2004.

9. M. A. Marsan, L. Chiaraviglio, D. Ciullo, and M. Meo, "Optimal energy savingsin cellular access networks," in Proc. of IEEE International Conference onCommunications Workshops (ICC'09, GreenComWksp.), Jun. 2009, pp. 1–5.

10. 3GPP TS 36.141 V11.2.0, Technical Specification Group Radio Access Network,
E-UTRA Base Station Conformance Testing, Release 11, Nov. 2012.

11. E. Oh, B. Krishnamachari, X. Liu, and Z. Niu, "Toward dynamic energy-efficient
operation of cellular network infrastructure," IEEE Commun. Mag., vol. 49, no. 6, pp. 56–61, Jun. 2011.

12. Z. Niu, Y. Wu, J. Gong, and Z. Yang, "Cell zooming for cost-efficient green
cellular networks," IEEE Commun. Mag., vol. 48, no. 11, pp. 74–79, Nov. 2010.

13. X. Weng, D. Cao, and Z. Niu, "Energy-efficient cellular network planning under
insufficient cell zooming," in Proc. of IEEE 73rd Vehicular Technology Conference (VTC-Spring'11 GreenetWksp.), May 2011, pp. 1–5.

14. S. Bhaumik, G. Narlikar, S. Chattopadhyay, and S. Kanugovi, "Breathe to stay cool: adjusting cell sizes to reduce energy consumption," in Proc. of 1st ACM SIGCOMM Workshops on Green Networking, Sep. 2010, pp. 41–46.

15. W. T. Wong, Y. J. Yu, and A. C. Pang, "Decentralized energy-efficient base station operation for green cellular networks," in Proc. of IEEE Global Communications Conference (GLOBECOM'12), Dec. 2012, pp. 5194–5200.

16. R. Wang, J. S. Thompson, H. Haas, and P. M. Grant, "Sleep mode design forgreen base stations," IET Commun., vol. 5, no. 18, pp. 2606–2616, Jan. 2011.

17. User Association and Base Station Sleep Management in Dense Heterogeneous Cellular Networks GongchaoSu,, Bin Chen, Xiaohui Lin1, Hui Wang and Lemin Li, KSII TRANSACTIONS ON INTERNET AND INFORMATION SYSTEMS VOL. 11, NO. 4, Apr. 2017 Copyright ⓒ2017 KSII, 2058-2074

18.Dynamic programming-based pico base station sleep mode control in heterogeneous networks, Gang Wu,*,, Liang Dong, Zhenting Qin and Zhikun Xu, INTERNATIONAL JOURNAL OF COMMUNICATION SYSTEMS Int. J. Commun. Syst. (2015) Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/dac.2967

19. Auer G, Blume O, Giannini V, Godor I, Imran MA, Jading Y, Katranaras E, Olsson M, Sabella D, Skillermark P, Wajda W. D2.3 Energy efficiency analysis of the reference systems, areas of improvements and target breakdown. EARTH (Energy Aware Radio and NeTworkTecHnologies), 2010.

20.Ambrosy A, Caretti M, Eilenberger G, Erdem A, Fantini R, Fazekas P, Fehske A, Gódor I, Héliot F, Holtkamp H, Imran MA, Marsch P, Maugars P, Olsson M, Pellón A, Alonso-Rubio J, Sabella D, Skillermark P. D2.2: Definition and parameterization of reference systems and scenarios. INFSO-ICT-247733 EARTH (Energy Aware Radio and NeTworkTecHnologies). Technical Report, June 2010.

21. A Proposed Solution to Knapsack Problem Using Branch & Bound Technique,Somya Goyal, Anubha Parashar, International Journal for Innovative Research in Multidisciplinary Field ISSN – 2455-0620 Volume - 2, Issue - 7, July - 2016

22.A Branch and Bound Algorithm for the Knapsack Problem, Peter J. Kolesar, Management Science Vol. 13, No. 9, May, 1967 Printed in U.S.A.