Adaptive power control scheme to mitigate cross cell interference in Macro-Femto small cell networks

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Abstract: In certain scenarios, the CCI may seriously degrade the system performance, and therefore should be avoided or mitigated. The interference conditions in a femto-cell network greatly depend on the access mode used by the femto-cell network. Closed-access and open-access are two different access options commonly used by femtocells. In the closed access mode, the macro-cell user equipment's (MUEs) that may join a particular femto-cell are restricted to a certain group, while all MUEs are allowed to make hand-off to femto-cells without any restriction for the open access mode. Even though interference problems may be greatly resolved with the open access operation, there may be some other problems such as privacy issues, extra burden on the backhaul of a femto-cell's owner etc. On the other hand, for the closed access mode, there may be scenarios where the interference reaches at intolerable levels. In order to overcome this issue of interference with macro users, variable power control algorithms are needed. In this work, we have presented four algorithms on group priority-based power transmission of femto cells in order to provide quality of service. First algorithm uses fixed home evolved NodeB (HeNB) power throughout whole process, second algorithm uses effective power control based on interference measure from macro-NodeB and third uses home evolved NodeB power-control depending upon home evolved NodeB and macro-cell user equipment's (MUEs) path losses such that home user is allocated to one of the three groups (low-mid-high throughput) having different target throughput needs as far as their power necessity is fulfilled in order to delivery of desired traffic loads. The fourth algorithm uses combination of all three depending upon interferences changes i.e., if the femto cell is in the boundary of hexagon (macro cell) it uses fixed power but as it goes towards the center, it starts using the other two algorithms as well. Simulation has been carried out on number of test cases by varying the quantity of macro and femto cells as well as varying number of femto and macro users. In among all the algorithms, presented hybrid algorithm works effectively as it can chose any algorithm depending upon the locality of femto cells in the topology i.e., its choses algorithm three when femto cell is nearest to center of macro cell polygon in which least power is required and when it is near boundary it uses algorithm three (more power) to mitigate the interference with that of macro cell.

Keywords – Femto cells, 5G networks, interference, LTE, power consumption etc

1. Introduction

Femtocells otherwise called Femto access points (FAP) are low power (10-100mW), short-range (10-30m), low-cost small femtocells that function in the licensed spectrum [1] and depicted in Figure 1. Femto means one-quadrillionth (10-15) and is installed in homes, workplaces, and other places by the user himself to ensure continuous coverage with a better voice and data reception. It can accommodate four users and beyond in a residential setting depending on the description number and hardware in place. This femtocell permits service providers to enlarge coverage indoors where access would otherwise be restricted or unavailable. It typically connects to the service provider's network employing broadband [1]. Since femtocells are meant to be operated by the user himself without any practical support from the operator, this is bound to result in very dense deployment situations and interference problems abound thereby making the entire network ineffective.

Figure 1: Typical indoor Femtocell [1]

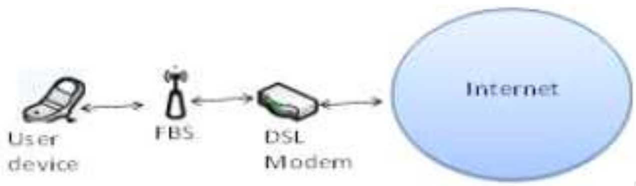

Figure 2: User device connected to an operator's core network in a femtocell

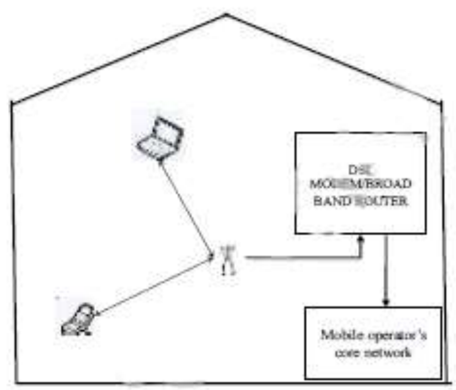

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Figure 3: A representative indoor femtocell and users

Interference Categories Experienced by Mobile Users

Interference is an unpleasant situation experienced among mobile users when two or more mobile devices share the same communication channel or frequency. Intercell interference occurs when a cell overlaps with subsequent cells because of reasons such as delayed multipath signals [1].

Co-Tier Interference

This relates to interference between neighboring femtocells occurring in two different forms. The two forms are uplink co-tier co-tier interferences [1]. This type is caused by network elements that belong to the same layer of the network.

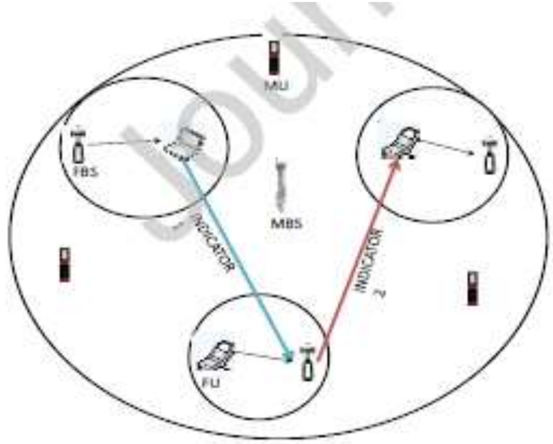

Figure 4: A scenario showing co-tier interference between neighboring FBSs

Cross-Tier Interference

This relates to interference between the macro-cell layer and the femtocell layer and vice versa. The uplink cross-tier interference is a situation where femtocell users (aggressors) cause interference to its neighboring macro-cell base station (victims) or where macro-cell users cause interference to a nearby femtocell base station as shown in indicator 3 in Figure 5 [1].

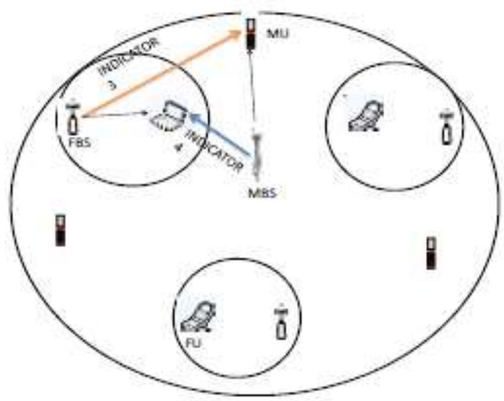

Figure 5: A scenario showing cross-tier interference between FBSs and MBSs [1]

The CoMP

Coordinated multipoint transmission and reception refers to transmission/reception of the data to/from user equipment's located at multiple cells. CoMP coordinates base station antennae deployed at a number of sites which are in feasible proximity to each other [6]. CoMP in LTE-A context includes various possible coordinating schemes among access points. The 3GPP technical report on further enhancements of E-UTRA physical layer aspects offer two major categories in CoMP scheme which are namely Coordinated Scheduling/Beamforming (CS/CB) and Joint Processing (JP) [7] which are explained below. eNBs should be in coordination to reduce the inter-cell interference in the system for both uplink and downlink. LTE requires the information of radio resource allocation, related to the reference UE to be available at all base stations in the coordination cluster. Therefore, the latency of the links should be very low so that the necessary coordination information can be exchanged in a very short time frame.

As soon as femtocells are deployed in large numbers, they can have a great impact on the current wireless network. Several interference improvements schemes have been developed already to handle interference between a femtocell and the macrocell. Moreover, interference amongst femtocells has also become an unavoidable issue, especially when they are densely deployed. This is therefore a motivating factor why this study is necessary at this time. To address the problem of interference between femtocells and macrocells, channel allocation schemes are implemented because of the manner femtocells and macro users are deployed. Femtocells are user deployed and can be operated by the users themselves. This shows that interference can occur at any time especially when the user is not prepared for it.
Ghazi et al. [3] notice that none of the studied scheduling algorithms, can satisfy all the required performances in the management of femto-cell traffic for the flows studied and for each of the evaluated criteria (spectral efficiency, Goodput

and Fairness). In order to meet the requirements of femto cells in 5G networks, in terms of throughput, capacity and quality of service, we should use other scheduling algorithms that offer a better QoE for the different multimedia streams. Lee et al. [4] proposed a novel CR-based resource allocation scheme for femto-cell networksin two-layered cellular operation environments. With the aid of spectrum sensing, the fBS can allocate the best sub-channels to its users, while effectively managing interference. Bhatia et al. [5] reduces the effect of cross tier interference reduces throughput of the macro-user and femto user. Further, the throughput of the macro-user was calculated with the application of Fixed, Threshold SINR power control and Adaptive power control. Rajeswari et al. [8] analyzed the performance of Macro and Femto cell and considered the radiation level in both the cells. It has been from the results that the throughput of Femto cell is higher than the Macro cell. It is evident that the radiation level in Macro cell is very much higher than that of Femto cell. The same advantage of power reduction and performance has been obtained in sectored Femto cell networks. Moon et al. [9] proposed a new RSS-based handoff algorithm that is suitable for the hierarchical macro/femto cell networks with respect to providing successful handoff from an m-BS to an f-BS. The proposed algorithm reflects large asymmetry in the transmit power of the cells and its performance is analyzed by using the statistical properties of RSSs. Fradi et al. [10] focused on how to allocate frequencies to macro-cells with femto-cells coexistence. They presented an efficient and simple allocation scheme based on FFR technique applied to a macro-cell divided into three neighbor regions. Lei et al. [11] analyzes the problem of location management for overlay LTE macro and femto cells. Based on the analysis, an efficient location management mechanism is proposed. In the proposed mechanism, different TA for macro and femto cell is adopted and two step paging is conducted for femto and macro cells. The main purpose is to minimize paging overload in macro cells and optimize the overall location management cost. Performance evaluation shows the advantage of the proposed mechanism.

The contribution of this research is to understand behavior three controlling power algorithm to reduce effect of diverse categories of interferences caused in LTE network.

2. Matrials and Methods

Presented a hexagonal Macro deployment function which localizes the macro cell in hexagonal pattern. Presented a femto cell deployment function in which femto cells can be deployed at three different locations of a Macro cell i.e., border, center and random. Implemented fixed power of femto cells-based behavior in which HeNB transmission power is set manually by network operator. HeNB power does not depend on the changes in the topology changes and the traffic scenario. It remains stable [2]. Implemented smart power control of femtocells in which maximum DL transmit power of HeNB is adjusted as function of air interface measurements to avoiding inquisitive with macro cell UEs [2]. Implemented HeNB-MUE path loss-based power control of femto cells in which the downlink transmit influence of HeNB is balanced by considering the way loss between the HeNB and an open-air neighbor MUE incorporating infiltration loss keeping in mind the end goal to give better impedance alleviation to the MUE while keeping up adequate HeNB scope for HUEs [2]. Carried out simulation in Matlab to investigate properties of these three algorithms and presented a hybrid algorithm which uses all three algorithms to reduce the interference with macro cells. Carried out simulation and analysis.

Parameters used for simulation

Following are the parameters that are used in simulation.

Table 1: Parameters used for simulation

Parameters	Value
inter-site distance (ISD)	1732m
Required Reference signal receive power (RSRP)	-70 milli decibels
Macro Power (max)	46 milli decibels
Macro Power (min)	36 milli decibels
Femto Power (max)	10 milli decibels
femto Power (min)	-10 milli decibels
Gain for Antenna	14 decibels
Parameters a, b, g, k respectively	0.7,60 ,-30,0.1
Frequency	2 kilo hz
Carrier Bandwidth	10 mega HZ
Number of Resource blocks	50
Number of Subcarriers	12
Bit error rate (BER)	10^ (-6)
Alpha	-1.5 / log (5 * BER)
MUE speed	3km/h
Distribution of MUS within Macrocell	Uniform
Target throughput	1.2, 0.2, 0.05 megabits/s for group 1,2,3 respectively

Steps in initial Random Deployment of Macro and Femto Cells and Users

Step 1: Initialize parameters

Step 2: Generate Macro cells in hexagon Grid and Femto cells in circle

Step 3: Deployment selection

Step 4a: In case of Border, Generate and localize Femto users by taking .80 to 100 as radius range of Macro for deployment.

Step 4b: In case of Center, Generate and localize Femto users by taking random b/w 0 and 1 as radius range of Macro for deployment.

Step 4c: In case of Random, Generate and localize Femto users by taking .50 to .80 as radius range of Macro for deployment

Step 5: Localize macro users in random fashion by considering No overlap between them.Step 6: Add more Femto users after few steps of running session.

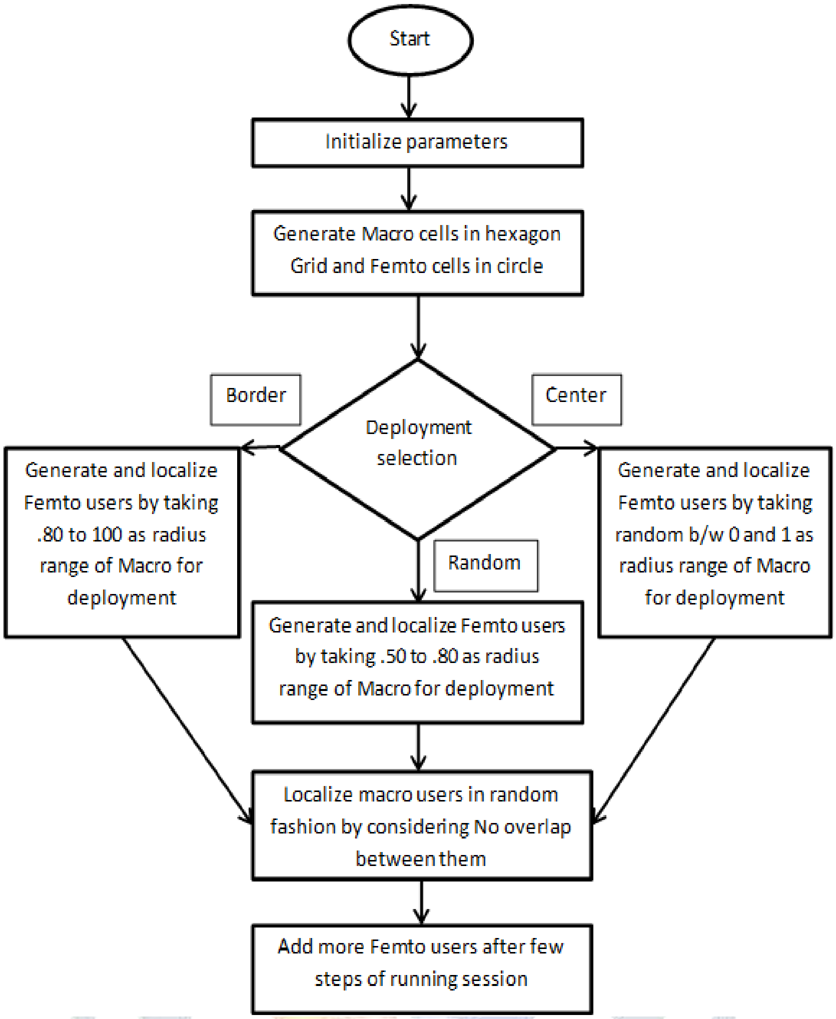

Figure 6: Flowchart for initial random deployment of Macro and Femto cells and users

Steps for Femto Power Calculation and Throughput Calculation

Step 1: Initialize parameters

Step 2: For each running step, allocate max power to Macro cell and to femto cell

Step 3: Calculate Subcarrier power using 50 RBs with 12 subcarriers each for Macro cell

Step 4: Algorithm used for femto subcarrier power

Step 4a: In Algorithm 1, Use fixed femto Power

Step 4b: In Algorithm 2, $P_{tx} = \max(\min(\alpha \times (CRS\,\hat{E}_C + 10\log(N_{RB}^{DL} \times N_{SC}^{RB})) + \beta, P_{\min})$

Step 4c: In Algorithm 3, $P_{offset} = MEDIAN(P_{offset\_o} + K * LE, P_{offset\_\max,} P_{off\_\min})$

Step 4d: In Algorithm 4, hybrid algorithm

Step 5: Calculate Subcarrier power using 50 RBs with 12 subcarriers each.

Step 6: Calculate user RSRP and user's throughput

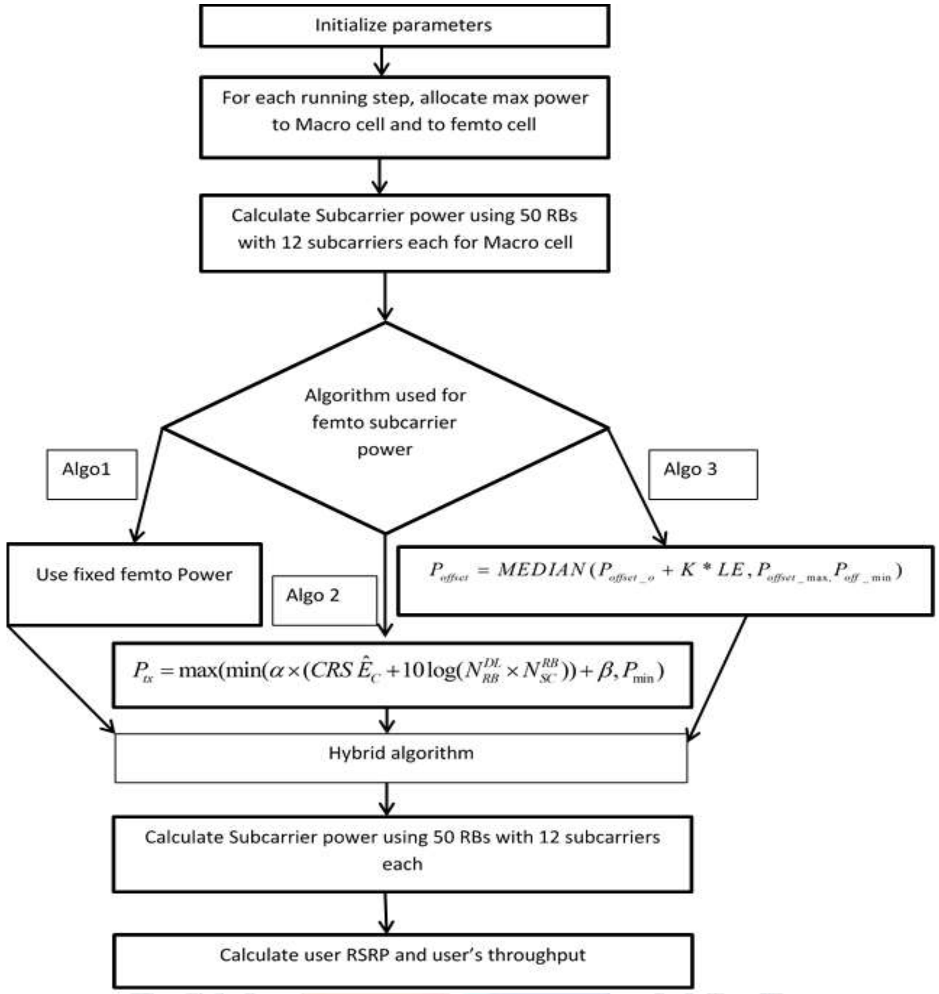

Figure 7: Flowchart for Femto power calculation and throughput calculation

4. Results and discussions

Experiment results have been taken by taking 3*3 size macro cell networks. For the needs of results' presentation, we conducted an experiment in which Nine macrocell and five femto cell network with 219 MUEs, 51 initial HUEs gradually distributed in time domain are considered. MUE population remains constant in the simulation but HUE (femto users) is in increased to 821 in which 770 are inserted during simulation as the iterations rises. Figures beneath show the diagram of whole SCN topology. To all the more likely present the outcomes, we center on femto cell number 10-16 of the topology that displays the correlation of the mean throughput and SINR accomplished by every one of the HUEs that live in the same femto cell. Besides, Figure portrays the advancement of HeNB transmit control for each power control calculation in time space. The terms used in the results are defined below according to which graphs has been presented.

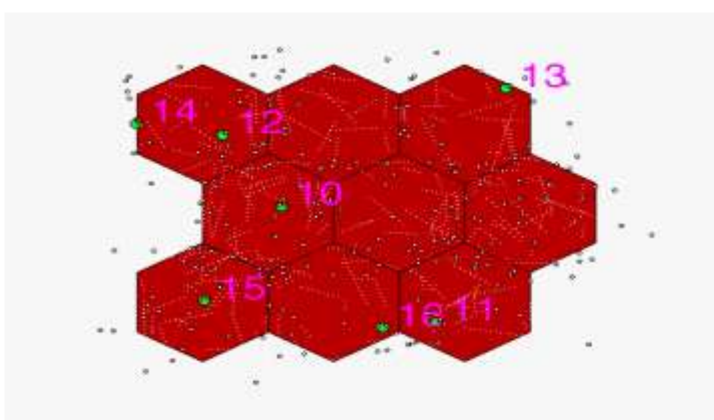

Figure 8: Location of macro users and femto cell users after simulation

Figure above shows the macro users and femto cells after simulation. As seen above. Macro users have been seen moved from their original locations as mobility of macro users has been used in the simulation but femto users are kept as without movement. Below are the throughput and power line graphs by considering four algorithms used for power control in the simulation. Graphs and data have been explained for femto cell one is 10 in topology diagram.

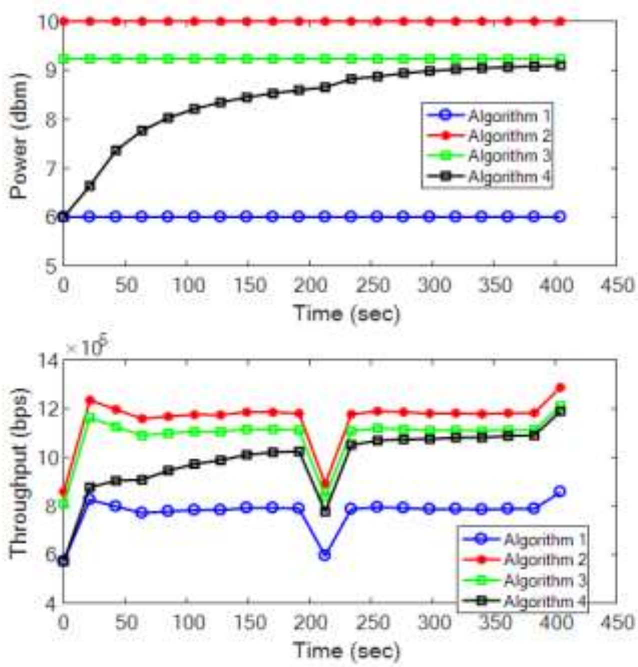

Figure 9: Femto power and throughput graphs for femto cell one (10 in topology diagram)

As seen above, for first algorithm fixed power of 6 dbm has been kept and its has been used by 12 subcarriers. The total throughput is more in first algorithm than the second and less than the third algorithm. It comes as throughput of users depends upon RSRP (Reference Signal Received Power) which in turn uses femto subcarrier power+ antenna gain and negative of pathloss. As subcarrier power in second algorithm is less than the other two it has low throughput. For algorithm three there is less power among all. It causes due to pathloss factor which in turn vary from one femto cell location to another and hence variable power for all five femto cells. For algorithm two it uses the max function from max femto power, power considers indoor femto pathloss and outdoor macro pathos. Hence it chooses the max value which comes to be maximum femto power supplied which is 10dbm.

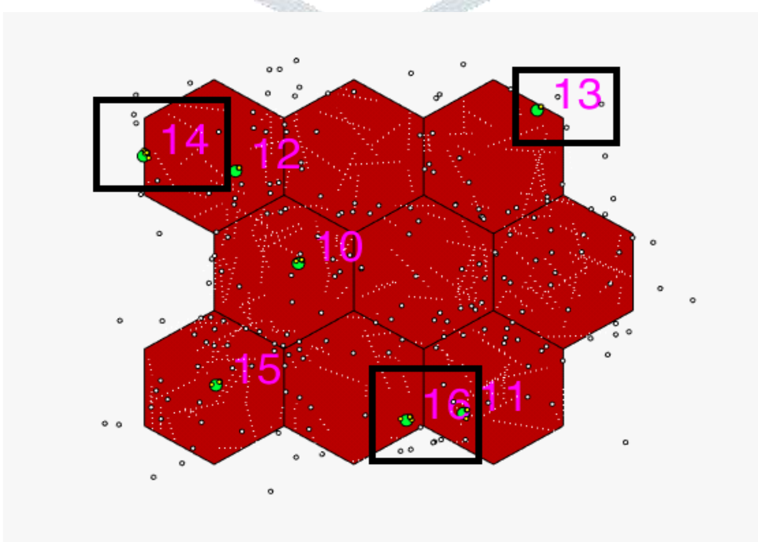

Figure 10: Image showing femto cells away from macro cell centers

Figure above shows that there is more path loss when femto cells are away from its main macro cell. As shown above, cell 14 is more away and near to border area and hence more path loss which results in fewer throughputs as it depends on it.

Table 2: Algorithm selection by hybrid algorithm for femto cell 10

Algorithm selection by hybrid algorithm		
Group 1	Group 2	Group 3
1	1	1
1	3	1
1	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1
3	3	1

Table 3: Power consumed at each time step by different algorithms for femto cell number 10

Power consumed at each time step by different algorithms for femto cell number 10			
Algo1	Algo2	Algo3	Algo4
6	10	9.234291	6
6	10	9.234291	6.63701
6	10	9.234291	7.362827
6	10	9.234291	7.768616
6	10	9.234291	8.028865
6	10	9.234291	8.210267
6	10	9.234291	8.344047
6	10	9.234291	8.446827
6	10	9.234291	8.528285
6	10	9.234291	8.594442
6	10	9.234291	8.649246
6	10	9.234291	8.824596
6	10	9.234291	8.872586
6	10	9.234291	8.939426
6	10	9.234291	8.98541
6	10	9.234291	9.018984
6	10	9.234291	9.044575
6	10	9.234291	9.064728
6	10	9.234291	9.08101
6	10	9.234291	9.09444

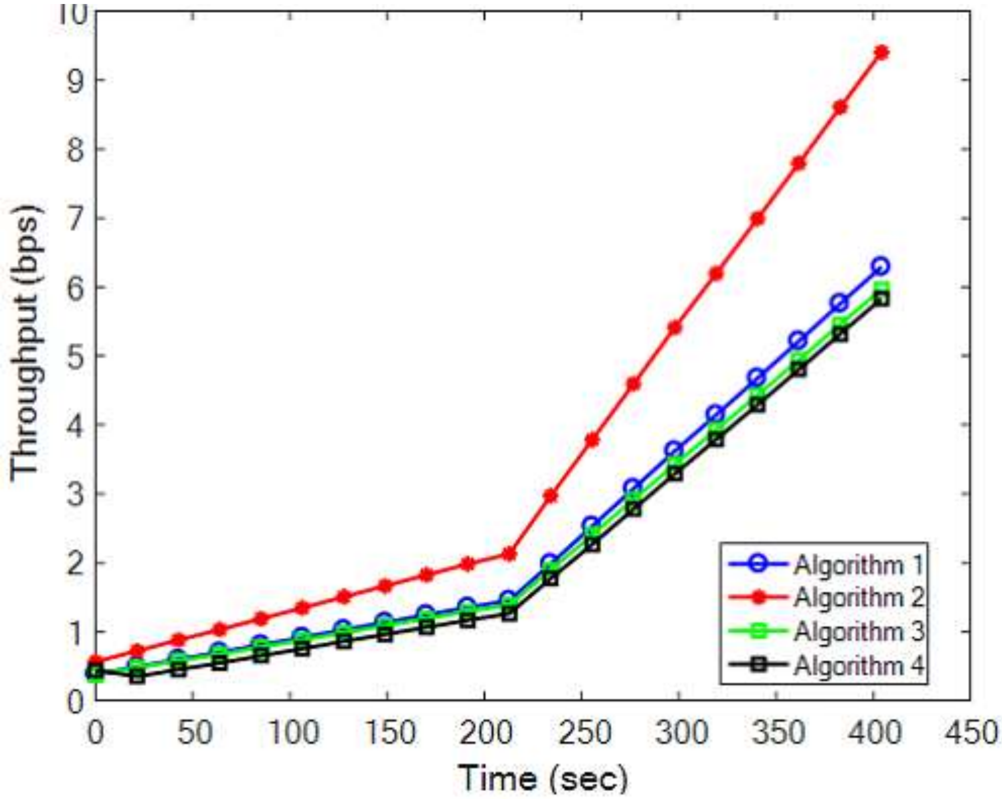

Figure 11: Achieved throughput using all four algorithms for femto cell 10

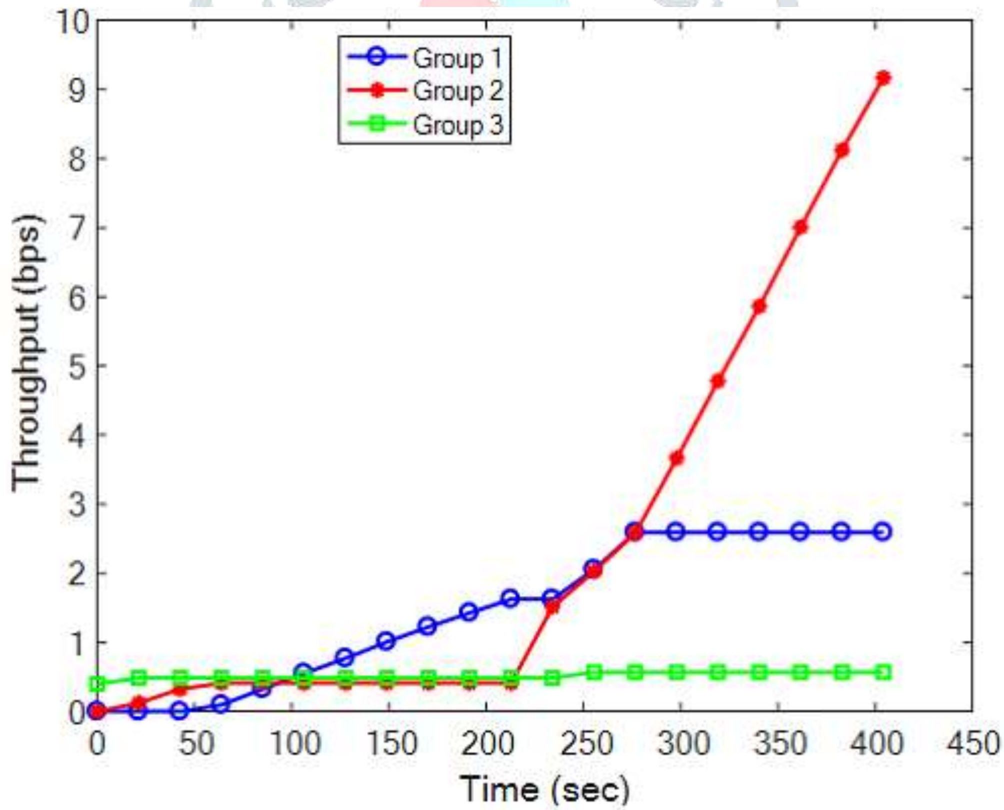

Figure 12: Groupwise achieved throughput for cell 10 using hybrid algorithm

5. Conclusion

The emerge of wireless cellular networks and their strive on providing high quality and high data rate services have led the researches toward introducing femto-cell as one of the leading technologies of LTE that deals with coverage issues in indoor environments. Femto-cell is a small, low power, and cost-effective home base station that is installed by the consumer to connect to the network through broadband connections such as digital subscriber line or cable modem. Also, system capacity and QoS enhancements are other reasons to deploy the femto-cells over the macro-cell layout in the next generation of mobile networks. Installation of femto cell in macro cells causes interference to femto cell users depending upon the location of femto cell which needs different amount of power. In this work, four algorithms has been presented 1) Fixed HeNB power setting 2) Smart power control based on interference measurement from macro NodeB 3) HeNB power control based on HeNB-MUE path loss 4) combination of first three algorithms. As different algorithms have its advantages and drawbacks, a combination of these has been observed and effectively utilized in fourth algorithm so that each femto cell choose one of the algorithms according to its users and its location from corresponding macro cell. Algorithm 3 is best in interference reduction from macro cell which uses about 9.23 dbm of power. If cell 10 is compared where femto cell is located in center of the macro cell, Proposed algorithm uses 8.374 dbm of power on average which gives 9.3 % of power saving and by achieving the desired target throughput for all three groups. It has been observed that algorithm four choses algorithm three when femto cell is on the boundary of the macro cells, as there is least interference to the macro cell center in which little power is efficient to achieve the target throughput. When femto cell is near to center, it uses algorithm one in group 3 as it needs smaller throughput target means less power so that least interference is achieved with that of macro cell users and algorithm three is used for the first and second group as more throughput was required.

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