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Cooperative Agent Based Message Exchange for Spectrum Sharing in Cognitive Radio Network

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Abstract: ***The radio spectrum is assigned statically for wireless communication. But large portion of the allocated spectrum is used sporadically. To alleviate this poor spectrum utilization problem, one effective technology is introduced with dynamic spectrum allocation and spectrum sharing namely as Cognitive Radio. To achieve effective spectrum utilization, an adaptable, sensible and cooperative spectrum sharing is necessary between cognitive users. Multi-agent system is constructed with multiple interacting intelligent agents within an environment to solve problems which are not able to solve by an individual agent. The objective of this research work is to design a novel cooperative framework for message exchange with channel information between primary and cognitive users. To design this framework, various cooperative spectrum sharing approaches using Multi-agent system are reviewed.***

Keywords: ***Cognitive Radio Network, Multi-agent System, Message exchanging scheme, Dynamic Spectrum Allocation, Cooperative Spectrum Sharing.***

I. INTRODUCTION

The radio spectrum is naturally limited, which is a crucial medium in wireless communication. The frequency spectrum is statically assigned and licensed by the government or some other government-aided organizations such as Telecommunication Regulatory Authority of India (TRAI) in India to different type of users like military and civil in order to avoid interference and collision. The radio spectrum frequency allocation in India (NFAP 2002) is illustrated in Fig. 1. In the static spectrum allocation, no more available band left for the future wireless network use [2]. In this assigned spectrum, a large portion of the spectrum is used sporadically and inefficiently. In addition, Industrial Scientific and Medical band is assigned to unlicensed users to develop and use new technologies such as Wi-fi, Bluetooth, etc. The unlicensed band users are gradually increased due to the role of new technologies in day to day life. To address the poor spectrum utilization problem, Cognitive Radio (CR) has emerged as a promising technology to enable the access of unused frequency bands and thereby increase the spectrum utilization in efficiently [1].

CR is used to identify the unused spectrum of the primary user and use the spectrum hole for efficient transmission of data between the secondary users, without any interference to the primary user. Hence, one main aspect of cognitive radio network is sensed independently for exploiting locally unused spectrum to provide new paths to spectrum access. In the term of functionality, CR has four main tasks. Those tasks are:

- Check the availability of the spectrum with spectrum sensing
- Choose the best available channel which fulfils the secondary users QoS requirements with spectrum detection

- Coordinate access between the users with spectrum sharing
- Leave the channel when the primary user is detected with spectrum mobility.

Similar to cognitive radio network, a Multi-Agent System (MAS) has the knowledge about its working environment and also has the knowledge about its neighbour agents based on message exchange between the agents [3]. This knowledge is used to solve the user requirements dynamically in the particular environment. The objective of this research work is to design a novel cooperative framework for message exchange with channel information between primary and cognitive users. This message exchange scheme, primary user agent gets a request message from secondary user agent whenever the required spectrum is available and then primary user agent replies for the same. In this message exchange scheme is based on cooperative spectrum sharing agreement between primary user and secondary user. In this cooperative agent based spectrum sharing, the primary user agents exchange the spectrum availability information message to the neighbouring secondary user agents to improve their spectrum usage in effective manner.

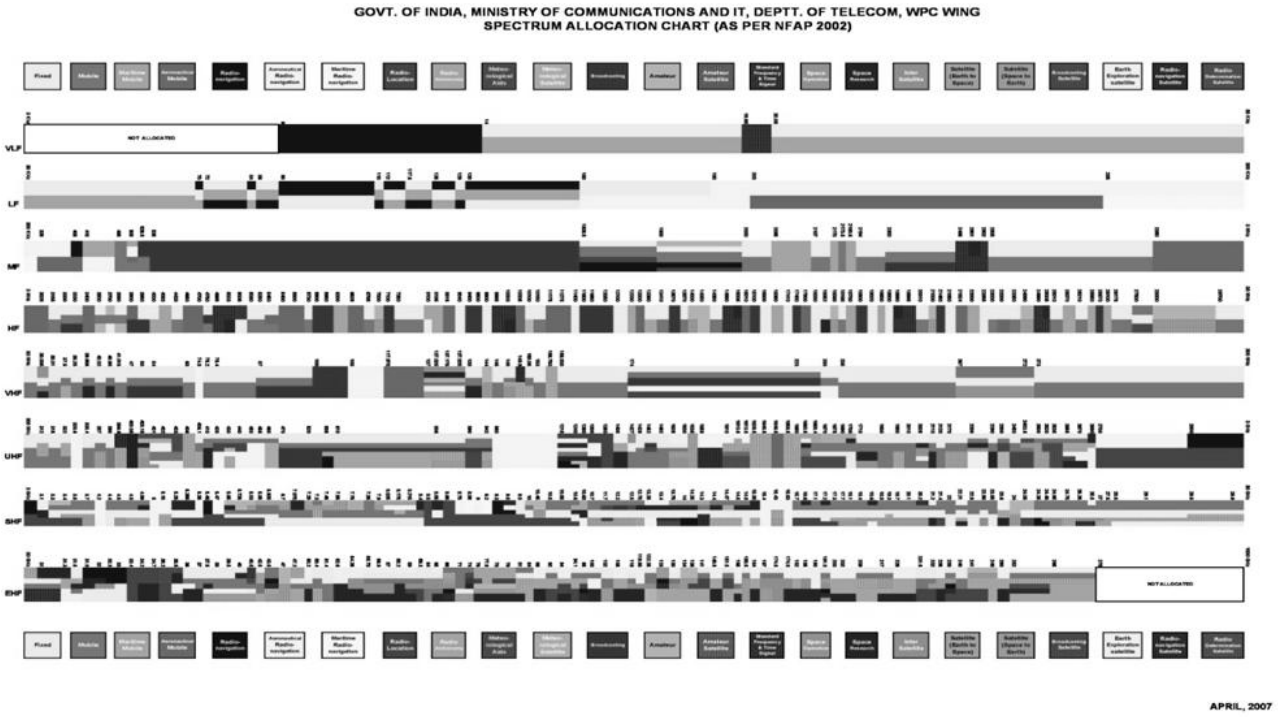

Fig. 1 Spectrum Allocation Chart by Govt. of India (As per NFAP 2002) [2]

This research work presents the similarities between MAS and CR in section II. In section III, the review of various spectrum sharing approaches based on MAS to effectively use the unused licensed spectrum in cognitive radio network. In section IV describes the design of a novel cooperative framework for message exchange scheme between primary agents and secondary agents to share spectrum on request basis. The key aspect of this research is to improve the spectrum utilization by both primary users and secondary users in cooperative based message exchange. The research challenges with agent reasonable activities are explained in future work.

II. FUNCTIONALITIES COMPARISON

In the MAS, research has been going with the task of resource sharing with intelligent decision. In the cognitive radio network, research has been going with same task of resource sharing for efficient use of spectrum. In this section, the similar functionalities of CR and MAS are compared. The environment has been sensed by both of them for fulfil their users requirements with local view [9].

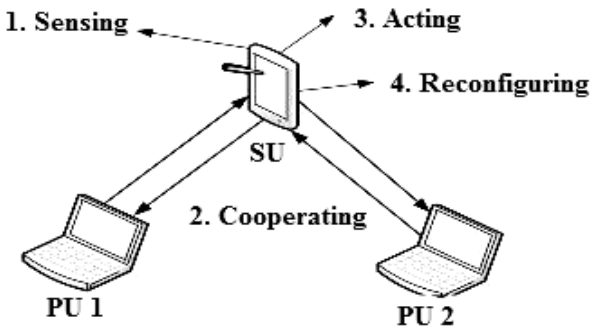

Fig. 2 Coordinate Access Steps in Ad hoc network

They can achieve the particular task with autonomy decision making process. When the capabilities are not able to achieve the task, they can communicate with their neighbours with message exchange scheme to finish that particular task. MAS is acting through interacting intelligent agents to solve the task. CR is deciding the bands or channel to be selected for communication [12]. CR and MAS are having the local knowledge and neighbouring or primary user information for efficient use of the resources [4]. MAS is working to achieve shared goals and CR is working together for efficient spectrum use.

When the secondary users are furnished with CR with multi-agent functionalities, it has best knowledge about the environment. When the secondary user can not able to directly access the radio resources and it does not have energy for the access technology, the secondary user applies the cognitive functionalities with primary user agents [8]. The steps to be followed by the secondary user for coordinate access with primary user agent are described below and these steps are illustrated in Fig. 2.

First, secondary user senses the neighbouring primary user (like PU1 and PU2) signals. After sensing the signals, cooperates with primary agents. In the cooperative process, secondary user is allowed by primary user for utilizing their available spectrum based on the agreement. Finally, secondary user reconfigures the access technology, spectrum band such that information received from primary user to fit the current state.

As an example, one primary user bought a spectrum portion to provide the internet service. Utilization of this statically assigned spectrum is illustrated in Fig. 3. When the office gets started, the utilization of the assigned spectrum is high due to the video conferencing and lecturing. In the Fig. 3, t_0 to t_1 denote the office timing.

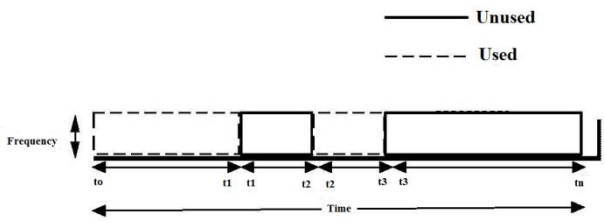

Fig. 3 Utilizing of Assigned Spectrum

But the other timing (like office gets over), the spectrum is idle or unused. This unused spectrum is used by the secondary users based on the agreement between primary and secondary user. In the proposed message exchange scheme design is used to select the best unused spectrum channel dynamically based on the secondary user requirements like amount of spectrum required for communication, allowed time to utilization and related price [5].

III. Related Work

Agents are autonomously performing tasks based on local view or through the neighbour agent's interaction. These agents are loosely coupled between them to form a MAS. Based on MAS, secondary users are interacting with their neighbouring agents with CR capability [7]. The cooperative MAS has a potential with message exchange scheme to increasing their capabilities. With this message exchange scheme, secondary user agents can identify and select the spectrum hole to communicate with other secondary user agents [11, 14].

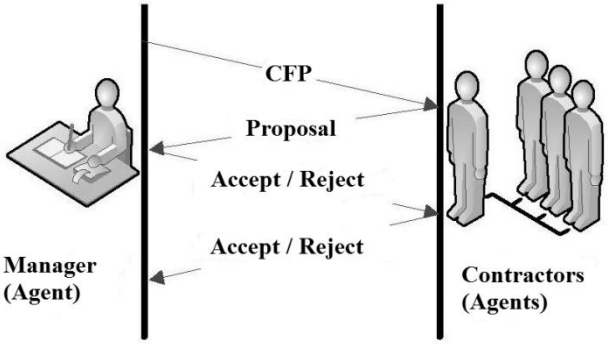

Fig. 4 Agents Message Exchange Scheme

In the MAS, the cooperation between the agents is done with several approaches. In this research choosing one of the best approaches called as contract net protocol for simple way to agent's cooperation and selection [6]. In this approach, agents are divided as manager agent and contractor's agents. This message exchanging scheme starts from manager agent. Manager agent is sending proposal message with task information. To solve the task, contractor show their interest based on fulfils QoS of the task. The manager selects the best contractor based on their QoS for solve the particular task and assigned task to the selected contractor agent. Then contractor agent gives the acceptance to the manager agent. Based on this simple and efficient nature, this message exchange scheme is modified for message exchange between primary and secondary user in cognitive radio network about spectrum usage [10, 13].

The Fig. 4 explains the steps involved in message exchange scheme between the agents.

IV. Proposed Design

In this proposed design, the message exchange scheme for ad hoc WLAN installed in the environment with set of primary users (like PU1, PU2, ….., PU_i) and secondary users (like SU1, SU2,…….,SU_j). This WLAN ad hoc environment is illustrated in Fig. 5.

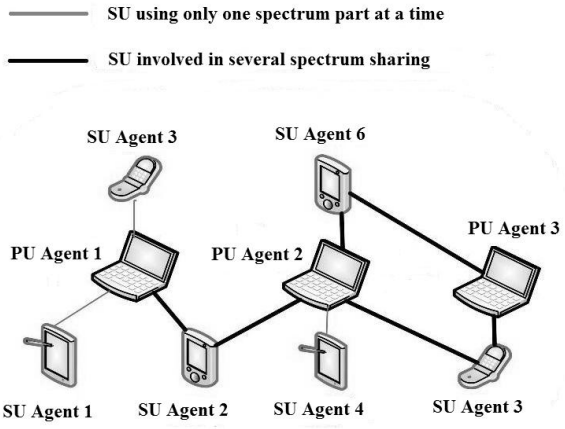

Fig. 5 Ad Hoc WLAN

Steps involved in proposed scheme are listed below.

- First, cooperative spectrum sensing is used to sense the spectrum hole in primary user. Decentralized cooperative spectrum sensing is used in this proposed research for primary user's status that Idle (when the spectrum empty or inactive) or Active (what time spectrum is occupied). In this cooperative spectrum sensing is simple and best when compares it to non-cooperative spectrum sensing.
- Next, the proposed scheme concentrates on system analysis function. In this step, analysis the spectrum and list the spectrum with quality of services information. This list has information about the entire available neighbouring primary user in the particular environment.
- In next step, secondary user interface send the secondary user request. That request message having secondary user ID for finding particular secondary user (SUID), needed spectrum (s), Usage Time (t). Like

Request (SUID, s, t)

- Request proposal step get the primary user list with QoS information from spectrum analysis step. Also get the request message from secondary user interface. In this step compile the both and give the request proposal with available primary user list. This primary user list is not permanent rather it is updated and maintained in regular interval time. This request proposal added new information about the deadline to receive primary user's proposal (d).

Request (SUID, s, t, d)

- Finally, the secondary user request send to neighbouring primary users available in the list. Having received the proposal, the interested primary user agent s sends their proposal to the corresponding secondary user agent (find with secondary user ID). The proposal is in the following form

Message (PUID, s, t, p)

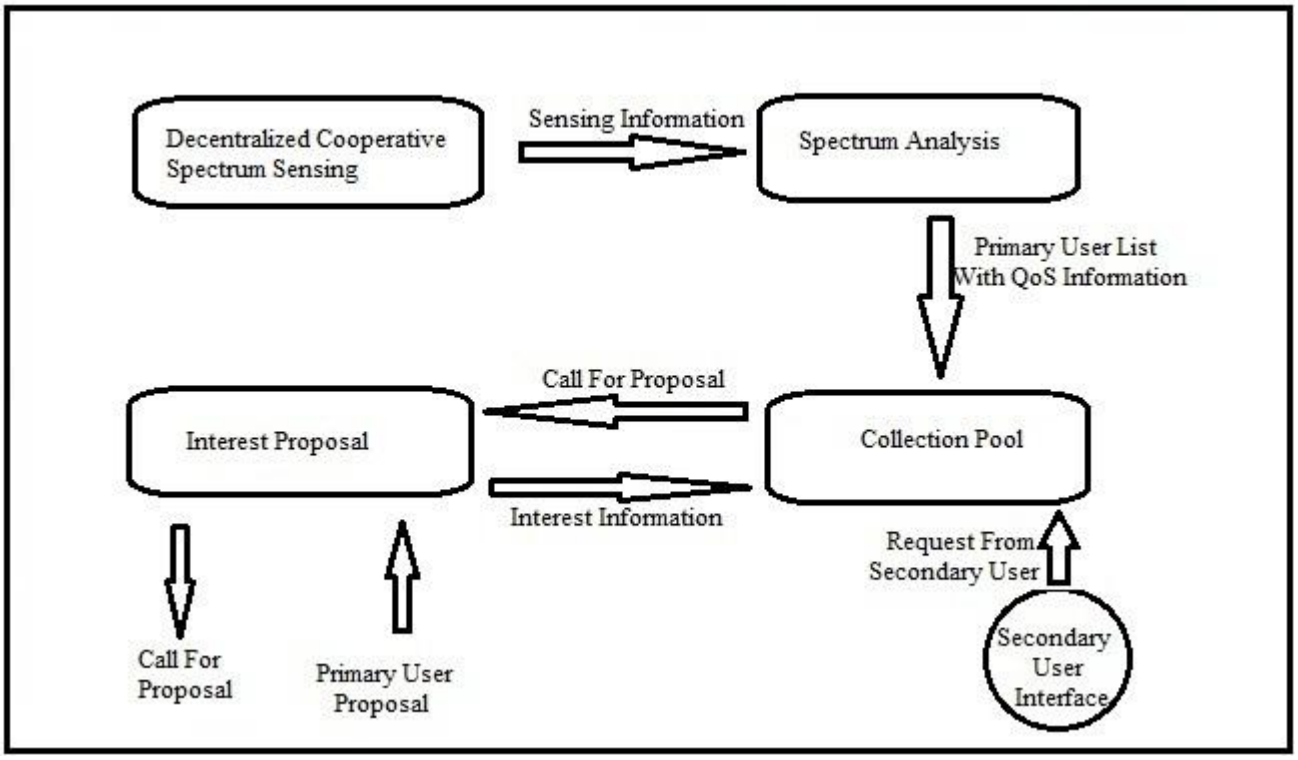

Fig. 6 Steps Involved in Proposed Design

PUID – Primary User ID
s – Ready to give to the corresponding Secondary user
t – Allowed time to utilize
p – Willing to receive

The steps involved in the message exchange scheme are illustrated in Fig. 6. After finished the above steps, the primary user is waiting for accept message from secondary user. When the primary user receive the accept message from secondary user, based on the cooperation agreement between these two users the spectrum sharing is started. If the primary user receives a reject message from secondary user, primary user continues to send the proposal for some other secondary user who is deadline is not yet to expired. When primary user has other spectrum portion after share the spectrum to one secondary user, it sends the proposal to some other secondary user who give request proposal. For future communication, primary user wants to maintain a list with the proposal cache from secondary user with spectrum needs and usage time. The selected primary user for particular secondary user information is maintained in collection pool.

V. FUTURE WORK

First, develop an algorithm for proposed message exchange scheme design. In this proposed design needed two different algorithms for each user side. The secondary user action algorithm wants to know the information provide time interval between the spectrum analyses to collection pool.

In future research includes the development of analytical model for proposed message exchange scheme to analysis the performance of proposed design. In addition, evaluate the message exchange scheme and validate the analytical model extend this work to simulation.

Later, extend this research to different spectrum sharing approaches like ISM bands, TV bands and cellular networks.

VI. CONCLUSION

In this research, the aim is to design a cooperative agent based message exchange scheme for spectrum sharing in cognitive radio network. This proposed message exchange scheme improves the spectrum efficiency with information proposal of each user and minimum communication cost. This design provides all the information for developing an action algorithm for the primary and secondary users involved.

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