

Cell Selection Technique for Offloading in Cellular Networks

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Abstract—The exponential growth in data traffic has led to the necessity of offloading the traffic from macrocells. In this direction, the deployment of femtocells has been of keen interest in the recent years. The offloading of heavy bulk of users from macrocells has been of high importance due to the availability of sufficient number of deployed femtocells. The unregulated offloading results in load imbalance in the two cells leading to congestion in the femtocell network and under utilization of resources in macrocell network or vice versa. Therefore, efficient offloading techniques are required for proper utilization of resources and good quality experience by the end users. This paper analyzes the performance of the conventional offloading strategy for selecting a target cell. It also proposes an offloading strategy to select a target cell based on multiple criteria and demonstrates its dominance on the conventional strategy in terms of fairness index and computational efficiency. A fair distribution of resources is indicated when proposed strategy is used. The computational efficiency of the system is improved by 39.3% and 19.2% when users are moving at speeds of 30 kmph and 120 kmph respectively.

Index Terms—Femtocells, offloading, cell selection, fairness index, CPU clock.

I. INTRODUCTION

There is a tremendous increase in the data traffic all over the world in the recent years due to the development of high quality applications and new technology smart phones [1]. To support this increase in traffic a significant evolution is also seen in the cellular networks. One of the most important challenges for network operators is to manage such huge data traffic. Consistent efforts are being made to increase the network capacity and coverage by emergence and implementation of new radio access technologies [2], [3]. However, cellular architecture consisting of the macro base stations (BS) only is not able to meet the user's requirements. This is because (i) poor signal quality in indoors due to wall penetration losses, (ii) poor Quality of Service (QoS) at the cell boundary due to signal attenuation with distance from the base station and (iii) congestion and interference due to increase in the number of users. One possible solution is deploying more number of macro BS. However, the high monetary cost of deploying even a single macro BS has led to introduction of some

alternative ways of offloading traffic from macro cellular networks. Offloading is making use of some alternative network technologies which can be used for sending data meant to be sent through macro cellular network [4]. Deployment of small base stations, femtocells, along with macro BS has proved to be a very promising solution to overcome the problem of poor quality signal in the indoor regions and to offload data traffic from the macro BS which reduces congestion in the macro cellular networks [5]. As a result, the femtocell offloading has gained a lot of attention in the recent past. Femtocells operate in the licensed spectrum and can be deployed by the user himself. Offloading the mobile users tactfully from macrocell to the femtocells can improve the network wide performance and has many other benefits like improved network coverage, reduced load on the infrastructure network, increased battery life of mobile device, increased overall network throughput and network availability [6]. To reap all the benefits of offloading, the network offloading strategy should be designed in such manner that it accounts for proper load distribution in both the networks and efficient utilization of resources at the same time [7]. Offloading more users to femtocells can overload femtocells and thus have an effect on the bandwidth. On the other hand, offloading fewer users will lead to improper utilization of resources. Therefore, it is difficult to realize the benefits of offloading unless there is an appropriate method to select a target base station for offloading. An efficient offloading technique targets to achieve user throughput maximization and makes efficient use of available resources.

The offloading has many challenges associated with it such as coordination of infrastructures of the two different architectures, mobility support, business standards and pricing policies etc. Keeping in view these challenges, this paper presents an offloading strategy in integrated overlaid macro femtocellular networks which makes an efficient use of resources and maximizes the individual user throughput. It offloads the users from macrocells to the femtocells based on Received Signal Strength (RSS) of the target cell, velocity of the mobile device, data rate provided by the target cell and number of users associated with the target femtocell.

Section II presents the work related to offloading in integrated macro femtocellular networks, the offloading

strategy is discussed in section III and the simulation results are presented in section IV. Finally, section V concludes the paper.

II. RELATED WORK

The tremendous growth in the mobile data traffic has sparked an interest of the researchers in the field of integrated heterogeneous networks and consequently traffic offloading. This section presents the work carried out in this direction. The authors in [8] have presented the various technical and business perspectives of mobile data offloading. A highlight of various key technologies like femtocells, wi-fi, IP flow mobility, core network offloading and media optimization for offloading has been given. The authors in [9] have proposed two possible solutions for managing growing data traffic. An analysis is made to optimize the tradeoff between cell densification and offloading strategies to give a cost effective solution to the mobile operators and improved services to customers. It concluded that the traffic offloading cost should be minimum in order to reap the full benefits of small cell deployment. The authors in [10] have emphasized that the use of an inaccurate cell selection technique can result in interference problems and load imbalance in LTE Advanced heterogeneous networks. They have proposed an adaptive cell selection technique based on cell load estimation which improved load balancing and throughput of users located on the cell edge. An on the spot offloading strategy for offloading the data traffic through wi-fi has been presented in [11]. The strategy is based on wifi availability, coverage ratio, user mobility and data rates of available cellular technologies. The results show significant offloading gains in terms of offloading efficiency and delay. A cost function approach is presented by authors in [12] for offloading the traffic to IEEE 802.11 hotspots. The cost function approach evaluates the cell load on WLAN together with the resources occupied by each stream of traffic. The proposed approach when compared with traditional RSSI based approach showed improvements in terms of greater capacity for simultaneous VOIP calls and higher aggregate goodput at MAC level. The authors in [13] have proposed a framework called Metropolitan Advanced Delivery Network (MADNet) which targets to provide the complete energy efficiency by offloading the mobile data traffic to wifi access points. The strategy is very useful for battery constrained smart phones as it chooses the most energy efficient wifi access point.

III. CELL SELECTION STRATEGY

The process of attaching a mobile device to a cell for communication using some defined criteria is called a cell selection process. The criteria for selecting a cell for offloading should aim to offload optimal amount of traffic so that maximum throughput per user is achieved with efficient consumption of bandwidth. In integrated macro femtocellular networks, the offloading is achieved by transferring the traffic from macro BS to femto BS.

A. Conventional Strategy

In conventional process of cell selection used in offloading, the target femto BS is chosen on the basis of Received Signal Strength (RSS). Whenever the RSS from the target femto BS is greater than the source, the mobile device is offloaded to the target cell. Additionally, offset is added to reduce the unnecessary switching of base stations. When such a femto BS is found, the mobile device is attached to femto BS [14]. The cell selection is done according to equation (1).

$$\text{femto}_{\text{RSS}} \geq (\text{macro}_{\text{RSS}} + \text{offset}_{\text{static}}) \quad (1)$$

This strategy helps to move the mobile users to femtocells, as soon as the desired signal strength is available but tends to put a heavy burden on the overall network in terms of frequent switching of base stations. Considering the difference between the characteristics of the two networks, a little improvement in the cell selection process is required to offload the traffic wisely to the femtocells.

B. Proposed Multicriterion Strategy

Femtocells support slow moving users due to small coverage area of 10-20m, therefore the users moving at a high speed should not be offloaded to femtocells as it would require frequent reallocation of resources. Similarly, a femtocell which already has sufficient number of users should not be used for offloading as this would lead to more interference among users and would account for reduced bandwidth to the users. Therefore, considering RSS alone for handover process to offload traffic does not result in achieving the optimal offloading efficiency. The cell selection strategy used for offloading in this paper first finds a femtocell having RSS greater than the RSS of macro BS by a dynamic margin calculated according to the distance of mobile device from the base station. When such a femto BS is found, the value of offloading function is calculated to decide for switching of base station. The offloading function is dependent upon velocity of user, number of users in a femtocell and data rate of the femtocell along with the RSS of the femtocell. Since multiple criteria are involved in the decision process for offloading, therefore the simple additive weighting procedure is used to select a target BS.

The complete step by step procedure of selecting a femtocell for offloading is explained as below:

Step by step procedure for cell selection

- | | |
|--------|---|
| Step 1 | Analyze the importance of each criterion one by one and construct a comparison matrix (4*4) of the four deciding criteria using the 1-9 scale of comparisons [15]. The criteria are ranked as RSS, speed, users and data rate in order of importance to be used for selecting a target femtocell. |
| Step 2 | Determine the weights w_i of each criterion i using the Analytic Hierarchy Process (AHP) method such that $\sum w_i = 1$. The values for weights when calculated according to rank |

assigned in step 2 come out to be 0.523198, 0.299334, 0.120963, and 0.056505 for RSS, speed, users and data rate respectively.

Step 3 Find a femto BS such that equation (2) is satisfied.

$$femto_{RSS} \geq (macro_{RSS} + offset_{Dynamic}). \quad (2)$$

where offset is based on distance between the mobile device and serving base station. It is calculated according to the following formula given in [16]:

$$offset_{Dynamic} = \max \left\{ offset_{max} \left\{ 1 - \left(\frac{Distance}{Radius} \right)^4 \right\}, 0 \right\} \quad (3)$$

where Distance is the distance between the mobile device and serving base station and Radius is the radius of the serving cell. Offset_{max} is difference in the RSS at cell boundary and near to the base station.

Step 4 If a femto BS is found in step 3 then
 (i) Calculate the scaled value of each criterion. The scaled value lies between 0 and 1. The reason for calculating the scaled value is to scale the existing situation in the simulation according to the ideal situation. Since femtocells support slow moving users, so a user moving at a speed of 30 kmph should have a scaled value near to 1 and a user moving at a speed of 120 kmph should have a scaled value near to 1.
 (ii) Calculate the value of the offload function using simple additive weighting method by multiplying the weight of each criterion with its scaled value. It is calculated as given in equation 4:

$$f_{offload} = w_{RSS} * \check{S}_{RSS} + w_{speed} * \check{S}_{speed} + w_{users} * \check{S}_{users} + w_{rate} * \check{S}_{rate}. \quad (4)$$

where w_{RSS} , w_{speed} , w_{users} , w_{rate} , \check{S}_{RSS} , \check{S}_{speed} , \check{S}_{users} , \check{S}_{rate} are weights and scaled values assigned to the RSS of the femtocell, speed of the user, users in the target femtocell and data rate of femtocell.

(iii) If $f_{offload} \geq 0.5$ then the mobile device is attached to the femtocell. The mobile device remains attached to the femtocell as long as femtocell provides the requisite RSS. When RSS of femtocell deteriorates less than the threshold value, another suitable femto BS is found using the same criteria described.

Step 5 If no femtocell is found in step 3 the mobile device remains attached to macrocell. This procedure is repeated every time a mobile user gets a minimum required RSS from a femtocell.

IV. SYSTEM MODEL AND PERFORMANCE EVALUATION

An overlaid heterogeneous environment is considered for simulation consisting of a single macrocell with 50 femtocells deployed inside the macrocell at random positions. The simulations are carried out for increasing number of mobile users generated randomly inside the macrocell and moving according to the random direction mobility model. The mobile users enter and leave the femtocell coverage zones during their movement. It is assumed that the coverage of macrocell is always available except some coverage holes. The mobile traffic is switched over to femtocell whenever coverage is available from femtocell. As soon as the femtocell connectivity is lost, a new femtocell which fulfills the requisite conditions is found otherwise the traffic is transmitted through macro BS. The simulation is carried out for 180 seconds with number of users varying from 50 to 100. A shared spectrum operating at a bandwidth of 20 MHz is considered.

The simulations are run for the conventional strategy by taking the values of 2, 6 and 10 dBm for the offset while the proposed strategy is run with dynamic offset as explained in section 3. The time for which the user stays in the femtocell depends upon the RSS of the femtocell in the conventional strategy and RSS of the femtocell and the value of the offload function, $f_{offload}$ in the proposed strategy. The two strategies are evaluated for their offloading efficiency. The offloading efficiency is considered to be dependent on fairness index and computational efficiency.

$$Offloading\ Efficiency = f(\text{fairness index, computational efficiency})$$

The results of the two strategies are analyzed with respect to above mentioned parameters which govern the offloading efficiency of the corresponding strategy.

A. Fairness Index

One of the major goals for offloading data traffic from cellular networks is the fair share of resources to all the users. Fairness can be measured in terms of all users having a fair share of bandwidth, the QoS requirements of all users being satisfied, energy consumption for all users being minimized, the throughput for all users being improved [17]. Jain's fairness index [18] is used here to measure the fairness level of the two strategies. It is a quantitative fairness measure which provides a description of overall system fairness. Jain's Index is defined and represented in equation (5):

$$Fairness\ Index\ (FI) = \frac{(\sum_{i=1}^n x_i)^2}{n * \sum_{i=1}^n x_i^2} \quad (5)$$

where x_i is the throughput (in Kbps) of the i th user and n is the number of users.

To calculate the throughput of each user, the size of each packet received by each user is measured and averaged over the simulation period as shown in Table I.

TABLE I: AVERAGE THROUGHPUT OF THE USERS

Number of Users	Speed = 30kmph				Speed = 120kmph			
	Conventional			Proposed	Conventional			Proposed
	HOM=2	HOM=6	HOM=10	Dynamic	HOM=2	HOM=6	HOM=10	Dynamic
50	5.92	5.53	5.17	8.05	2.03	1.83	2.66	3.03
60	5.87	5.68	5.04	8	1.98	1.98	2.53	2.98
70	5.55	5.41	4.86	7.68	1.66	1.71	2.35	2.66
80	5.42	5.18	4.79	7.55	1.53	1.48	2.28	2.53
90	5.26	5.02	4.71	7.39	1.37	1.32	2.2	2.37
100	4.38	3.79	4.91	6.51	0.49	0.09	2.4	1.49
Average	5.4	5.10	4.91	7.53	1.51	1.40	2.40	2.51

TABLE II: AVERAGE THROUGHPUT AND FAIRNESS INDEX

Strategy	Offset	Speed = 30kmph		Speed=120kmph	
		Average throughput (in Mbps),	Fairness Index, $\frac{(\sum_{i=1}^n x_i)^2}{n \cdot \sum_{i=1}^n x_i^2}$	Average throughput (in Mbps)	Fairness Index, $\frac{(\sum_{i=1}^n x_i)^2}{n \cdot \sum_{i=1}^n x_i^2}$
Conventional	Static=2	5.40	0.55	1.51	0.54
	Static=6	5.10	0.56	1.44	0.54
	Static=10	4.91	0.56	2.40	0.67
Proposed	Dynamic	7.53	0.60	2.51	0.75

A significant improvement in the average throughput per user is seen when proposed strategy is used. The increase in throughput is because of the fact that the mobile device maintains a stable connection with the base station and therefore more number of bits is received per second.

The throughput derived in this manner is used further to calculate the fairness index. The average throughput per user and average fairness index for the two strategies with different values for static offset in conventional strategy and dynamic value for offset in proposed strategy is shown in Table II. The value of fairness index (FI) falls between 1/n and 1 for n users. FI = 1/n is the worst case when only one user is using the complete bandwidth while FI = 1 is the best case when each user is having an equal share of the bandwidth. Higher value of fairness index depicts that the scheme is fairer in allocation of resources. Fig. 1a and 1b show the variation of fairness index with increasing number of users at the speed of 30 kmph and 120 kmph.

The results presented in Fig. 1a and Fig. 1b are summarized as

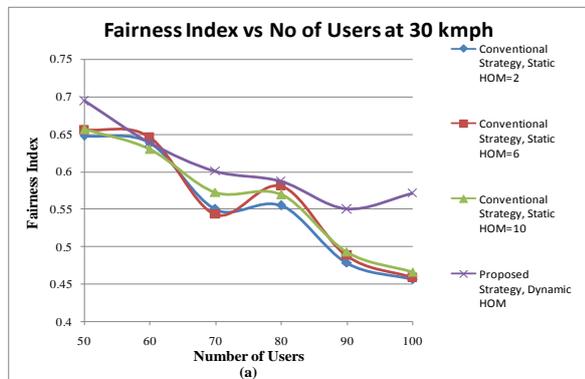


Fig. 1a. Fairness index vs No of users at 30 kmph

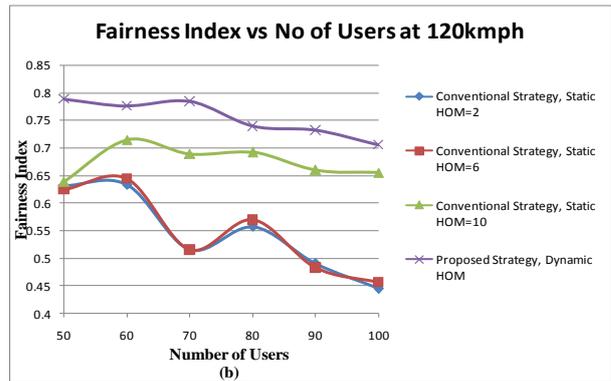


Fig. 1b. Fairness index vs No of users at 120 kmph

- (i) The proposed strategy results in the better distribution of resources at both the speeds.
- (ii) For high speed users, the fairness index drops significantly in conventional strategy with a small offset value as the number of users increase while proposed strategy shows a stable value for large number of users also.

B. Computational Efficiency

The time taken to perform the total operations during a cell selection process defines the computational efficiency of the strategy.

The conventional strategy compares only the RSS of the source cell with the target cell in the cell selection process and therefore the time taken in terms of CPU clock cycles is very less. However, insufficient input to the cell selection process leads to frequent calls to cell selection process and inefficient use of resources. In proposed strategy, four input parameters are required and the scaled value for each parameter is also calculated. The total CPU clock cycles for doing all these operations are large.

The number of CPU clock cycles is measured during the simulation each time a target cell is searched for offloading and averaged to get average time required to complete the cell selection process once, denoted by Avg_time_{Cell_Selection}. The computational efficiency is calculated as given in equation (6):

$$\text{Computational efficiency} = N * \text{Avg_time}_{\text{Cell_Selection}} \quad (6)$$

where N is Number of times a cell selection process is invoked.

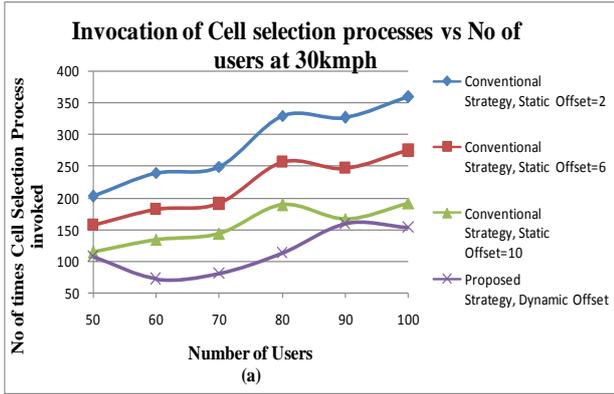


Fig. 2a. Cell selections vs No of users at 30kmph

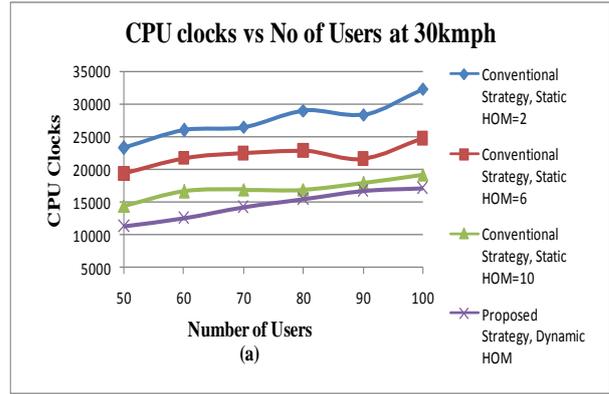


Fig. 3a. CPU clock cycles vs No of users at 30kmph

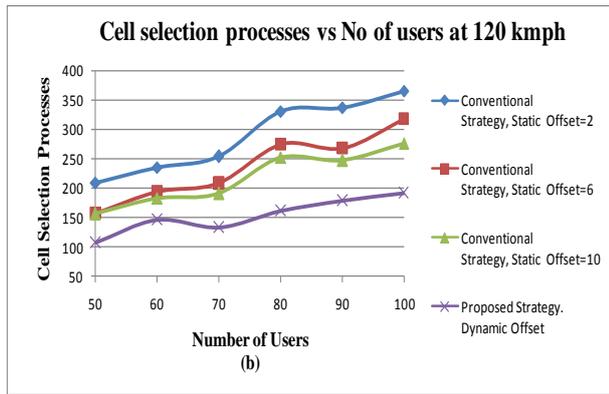


Fig. 2b. Cell selections vs No of users at 120kmph

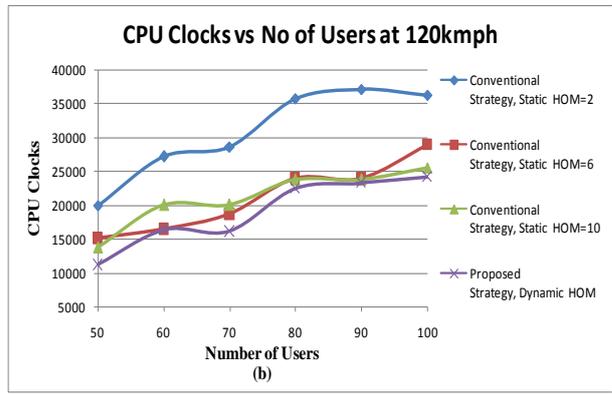


Fig. 3b. CPU clock cycles vs No of users at 120kmph

Fig. 2a and Fig. 2b show the number of cell selection processes at 30kmph and 120kmph.

As shown in Fig. 2a and Fig. 2b, the cell selection process is invoked less number of times in proposed strategy as compared to the conventional strategy.

This is because of the fact that sufficient number of input is taken to decide for cell selection resulting in a stable decision. In the conventional strategy, the use of insufficient input parameters for cell selection leads to invocation of cell selection process more frequently. Although the complexity of proposed strategy is high due to involvement of multiple criterion but the reduced number of cell selections leads to less number of overall CPU clock cycles used in the cell selection process during the simulation time as shown in Fig. 3a and Fig. 3b.

TABLE III: CPU CLOCK CYCLES USED IN CELL SELECTION PROCESS

Strategy	Offset	Average CPU clock cycles = Average CPU clocks required to complete the cell selection process * Average number of cell selections	
		Speed=30kmph	Speed=120kmph
Conventional	Static=2	99.1*284=28144.4	106.6*288=30700.8
	Static=6	104.4*218=22759.2	87.8*236 = 20720.8
	Static=10	106.8*156=16660.8	97.5*217 = 21157.5
Proposed	Dynamic	119.9*114=13668.6	126.1*155=19545.5

As shown in Table III, the average number of CPU clock cycles required to complete the cell selection is more in the proposed strategy as compared to the conventional strategy. However, the average number of cell selection processes are less and therefore the average CPU cycles required in the complete simulation process is less.

Fig. 3a, 3b and Table III show a tradeoff between the computational complexity and the number of cell selection processes. In conventional strategy, the computational complexity is less but there is huge number of cell selection processes invoked. The overall improvement in the computational efficiency provides a support for the proposed strategy for offloading. Further, the computational complexity can be reduced as technology advances.

The CPU cycles used in the two strategies for the speeds of 30kmph and 120kmph is shown in Table II.

Table III can be used to calculate the system efficiency of proposed strategy. The proposed strategy improves the system efficiency by 39.3% and 19.2% when simulations were carried out for the speeds of 30kmph and 120kmph respectively.

V. CONCLUSION

The exponential increase in the data traffic in past years is going to be more intensified in the years to come. Femtocell deployment can reduce the load on macrocell to a great extent. A novel strategy to offload macrocell has been proposed in this paper. The two strategies of

cell selection for offloading namely, conventional strategy and proposed strategies have been discussed. The conventional strategy is based on RSS only. This strategy is very simple and tries to offload maximum traffic to femtocells as soon as the desired RSS is available. However, the small input in selecting a target cell for offloading causes frequent switching of base stations and unfair use of resources. The proposed strategy is based on an offload function, f_{offload} dependent upon the RSS, speed of the user, number of users in the target cell and data rate offered by the target cell. More number of input parameters for cell selection makes the process complex but provides a fair share of resources to all the users. For both the approaches, the fairness index and computational efficiency based on the number of CPU clock cycles used in the cell selection over the complete simulation period is measured and compared by changing the number of users at a speed of 30kmph and 120kmph.

The simulation results show that as the number of users increase the proposed strategy maintains the fair distribution of resources at 0.55 and 0.7 at the speed of 30kmph and 120kmph respectively. A tradeoff is seen between the increased complexity of cell selection process and total number of times the cell selection process is invoked. It is observed that even if the proposed strategy is complex but the overall number of CPU clock cycles required are still less showing that the proposed strategy improves the computational efficiency of the system by 39.3% and 19.2% when simulations were carried out for the speeds of 30kmph and 120kmph respectively.

REFERENCES

- [1] H. A. Mohammed, R. Nordin, and M. Ismail, "A review on intelligent base stations cooperation management techniques for greener LTE cellular networks," *Journal of Communications*, vol. 9, no. 12, pp. 937-945, 2014.
- [2] J. Gozalvez and B. Coll-Perales, "Experimental evaluation of multihop cellular networks using mobile relays," *IEEE Communications Magazine*, vol. 51, no. 7, pp. 122-129, 2013.
- [3] Y. Song, P. Y. Kong, and Y. Han, "Power-optimized vertical handover scheme for heterogeneous wireless networks," *IEEE Communications Letters*, vol. 18, no. 2, pp. 277-280, 2014.
- [4] S. Dimatteo, P. Hui, B. Han, and V. O. Li, "Cellular traffic offloading through WiFi networks," in *Proc. 8th International Conference on Mobile Adhoc and Sensor Systems (MASS)*, October 2011, pp. 192-201.
- [5] V. Chandrasekhar, J. Andrews, and A. Gatherer, "Femtocell networks: A survey," *IEEE Communication Magazine*, vol. 46, no. 9, pp. 59-67, Sep. 2008.
- [6] F. Rebecchi, M. D. De Amorim, V. Conan, A. Passarella, R. Bruno, and M. Conti, "Data offloading techniques in cellular networks: A survey," *IEEE Communications Surveys & Tutorials*, vol. 17, no. 2, pp. 580-603, 2015.
- [7] S. Singh, H. S. Dhillon, and J. G. Andrews, "Offloading in heterogeneous networks: Modeling, analysis, and design insights," *IEEE Transactions on Wireless Communications*, vol. 12, no. 5, pp. 2484-2497, 2013.
- [8] A. Aijaz, H. Aghvami, and M. Amani, "A survey on mobile data offloading: Technical and business perspectives," *IEEE Wireless Communications*, vol. 20, no. 2, pp. 104-112, 2013.
- [9] C. C. Hsu, J. M. Chang, and Y. W. Chen, "Joint optimization for cell configuration and offloading in heterogeneous networks," in *Proc. 35th Annual IEEE International Conference on Computer Communications, IEEE*, pp. 1-9, April 2016.
- [10] M. A. Gadani, M. A. Ahmed, C. K. Ng, N. K. Nordin, A. Sali, and F. Hashim, "Review of adaptive cell selection techniques in LTE-Advanced heterogeneous networks," *Journal of Computer Networks and Communications*, vol. 3, 2016.
- [11] F. Mehmeti and T. Spyropoulos, "Performance analysis of mobile data offloading in heterogeneous networks," *IEEE Transactions on Mobile Computing*, vol. 16, no. 2, pp. 482-497, 2017.
- [12] S. Wiethater, M. Emmelmann, R. Andersson, and A. Wolisz, "Performance evaluation of selection schemes for offloading traffic to IEEE 802.11 hotspots," in *Proc. International Conference on Communications*, June 2012, pp. 5423-5428.
- [13] A. Y. Ding, B. Han, Y. Xiao, P. Hui, A. Srinivasan, M. Kojo, and S. Tarkoma, "Enabling energy-aware collaborative mobile data offloading for smartphones," in *Proc. 10th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON)*, pp. 487-495, June 2013.
- [14] M. N. Halgamuge, H. L. Vu, K. Rarnamohanarao, and M. Zukerman, "Signal-based evaluation of handoff algorithms," *IEEE Communications Letters*, vol. 9, no. 9, pp. 790-792, 2005.
- [15] T. L. Saaty, "Decision making with the analytic hierarchy process," *International Journal of Services Sciences*, vol. 1, no. 1, pp. 83-98, 2008.
- [16] B. Zdenek and P. Mach, "Adaptive hysteresis margin for handover in femtocell networks," in *Proc. The 6th International Conference on Wireless and Mobile Communications*, 2010, pp. 256-261.
- [17] H. Shi, R. V. Prasad, E. Onur, and I. G. M. M. Niemegeers, "Fairness in wireless networks: Issues, measures and challenges," *IEEE Communications Surveys & Tutorials*, vol. 16, no. 1, pp. 5-24, 2014.
- [18] R. Jain, D. M. Chiu, and W. R. Hawe, "A quantitative measure of fairness and discrimination for resource allocation in shared computer system Hudson," MA: Eastern Research Laboratory, Digital Equipment Corporation, vol. 38, 1984.



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