Cognitive Radio Handover in Cellular Networks

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Abstract

In cellular networks the continuity of communication has high significance in real-time services, therefore, the Handover (HO), transferring communication from one base station to another one, always has been the main concept of all mobile's generations.
In cellular networks for avoidance of frequency interference, different channel allocation scheme are proposed; static, semi-static and dynamic schemes. Dynamic scheme allocates frequency band more efficient. However, dynamic schemes usually are not used by operators because of the too much signaling overhead. We propose a new scheme for resource allocation based on Cognitive Radio (CR) technology to use provide frequency bands for HO. While the frequency bandwidth allocated to an operator is specified this opportunity exist with CR technology the frequency of the same network, which is employed for the farther distances, recognize and get used, to supply the required resources for HO. We named our proposed HO schemes Cognitive Radio Handover (CRHO).
Keywords: *Cognitive radio, Cellular networks, Hand Over*

1. Introduction

The continuity of communication in real-time services enjoys a special importance in telecommunication systems. Considering the limitation of cellular wireless telecommunication system's coverage and the users' mobility, the disconnection of user communication with a service provider is very likely; hence the HO or the communication transfer has been under consideration to maintain the continuity with another service provider. The first HOs in the cellular networks have been under considered and evolved to protect the vocal communication. Today, in the heterogeneous networks that support both types of wireless and cable communications and enjoy the diversity of different wireless systems not only maintenance of connection is gotten under consideration, but also improvement of QOS and decreasing the varieties of costs is considered. HO has four different distinctive phases, which are: HO determination, resource allocation, performing the HO and the release of resources. Each of the mentioned stages has been the subject of detailed researches. In this paper, we focus on the provision of HO resources in the systems of cellular wireless. The aim of resource here is the required bandwidth to have a successful HO.

The allocation of spectrum in the present wireless networks is in the static form, in other words the allocation of frequency spectrum is performed by official agencies, in a way that these organizations allocate specific frequency to the legal users and such users are bound to exploit the band allocated for them. The major part of this allocated bandwidth is generally used rarely [1]. The use of spectrum in different time and zone is usually between 15 to 85 percent (Fig.1). Although this policy of allocation was appropriate in the past, but considering the requirements of fourth generation mobile, the limitation of in access spectrum and un-optimal use of present spectrum has led the research path towards the use of some schemes to increase the spectral productivity [2].

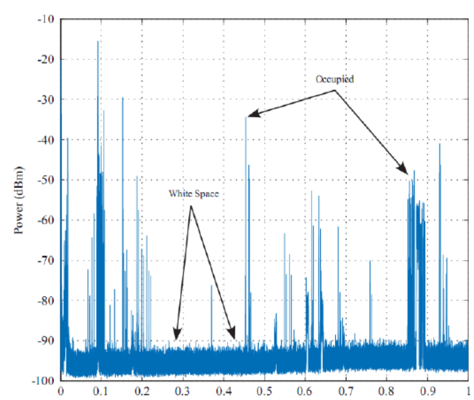

Fig. 1 parts used without employing the spectrum [6]

CR is the key to dynamic use and opportunist access to the frequency spectrum. The ability to sense the environment

and conformity with the existing environmental conditions are included in the attributes of CR networks [3]. CR use was first discussed by J. Mitolla [4], and the persons such as Akyildiz studied its particular place in the networks of future generations [5].
The remainder of this paper is organized as follows. In Section 2 we have a revision on cellular networks, a survey of resource allocation schemes in cellular network and the importance of HO process in cellular networks. In Section 3 the CR technology and its features is studied; different schemes of dynamic spectrum access by CR technology is described. In Section 4 different CR network architectures is surveyed. In section 5 HO in CR Networks is surveyed. Related work on using CR in HO process is discussed in section 6 and proposed scheme is introduced in section 7. Section 8 concludes this paper.

2. Cellular Networks

An area which a central antenna could cover is called a cell. If two different antennas exist in an individual system, each of them would constitute a system for their selves, with no communication with another one. In the radio networks, the individual cells are connected to each other via ground cable by means of a central switch, through this scheme, connection can be established between two Subscribers, one of which exists inside a cell with other Subscriber present in the other cell. The radio coverage is appropriate with antenna height, transmitter power and the sensitivity of the receiver, meanwhile the antenna height is of more significance in it; the more the height of the antenna, the more vast is the area covered by cell. In the cellular networks, the frequency reuse is used to increase the capacity of the system, for this reason to cover the vast area, large number of base stations (antennas) are employed that each of them have limited coverage.

The major sources of mobile network, is the bandwidth frequency allocated to it. Bandwidth is divided into two groups. The upper part of the band is called down link, and the lower part of band is called uplink, a distance is also considered among them called protector.

For the optimal use of frequency, a concept was expanded in the name of frequency reuse. The frequency reuse is discussed in the two areas of time (frequency band that is allocated to a user, if not used by it can be provided to others) and location (a frequency band that is used in an area by a user, to be used in a farther geographical zone) contexts. For possible exploiting of frequency reuse in location field, the frequency band that has been allocated to a mobile network is further divided into a number of sub bands. Then these sub-bands are clustered. A k cluster pattern can be assumed in this manner that each cell of this cluster could use a set of bands. These clusters can be lined or put together and the geographical space can be filled such that a symmetrical distribution of cells with similar frequencies can be established in the geographical bandwidth (Fig. 2).

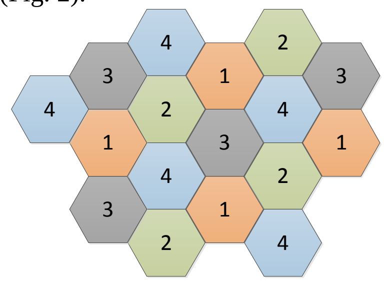

Fig. 2 four times cluster model (k=4) [7]

2.1 Mobility in cellular networks and HO

When the mobile employs a telecommunication channel inside a cell and its connection is established, it is possible that it moves and exits from a cell zone, because the exit from a cell causes attenuation of telecommunication wave, this finally causes the disconnection of attenuated connection. To save this connection and continue the dialogue, a new connection must be established between mobile and the base station of that cell. This process is called HO [7]. The schemes of HO are divided into two major sets of HO called hard and soft HO. The hard HO uses the Break before make scheme. It means the connection is disconnected with the old base station before the new connection establishes with the new base station. The soft HO uses the Make before break scheme. It means the communication is established with new base station, before the mobile connection disconnects with old base station.

The roaming service is used for more support of user mobility in the cellular networks. In fact, the roaming is the protocol that is enacted between two telecommunications networks. Based on it, the users of the two networks are licensed to use the network services of both telecommunication networks. The contracts that are signed on paper between two companies should be implementable electronically, that is performed through VLR and HLR. The HLR is a database that when a mobile is registered in a company, the information related to that subscriber are kept in this database for said company and VLR is a database that when a mobile enters in a new network other than the main network a temporary record of it is maintained in this database in which the mobile update its information periodically by informing its location to VLR and HLR.

2.2 Dynamic Spectrum allocation in cellular networks

As mentioned before the spectrum allocation has been assumed statically in cellular networks. It means the constant numbers of frequency (channel) are allocated to each of the cluster cells in a network that is not used by the user in the other cells of that cluster. If the user moves from one cell to other surrounding cell, he does HO, however the new cell that has been entered to it and its all channels are filled, the connection is disconnected, this is while it is possible that an empty channel exists in other cells of that cluster. Therefore, if the allocation of those channels was possible to the cell whose congestion is more, contact disconnection was impossible in this case. In this way, vast research has been conducted to remove this problem. In fact, the subject of this research is the dynamic allocation of spectrum [8]. Considering the concept of cellular network the reuse of a channel does not exist in a location provided the interference of the same frequency in that location is very negligible that could be considered as a noise [7].

Numerous algorithms have been presented for dynamic allocation of spectrum. In all such algorithms when a request is produced to allocate the channel, the network controller acts to allocate the spectrum in a dynamic form, no matter this controller is a M.S or B.S, this depends on the being centralized or decentralized of an algorithm for dynamic spectrum allocation. The controller selects a channel that leads to the least interference of the same frequency, for this purpose, it performs a whole search in the network [9].

One advantage of the dynamic spectrum allocation is the least number of unsuccessful HOs and disconnection of a connection under execution. However, the schemes of dynamic allocation of spectrum are not enough fast due to the use of algorithms that need search and general update of information. Hence, leads to decrease the presented service quality [10].

3. Cognitive Radio

Cognitive Radio (CR) can be defined as the radio that is cognitive or this can be explained in other words, a radio that thinks is CR [11]. Of course, due to the non-conformity and non-consistence that exists on the cognition rate required for CR among researchers, has created the differences on the definition of CR. Based on the definition of FCC (Federal Communication Commission) the CR is defined in this way: the CR is a radio that can change its parameters based on the interaction it has with its work environment [12], while based on the CR definition of ITU (International Telecommunication Union) it is a radio or a system that senses its work environment and aware of it and can adjust its work parameters in accordance with it, automatically and dynamically [13]. This can be described in fact, that the difference existing in the definition of CR is related to the expected differences that can be presented from the word CR.

CR has enabled the effective exploitation of spectrum by defining two types of the primary and secondary users. CR works in the frequencies that have been licensed in principle and in the beginning by governmental agencies to radio services, in addition, it can work in the frequency bands without license. The primary users are the license holder users, specific channel has been affiliated to them and the secondary users are those who are without license and allowed to use the channels allocated to the primary users only during the conditions when no destructive interferences are created for the primary users. For example, in IEEE 802.22 WRAN the transmitting TV tower/antenna is as the primary user and the radio devices that use TV channels to establish connection are considered secondary users.

The secondary users seek to access the existing spectrum using the opportunist schemes to avoid any interference in the primary users. A secondary user selects the best channel that is not under use of a user, without permission, by sensing all existing channels and uses it for a while; of course this use should continue until the return of secondary user [14].

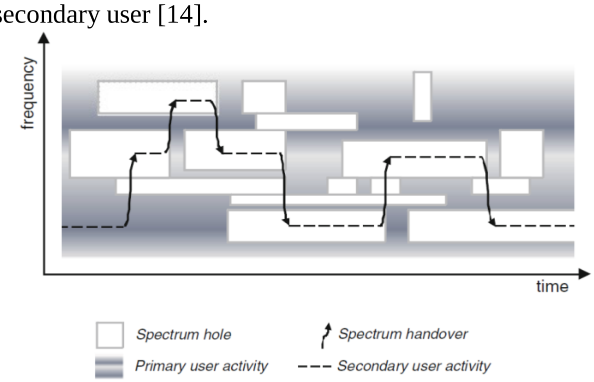

Fig. 3 opportunist access to spectral holes [15]

Optimal use of spectral holes is main goal in CR. Fig.3 expresses the concept of spectral hole and the jumping of frequency.

3.1 Dynamic Spectrum access scheme

The schemes related to dynamic access of spectrum are divided into three similar groups (Fig.4).

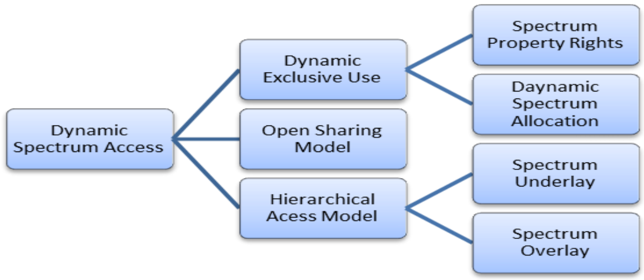

Fig. 4 dynamic spectrum access schemes [16]

3.1.1 Dynamic Exclusive Use

This spectrum access model is like the prevalent model of spectrum access in which the spectrum bands are licensed to service providers for its exclusive use. This model uses two schemes: spectrum ownership right and spectrum dynamic allocation. In the scheme of spectrum ownership right, the licensed users have the exclusive right for free selection of technology and can sell or exchange their spectrums. In the scheme of dynamic allocation of spectrum, the spectrum is allocated in exclusive way in a specific time and location to service providers [16].

3.1.2 Open Sharing Model

This model includes the wireless service that operates in without-license methods and all users have equal opportunity to access the spectrum. Anyway, the CR users can select the channels with less traffic rather the channels with high traffic.

3.1.3 Hierarchical Access Model

This model includes the hierarchy among the licensed users and the cognitive unlicensed users (secondary users). In this model of spectral subscription, the users without license can dynamically access the spectrum (for which they do not have the access license), though they must be satisfied that the interference created by them must be tolerable or use the spectrum in opportunist form and without interference with primary users. This model uses two basic schemes: Overlay and Underlay.

Overlay scheme: In this scheme, the CR must identify the useless bands of spectrum that have not been used by licensed system in a specific time and location and use these empty bands in dynamic form. This scheme has been illustrated in Fig. 5.

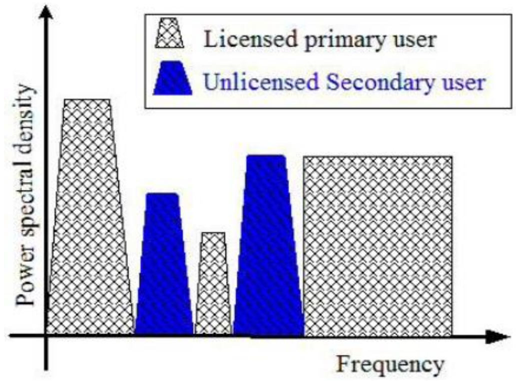

Fig. 5 Access to spectrum, Overlay scheme

Underlay scheme: in this scheme, the secondary users have the permission to send concurrently by primary users but with controlled and limited power. The interference created from the secondary user on primary users must be placed under a threshold limit and does not cause a harmful interference on the primary users. This scheme has been illustrated in Fig. 6.

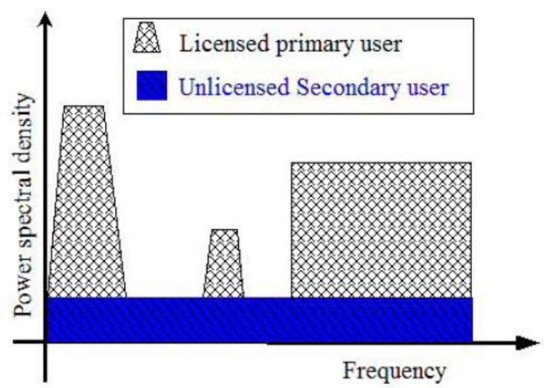

Fig. 6 Access to spectrum, underlay scheme

The significant point that is discussed in connection with the Underlay access scheme is the secondary user numbers accepted in the system that affects on the quality of network service. This point that how many secondary users must be present concurrently in a channel and on the other hand, the service quality must be satisfactory for primary and secondary users is related to 'NP-Complete' matter. The optimal resolution is the use of BFA algorithm that needs a comprehensive search that has a long processing. [17] Suggests an algorithm to solve this problem. In addition a power controller is also used that causes the speeding up of search work to eliminate the secondary users. Considering Fig. 7, the interference rate on first user decreases by increasing the distance from the receiver antenna of primary user, therefore, this possibility exists that more secondary user numbers could be supported at a farther distance from the primary user.

In addition, this theme has been illustrated in Fig. 8; by increasing the distance from primary user more numbers of secondary users can use one channel.

In diagrams 3 and 4, the enhanced JPAC-CR standard is related to the mode in which the algorithm parameters have been changed in a way that against the parameters change, the search speed is further slow downed, while its accuracy is increased.

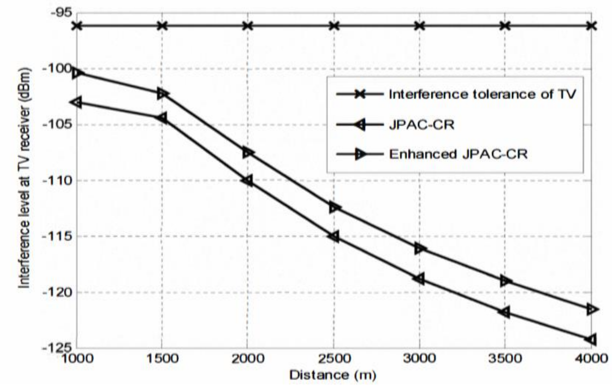

Fig. 7 Interference level at receiver

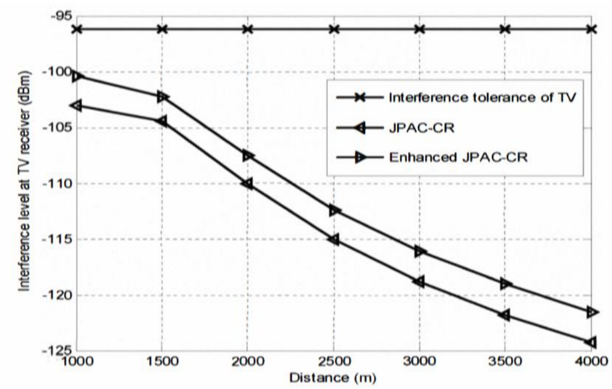

Fig. 8 Comparison of supportable secondary users [17]

Each of the two accessing schemes has advantages and disadvantages. For example, in the Overlay scheme, the secondary users can perform their transmission with a higher power, however the empty bands of spectrum must be identified to dispatch on it. Similarly, in the scheme of access to Underlay spectrum, the secondary users do not need the recognition and specifying the spectrum opportunities and can perform their dispatch concurrently in the presence of primary users; however, they are not allowed for higher dispatch power even when the whole frequency band is empty [16]. Therefore, this is to be discussed that which of the access schemes would have the more efficiency. Enormous researches have been carried out in order to respond to this question [18, 19].

3.1.4 Comparison of Underlay and Overlay access schemes based on the secondary user interference on the primary user

Three access schemes have been considered in [18]: Overlay scheme (for interference prevention), underlay scheme as well as a hybrid scheme (underlay scheme using the prevention of interference), in this scheme the user distributes its communication on a complete spectrum as well as the frequencies that are transmitted by the primary user, examined by it.

Exact, similar to all existing works, when a defect-less knowledge system is supposed, the overlay scheme would have extra expectation performance as compared with underlay scheme and when no system knowledge exists, all three schemes would have very weak performance, however, it shows underlay scheme has better performance as compared with other schemes. When prevention of interference is combined by sharing the spectrums, the underlay scheme accompanied with interference prevention guarantees less disconnection possibility of intervention as compared with the time when the prevention of pure interferences are under consideration. When the rate of system knowledge is close to reality, means, when the system knowledge is supposed to be limited, the importance of hybrid schemes manifests themselves. The overlay scheme by having the limited information has defect in identifying the spectral holes. In the more accurate form, a secondary user can use one channel while a primary consumer in use of a channel, however when the underlay scheme is used with prevention of interference, the interferences become least that are created in the primary consumer.

3.1.5 Comparison of Underlay and Overlay access schemes based on Markov model

The modeling of dynamic access to underlay spectrum has dealt with the Markov model by considering SINR in the primary user. If the interference resulting from secondary users and surrounding noise in primary user is less than a threshold limit such that no disturbance is created for the primary user, in this situation, the primary and secondary users can use same channel together. As shown in Fig. 9, a spectral sharing has been done between a primary user and two secondary users.

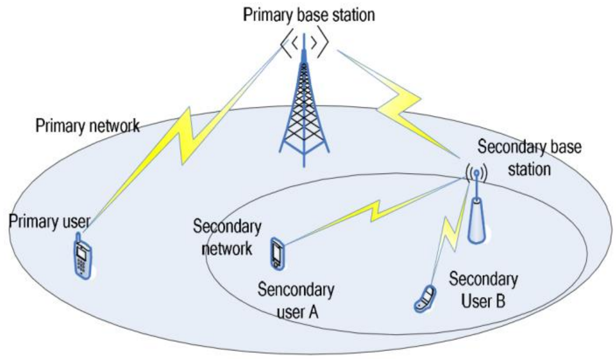

Fig. 9 spectral sharing between a primary and secondary users

Markov model related to this spectral sharing has been shown as follows in two modes of dynamic overlay access and underlay access.

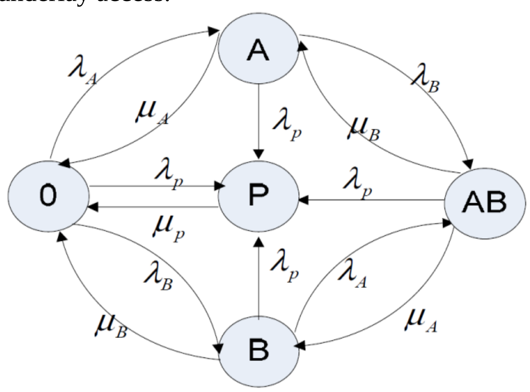

Fig. 10 Markov chain to model the overlay access [19]

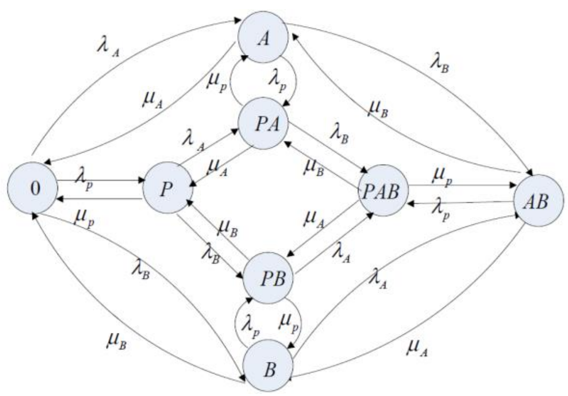

Fig. 11 Markov chain to model the underlay access

In these models, the interpretation of each state is as follows: the '0' state expresses the presence of no user in the channel, P state expresses the presence of primary user in the channel, A state describes the presence of secondary user A, the B state, indicates the presence of secondary user B, the AB state indicates the presence of secondary user B, PA state indicates the presence of primary user P and secondary user B and finally the PAB state indicates the presence of primary user P, secondary user A and secondary user B.

This is suggested in these models that the entrance traffic of primary and secondary users is Poisson that in the (Fig. 10) and (Fig. 11) are the reference of these two parameters, λp and λy. And the time of service providing for both primary and secondary users is considered exponential that the parameters of μp and μy are respectively the expressive of these two parameters. The given rate can be obtained for secondary users for both modes. It was concluded by simulating in MATLAB software that the permittivity is more in underlay mode as compared with overlay mode.
According to the features of underlay spectrum access, which discussed above, the underlay spectrum access is used in proposed scheme by aim of more efficient usage of frequency resources.

4. CR Networks

Two major abilities of CR include the ability of cognition and the ability of reconfiguration.

Cognition Ability: Cognition ability is the technological ability; the information of radio medium is sensed and received with the help of it. The information of radio medium is not received easily with the supervision of radio signal power but needs more smart techniques to achieve the dynamic behaviour of spectrum. The unused parts of spectrum can be identified and their attributes can be specified for the use of rest users with the help of this ability by investigating the dynamic behaviour of spectrum.

Reconfiguration ability: Cognition ability gives the necessary information to identify the dynamic behaviour of spectrum while the ability of reconfiguration provides the possibility of dynamic use of spectrum with the help of information obtained from cognition ability.
One of the most important objectives of CR is to provide the best existing spectrum with the help of mentioned abilities. The network that uses the CR or the two abilities of cognition and reconfiguration is called CR network. The main equipment of a CR network are access points (AP), Mobile Stations (MS) and backbones of network. With these three fundamental parts, three types of architecture are possible for CR networks: centralized architecture (sub-structural), distributed architecture (ad-hoc) and combinational architecture (mesh).

4.1 Centralized Architecture

In this architecture one MS can access to an AP and in a scheme of single jump. In this scheme, the MSs under the cover of single AP transmit can communicate with each other via AP. Communication across different cells are path given through central part of network. AP can implement one or more communication protocols to satisfy the different requirements of MSs. One CR terminal can also access to different types of communication systems via their APs [20]. This architecture is shown in Fig. 12.

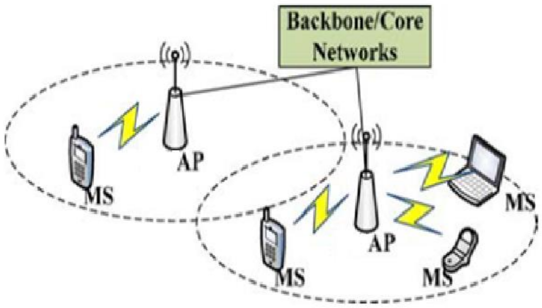

Fig. 12 centralized architecture for CR network

4.2 Distributed architecture

No sub-structural support exists in the distributed architecture of CR networks. In this architecture, the network is established on the air. If one MS specifies the presence of other one in the vicinity and it is accessible through specific communication protocols, they can establish a connection and constitute an ad-hoc network. This must be notified that these connections across the nodes can be established by different communication technologies. In addition, two CR terminals can communicate with each other through the use of existing communication protocols (Bluetooth, Wi-Fi etc.) or the dynamic use of spectrum holes [20]. (Fig. 13) shows the distributed architecture for CR networks.

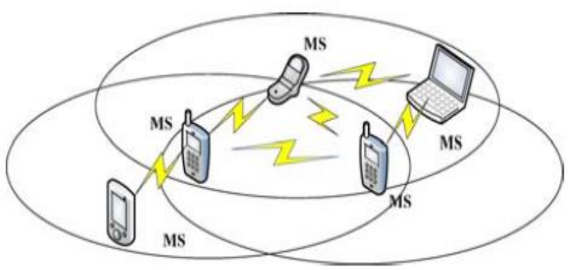

Fig. 13 distributed architecture for CR networks

4.3 Combinational architecture

This combinational architecture is from centralized and distributed architectures; in addition, it enables the wireless communication across APs. The network architecture is similar to the wireless networks of hybrid mesh. In this architecture, the APs act as wireless pathfinders and constitute the backbones of wireless. The MSs can also access to APs in direct form and/or using the other MSs as the multi jumping relay nodes. Some of the APs can connect to the backbone network and act as a gate. Because the APs can be expanded without necessarily connecting to the backbone cable networks, therefore, their flexibility has been more and in addition, less cost is necessary to design the location of APs. This architecture is shown in Fig. 14.

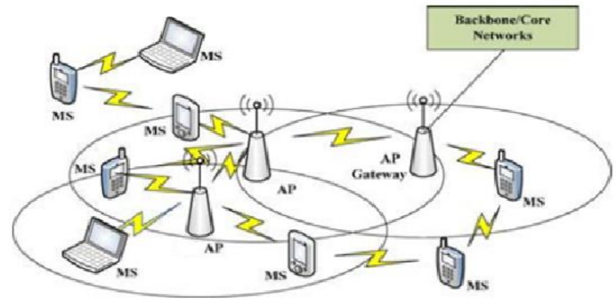

Fig. 14 combinational architecture for CR networks [20]

If the APs have the ability of CR, can use spectrum holes to establish the communication; because, several holes are identifiable in the spectrum, due to the present inefficient use of spectrum. Therefore, the capacity of wireless communication connections across APs of CR can be more and this matter, make the cable backbone powerful for service providing to more traffic [20].

The point that must be considered is the frequency resources used by users of CR networks (secondary users), that in fact, are the frequencies allocated to primary users. In other words, no frequency is allocated to CR networks and the secondary users by dynamic access and in opportunistic form use the frequency resources of all wireless applications such as the radio and TVs broadcasters, mobile radio operators, firms, army, general security agencies etc.

The centralized architecture has been used to design the CR network in [21]. The important point that has been considered in such type of architecture is the locating of access point of CR network as well as the frequency resources. In this CR network, AP have been placed on the BS poles of cellular network and has used frequency channels allocated to mobile radio operators to meet the user resources. The architecture of this network has been shown in Fig. 15, CRN AP is the reference of access point in CR network and PRN BS is the reference of base station in primary networks or the very networks of mobile.

The CR network which will establish by using proposed resource allocation scheme in this paper will be categorized as this architecture.

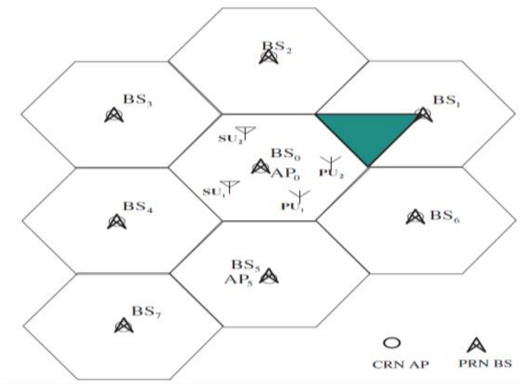

Fig. 15 cellular substructure for CR network [21]

5. HO in CR Networks

In a CR network the request of HO is happened by primary and secondary users. The request of HO by primary user is due to the quality decrease of communication channel and/or existence of a channel with better quality; the request of HO by the secondary user is due to the return of primary user, quality decrease of communication channel, existence of a channel with better quality. The manner of channel allocation's scheme in a CR network affects in the quality of service providing and the optimal use of spectrum in addition to the number of successful HOs. In this way, numerous algorithms have been presented to allocate the channel in the networks of CR. For example, an algorithm has been used in [22] for allocating the channel in the networks of CR in which a request of HO has been more prioritized in relation with the new connection request. Considering that two types of primary and secondary users exist in the network of CR, if the channel request for HO by primary user is indicated by PH, channel request for connection is shown with PI, channel request for HO by secondary user is indicated with SH and the channel request for connection by secondary user is shown by SI, the prioritization performed for response to channel request is as under:

PH>PI>SH>SI

This type of prioritization leads to the optimal use of channel and decrease of Unsuccessful HOs. However, it decreases the rate of traffic existing in network. That is due to the less prioritizing of the new connection requests as compared with the HO requests. To prevent this situation, it has divided the channels into two groups: the channels allocated to HO and the channels allocated to new connections. If there is a request for HO in the network, must use the channels allocated for HO.

1- If the time between two successful HOs is more than a threshold limit
2- If the request abundance of HO is less
3- If traffic is less than a threshold limit, following that the necessity rate becomes less for HO

Fig. 16, has dealt with the comparison of success rate of these four types of channel requests (SI, SH, IN, PH), as observed, maximum rate is related to the HO rate of primary user that is due the most prioritizing to this channel request.

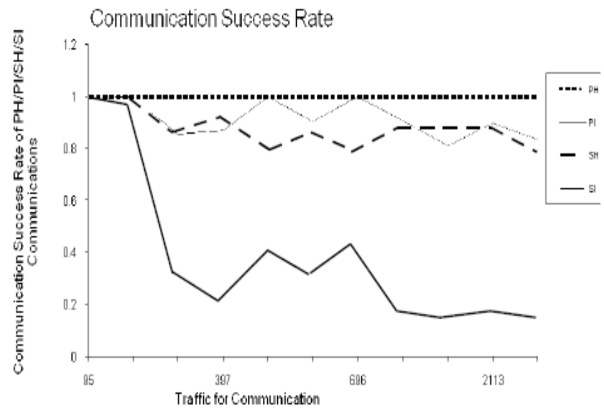

Fig. 16 comparison of success rate in the requests of channel by IN, PH, SI, SH [22]

Fig. 17 shows that by suggestive algorithm in this paper, the rejection rate of channel request for HO becomes zero for HO of primary user, and rejection rate of channel request for connection by primary user and the rate of channel request for HO by secondary user almost remain constant by increasing network traffic.

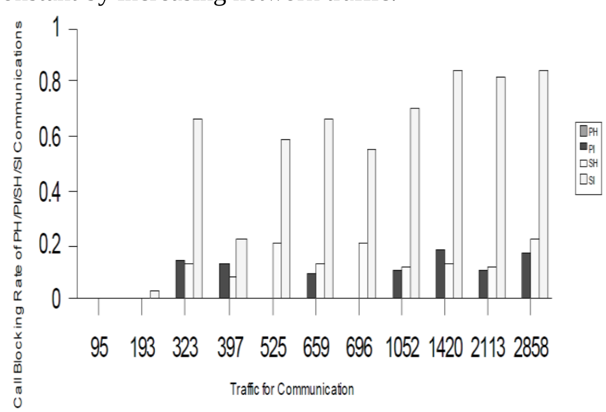

Fig. 17 comparison of rejection rate of channel requests by IN, PH, SI, SH [22]

6. Related works

The GSM system is a network of ground mobile and different companies can mount such a network on the ground and several companies can cooperate together concurrently. This network uses a cellular structure. GSM has three specific parts:

Radio sub-system (RSS): related to whole radio related issues
Network sub-system and switching (NSS): performs issues related to dialogue transfer, HO and switching
Sub system of operation: performs the management of the network

In the GSM system to establish the communication of networks operator with different resources and the cellular infrastructural equipment, not only the aerial connector but several other main connectors have been defined to connect the different parts of this system. Three important connectors in GSM have been shown as under:

- The connector A that exists between MS and BS
- The Abis connector that exists between BTS and BS
- The UM connector that exists between MS and BTS

The GSM radio sub system including the equipment and the related functions with connections management of radio path is similar to the HOs. This sub system includes BTS, BSC and MSC. MS exists in the radio substructure in contractual form and it is always the last path of a dialogue. MS has the ability of network terminal as well as the user terminal. Each cell in GSM system has one BTS or several receivers and transmitters. One group of BTSs is controlled by one BSC. BSC and BTS are identified together as BSS. It seems that BSS is permanently connected with a radio channel management, transfer duties, radio link control, quality and preparation of system for HOs. Each MSC has a data base of VLR and minimum a data supply base of HLR that is used for HO [23].

In GSM system, if a user passes through the cell limits during dialogue will be more declined to use radio resources in the new cell. Since the signal power provided by old cell has been attenuated due to the distancing of user from the zone of old cell coverage. The whole process of existing disconnection with BTS and establishing of a new connection with appropriate BTS is called HO. Based on the location and use; four other types of HOs are used in the GSM systems (Fig. 18).

1- HO across the channels (time slot) in the same cell or inter carrier HO. In this case the user is transferred across different traffic channels inside the same cell. This channel is developed with frequency or the different time groove. Decision on the HO is taken by BSC that controls the cell.
2- HO among cells (BTSs) under the control of different BSC or the HO across BSCs.
3- HO among cells (BTSs) under the control of different BSC or the HO across BSCs.
4- HO across the cells under control of different MSCs or the HO across MSCs (in the HOs across MSCs, if the MSCs are specific to the networks of different companies, the HO done is called internetwork type of HO).

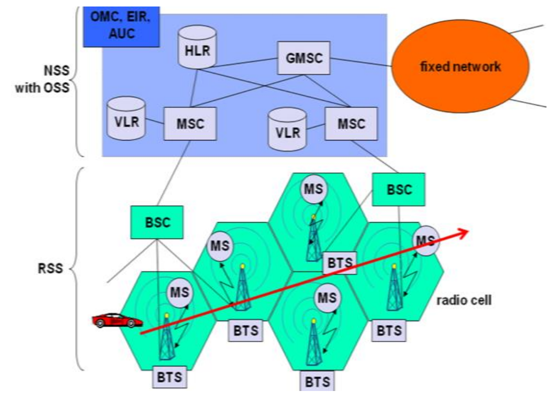

Fig. 18 HO in GSM network

In [23], a scheme of Inter-network HO has been introduced to increase the capacity and decrease of dialogue disconnection that is in fact, a type of inter-network HO. Suppose, there are three different companies called A, B and C and they signed a contract among them in a geographical zone (at province level), if the HO request is performed due to the replacing of a user who has purchased his/her SIM Card from the telecommunication company of A, if all channels of destination cells are without capacity/full in A network, the connection is disconnected, but if the user could use the channels allocated to the other networks that are reusable [the use of them lead to develop an interference of same frequencies in the users of that networks (primary users)], the connection would not disconnect. It is suggested in this paper to solve this problem, that CR is used in place of software radio that is used in the mobiles of GSM systems. SDR is a programmable radio that can change the parameters of transmitting and receiving in the dynamic form during a dialogue while the CR is a smart SDR radio that can sense the frequencies existing around it and access the each empty frequency present around it.

The CR performs four actions to provide the intelligence sense and dynamic spectrum access: sensing the spectrum, sharing the spectrum, spectrum decision and spectrum mobility. Therefore, when a request is taken place for connection, whether this connection is on the behalf of primary user (the user who has the first priority to use the frequency resources of its network) or the secondary user (the user who uses the frequency resources opportunistically from other networks), the CR first studies

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that is there any empty frequency in the network the mobile belongs to it, if does not exist then it performs the operation in the following manner:

1- Sensing the spectrum: senses its surrounding environment and collects the related information of different frequencies and prepares a list of empty frequencies as well as the networks related to them.
2- Spectrum sharing: as it is possible to have several secondary users concurrently requesting to use empty frequency related to a network. In this stage, the necessary examining is done to prevent the interference in sharing of spectrum.
3- Spectrum decision: it selects the best by considering the list of usable frequencies.
4- Mobile's mobility/movement: in case of mobile's movement or the primary user used himself in the network frequency, must perform all stages from beginning.

Fig. 19 shows the stages of this algorithm. As mentioned above, this type of HO is an inter-network HO. Therefore, for the legal issues and the expenditures, it is necessary to use roaming in this HO.

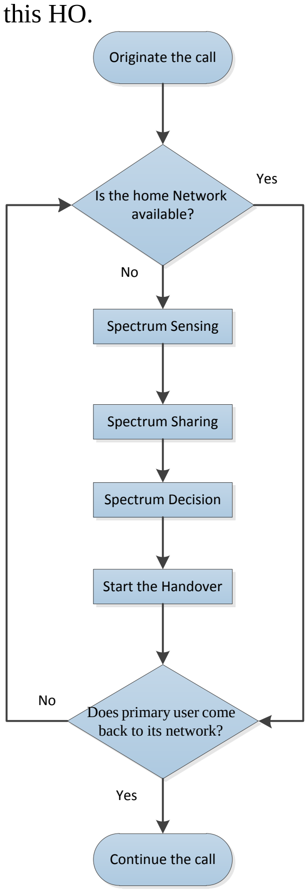

Fig. 19 Use of CR for inter-networks HO in GSM cellular networks [23]

7. Proposed scheme

This scheme assumes the use of CR by the BTSs and users' devices, which were equipped with these components in the network; all transmitters are able to identify empty channels. Many ways and algorithm are introduced to optimize the four stages of CR: sensing, spectrum sharing, spectrum decision and spectrum mobility. But the fundamental basic condition of all these algorithms is to select channel for secondary users with no cause inconvenience for primary users, and this goal is satisfied just by lowering the noise in certain limit on the primary users.

The proposed algorithm has both primary and secondary users. Primary users mean users who are permitted to use certain frequency resources in one cell by spectrum allocation schemes and this is based on radio operators. For example, as it is shown in Fig. 20, it is proposed the operators use static spectrum allocation with reuse factor 3.

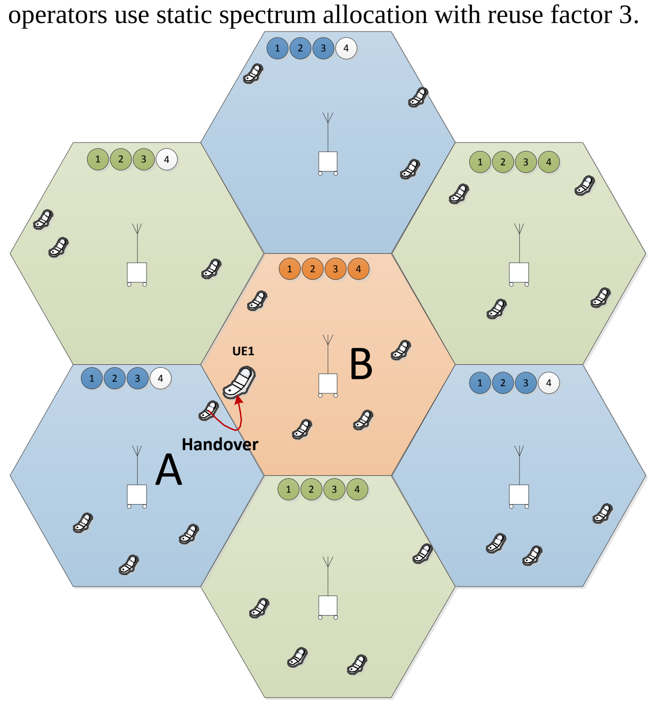

Fig. 20 Request of frequency resource for HO

In this way, the secondary user means user who is not permitted to use certain resources block due to used resource allocation scheme by operators(such as static) but without disturbing the primary users, they can use the same channel opportunistically. For example, as mentioned in accordance with static scheme, the user UE1 (after HO and entrance to cell B) only allowed using the orange channels' (4, 3, 2, 1). but when the same user use other channels, he is considered as secondary users and he must leave the block as soon as the primary users returns to the same channel without causing to inconvenience to them .

The proposed scheme could implement on previous resource allocation schemes. This means all stages of frequency resources allocation to users is based on previous schemes except if user enters to new cell and request the resource block for HO process, while there isn't provide resource for user by using the resources allocation schemes, in this case, the proposed scheme will search the resource block for user during the HO process.
This means that the secondary user (the user who do HO and has not found channel by using resource allocation scheme) has identified the usable channel by using CR and then used it over underlay spectrum access scheme, but when he cause to inconvenience for the primary user, he will leave the same channel . Fig. 21 shows the proposed scheme on static resource allocation scheme.

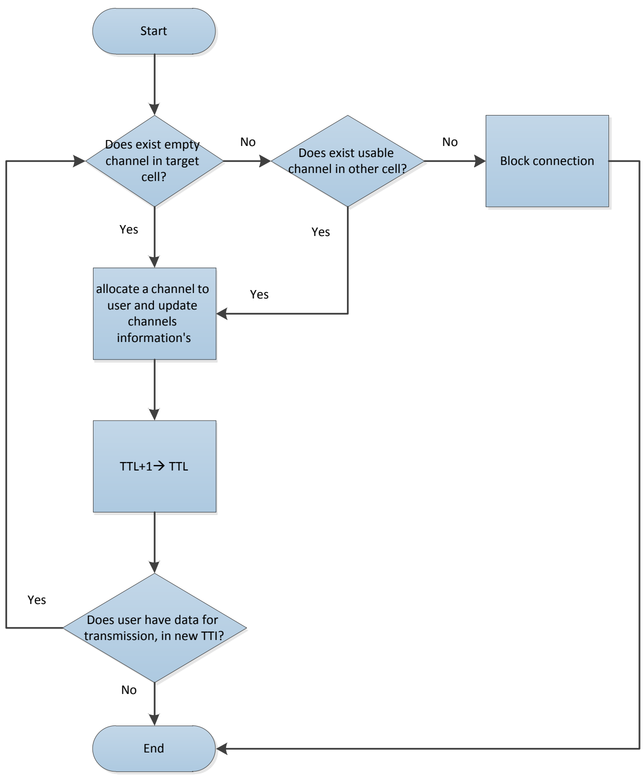

Fig. 21 algorithm of proposed scheme

This process of providing frequency resources for HO by proposed resource allocation scheme which is based on CR technology is called cognitive radio hand over (CRHO).

8. Conclusion

In this paper the problem of bandwidth lack was studied in the cellular networks, on the other hand, articles were scrutinized in the field of CR and issue discussed in connection with this technology including the schemes of dynamic spectrum access, attributes related to overlay and underlay access schemes, CR, architectures presented for CR networks and HO in CR networks.

Quantitative works have been carried out in the application context of CR technology for HO in the cellular networks. Of course, this matter provides the necessary ground for more research in relation with this subject. The only scheme suggested in relation with the use of CR for HO in cellular networks is the scheme suggested in [26], that has used the CRHO in the GSM cellular networks for inter-networks HOs. Considering that the third generation of mobiles only uses the one frequency spectrum across the whole network, has no ability to use the technology of CR, however, second and fourth generations of mobiles is void of this defect and has the using ability of this technology.
This possibility exists considering the abilities of CR that the schemes of CR could be employed to satisfy the required resources for HO in cellular networks of future generation. This type of HO could be labeled in the CRHOs.

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