Performance Enhancement of Heterogeneous Complex Wireless Network for Communication Systems Using Optimization Techniques

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Abstract - The next generation wireless communication technology demands high data transmission rate and system capacity, cognitive radio is one of the technologies that utilizes the spectrum resources in a more efficient and fruitful way to improve the network performance of heterogeneous complex networks. However, achieving these is a challenging task when it is to deal with multiple heterogeneous networks having overlapping coverage and diversified requirements of the users. This Challenge can be overcome by efficiently selecting the network and reasonably allocating the ideal spectrum resources. The work in this dissertation aims to maximize the total bandwidth utilization while minimizing the total cost with the help of optimization techniques. The proposed work aims to modify the existing optimization techniques and apply it to enhance the performance of heterogeneous complex wireless networks for communication systems. Finally, the performance of traditional methods is compared and analyzed through experiments with the proposed methodology.

Key Words: optimization techniques, wireless communication

1. INTRODUCTION

Wireless systems rely on the utilization of spectrum to operate. Different bands of the spectrum have traditionally been assigned to different wireless systems, such as mobile cellular networks and television, and licenses have been necessary to operate within those bands. The principal users (PUs) of the spectrum are the licensed systems. The possibility for fresh spectrum allocations, on the other hand, is dwindling as wireless communications expands and new systems emerge at a quicker rate than the present, aging systems fade away. The scenario has resulted in a global spectrum shortage. Spectrum sharing strategies appear to be promising answers to the growing demand for wireless services by allowing for more effective use of the limited spectrum resource. To address this issue, a new spectrum assignment policy called Dynamic Spectrum Access (DSA) and a spectrum allocation mechanism called Cognitive Radio Networks (CRN) were proposed.

Fixed Spectrum Allocation (FSA) is a long-term method of allocating spectrum resources to licensed users by governmental agencies or services. Unlicensed users are unable to temporarily utilize the idle spectrum to increase usage efficiency. The Dynamic Spectrum Access (DSA) technology allows users to dynamically sense spectrum gaps and employ white spaces in spectrum wherever possible to solve the problem and enhance wasteful fixed spectrum use .

A software defined radio (SDR) is a wireless communication device that can be reprogrammed to operate on multiple frequencies and protocols using software. The SDR platform is commonly used to implement CR . Joseph Mitola invented the phrase cognitive radio in the year 2000. . He defined cognitive radio as "enough computationally sophisticated about radio resources and related computer-to-computer communications to recognise user communications needs as a function of usage context, and to supply radio resources and wireless services most relevant to those needs." A CR is constantly observing, orienting itself, making a plan, making decisions based on the plan and orientation, and acting on those decisions .

A smart network system with self-monitoring capabilities is a wireless sensor network. It consists of a large number of low-cost, low-power, and compact sensor nodes that link to conduct sensing and data processing. Because network coverage is such an important part of the system, it has a big influence on how long it lasts. In this thesis, the particle swarm method was used to maximize the coverage of a wireless sensor network. The approach was implemented in MATLAB using a particle swarm optimization-based network coverage optimization technique. In this thesis, the probability sensing model is applied, and the coverage type is area coverage. The efficiency of the method is demonstrated through simulation.

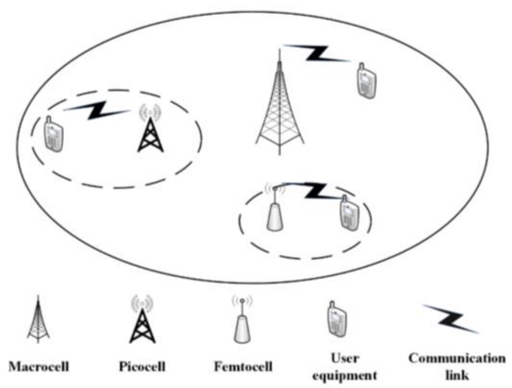

Figure-1 Three Tier Heterogeneous Networks

2. Background

Wireless communication is rapidly expanding and garnering increasing investment. Because the number of users continues to grow, the available radio spectrum, which is a limited resource, is constantly under demand. As a result, there is always a need to maximize the use of available spectrum at any given time. Currently, the spectrum is supplied to licensed users as an exclusive fixed bandwidth. As a result, it is only used when the user activates it [1]. This leads to an inefficient use of the available spectrum, as some users may be experiencing significant traffic while others may be utilizing very little. Furthermore, as technology advances, the bandwidth requirements for various applications alter.So, the concept of dynamic spectrum allocation has come to the fore, which refers to changing the allotted spectrum to different users as per the requirement during data transmission through the allocated channels. In other words, considering spectrum allocation as a time-variant system improves performance.

This dynamic spectrum allocation mechanism is popularly known as cognitive radio [2, 3]. Cognitive radio is a software-based radio system that uses environmental sensing and learning to intelligently tune transmission elements such as operational frequency, waveforms, and other parameters in a dynamic situation [4]. Its major task is to identify any principal user's unused spectrum and decide whether to temporarily give it to other secondary users, while ensuring that interference to the prime user is avoided and that it is reassigned to the primary user on a priority basis if the need arises. As a result, cognitive radio handles spectrum sensing, resource allocation, resource optimization, and mobility [5]. These tasks are depicted as a cognitive cycle in Figure 2.

Spectrum sensing is the cognitive radio's monitoring of the external world, keeping track of the usage behaviour of various primary users, and finding spectrum holes. Based on this information, spectrum is allocated and parameters are set appropriately to give the optimum quality of service and reduce interference. The best resource usage is attempted by striking a balance between transmission efficiency and spectrum sharing among different users. Mobility must also be maintained, which means that anytime the primary user requires their assigned spectrum, it must be made accessible by de-allocating it from any secondary users who may be using it, minimizing interruption to the primary user. This procedure should be conducted in real time, therefore the cognitive radio system's job is to constantly monitor the surroundings for the best available free spectrum area [6, 7].

Due to their capacity to simultaneously search enormous spaces for optimal solutions, swarm-based and evolutionary techniques have recently gained a lot of traction in solving difficult problems that would otherwise be impossible to solve with standard algorithms. Their capacity to answer issues heuristically in real-time has made them the favoured choice for scientific and business applications. Swarm-based techniques such as Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO), and more modern ones like Cat Swarm Optimization (CSO), Bat Algorithm (BA), and others have also been used to handle such problems [8, 9]. The authors use PSO to create a solution for the spectrum allocation problem in cognitive radio in this research.

A suitable mapping of resources to devices has been achieved while considering certain limits. When compared to the present GA-based approach, the performance is determined to provide more optimal solutions in less iterations.

The primary and secondary networks are the two major components of the CR network. The principal network, also known as the licenced network, has a frequency band licence. Primary users (PUs) with or without primary base stations make up this group (BSs). CR functions are rarely found on PUs. The secondary network, on the other hand, can share/access the licenced spectrum without interfering with the transmission of the primary network.

Secondary users (SUs) with or without secondary BS make up the secondary network. Spectrum brokers can also be employed to allow for efficient and fair spectrum sharing when many secondary networks coexist in the same frequency band. CR must execute the following four functions to support this type of spectrum sharing between the primary and cognitive networks, as well as to ensure efficient resource utilisation in both networks.

Spectrum sensing: The CR uses this function to scan its radio surroundings and detect PU activity. CR can determine the available spectrum holes for CR transmission in a specific time, frequency, and location based on the sensing information. Furthermore, the CR must maintain

To avoid interference with other PUs, the frequency spectrum is sensed during the CR transmission. Spectrum sensing can be carried out in a centralised or distributed manner. The sensing process in centralised spectrum sensing is controlled by a central unit, also known as a sensing controller.

Using a control channel, the sensing data is transferred among the several SUs. Although the centralised solution minimises the complexity of the SUs devices, it suffers from the difficulty of hidden/far PUs detection. The spectrum sensing is done in a dispersed manner by the SUs.

Each SU can make a decision based on his own sensing information (noncooperative sensing) or on sensing information shared with the other nodes in the network, depending on the extent of cooperation in the network. A central unit can also collect data. The information from distributed sensing to manage cognitive traffic Cooperative spectrum sensing is more accurate and can shorten the time it takes to detect a primary signal. Cooperative, on the other hand, adds signalling overhead, which rises with the number of SUs and with rapidly changing spectrum usage. Spectrum sensing can be divided into two categories, depending on the signal that is detected. The primary transmitter is detected by measuring the weak signal received at the CR terminal from the primary emitter. The performance of this type of sensing is degraded by increasing the distance between the CR terminal and the primary transmitter, as well as by shadowing. Cooperation among nodes boosts performance and accuracy.

Matching filter detection, energy detection, and cyclostationary feature detection are three common practical approaches for main transmitter detection. When the CR terminal has a priori knowledge of the PU's waveform, the matching filter detection is the best option. The energy detector is the most frequent type of spectrum sensing due to its ease of installation and the fact that it does not require any prior knowledge of the PU signal. It is, however, quite new, sluggish, susceptible to noise, and unable to distinguish between the PU and SU signals.

Finally, cyclostationary feature detection analyses the spectral correlation function to detect the primary transmitter based on the bulid in periodicity in the primary signal. It is resistant to noise power uncertainty, but it is computationally expensive and requires extensive observation times. Table summarizes the benefits and drawbacks of certain sensing schemes.

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Sensing Approach	Advantages	Disadvantages
Matched filter detection	- Optimal Performance - Fast detection and low cost - Robust to the noise uncertainty - Requires low number of sapmles	- Prior knowledge of the primary signal - High complexity
Energy detection	- No prior information is required - Low cost - Easy to implement	- Unreliable in Low SNR regime - High False Alarm - Cannot differentiate PU signal from other SUs - Doesn't work for spread spectrum signals
Feature detection	- Robust to noise uncertainty and performs well in low SNR regimes. - Can differentiate between	- Partial knowledge of the primary signal -High computational complexity

Table -1: Sensing Approaches

Primary receiver detection: this sort of sensing detects the local oscillator leakage power emitted by the primary receiver's RF front-end. At the moment, this approach can only be used to detect TV receivers.

Spectrum decision: this function examines the data collected during the spectrum sensing phase. Before making a spectrum access decision, evaluate the characteristics of the discovered spectrum gaps, the likelihood of the PU appearing, and the possible sensing errors. Following the selection of the right band, the CR must optimise the available system resources in order to meet the needed goal.

This function examines the data collected during the spectrum sensing phase. Before making a spectrum access decision, take into account the characteristics of the discovered spectrum gaps, the likelihood of the PU appearing, and any probable sensing errors.

Following the selection of the right band, the CR must optimise the available system resources to meet the needed goal.

Spectrum sharing: this function selects the best MAC protocol for gaining access to the spectrum holes. Fair spectrum sharing amongst SUs can be guaranteed thanks to the MAC protocol. In order to avoid collisions with PUs and other SUs, coordination between nodes can also be established.

Spectrum mobility, also known as spectrum handover, allows CR to change the operating band in order to prevent PU activity. Furthermore, the CR can undertake a spectrum handover to boost secondary network performance by transmitting in a better-performing spectrumhole. The protocol settings at each level should be adjusted to match the new operating band.

3. Problem Statement & Objectives of Proposed Work

The spectrum allocation part of cognitive radio is primarily concerned with determining the most efficient and non-dominant way for alternative resources to use the available regions of the entire spectrum on-demand, while ensuring that the primary user can use its own spectrum without interference due to the sharing process. In this case, a fair distribution is also desirable. This problem has been recast as an NP-hard problem, and appropriate solutions, such as game theory and graph colouring, have been developed [8].

Base stations are highly spread, and several users and sensor nodes make up cognitive radio networks. The bit error rate, available free carriers, and other factors all influence spectrum distribution among secondary nodes.

The objectives of the work are as listed below:

1. To maximize the total bandwidth utilization while minimizing the total cost with the help of optimization techniques.
2. To modify the existing optimization techniques and apply it to enhance the performance of heterogeneous complex wireless networks for communication systems

4. Methodology of the work

Particle Swarm Optimization (PSO) is a computational method that optimizes a problem iteratively and trying to enhance a current solution with regard to a given measure of quality. A Swarm can be defined as a structured collection of interacting organisms. Interaction among individuals refines the experiential knowledge about the environment, and improves the progress of the swarm toward optimality. PSO algorithm is inspired by the social behavior of bird flocking or fish schooling.

In PSO, a set of particles (NP) of swarm is defined. Each particle represents a potential solution in the solution space and is characterized by its position and velocity. Each particle updates its position and velocity based on its own best position (pbest) as well as the best position of the entire swarm (gbest).

PSO is made up of a swarm of particles, each of which has a position in the search space [3]. Each particle's position is represented by a vector that represents a solution. The PSO technique's algorithmic flow begins with an initial population of n random particles. In the search space, each particle is given a random position and velocity.

Because PSO is an evolutionary algorithm, every iteration updates the position and velocity of each particle. Following the update, a fitness function is used to calculate the fitness value of each particle. The quality of a particle's position is represented by its fitness. Each particle's velocity is influenced by its own best previous position (pbest).

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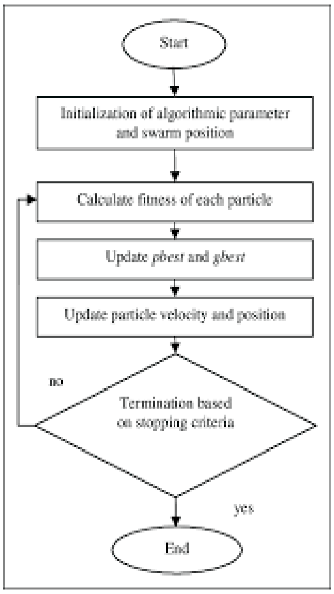

Figure-5 PSO Flow Chart

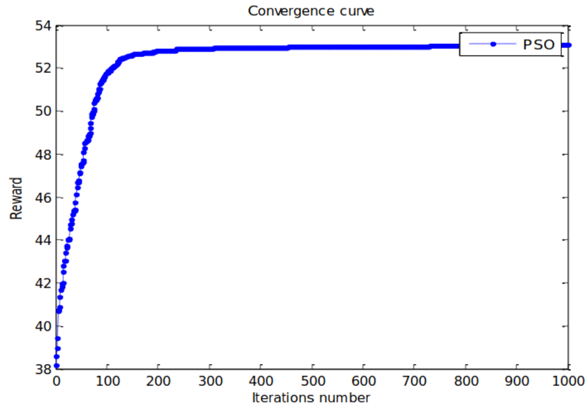

Figure-7 PSO for pu=30, su=10, ch=2

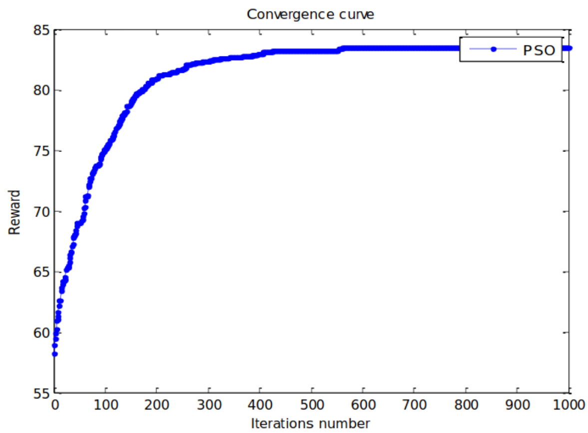

Figure-8 PSO for pu=20, su=10, vacant channel=30

5. Results & Discussion

The results show different scenarios depending on the number of primary users and number or secondary users and number of vacant channels have been studied, the simulation results show that the spectrum reward by using PSO is higher. The spectrum reward increase where the number of vacant channels increase and number of primary users and secondary users decrease, from the scenario PU=20, SU=10 and vacant channels=30 the increasing of number of channels is the importance factor of increasing the spectrum reward, and from the scenario PU=20, SU=30 and vacant channels=20 the increasing of SUs is the importance factor of decreasing the spectrum reward.

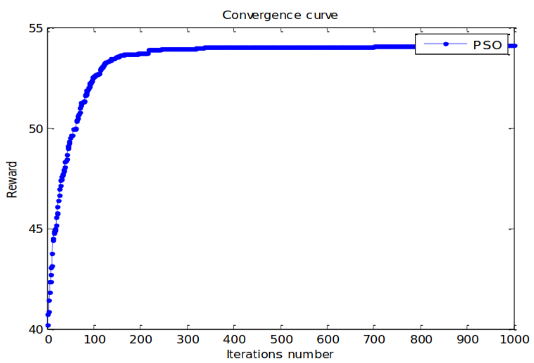

Figure-6 PSO for pu=20, su=20, ch=1

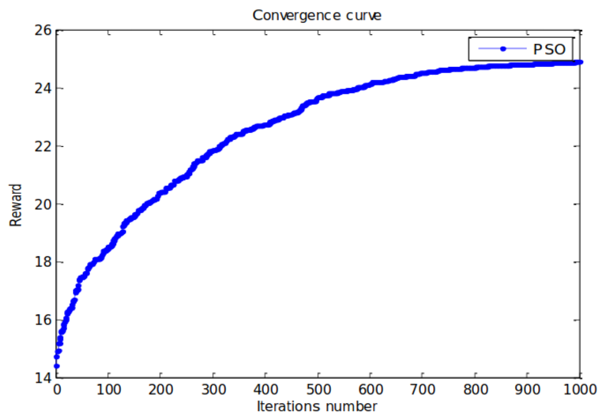

Figure-9 PSO for pu=20,su=30,ch=20

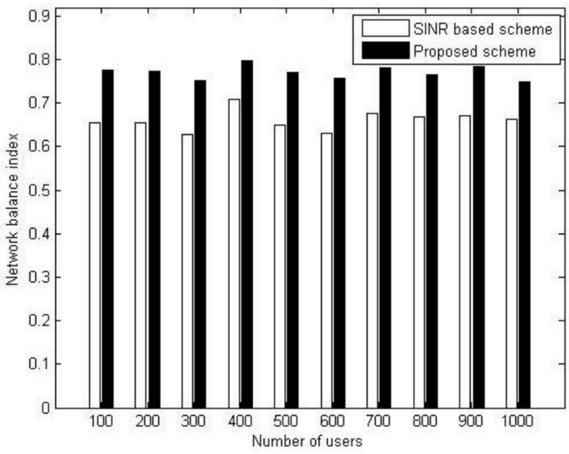

Figure-10 Network balance index of the proposed scheme and existing scheme

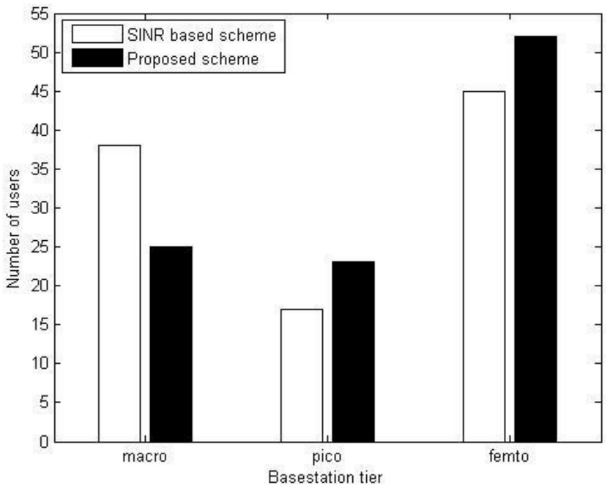

Figure-11 Number of users connected using the proposed scheme and existing scheme for different tiers

6. CONCLUSION

The next generation wireless communication technology demands high data transmission rate and system capacity, cognitive radio is one of the technologies that utilizes the spectrum resources in a more efficient and fruitful way to improve the network performance of heterogeneous complex networks. However, achieving these is a challenging task when it is to deal with multiple heterogeneous networks having overlapping coverage and diversified requirements of the users. This Challenge can be overcome by efficiently selecting the network and reasonably allocating the ideal spectrum resources.

The work shows that the total bandwidth utilization is maximized while minimizing the total cost with the help of optimization techniques. The proposed work aims to modify the existing optimization techniques and apply it to enhance the performance of heterogeneous complex wireless networks for communication systems.

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