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Hap Assisted Cooperative Spectrum Sensing for Cognitive Networks

Yaser A. Salem
[1](Department of computer science and information, College of science/ MajmaahUniversity KSA)
[2](Departmen of electrical Engineering, Faculty of engineering at shoubra/ BenhaUniversity Egypt)
Corresponding Author: Yaser A. Salem

ABSTRACT: *Cooperative communications has recently granted a great attention. High Altitude Platform assisted cooperative spectrum sensing (HAP-ACSS) is adopted as a step towards achieving this goal. This research employ High altitude platform HAP with smart database fusion center FC to control spectrum assignment to secondary users SU according to available spectrum and the received signal to noise ratio SNR from surrounded secondary user equipment SUE. Base station is equipped with Received Signal Strength Indicator (RSSI) and channel allocation mechanism to handle its assigned channels between licensed primary users PU and SUs within the cell. With the aid of collected BSs-RSSI measurements, SU and PU registered information and the other collected information from all BSs in HAP coverage range, the FC can collect the sparse SUE transmitted power and translate it into a spatial spectrum distribution. The proposed network configuration with adopted algorithm is explained, and a simulation of SU localization is provided. The adopted scheme is promising to help the mobile network achieving significantly improved performance with the coexistence of SUs acquiring to share PU spectrum.*

Keywords: *Mobile communication networks, Cognitive networks, HAP communication*

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I. INTRODUCTION

With the ever growing of wireless applications and services, spectrum resources which are limited are facing huge demands. Currently, spectrum allotment is established by providing individually services with its own fixed frequency block. With the advanced development of new technologies in smart devices and its applications, a massive demand for spectrum are expected to intensively increase while the spectrum is not stretchable. To cope with the technologies of fully wireless system expansion, researchers are looking for enhancing spectrum utilization. Most of the primary spectrum is already captured, so it becomes very difficult to find excessive spectrum for either new services or expanding existing services. Wireless regulations do not allow the access of unlicensed users to the licensed spectrum, comprises them instead to use several heavily populated, interference-prone frequency bands. As the consequences there is huge spectrum scarcity problem in certain bands. In particular, when the radio spectrum is scanned, within the revenue-rich urban areas, it can be seen that many frequency band are only partially occupied, and some other frequency bands in the spectrum are unoccupied for most of the time, whereas the remaining frequency bands are heavily used [1-2]. While everything is going to become wireless and there is a spectrum scarcity in some bands, it is obviously noted that, the radio frequency spectrum is inefficiently utilized [3].

II. COGNITIVE NETWORKS CN

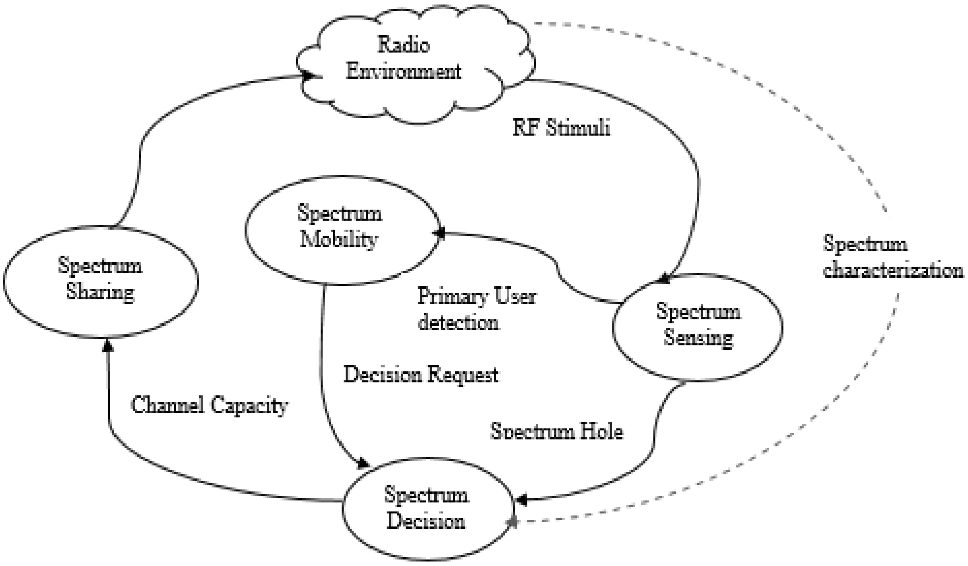

Figure 1. Cognitive Radio Architecture [4]

Cognitive networks CN is the forth-coming technology intended for solving the problem of spectrum underutilization caused by static spectrum allocation [5]. This technology uses cognitive control algorithm to allow unlicensed or secondary user to have full utilization of any unoccupied spectrum (white space) when needed. The process of Spectrum utilization is a dynamic process, it depends on many factors like time, place and frequency [6]. The cognitive radio (CR) concept is developed as one of the most promising techniques in wireless networkswhen addressing the spectrum scarcity by enabling dynamic spectrum accessDSA. As discussed in [7], the CR transmission process is established in two principal phases: first, the spectrum sensing phase, where CR users attempt to sense the unused spectrum (spectrum hole), and second, the cognitive transmission phase, where CR users transmit their data withinthat spectrum holes. Hence, a lot of research efforts have been worked on the CR concept, most of which are focused on spectrum sensing, access, allocation and sharing [8-9]. aiming for improvingthe spectral efficiency, rather than the energy efficiency.Cognitive Radio Network has three basic components. They are: 1) Mobile station (MS), 2) Base station/Access points (BS/Aps), 3) Backbone networks. Three different architectures of Cognitive radio networks are reviewed in [23]

III. HIGH ALTITUDE PLATFORM HAP

High altitude platforms (HAPs) are adopted as most advanced telecommunications services for a wide range of smart wireless and cognitive radio network (CRN)[11].In the recent years there is an increasing interest in the development of HAPs that serving in telecommunications, digital broadcasting, and remote sensing. It can keep stationary in its altitude between 17-22 km in the stratosphere layer for long period 3-5 years and cover a wide range in the order of 200 km in radius and with minimum elevation angle of 15°. This makes them very attractive for the future smart wireless access[12].Recent researches have proposed consideration of the HAP as a base station (BS) in 4G and 5G mobile networks. It was proposed that the HAP could enhance the network coverage while reducing the cost of network infrastructures[13], the HAP as well is one of the most promising alternative infrastructures for deploying a wide range of high-data-rate collection applications for CRNs and forth coming wireless networks [14-20].

IV. CELLULAR NETWORKS

The area which a central antenna (BS) could cover is called a cell. When two different antennas exist in a separate system, each of them would be observed as a system for their selves, with no communication with another one. In the wireless networks, the separate cells are connected to each other via ground cable by means of a central switch, through this scheme, the connection can be established between two Subscribed users, one of which exists inside a cell with other Subscriber present in the other cell. Radio.

A base station (BS) in a mobile cellular network is responsible for managing the bandwidth requests and scheduling bandwidth to the UE's according to the service flow requirement of the UE. The resource management procedure includes determining which users to schedule and how to allocate the available radio resources to them. An efficient scheduling algorithm should guarantee system performance by concerning different quality of service (QoS) requirements and various system performance factors as well as available radio resources in scheduling decision. In cellular networks, each BS has its own scheduler and UE follows the scheduling command from the serving BS. In this section, we present basic scheduling algorithms for the mobile cellular network. [21-23].

V. THE HAP-ACSS SCHEME

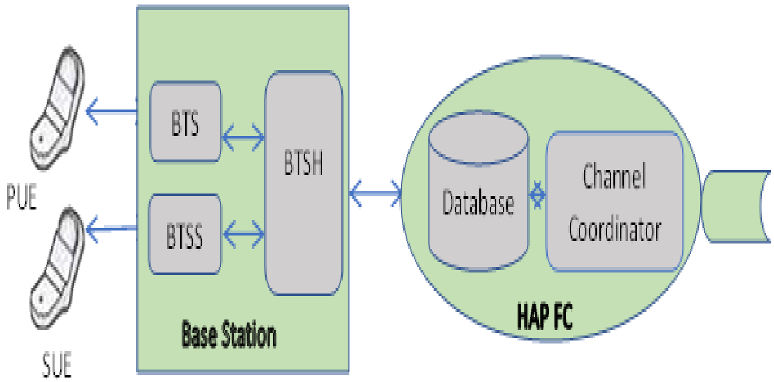

Figure 2. Hap-acss architecture

The adopted schemeis summarized in the following Pseudocode, and is consisted of a mobile base station which equipped with :

1- BTS base station transceiver which is a device that facilitates wireless communication between user equipment (PUE) and a network.
2- BTSS which is a device that facilitates wireless communication between secondary user equipment (SUE) and the base station.
3- BTSH which is a device that facilitates wireless communication between nominated base station and the

HAP. The BTSH use another spectrum to communicate with the HAP.

Each cell in the adopted system includes PUs which is licensed user using licensed spectrum, and SUs seeking communication on any available channel until the appearance of (PUE) activity on that channel.

```
Pseudocode for Channel allocations
Begin:
      Record PU-ID, PU-SNR, BS-ID
      Check available free channelNf. exist.
IFNf> 0 THEN
             Begin:
      Assign PU←Nf
      Update Database
             End
      ELSE
      Begin:
                ▪  Search the database for SU with
                   lowest SNR and release his channel.
                ▪  Assign this channel to the PU.
                ▪  Update the database.
      End
      END IF
             IF Nf> 0 &&SU within SNR wall of that BS THEN
      Begin
                   Assign SU←Nf
             Update Database
      End
             ELSE
             Begin
                    ▪  Put SU in hold
                    ▪  Update the database
             End
             END IF
      End
      END IF
END
```

The suggested equipment within the HAP payload are:

1- Fusion center FC which store and update all user equipment UE identifications, their SNR, user class (Primary/Secondary), allocated channel IDs. It also store BS IDs and all its affiliated channels with their state (occupied/free), and if any channel is occupied it record the allocated user ID and class.

FC also make a sorting process for active secondary users per each base station according to their SNR.

2- Cognitive spectrum coordination CSC assign BS channels to the PUE in its coverage cell, while in case of SUs it allocate them to unoccupied channel if any, or according to the FC database it allocate that SU to the nearest base station within the SNR wall.

3- The cell area is divided into tracks according to the UE SNR

The channel allocation strategy between each BS to PU is controlled by the mobile GSM strategy, for connection and hand overs. The SNR received by BTSS is a measure index of how close is the SUE to the base station. There is a synchronization between the HAP and all affiliated BSs and according to that, the FC database is updated, and as well the channels allocation information. MUE and SUE use BS control channel to register with the base station. The adopted protocol is represented in the Figure 2.

VI. SECONDARY USER LOCALIZATION

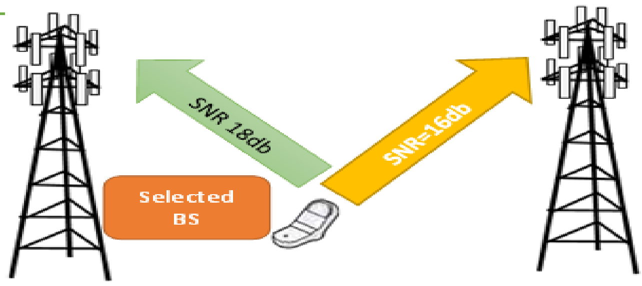

FIGURE3 Assumed values describing the BS assignment according to received SNR

To estimate the position of SUE it is proposed to use linear least squares algorithm based on time of arrival of SNR ranging data. The explanation of the relation between SNR and BS selection is depicted in figure 3. For the adopted system it is assumed that the tested area is three contagious cells each with a BS in the center of the cell. Each BS is equipped with Received Signal Strength Indicator (RSSI). the RSSI-based positioning device is used to translate received signal strength into distance.

The transmitted signal is attenuated to reach the receiving end, and the T-R distance is calculated according to the strength of the received SNR. The received SNR from SUE should be derived from the actual measurement, However, in the absence of experimental equipment, it is also possible to derive simulated measurements using assumed unknown nodes.

VII. THE ALGORITHM

According to the assumed unknown SUE location, each BS gets accurate received power. On this basis, the Gaussian random variable is added as an System interference, and the received SNR is proposed as the measured value of received power Pr. The measured value of Pr is then used as the RSSI to find the BS-SUE distance. The area is divided virtually into a number of adjacent triangles, the BSs are placed at the apex of the triangles.

While SUE is randomly Distributed but as evenly as possible in the area, SUEs use BS control Channel to transmit positioning signals to the surrounding BSs. After receiving the SU signals, the BS use the RSSI ranging algorithm to obtain the estimated distances from the unknown SUEs and report them to the FC. The FC harvesting RSSI information from BSs and use them to Select the SUE with the smallest distances to the corresponding BS.

Let $p = [x \;\; y]^T$ be the unknown two-dimensional (2-D) coordinate of the SUE, which is to be estimated, and let $p = [x_i y_i]^T$ be the known 2-D coordinate of the i^{th} BS as an anchor. The error-free range between the agent and the i^{th} anchor is calculated as [24-26] .

di =P-Pi $=\sqrt{(x-x^i)^2+(y-y^i)^2}$ (1)

The range measurement is modeled as

$$\widehat{d_i} = d_i + n_i \quad (2)$$

where n_i is the ranging error in $\widehat{d_i}$, which results from RSS estimation disturbance. It is assumed that {ni} are independent Gaussian processes with zero mean and variances $\{\sigma^2\}$.
Obtaining all the range measurements in (2) leads to the following inconsistent equations

$$(x-x_i)^2 + (y-y_i)^2 = \widehat{d_i}^2,\ i=1,2,\dots,N \quad (3)$$

$$x^2 - 2xx_i + x_i^2 + y^2 - 2yy_i + y_i^2 = \widehat{d_i}^2 \quad (4)$$

$$-2xx_i - 2yy_i + (x^2+y^2) = \hat{d}_i^2 - x_i^2 - y_i^2 \quad (5)$$

The simulation area has three BSs, so these equations can be written in the matrix form:

$$\begin{bmatrix} -2x_1 & -2y_1 & 1 \\ -2x_2 & -2y_2 & 1 \\ -2x_3 & -2y_3 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ x^2+y^2 \end{bmatrix} = \begin{bmatrix} \hat{d}_1^2 - x_1^2 - y_1^2 \\ \hat{d}_2^2 - x_2^2 - y_2^2 \\ \hat{d}_3^2 - x_3^2 - y_3^2 \end{bmatrix} \quad (6)$$

This gives us the standard form:

$$\begin{bmatrix} x \\ y \\ x^2+y^2 \end{bmatrix}_{ls} = \begin{bmatrix} -2x_1 & -2y_1 & 1 \\ -2x_2 & -2y_2 & 1 \\ -2x_3 & -2y_3 & 1 \end{bmatrix}^{\dagger} \begin{bmatrix} \hat{d}_1^2 - x_1^2 - y_1^2 \\ \hat{d}_2^2 - x_2^2 - y_2^2 \\ \hat{d}_3^2 - x_3^2 - y_3^2 \end{bmatrix} \quad (7)$$

The calculation of the first two terms of the vector: x and y are required to find the solution of left side of the eq. (7). To solve the right side of this equation (the matrices), the pseudo-inverse method is used. The number of BSs should be fixed during the simulations. This is very important because taking the pseudo-inverse requires a non-trivial number of computations, especially when start adding more BSs.

VIII. SIMULATION RESULTS

To take a test on performance of the proposed algorithm, we take a simulation in the area shown in Figure 10. There are three BSs in the area of the center cell. This means the center cell is the serving cell of every SU, and the cells are contagious. The location of SUs is assigned while the estimated location using RSSI is calculated. In this simulation the SUs can only be within the testing area covered by the HAP. The RSSI in this simulation is calculated according to [24], regardless of the environmental change. The simulation started with locating the three BS in the center of each cell where there coordination are BS1:[5,500],BS2:[500,5] and BS3[100,100] the actual location of the SUE is set on the coordinate [400,400]
As explained in Figure 7.

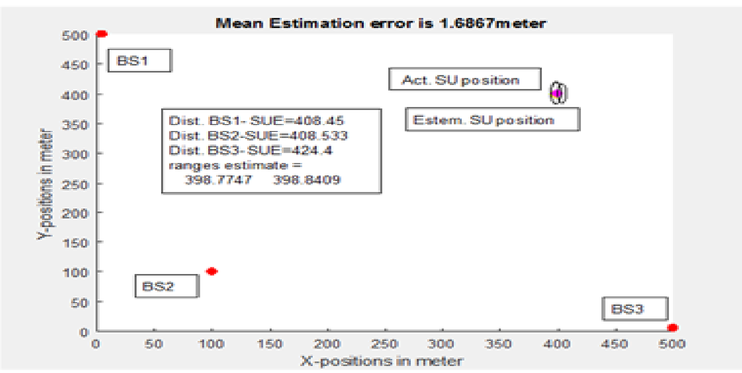

Figure 4 Localization using SNR

IX. CONCLUSION

The complex of technical issues and its regulatory concerns mostly can be alleviated by avoiding ambiguities and providing solid definitions for the basic development framework of an forth coming technology. In the case of cognitive radio (CR) communication,the main point is relate to the exploitation of white spaces. In this paper, we reviewed the relevant technologies adopted in the HAP-ACSS scheme. We outlined a broadening of the definitions of white space to combinationsof the three perspectives of radio signal dimension, license status, and channel assignment strategy. Then, an explanation of the algorithm is briefly described. The use of RSSI embedded in the BS and a smart fusion center in the HAP payload will help in utilizing the limited spectrum .

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