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Femtocell network optimization applying vertical handoff algorithm

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Abstract. Femtocells are low power base stations that provide better radio coverage to portable users through femtocell access point (FAP) at the indoor scenario. The access node named as FAP, perform as the base station (BS) for the femtocell and take help of internet as backhaul to get connected with MBS. In these emerging dual layer networks, handoff facilitates for a mobile user moving from a network coverage of macro base station (MBS) to a network coverage of femto base station (FBS) to get advantages of quality network service of femtocells with respect to user satisfaction and system performance. In this paper, a strategy-based framework that implicates handoff strategies into network configuration is invoked to enact vertical handoff protocols in order to get a satisfactory outcome for both the user and the network. In vertical handoff, the process of deciding to accomplish handover based on the assessment of handoff metrics, which are the calculated quantities that provide piece of information of whether or not a handoff is require. Here, we optimize the femtocell network by vertical hand off considering salient features like reliability, latency and data rate, mobile terminal conditions, price function, network conditions, and user priority. Several optimization scheme like received signal strength (RSS) base algorithm, RSS base algorithm including mobility, multiservice vertical handoff decision algorithm (MUSE-VDA) are introduced to escalate the hand off decision. At the end, effectiveness of the scheme is verified by extensive Matlab simulations.

Keywords: Cognitive femtocell networks, blocking probability, APUSR, RSS only scheme, RSS plus mobility scheme, MUSE-VDA

1 Introduction

The fifth generation (5G) of wireless communications make reference to the next evolutionary step after standardization of the 4G infrastructure and the next revolutionary step for wireless telecommunications in general[1, 7]. The evolutionary objectives of 5G beyond 4G include structure of packet-based orthogonal-frequency division multiple access (OFDMA) networks under such networks as the cognitive-femtocell networks[10]. Femto Cell is a low power radio access point which operates in both licensed and unlicensed spectrum and it offers network coverage from 10 meters to several hundred meters. Energy-efficient networks are required in order to protect the environment, cope with global warming, and facilitate sustainable communication growth[5]. Cognitive radio (CR) technology can play an important part in increasing the energy efficiency in radio networks. The cognitive abilities have many salient properties: accounting spectrum sensing, spectrum sharing, and adaptive transmission, which are advantageous to revamp the trade-off among energy efficiency, spectrum efficiency, bandwidth, and deployment efficiency in dual-tier networks. The femtocell has been contemplated as an encouraging technique, and non-discriminatory in current and future radio access networks[5]. Owing to its small transmitCreceive path and low transmit power property, the femtocell can reduce the consumption of energy, elongate handset battery life, and enhance the efficiency of network coverage in terms of quality of service (QoS)[5]. Handover is an occurance when a mobile user moves from one network coverage

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to network coverage of different types in heterogenous networks[11]. This can be categorized into horizontal or intra-system and vertical or inter-system cases. Horizontal handover signifies handoff within the network of same types, and vertical handover signifies handoff among the network of different types in heterogeneous networks[12]. In comparison to macro user and femto user mobility, the terminology of horizontal handoff and vertical handoff signifies the wireless access network technology rather administrative domain (such as an IP subnetwork).

The motion of a user within or among different types of service entity can be treated as intersystem mobility mechanism. One of the significant challenges for seamless vertical mobility can be referred as vertical handover, where handover is a mechanism of maintaining a mobile user's active links as it changes its point of attachment[3]. In general, handover mechanism has been reviewed based on an assessment of RSS at the mobile node, followed by a change in access point, if required, and an upgraded routing path for the user link. Another matter in vertical handover is the timely and safely transfers of a mobile user's link(s). When traditional connection transfer scheme[4] can obtain by fast handovers, there is now a essence to include the context of the link transfer, considering security interconnections, QoS assurance, and any notable processing operations. Hence, the vision of 5G needs analysis of a more adaptive and intelligent service approach to vertical handover[13]. In this paper, many optimizations scheme are introduced to increase the handover decision process and to make the following contributions: (1) the development of a handover price function which addresses a network scenario where users conduct several influential sessions among the different network entity, (2) the mechanism of MUSE-VDA, which integrates a network elimination process to decrease delay and processing in the handover evaluation, and (3) an impediment optimization evaluation for the introduced handover price function for different types of user services grow among several networks. Section 2 introduces the MUSE-VDA price function and scheme to determine service networks depending upon a diversity of user and network metrics. (4) With the help of APUSR and blocking probability matrices the efficiency of different handover optimization scheme has been judge. Finally, in Sections 4, efficiency analysis of different handover optimizations scheme and numerical outcomes exhibits the load-balancing merits of the introduced schemes, as well as the noticeable gains in satisfied user requests and a more effective use of resources. Section 5 concludes the paper.

2 System model

To define the functional role of different techniques, the performance analysis contemplates the instance of Macrocell/Femtocell handoff scenario, where RSS, channel accessibility, and spectrum are the hindrance to the development process. The review of a typical 5G network overlay scenario is illustrated in Figure 1, where two femtocell networks of different utmost transmission data rates coexist with the macrocell network. Network 1 (located at macrocell edge area) and Network 2 (located at macrocell edge area) each represent a femtocell, whereas Network 3 represents a macrocell network. The distinctive nature of mobile user is described by the extensively used random waypoint (RWP) scheme in [9]. Reconciliation has been made for the imperfections of the waypoint model detailed in [14]. A user goes in direction to reach the destination with a velocity v, that is having been selected uniformly in the interim (v min, v max). The v min and v max are having been selected to be 0.4m/s and 13m/s, respectively. When user reaches the destination point, it continues to exist as steady for a prior set pause time, and then goes in specific direction again according to the same approach. A portable user with dynamic sessions that gets into the overlay networks should make a choice of execution time and place for handoff request. If the request is recognized to be valid, the right amount of spectrum is allocated by the serving network entity. If the request is refused by one network, the request can possibly be reallocated to another network, if resources are adequately available at the second network. If 2nd / 3rd network is not accessible, the request is refused from the system.

2.1 Muse-vda price function

The MUSE-VDA vertical handover price function measures the advantage achieved by handing off to a specific service entity. It is assessed for each network n which provides the network coverage area of a

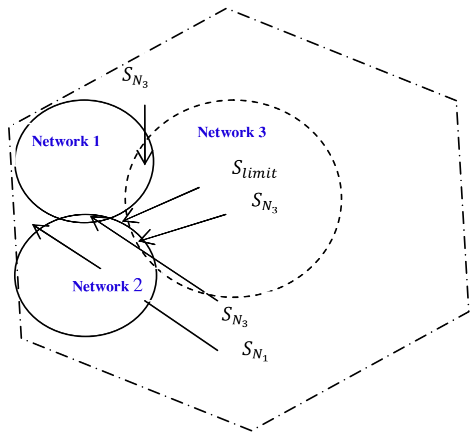


Fig. 1: Macrocell/Femtocell overlay network scenario

user. If the network select smallest outcomes of the price function, then the network can be treated as that service network entity which gives the most advantage, where the advantages are defined by the provided handover strategy. The price function assessed for network n incorporates the price of receiving each of the user's requested services from network n and can be expressed as:

$$U_n = \sum_s U_s^n, \tag{1}$$

where s indicates the user-approached services, and U_n indicates the price function per service for network n. U_s^n indicates the QoS experienced by selecting receive user approached service s from network n and can be expressed as:

$$U_s^n = \sum_j W_{s,j}^n Q_{s,j}^n, \tag{2}$$

where $Q_{s,j}^n$ depicts the normalized QoS offered by network n for the impediment parameter j and service s. Here, j is a parameter that indicates constraints like limited spectrum, battery life, and delay. $W_{s,j}^n$ Indicates weight that represents the impact of the QoS parameter for the user in a concern service network. U_s^n adds both a normalized value for the QoS parameter and a weight for influence of the parameter for the user in a concern service network.

The handover decision problem thus equals the following constraint optimization problem: In the handover decision issue, optimum choice of price function for a given service and impediment parameter, can be expressed as:

$$U^* = \arg U_{\min}^n = \sum_s \sum_j W_{s,j}^n Q_{s,j}^n \; for \; E_{s,j}^n \neq 0; \;\; \forall s, i, \tag{3}$$

where $E_{s,j}^n$ is the network elimination parameter, representing whether the impediment parameter j for service s are met by network n. Thus, $E_{s,j}^n = 1$ if j fulfilled the desired level and $E_{s,j}^n = 0$ if j unable to satisfy the desired level. It is put in place to contemplate the incapability of a network to make sure the requested QoS constraints for a specific service.

2.2 Average percentage of satisfied user requests (apusr)

Each and every user travels towards or into the overlay network area with a certain set of requests, considering different services and data rates. As explicitly stated so far, capability of the network to please user requests relies on whether the influential sessions are dealt based on RSS only scheme, RSS with mobility scheme or MUSE-VDA scheme. In collective approach, all requests from one user are included conjointly.

Hence, if a target network entity unable please total requests as a collective, then blocking up the user from the system. In the prioritized approach, each session is dealt separately, and therefore one user can have a subset of their requests fulfillment, while other part are blocked. Here, APUSR exhibits the percentage of incoming requests which successful receive service at one of the existing networks.

The APUSR for the proposed networks can be written as:

$$E[S_R] = \sum_i S_{R_i} P(R_i), \tag{4}$$

where S_{R_i} indicates APUSR for region i (Simulation model). S_{R_i} can be expressed as

$$S_{R_i} = \sum_j m_{ij} P(N_{ij}), \tag{5}$$

where m_{ij} indicates the highest APUSR which is received from network N_{ij} in region i, and $P(N_{ij})$ indicates the possibility that network N_{ij} is accessible and selected by a user, whereas $P(R_i)$ indicates possibility that a user positioned at region i.

$$P(R_i) = S_i / S_{\text{limit}}. \tag{6}$$

2.3 Blocking probability

Each of the network in Fig. 1 is replicated as an M/M/1/Nn queue model as in [2], where N_n is the number of accessible channels in network n. N_n can be written as

$$N_n = B_n / R, \tag{7}$$

where B_n is the entire bandwidth (BW) of network n. We consider that the each user transmits L information bits in a frame which contains M number of bits at a R bits/second where $M > L$. Therefore, data transmission rate R can be written by,

$$R = T_f / f(\gamma^x_{n,k,i}), \tag{8}$$

where $\gamma^x_{n,k,i}$ can be found in [8] and T_f can vary from 0 to 5 bits/s/Hz [6]. Assuming coherent FSK modulation for data transmission and that SINR is unchanged over a frame (which means channel fading is constant over a frame), the FSR for the i^{th} user can be expressed as

$$FSR_k = [1 - Q_v(\sqrt{\gamma^x_{n,k,i}})]^M. \tag{9}$$

The channel is time varying random process and SINR itself is a random process, thus frame outage probability (FOP) is an important concern from analytical point of view. The FOP (O^F_k) for the k^{th} user can be formulated as the possibility that the FSR for the k^{th} user drops below a lowest FSR acceptance level, $FSR_{\min}$. Note also that $O^F_k = 1$ when $P^*_{n,k,i} = 0$.

The traffic load within the overlapping cell region is $p = \lambda/\mu$, where λ is the arrival rate of beneficial requests, μ is the departure rate; arrivals and departures are considered as Poisson distributions. Handover request are provided more priority than new calls, and for sake of simplicity, a memory less handoff algorithm is utilised. We expressed the blocking possibility of an M/M/1/Nn queue for Nn number of user equipments in the networks for the blocking probability of Network n, P_{bn}[2]:

$$P_{bn} = (p_n^{N_n}(1 - p_n))/(1 - p_n^{N_n+1}), \tag{10}$$

where p_n is the effective load experienced by Network n:

$$p_n = r_n p \tag{11}$$

and r_n is the percentage of entire requests which will pass to Network n, depend on the vertical handover verdict metrics. As it is considered that the user equipments are distributed uniformly within the network coverage, the beneficial request load can be expressed as stated by the proportion of the network coverage within the boundary region. The coverage regions are marked in Fig. 1.

For the RSS-based handover scheme, the values of r_n for $n = 1, 2, 3$ are expressed as follows:

$$\begin{cases} r_3 = (S_{\text{limit}} - S_(N_1N_2 - N_3))/S_{\text{limit}} \\ r_1 = (S_(N_1N_2 - N_3) + S_(N_(3 - N_1))P_b3)/S_{\text{limit}} \\ r_2 = (S_{N_1N_2-N_3} + S_{N_(3-N_2)}P_b3)/S_{\text{limit}} \end{cases} \tag{12}$$

where P_{b3} is explicated in (10), S_i is the geometric area of area i explained in Table 1, and S_{limit} is the geometric region of the boundary area. For the MUSE-VDA handoff scheme, the values of r_n for $n = 1, 2, 3$ are expressed as follows:

$$\begin{cases} r_1 = (S_{N_1N_2-N_3} + S_{N_3-N_1} + S_{N_3-N_1N_2})/S_{\text{limit}} \\ r_2 = (S_{N_1N_2-N_3} + S_{N_3-N_2} + S_{N_3-N_1N_2}.P_b1)/S_{\text{limit}} \\ r_3 = 1/S_{\text{limit}}(S_{N_3} + (S_{N_1N_2-N_3} + S_{N_3-N_1}).P_b1 + (S_{N_1N_2-N_3} + S_{N_3-N_2} + S_{N_3-N_1N_2}).P_b2) \end{cases} \tag{13}$$

3 Simulation model

The simulation testbed model is carried out considering the following steps-

(1) N_3: Network entity 3 gives the only coverage.

(2) $S_{N_3-N_1N_2}$:
- Network entity 3 has the strongest RSS.
- RSS scheme: if the entreaty is refused by network entity 3, the user can attempt either network entity 1 or network entity 2 with equal probability.
- MUSE-VDA scheme: The network succession with reference to the reducing data rate is as follows: network entity 1 > network entity 2 > network entity 3. The results of the price function will select network entity 1, then network entity 2 if network entity 1 is refused, then network entity 3, if network entity 2 is refused.

(3) $S_{N_3-N_1}$:
- Network entity 3 has the strongest RSS.
- RSS Algorithm: Network entity 3 is selected first. If the entreaty is refused by network entity 3, the user attempts network entity 1.
- MUSE-VDA: Depending upon the reducing data rates, the choice made by the price function is initially network entity 1, then network entity 3 if network entity 1 is refused.

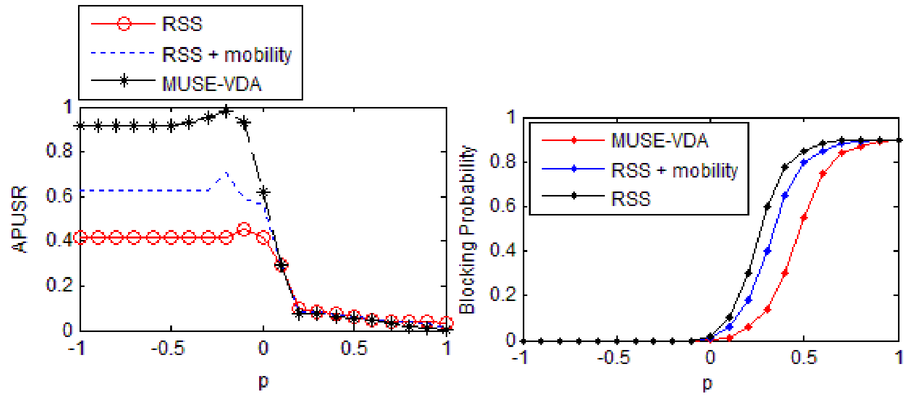
(4) $S_{N_3-N_2}$:
- Network entity 3 has the strongest RSS.
- RSS Algorithm: Network entity 3 is selected first. If the entreaty is refused by network entity 3, the user attempts network entity 2.
- MUSE-VDA: Depending upon the reducing data rates, the choice made by the price function is initially network entity 2, then network entity 3 if network entity 2 is refused.

(5) $S_{N_1N_2-N_3}$:
- Network entity 1 and 2 both are having the strongest RSS.
- RSS Algorithm: The user first attempt either network entity 1 or network entity 2 with equal probability. If the entreaty is refused by network entity 1 or 2, the user attempts network entity 3.
- MUSE-VDA: Depending upon the reducing data rates, the choice made by the price function is initially network entity 1 or 2 with equal probability, then network entity 3 if network entity 1 or 2 is refused.

(6) S_{limit}: Boundary Region.

4 Results and discussion

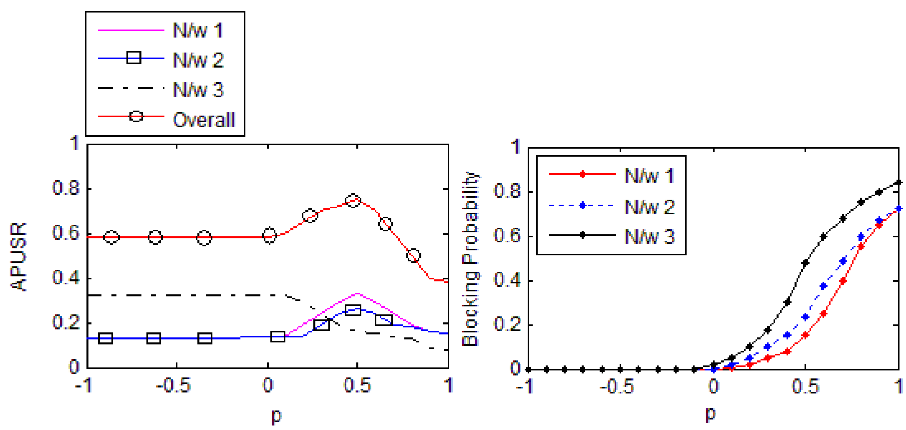
The system performance evaluated as a function of traffic load and network availability. One particular interest of performance is the APUSR. The network performance is compared for three case study such as RSS only algorithm, RSS plus mobility algorithm and MUSE-VDA algorithm. The traffic is not a steady state phenomena and quality of network service fluctuates dynamically in simulated cognitive-femtocell model.



(a) (b)

Fig. 2: APUSR provided by different optimization scheme (a) and blocking probability vs. p keeping traffic load fixed in different optimization scheme (b)

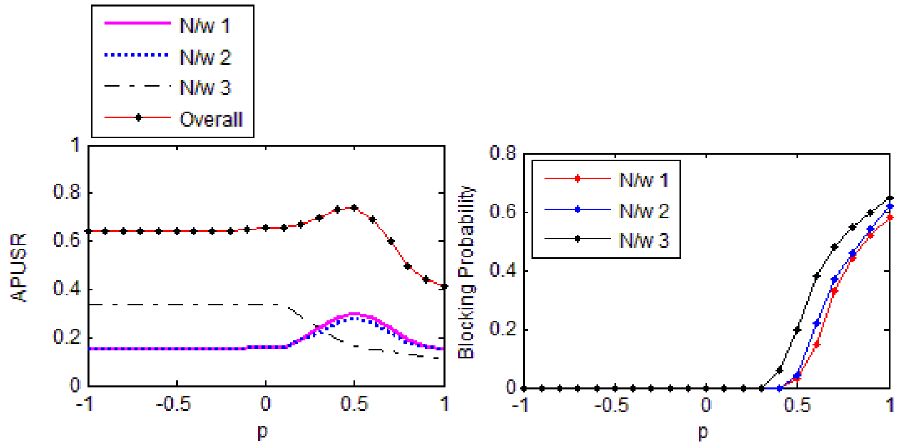
In Fig. 2, we note the similarity and dissimilarity between RSS only and RSS plus mobility based algorithms. Mobility is a standard of measurement which can be added with RSS base technique to enhance the performance level of the networks. Fig. 3 depicts the APUSR and blocking probability contrast of RSS only and RSS plus mobility algorithms, where, fast moving users (v¿vthreshold) get network service from the macrocell, whereas medium to slow users (v¡vthreshold) get network service from the femtocell. Now, RSS plus mobility algorithm indicates better APUSR results. Even though, outcomes of APUSR in RSS plus mobility based algorithm is underneath, in contrast to MUSE-VDA.



(a) (b)

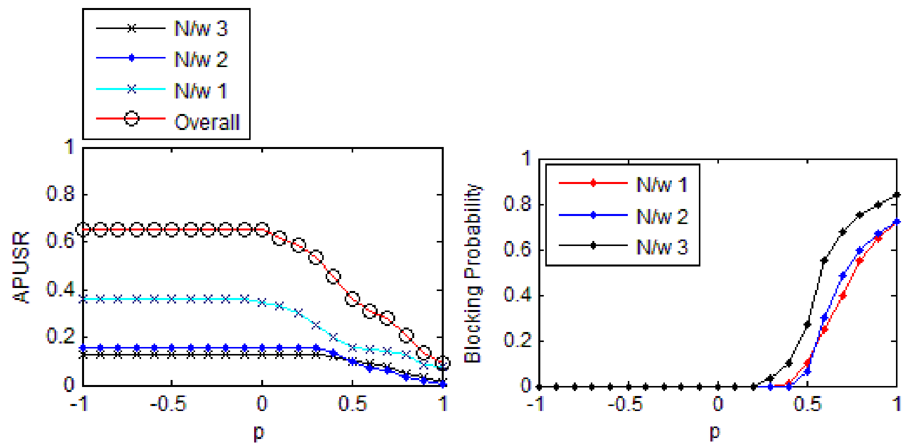
Fig. 3: RSS based algorithm: APUSR vs. p with enhancing network load (a) and RSS based algorithm: Blocking probability vs. p with enhancing traffic load (b)

In Fig. 3, RSS only algorithm is first inspected to contrast with the performance of mobility added RSS algorithm and MUSE-VDA, respectively. In Fig. 3(a), APUSR is shown as a function of traffic load for RSS only handoff algorithm. As a service provider, network 3 takes priority over any other two networks. Hence, Network 3 fulfils a major part of user request at low traffic load region. So naturally resources of Network 3 are used up quickly with the increase in traffic load in contrast with the resources of other two networks. Fig. 3(b) illustrates the corresponding blocking probability as a function of traffic load for the percentage of total request reach to Network 1, Network 2 and Network 3. Portable user therefore finds greater chance to choose Network 1 and Network 2 as a service provider due to the fact that blocking probability of Network 3 escalates prior to the Network 1 and Network 2.



(a) (b)

Fig. 4: RSS based algorithm with mobility: APUSR vs. p with enhancing traffic load (a) and RSS based algorithm with mobility: Blocking probability vs. p with enhancing traffic load (b)



(a) (b)

Fig. 5: MUSE-VDA: APUSR vs. p with enhancing traffic load (a) and MUSE-VDA: Blocking probability vs. p with enhancing network load (b)

Fig. 4(a) exhibits MUSE-VDA consequences produced by individual networks for APUSR and on the condition of collective handoff algorithm overall APUSR validated in contrast with Fig. 3, the RSS-only algorithm. Network 1 and Network 2 are behaved as a default network service provider entity due to the fact that network 3 gives relatively small data rate compare to other two networks. Hence, Network 1 and Network 2 fulfil a major part of user request at low traffic load region. So naturally resources of Network 1 and Network 2 are used up quickly with the increase in traffic load in contrast with the resources of network 3. Thereafter, portable users start to choose Network 3 more often at the upper traffic load region. A part of user request satisfied by Network 3 is now started growing particularly in the upper traffic load region.

5 Conclusion

In this paper, we developed handoff policy based analytical framework and simulation testbed model to provide privilege for the users located under the network coverage of macrocell but irrespective of location to the network coverage of femtocell by means of vertical handoff algorithm using various optimization scheme. Several metrics such as APUSR and blocking probability have been incorporated to adapt handoff blueprint and to take measure on the efficiency of different algorithms.

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