Ultimate Dynamic Spectrum Allocation via User-Central Wireless Systems

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***Abstract* - Current wireless systems are called *vendor-central* systems because, users should subscribe to a service provider (vendor) and receive the service through the spectrum assigned to that vendor at all times. Vendor-central systems suffer from low *utility* performance defined in terms of spectrum efficiency, blocking rate, and revenue. Variety dynamic channel allocation schemes have been proposed to address the weak utility performance of vendor-central systems.**

In this work, a futuristic *user-central* wireless system architecture that leads to an ultimate freedom in channel allocation will be introduced. This architecture is implemented based on the capabilities of cognitive radios. In user-central systems, a user has the freedom of receiving the service through a[1]n *optimum vendor* at any time instance and geographical location. The optimum vendor is selected by an intelligent mobile based on parameters such as the vendor signal power, channel availability, congestion rate, cost-per-second, and quality-of-service. We propose that vendors form a *vendor area network* (VAN) controlled by an *inter-vendor mobile registration center* (MRC). This paper discusses the system's structure, call procedure, and utility performance benefits attained by this system.

***Index Terms* – dynamic spectrum allocation, user-central, spectrum scarcity, optimum vendor, call procedure, utility performance.**

I. Introduction

There is an increasing demand for higher capacity of wireless networks due to the rapid growth of wireless industry and continuous emergence of new applications such as web browsing, real-time media streaming and interactive gaming raise a tremendous [1]. Hence, the available resources should be used more efficiently to address the growing demand for both quantity and quality of service. Among these resources, spectrum needs the most attention.

At present, agencies such as Federal Communication Commission (FCC) allocate spectrum to a service provider (vendor) in a fixed manner. This technique is called fixed channel allocation (FCA) [2]. In FCA, spectrum is allocated to vendors to support users during peak hours. Hence, most of the allocated spectrum remains under utilized the majority of the time. On the other hand, in peak hours, FCA leads to a high blocking rate. Thus, FCA scheme has a low utility performance measured in terms of: (a) spectrum efficiency, (b) blocking rate, and (c) revenue.

Dynamic channel/spectrum allocation (DCA) techniques improve wireless system spectral efficiency via sharing the available spectrum in cell domain, i.e., within the cells of a vendor, or, in vendor domain, i.e., within the vendors of a cell [3]-[16]. If DCA is performed in cell domain, it is called intra-vendor *inter*-cell spectrum sharing (or simply inter-cell DCA) [3]-[12]. If DCA is applied within each cell, it is called *inter*-vendor intra-cell spectrum sharing (or simply inter-vendor DCA) [13]-[16].

Incorporating a more complex algorithm than FCA, inter-cell DCA handles non-uniform traffic distributions, handoff requests and co-channel interference with a better performance [18], [19]. However, all proposed inter-cell DCA techniques in the literature such as borrow from the richest (SBR) [3], simple hybrid borrowing strategy (SHCB) [4], [5] and borrow with channel ordering (BCO) [6] may lead to call blocking, high co-channel interference, or carrier locking. Call blocking occurs if the vendor is fully loaded in the neighboring cells to avoid high co-channel interference. Carrier locking stands for avoiding the usage of the same channel in the neighboring channel reuse pattern in order to avoid co-channel interference. Carrier locking leads to lower spectrum in neighboring cells which itself reduces the network capacity [5]. In addition, centrally controlled inter-cell DCA algorithms suffer from long call setup times [5], [7-8], and distributed inter-cell DCA algorithms (in which mobiles and base stations incorporate in the process of channel assignment) suffer from the termination of ongoing calls in heavy traffic scenarios [3], [9]-[12].

The basic idea behind inter-vendor DCA scheme is sharing the spectrum in the dimension of time within the vendors [13]-[16]. In [13], it is assumed that a spectrum

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pool is available to all vendors, i.e., a bandwidth is not uniquely allocated to a specific vendor but to a group of vendors sharing the spectrum. However, the authors in [13] do not address how spectrum sharing enhances bandwidth efficiency while increasing the revenue of the vendors. The technique has been applied to the direct sequence code division multiple access (DS-CDMA) systems without any study of the flexibility and the capability of DS-CDMA and its pros and cons.

In [14]-[16], a novel inter-vendor spectrum sharing technique has been introduced and proved that leads to a high utility performance for multi-carrier CDMA (MC-CDMA) systems. The technique is implemented via: (1) Exploiting the capabilities of programmable radios; and, (2) A global spectrum allocation server (GSAS). GSAS receives the request for bandwidth from over-loaded vendors, checks the availability of spectrum by other vendors and assigns their unused spectrum to the over-loaded vendors. In other words, in inter-vendor spectrum sharing, all vendors should form a vendor area network (VAN) which sends the vendors traffic information to the GSAS. It has been shown that the proposed technique enjoys a high utility performance for multi-carrier systems. However, inter-vendor DCA schemes only address blocking rate, spectrum efficiency and revenue performance measures, and in these systems both mobile and base station devices must be capable of operating on all available frequency bands. Hence, cognitive radio implementation at both mobiles and base station is required;

In general, prior discussed DCA techniques have limitation mainly because a portion of spectrum which we call hard spectrum should be exchanged from one cell to another or from one vendor to the other. The problem arises as currently users should receive the service only through one vendor, i.e., the vendor which holds their membership. The current wireless system is called *vendor-central* system.

In this paper, we introduce the novel idea of *user-central* wireless communication system. Here, users have the freedom of selecting and joining a vendor at any time instance and geographical location. In this system, mobiles are made intelligent enough to select an *optimum vendor* via a cost function defined in terms of: (a) channel availability, (b) congestion rate, (c) the vendor quality of service in terms of bit-error rate (BER) performance, (d) cost-per-second, and (e) signal power. Similar to the inter-vendor spectrum sharing (in vendor-central systems), vendors form a VAN controlled by an inter-vendor mobile registration center (MRC). Thus, the notion of hard spectrum allocation is not required for user-central systems with intelligent mobiles. As a result, we call the user-central system an *ultimate dynamic channel allocation* technique. A comparison between user-central and vendor central systems has been presented in Table 1.

User-central wireless system is not limited to a specific communication scheme (e.g., modulation, multiple access, and protocol). It is a futuristic system possible via cognitive radios [17]-[22], wherein, mobiles are intelligent enough to search, select and lock on the optimum vendor. Considering that cognitive radio systems are under development for future generation of wireless networks to support an ultimate and robust communication, user-central systems would not add major complexity on the top of future generation of wireless networks equipped with cognitive radios. In addition, user-central system does not add a major complexity to the network layer compared to DCA techniques such as inter-vendor spectrum sharing techniques.

Table 1: User central versus vendor central.

	Vendor Central	User Central
Vendor Access	Users should subscribe to a service provider (vendor) and can only enjoy the service offered by this vendor.	Users have freedom to select and join an optimum vendor at any time instance and geographical location.
Working Model	SIM (Subscriber Identity Module) card support mobiles for a specific vendor.	Mobiles are made smart to select an optimum vendor via a cost function.
Network Operation	Each vendor operates its own private network.	Vendors form a VAN controlled by inter-vendor mobile registration center (MRC).
Spectrum Allocation	Dynamic spectrum allocation is hard spectrum allocation	The hard spectrum allocation is not required for user-central systems with intelligent mobiles.
Com. Scheme	Each wireless system has its own communication scheme.	User-central wireless system is not limited to a specific com. scheme (e.g., modulation and protocol).

In this work, simulations are performed to compare a user-central system with a vendor-central system implemented via FCA. A comparison with vendor-central systems implemented via DCA techniques is the target of our future works. Simulations confirm the superiority of user-central over vendor-central technique in terms of the utility performance measures.

Therefore, user-central systems increase the revenue earned by wireless companies and decrease the blocking rate. Hence, the results of the proposed system could create significant market opportunities for wireless technology, thereby contributing to the economic prosperity. The impact of the implementation of this system is not limited to wireless companies, and extended to homeland security and emergency services. This is due to the flexibility offered by user-central systems that supports the expansion of the range of services available for homeland security applications.

The paper structure follows: In Section II, we introduce the details of user-central wireless systems. Section III discusses the utility performance measures. In Section IV, we present the simulation results, and Section V concludes the paper.

II. Introduction of User-Central Wireless Systems

In user-central systems, an inter-vendor competition process is initiated to win a customer within each instance of time and each geographical location. This process is started as soon as base stations (BSs) of different vendors receive an inquiry from a mobile to broadcast their self-information which consists of a set of parameters such as the number of available channels,

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congestion rate, and cost-per-second. We call this process as *self-information broadcasting*. Upon receiving the requested information, mobiles identify and lock on their optimum vendor based on a cost function. In this section, we introduce the structure of user-central wireless systems. We also introduce the details of the cost function for the optimum vendor selection. Then, we explain vendor identification, locking and updating processes. Finally, we discuss user-central call initiation and call reception processes.

The structure of user-central wireless system: The basic structure of user-central wireless system is shown in Fig. 1. A user may select any vendor n_v, $n_v \in \{1,2,..., N_v\}$ to initiate or receive a call. Vendors form a VAN controlled by an inter-vendor Mobile Registration Center (MRC). Inter-vendor MRC works as a center which manages all mobiles independent on vendors and records all available vendors that can reach a mobile user at any time, and it can be deployed centrally or distributed in the network. In user-central wireless systems, mobiles are not required to subscribe to any vendor; they become legal users of wireless network as long as they register to the MRC. A correlation between a unique identification (ID) for a mobile and the user's bank account could be a prerequisite for flexible billing purpose.

Optimum vendor selection: Mobiles select an optimum vendor at each time through a cost function defined in terms of many parameters of the vendors including: (a) channel availability, (b) congestion rate, (c) the vendor quality-of-service in terms of bit-error-rate (BER) performance, (d) cost-per-second, and (e) signal power. The weight of these parameters may vary with the BS's dynamic performance, user's relative location to the BS, or user's customized criteria in selecting a vendor. The cost function should be updated within reasonable periods (*T*) depending on parameters such as the user's mobility, battery life and vendor's congestion rate.

This leads to a lower blocking rate due to the fact that mobiles' traffic would be distributed over all vendors based on the weights assigned by users to the mentioned parameters. Basically, the user can select the vendor, if (a) the probability that the vendor becomes overloaded within the updating periods *T* is low, (b) its congestion rate is low, (c) its BER is low, (d) its cost per second is low enough, and (e) its received power is high enough. This ensures that the mobile selects a vendor which guarantees a high utility performance (e.g., low blocking rate). Hence, the cost function, $C_s^{(n_v)}$, of vendor n_v, $n_v \in \{1,2,..., N_v\}$ corresponds to:

$$C_s^{(n_v)} = \frac{\left[C_{\cos t\_nor}^{(n_v)}\right]^{\beta} \cdot \left[R_{ber\_nor}^{(n_v)}\right]^{\gamma} \cdot \left[R_{cgst\_nor}^{(n_v)}\right]^{\phi}}{\left[P_{full\_nor}^{(n_v)}\right]^{\alpha} \cdot \left[P_{power\_nor}^{(n_v)}\right]^{\kappa}} , \quad (1)$$

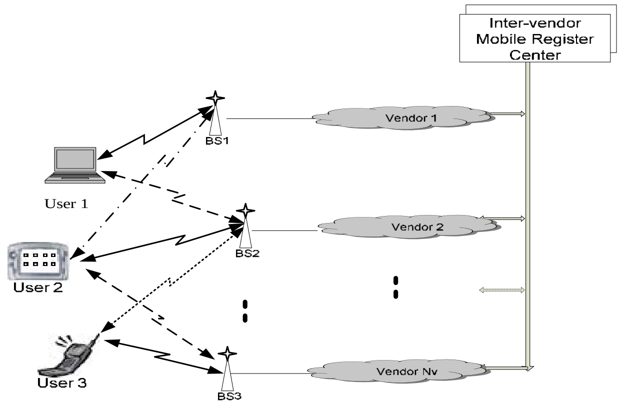

Figure 1. Structure of user-central wireless system.

A user locks on a vendor that minimizes the cost function $C_s^{(n_v)}$. In (1),

$$P_{full\_nor}^{(n_v)} = P_{full}^{(n_v)} \Big/ \sum_{n_v=1}^{Nv} P_{full}^{(n_v)} , \quad (2)$$

where $P_{full}^{(n_v)}$ is the probability that vendor n_v does not get overloaded within *T* seconds. Here, the denominator is applied to normalize the probability $P_{full}^{(n_v)}$ with respect to the total probability for all N_v vendors. Assuming call arrival and departure follow a Poisson process, the probability $P_{full}^{(n_v)}$ can be defined as:

$$P_{full}^{(n_v)} = 1 - e^{-\left(\lambda^{(n_v)} + \mu^{(n_v)}\right)T} \left(\frac{\lambda^{(n_v)}}{\mu^{(n_v)}}\right)^{N_a^{(n_v)}/2} I_{\left|N_a^{(n_v)}\right|}\left(2T\sqrt{\lambda^{(n_v)}\mu^{(n_v)}}\right) \quad (3)$$

where,

$$I_n(x) = \sum_{k=0}^{\infty} \frac{(x/2)^{n+2k}}{k!(n+k)!} . \quad (4)$$

In (3), $\lambda^{(n_v)}$ and $\mu^{(n_v)}$ are the call arrival and departure rate individually for vendor n_v, and T is the period within which the cost function is updated, and,

$$N_a^{(n_v)} = N_{total}^{(n_v)} \cdot (1 - R_{cgst}^{(n_v)}) , \quad (5)$$

refers to the number of available channels, In (5), $N_{total}^{(n_v)}$ is the number of total channels owned by vendor n_v, and $R_{cgst}^{(n_v)}$ is the congestion rate of vendor n_v, which corresponds to:

$$R_{cgst}^{(n_v)} = N_{busy}^{(n_v)} \Big/ N_{total}^{(n_v)} , \quad (6)$$

In (6), $N_{busy}^{(n_v)}$ is the number of busy channels of vendor n_v. Moreover, in (1),

$$C_{\cos t\_nor}^{(n_v)} = C_{\cos t}^{(n_v)} \Big/ \sum_{n_v=1}^{Nv} C_{\cos t}^{(n_v)} , \quad (7)$$

where $C_{\cos t}^{(n_v)}$ is the call cost-per-second for vendor n_v, and,

$$R_{ber\_nor}^{(n_v)} = R_{ber}^{(n_v)} \Big/ \sum_{n_v=1}^{Nv} R_{ber}^{(n_v)} , \quad (8)$$

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with $R_{ber}^{(n_v)}$ corresponds BER performance of vendor n_v. In addition, in (1),

$$R_{cgst\_nor}^{(n_v)} = R_{cgst}^{(n_v)} \Big/ \sum_{n_v=1}^{Nv} R_{cgst}^{(n_v)} \, . \tag{9}$$

In which, $R_{cgst}^{(n_v)}$ was introduced in (6). Moreover, in (1),

$$P_{power\_nor}^{(n_v)} = P_{power}^{(n_v)} \Big/ \sum_{j=1}^{Nv} P_{power}^{(j)} \, , \tag{10}$$

In (10), $P_{power}^{(n_v)}$ is the signal power of vendor n_v. All denominators in (7) – (10) correspond to a normalization factor. Finally, in (1), α, β, γ, ϕ, κ (all greater than one) are the parameters (weights) that might be customized independently by each user based on the preference of the user toward the introduced cost function variables (e.g., a user may assign a higher weight to the cost-per-second compared to the power).

Lock process: Refers to the establishment of a link between the mobile and the BS. In vendor-central wireless systems, lock process is started as soon as a mobile is turned on. Then, the mobile starts looking for the beacon (or pilot) transmitted by its vendor to identify a nearby BS of that vendor [23]. The identification process is completed by receiving control channel messages from BS.

In user-central wireless systems, a mobile is capable of communicating with the base stations of all vendors simultaneously, which is possible via the capabilities of cognitive radios. In these systems, when the mobile is switched on, it starts sensing the spectral environment over a wide frequency band associated to all vendors to select the optimal vendor. Sensing the spectral environment refers to *tuning* to all available vendors and establishing a communication link with the BS of those vendors. This allows the mobile to create a *model* for each vendor which includes the frequency band, modulation, channel set and related protocols.

Therefore, as soon as a communication link is established between the mobile and vendors, it sends an inquiry to obtain parameters such as channel availability, congestion rate, call cost-per-second, and quality-of-service. After receiving the response from each vendor (BS), the mobile will create the cost function for the BS of that vendor according to (1).

Hence, in user central systems, if a vendor gets congested, the mobile may update the vendor, and the incoming call would reach the mobile through another vendor. It should be added that although the model is updated every T seconds, but if the power drops below a threshold level, the model might be updated regardless of the period T. In general, the updating period (T) is determined by parameters such as the user's mobility, battery life and the dynamic performance of base stations. This process is presented in Fig. 2. In this figure t_{N_v} is the time required to sense and to create vendor model and the cost function.

The set of all cost functions and their associated models is called *model pool*. A user selects the optimum vendor based on the optimum cost function defined in (1). Then, the user locks on that vendor and the vendor sends the lock information to the MRC (see Fig. 1). The optimum vendor would be considered for communication (initiating a call or incoming calls) within the updating time period T. The steps required for a mobile to sense the environment and build the model pool are presented in Fig. 3.

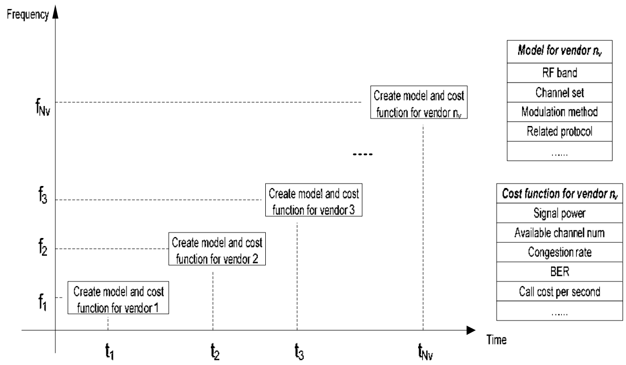

Figure 2. Mobile sensing process.

Model pool updating: The mobile periodically updates the model pool based on the approach explained in Fig. 3 and selects an optimum vendor. This allows the mobile to initiate or receive a call at any time instance through the optimum vendor. As soon as a new optimum vendor is selected, the MRC is notified. Therefore, the MRC updates the optimum vendor information periodically, as well. Consequently, if a vendor gets congested, the mobile would update the vendor, and the incoming call can reach the mobile through another vendor.

Call Initiation and Incoming calls: After the optimum vendor is selected by the mobile, it follows the same steps as vendor-central wireless systems to initiate a call, as shown in Fig. 4. The MRC routes the incoming calls just through the selected vendor (optimum vendor). Hence, as shown in Fig. 5, one user (User 4) may initiate a call through Vendor A, while, the called user (User 2) have selected Vendor B. In general, MRC controls the process of incoming calls, as well as the hand off process. MRC tracks and updates the location information and their selected vendor, and routes the incoming calls to that user. As we mentioned, the mobile updates the optimum vendor every T seconds. Hence, the optimum vendor and the connecting BS might vary while call is in progress.

Hand off process: It should be mentioned that the process of hand off is more general in user-central systems compared to vendor-central systems. In vendor-central systems, hand off occurs within the base stations of one vendor, but in user-central systems, the hand off may occur within the base stations of one vendor or different vendors. In addition, in vendor-central systems, hand off occurs only if the power level drops below a threshold, while in user-central systems hand off may occur every time the model pool is updated. For example, during a

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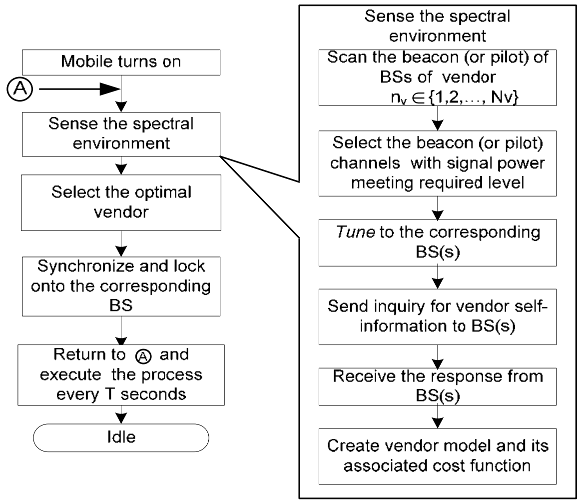

Figure 3. Lock process for a mobile in user-central system.

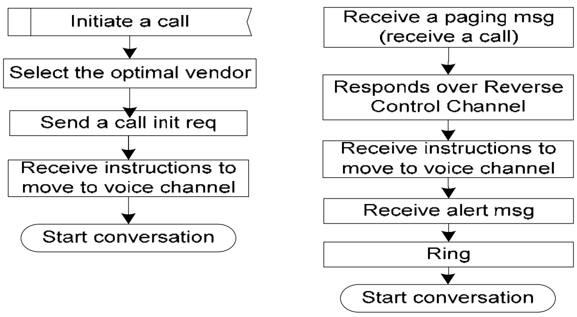

Figure 4. Call procedure for a mobile in user-central wireless system.

call in progress, if the mobile is not satisfied with the quality-of-service of a vendor, the mobile may switch the call from a vendor to another, while keeping current call uninterrupted. This process needs extra signaling messages between the mobile and vendors' BS, which are used to instruct vendors' BS to make a handover to another vendor. This process is accomplished through the MSC.

Billing process: This process is more flexible in user-central systems than that of vendor-central systems. In user-central systems, all vendors share the database of user registration and location information. The user is entitled to access the wireless network after it registers at the MRC. A global account should be assigned to users. Whenever a user initiates or receives a call, it will be charged by the involved vendors and the charging information is stored in the MRC. Billing statements may include phone number, cost-per-minute, and vendor information. As it has been depicted in Section IV, user-central process ultimately enhances the total revenue of all vendors. The increase in the earned revenue is a direct result of an ultimately efficient spectrum allocation offered by user central systems.

Applications: In emergency situations or when users enter an isolated area, where minimal vendors are present, if the users in vendor-central system can not detect the signal from its subscribing vendor, they will lose the chance to make an emergency call. But in user-central

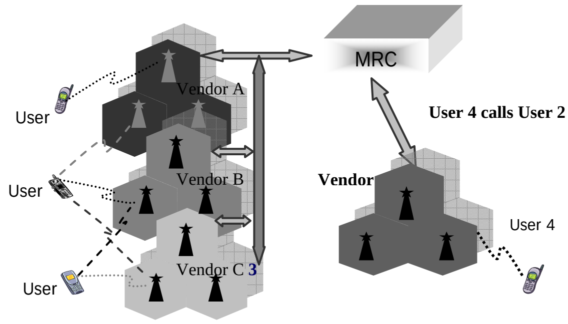

Figure 5. The process of incoming calls.

system, mobile terminal can search the available vendors for access, as long as it can detect the pilot signal from one vendor.

III. UTILITY PERFORMANCE MEASURES

Some performance measures are significant for both user-central and vendor-central wireless systems while there are some differences between these two systems. Here, the utility performance is measured in terms of call blocking rate, spectrum efficiency, and revenue. In Section IV, a comparison of the utility performance is conducted between the user-central and vendor-central systems. The definitions for the utility performance components follow.

Call blocking rate: Different from vendor-central systems (see [15] and [24]), the call blocking rate $\rho_b{}^{(i)}$ is defined for user *i* that corresponds to:

$$\rho_b{}^{(i)} = \lim_{t\to\infty} \frac{n_b^{(i)}(t)}{N_c^{(i)}(t)} , \qquad (11)$$

where $n_b^{(i)}(t)$ is the number-of-blocked calls till time *t* for user *i*, and $N_c^{(i)}(t)$ is the number-of-initiated calls till time *t* for user *i*. Obviously, in user-central systems the call blocking rate for a user drops because the user has a freedom to select a vendor with available channels. In user-central systems, the call would be only blocked, if all vendors are over-loaded.

Compared to vendor-central systems without DCA, the blocking rate of user-central systems is lower because in these systems user can select another vendor to communicate, when one vendor is unavailable. In addition, vendor-central systems even with DCA lead to higher blocking rates compared to the user-central systems. For example, in the traffic-aware inter-vendor spectrum sharing [24], some part of the spectrum is reserved for the lending vendor to prevent the blocking rate of that vendor. Hence, the call might be blocked even though some of the vendors might have available spectrum. Therefore, user-central systems can be considered as an ultimate DCA.

Spectrum efficiency: Similar to the vendor-central, the spectrum efficiency $\eta_s{}^{(n_v)}$ is defined for vendor n_v as:

$$\eta_s{}^{(n_v)} = \lim_{t\to\infty} \frac{1}{t} \int_0^t \frac{n_{busy}^{(n_v)}(t)}{N_{ch\_total}^{(n_v)}} dt , \qquad (12)$$

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where $n_{busy}^{(n_v)}(t)$ is the number of channels used at time t for vendor n_v, and $N_{ch\_total}^{(n_v)}$ is the number of total channels owned by vendor n_v. Higher spectrum efficiency is anticipated compared to vendor-central systems, because the call blocking rate of user-central system is lower; thus, more calls can contribute to the spectrum utilization.

Revenue of vendors: The accumulative revenue $R_u^{(n_v)}(t)$ earned by vendor n_v at time t is defined as:

$$R_u^{(n_v)}(t) = R_u^{(n_v)}(t-1) + \sum_i \kappa \cdot N_{assign}^{(i,n_v)} \cdot D_{assign}^{(i,n_v)}(t),\ t \geq 1,\ R_u^{(n_v)}(0) = 0\ , \quad (13)$$

where $\sum_i \kappa \cdot N_{assign}^{(i,n_v)} \cdot D_{assign}^{(i,n_v)}(t)$ is the revenue earned by vendor n_v within the time period [t -1, t], $N_{assign}^{(i,n_v)}$ is the number of channels assigned to user i by vendor n_v and used for the duration $D_{assign}^{(i,n_v)}(t)$; finally, κ corresponds to the \$/channel/minute. Compared to vendor-central systems, the total revenue for vendors in user-central system would be higher. This is a direct result of the lower blocking rate and higher spectrum efficiency of user-central systems.

IV. Simulation Results and Discussion

We conduct simulations to verify the potential of the user-central system compared to a vendor-central system (which uses FCA) in terms of utility performance measures. Here, we assume:

1) Three vendors, $N_v = 3$, (each owns 32 channels) provide their service to the same area;
2) A vendor would be available, if the number of its idle channels is more than 0;
3) The cost-of-connection per vendor is \$0.35/channel/minute, i.e., $C_{cost}^{(n_v)} = C_0$, in (7), C_0 is constant);
4) Vendors have similar signal power, i.e., $P_{power}^{(n_v)} = P_0$, in (8), P_0 is constant,
5) BER performance, i.e., $R_{ber}^{(n_v)} = B_0$, in (10), B_0 is constant;
6) The possibility-of-observing a vendor over-loaded within T (updating period) is ignored, i.e., $P_{full}^{(n_v)} = 1$, in (1);
7) α, β, γ, κ, and ϕ in (1) are equivalent;
8) Call holding time is exponentially distributed with the mean of $1/\mu = 180$ seconds [23]; and,
9) Three call generators create calls using homogenous Poisson processes with rates in the range of $\lambda = 50 - 3600$ calls/hour for different vendors in vendor-central systems. This allows us to investigate the impact of different call arrival rates in vendor-central systems.

Considering assumptions 3 – 7, (1) is simplified to

$$C_s^{(n_v)} = R_{cgst\_nor}^{(n_v)} \quad (14)$$

In other words, in these simulations, a vendor is selected as long as channels are available. We compare the performance measurements between vendor-central and user-central systems under two scenarios:

(i) Equal call generating rates, i.e., $\lambda_1 = \lambda_2 = \lambda_3$, and,
(ii) Different call generating rates, i.e., $\lambda_1 > \lambda_2 > \lambda_3$.

Simulation results are shown in Figures 6 – 8. In these figures, the x-axis corresponds to the summation of the traffic rate, i.e., $\lambda_s = \sum_i \lambda_i$. Here, λ_s corresponds to the total call arrival rate to the user-central system and handled by the three vendors jointly, while λ_i, $i \in \{1,2,3\}$ corresponds to the call arrival rate to Vendor n_v, $n_v \in \{1,2,3\}$ and handled by corresponding vendor individually in vendor-central system. In the simulation, the total call arrival rates for user-central and vendor-central systems are equivalent, i.e., $\lambda_s = \lambda_1 + \lambda_2 + \lambda_3$.

The simulation results are depicted for the traffic rate $\lambda_s = 1800 - 9000$. This range is selected for the traffic rate as simulations depict that under low traffic rates (low λ_s) user-central systems would perform similar to vendor-central systems. Indeed, based on the defined utility performance measures of Section III, user-central systems are distinguished from vendor-central systems under high traffic rate scenarios. In these scenarios, the communication of mobiles in vendor-central systems is likely to get blocked, while mobiles in user-central systems have a higher chance to make a communication through a pool of available vendors. In addition, as λ_s increases beyond 9000 call/hour, vendor-central and user-central would perform equally. This is due to the fact that all vendors would be completely overloaded.

Fig. 6 shows the call blocking rate results. The blocking rate of user-central system is lower than that of vendor-central system, particularly under Scenario 2, because mobiles in user-central systems can select another vendor to communicate when one vendor can not accommodate any user due to heavy traffic. In user-central system, calls will not be blocked unless all vendors available in the mobile coverage area are over-loaded. Under Scenario 2, Vendor 1 with a high traffic rate λ_1 ($\lambda_1 > \lambda_2 > \lambda_3$) experiences heavy traffic in vendor-central systems, and more calls would be blocked by that vendor. However, user-central system exhibits even better performance compared to Scenario 1.

In general, the bigger the difference between λ_1, λ_2 and λ_3, the higher the average blocking rate in vendor-central system, because the call arrival rate of Vendor 1 would be much higher than the call arrival rate of other vendors. But, this will not affect the blocking rate of user-central system unless the call arrival rate is high enough to make all vendors over-loaded. At that point, the blocking rate of vendor-central and user-central systems tends

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toward the same value. Table 2 summarizes the average improvement in blocking rate achieved via user-central systems. It is seen that up to 23% improvement in blocking rate is achieved via user-central systems.

Fig. 7 depicts the spectrum efficiency results. Vendor-central system leads to lower spectrum efficiency due to the fact that the calls blocked by one vendor can not use the spectrum owned by other vendors. In vendor-central systems, the average spectrum efficiency is lower than that of user-central system, because users blocked by one vendor can not use the spectrum owned by other vendors. This leads to lower average spectrum efficiency from the whole spectrum management perspective. Similar to the blocking rate results, the bigger the difference between λ_1, λ_2 and λ_3, the lower the average spectrum efficiency in vendor-central system. Table 2 shows that the spectrum efficiency of user-central system is improved up to 8% compared to vendor-central systems.

Fig. 8 shows the revenue simulation results. It is seen that user-central systems lead to higher revenue than vendor-central. In vendor-central systems, when a vendor is over-loaded, call initiation as well as incoming calls are blocked, because the user can not communicate through any other vendor except its own. Thus, vendors will not be able to profit from providing service to this user. In contrast, in user-central wireless systems, if one vendor is not available, the user can select other vendors to initiate or receive a call. Hence, the user still can contribute to the revenue of the vendors, namely, at least one vendor will profit from handling the user's call under most cases.

Therefore, in user-central wireless system, the total revenue of the vendors is higher than that of vendor-central wireless system, particularly under unbalanced traffic rates for different vendors (i.e., Scenario 2): The bigger the difference between λ_1, λ_2 and λ_3, the lower would be the revenue in vendor-central system. The average revenue is calculated in Table 2. It is seen that user-central increases the revenue of the vendors up to 10% compared to vendor-central systems.

V. CONCLUSIONS

A futuristic DCA technique called user-central wireless architecture was introduced. This architecture launches an era of spectrum freedom in wireless systems via the notion of cognitive radios. This system allows users to have complete freedom to select their optimum vendors based on their desired criteria. Moreover, in contrast to the vendor-central DCA techniques, the allocation of hard spectrum (i.e., a portion of spectrum) is not required in user-central systems. Hence, we call this technique "*the ultimate dynamic channel allocation*" structure.

The paper sketches the structure of user-central system, the process of selection of an optimum vendor, call initiation and reception, and a general definition of hand off process. The technique highly enhances the utility performance of wireless systems in terms of blocking rate, spectrum efficiency and revenue. Hence, the novel user-central system introduced in this paper is a promising technique for future wireless communication systems. In addition, the results of the proposed system could lead to significant market opportunities for wireless technology, thereby contributing to the economic prosperity. Finally, due to the flexibility offered by user-central systems, the implementation of this system impacts homeland security and emergency services.

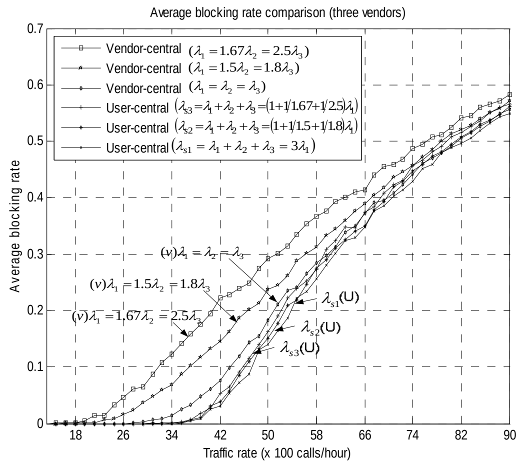

Figure 6. Blocking rate comparison: User-central vs. vendor-central.

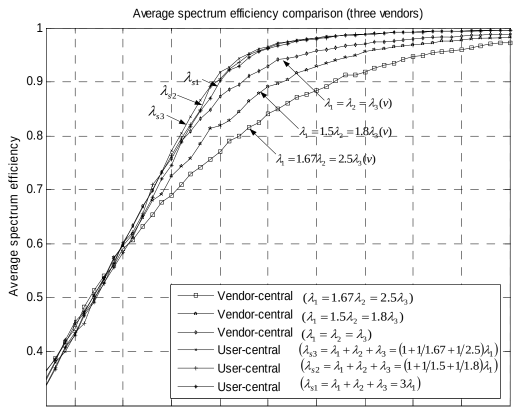

Figure 7. Spectrum efficiency comparison: User-central vs. vendor-central.

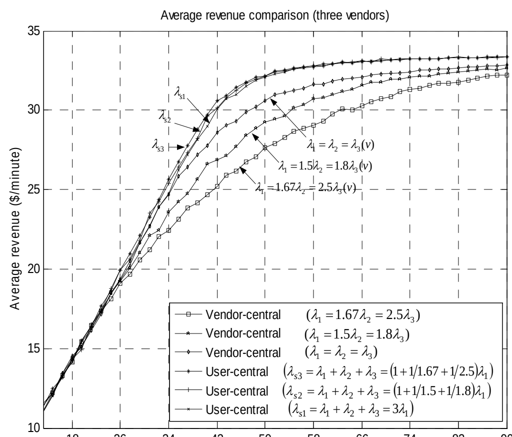

Figure 8. Revenue comparison: User-central vs. vendor-central.

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Table 2. Utility Performance of Vendor-Central vs User-central Systems.

Call arrival rate (Three vendors)	Average call blocking rate		Average spectrum efficiency		Average revenue ($/minute)	
	Vendor-central	User-central	Vendor-central	User-central	Vendor-central	User-central
vendor-central: $\lambda_1 = \lambda_2 = \lambda_3$ user-central: $\lambda_{s1} = \lambda_1 + \lambda_2 + \lambda_3 = 3\lambda_1$	**0.2252**	**0.2087**	**0.8323**	**0.8411**	**27.3411**	**28.0522**
vendor-central: $\lambda_1 = 1.5\lambda_2 = 1.8\lambda_3$ user-central: $\lambda_{s2} = \lambda_1 + \lambda_2 + \lambda_3 = (1 + 1/1.5 + 1/1.8)\lambda_1$	**0.2545**	**0.2151**	**0.8119**	**0.8444**	**26.6551**	**28.1711**
vendor-central: $\lambda_1 = 1.67\lambda_2 = 2.5\lambda_3$ user-central: $\lambda_{s3} = \lambda_1 + \lambda_2 + \lambda_3 = (1 + 1/1.67 + 1/2.5)\lambda_1$	**0.2880**	**0.2217**	**0.7859**	**0.8471**	**25.7831**	**28.2520**

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