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Research Article

Secured Emergency Based Adaptive Batch and Fuzzy Inference System Management in Cognitive Radio

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Abstract

Background: Cognitive Radio (CR) is an intelligent Software Defined Radio (SDR). The CR technology facilitates spectrum reuse and assuages spectrum chomp. Effective spectrum sensing confirms cognitive radio users resourcefully using the under-utilized frequency band without triggering destructive interference to primary users. Recently CR plays a vital role in the development of unguided communications system. **Materials and Methods:** This study examines the use of adaptive batch testing to find the spectrum holes of a specified bandwidth in a given Wide Band (WB) of interest and also designed a crisis based adaptive batch and Fuzzy Inference System (FIS) management in CR. **Results:** In place of testing and allocating a single slot for a user, this method can accommodate N number of users in a set of band during emergency conditions. The FIS is used to estimate the channel condition by analyzing the four parameters like signal power, speed, remoteness and effectiveness. **Conclusion:** The proposed system reduces the average sensing time, management time as a function of SNR. Number of users and the efficiency is also high when more number of users was managed at same time.

Key words: Cognitive radio, adaptive, fuzzy logic, spectrum management, FIS

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INTRODUCTION

Cognitive Radio (CR) is a vital adaptive system which provides intellectual wireless communication across any boundary and over any dimension[1,2]. The CR enables formation and continuance of communication over different networks and over any available services even if the network and service are non-cognitive. The cognitive skill can afford suitable bandwidth needed message transmission and select suitable modulation, coding techniques to provide the most excellent wireless communication using the spectrum hole. At the time of need, CR can scrutinize the environment for available networks and possible services and choose the suitable network and service dynamically[3-5]. This in turn a non-stop communication link during public safety and disaster relief situations. The CR can find possible handoff in advance take suitable decision for handling that situation[6-8]. The cognitive transmitter and the receiver, both may tackle channel impairments to produce desired signal quality at the receiver. The CR can detect the environment noise around the receiver and apply noise cancellation techniques dynamically to adapt, adjust and maintained desired signal quality[9,10].

A mobile cognitive device with its GPS capabilities can select either a preferred cell within an existing network type or select an entirely different network, based on the available options in the mobile's current path. The GPS capability of CR can come in handy to approximately detect the position of the rescued person[11]. The CR can help to minimize mine accidents in future by maintaining continued wireless communication between the people inside and the people outside the mine. The CR finds application in medical field also. The CR can detect abnormal tissues or blood cells within a human body and notify the doctor. This can play a vital role in saving human lives[12]. Cognitive tag can record the vital signs of the patient and intelligently inform the respective authority if an abnormality is detected even the patient is away from the hospital. The CR can intelligently access impurities in air, retrieve various pollution related data and notify authoring when limit crosses the predetermined threshold in order to avoid global warming and to produce a green environment and communication to the public[13-15].

Radio band is the medium for all the types of wireless transportation. Most of the utilizable spectrum has been owed to active services like cellular phones, satellite based services and so on. The radio spectrum has become treasurable, inadequate resource and swarming and there is a vital concern like in military, hospitals and even in disaster situations we are unable to exploit this alive wireless networks. The CR enables an unremitting communication link during public security and catastrophe relief scenarios[16]. In disaster situations the private wireless networks such as cellular network can be untreatable and the public safety spectrum can be overloaded due to numerous connections. Under such circumstances CR can consume the obtainable certify or unlicensed spectrum holes and various network component to generate and maintain transitory emergency connections[17,18]. The proposed system is to consume the time level. Instead of testing a single slot, all the N-slots to find the channel availability during the same time and also this analyzed the four parameters like signal power, speed, remoteness and effectiveness for the unused channel to find which is most excellent channel for transmission by using the fuzzy logic. Fuzzy decides the output based on input membership function high, medium and low.

In different methods of spectrum sensing like energy detection, matched filter and cooperative sensing techniques have discussed, but adaptive sensing and learning are not considered. In Fuzzy logic techniques are used to process cross layer communication quality metrics and to estimate the expected transport layer performance. In various handoff methods is considered in terms of handoff latency. In the fundamental tasks of CR like spectrum sensing, sharing, management and mobility are explained. In the derivation of probability of detecting the spectrum and false alarm for energy detectors is done.

A schematic overview on CR networking and communications by looking at the main functions of physical, medium and network layers are crossly related. In a study of Arslan[19], a proactive spectrum handoff approach based on time estimation is discussed to minimize the communication interference to primary users and to increase the spectrum utilization efficiency. In study of Doyle[20], CR enhances the flexibility of personal services through Radio Knowledge Representation Language (RKRL). In the study of Fette[21], several approach for mobility measurements including sharing solution and a handoff decision mechanism. In the study of Wyglinski *et al.*[22] cooperative sensing, to eliminate the hidden node problem and external local sensing methods were discussed.

Practical challenges such as noise power uncertainty and possible solutions in terms of system SNR are provided. Fuzzy arithmetic is used to check the communication quality of available channel. Applications of fuzzy logic and novel fuzzy combining for cooperative spectrum sensing are discussed. Multiple Input Multiple Output (MIMO) techniques are used for sensing the spectrum. Different non cooperative spectrum sensing techniques are explained. Several concepts for CR are proposed in the area of spectrum awareness, spectrum management and transmit power control. Various transmitter detection techniques in SDR are done by using MATLAB. In this study, spectrum sensing is done by bin-by-bin only not by a group or batch. Group testing was done for only sensing the spectrum not for finding the best spectrum[23].

This study proposes an adaptive batch sensing algorithm to find the spectrum holes and to find the best available channel fuzzy inference system is used with four basic parameters like power of signal, speed, remoteness and effectiveness. This system reduces the sensing time and management when N users are managed at the same time. Proposed model analyzes these matrices like probability of detection, sensing time, management time, SNR and efficiency.

MATERIALS AND METHODS

Proposed system model: In this model, a band of frequency spectrum to be sensed is given as input to the adaptive batch sensing block, the length which is given by the user is adaptable and is given as batch length 'N'. If the corresponding batch or sub-batch is idle, the FIS management decides the best available channel for higher priority transmission and the resultant idle spectrum is allocated by batch management for high demand transmission, otherwise the system will declare that the channel was occupied by the primary users and the block diagram of the proposed system is shown in Fig. 1.

Multistage sensing and management: This method presents a batch wise spectrum sensing algorithm that consists several batch length sizes to check a huge part of the available channel as early as possible, in order to allocate the spectrum for some emergency purposes[18]. The use of this multistage sensing algorithm guides to quicker acquisition of the good spectrum space. This greatly increase the spectrum efficiency since a shorter sensing time period gives more time for data transmission. This algorithm reduces the total number of tests when compared to a conventional bin-by-bin spectrum sensing method.

This method describes an N-slot test based multistage sensing algorithm to find the accessible spectrum holes in a given WB of interest. The basic idea is to search for a spectrum of holes of different bandwidths by making multiple passes of search on a given WB with each consecutive pass the width of the hole. Being searched for is halved and only the parts of WB that have been declared occupied in the previous stages are considered in the search. A multistage algorithm can be used for example in a spectrum hole search with a frequency hopping primary. Here the tenancy pattern keeps shifting episodically and in terms of CR usage, each hopping interval is split into two phases, i.e., a sensing phase to find an untenanted spectrum and a usage phase to make use of the spectrum hole found.

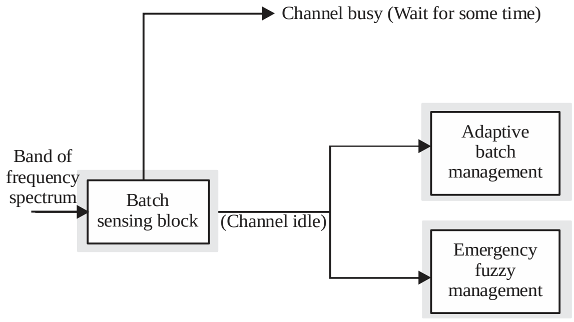

Fig. 1: Block diagram of proposed system

Fuzzy Inference System (FIS): This algorithm uses a simple fuzzy logic system to decide whether the channel is idle or not and also to find the best available channel[2]. The planned fuzzy logic system is modest with 4 inputs includes 3 membership functions (low, medium and high) which point out the likelihood of the licensed user. For 4 inputs, there are total of 81 rules[12]. To find the best channel among the idle, the FIS calculates the decision parameters in order to assign it for unlicensed users and shown in Fig. 2. The unused channel which is having maximum value will be declared as best channel and that can be allocated to the higher priority users like military, hospitals and so on during the emergency time. Wherever the clear communication is must the FIS can solve their requirement and necessity.

This FIS model is well suited for blurred and unsure environments where real time decision making is needed in the presence of un-finished and assorted information. The 81 rule base FIS system proposed in this study can compute the possibility factor of the decision surface for opportunistic spectrum scheduling by cognitive users. The effect of CR parameters like spectrum utilization effectiveness, speed, signal power and remoteness are used to find the best available channel for transmission.

Adaptive batch testing and management: For individual slot spectrum sensing it was used blind detection. In that periodogram and welch methods are used to determine the power level of the signal[5].

Periodogram method: It is a nonparametric method to measure Power Spectral Density (PSD):

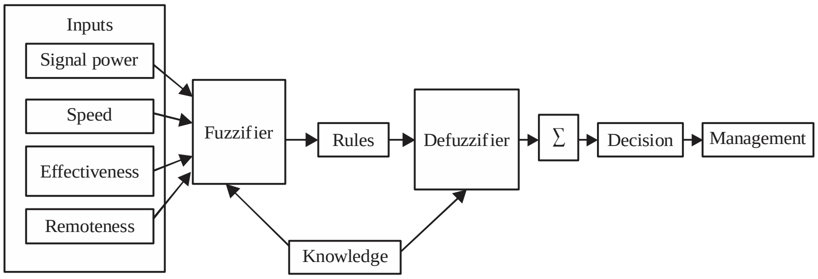

Fig. 2: FIS based spectrum management

$$W_B(e^{j\omega}) = \frac{1}{N}\left(\frac{\sin(\omega N/2)}{\sin(\omega/2)}\right)^2 \quad (1)$$

The variance of the periodogram is:

$$\lim_{N\to\infty} \text{var}[I_N(\omega)] = P_{xx}^2(\omega) \quad (2)$$

Welch method: This method is used to find the average PSD:

$$\text{Var}[P_{xx}^{w}(\omega)] = \frac{1}{M} P_{xx}^2(\omega) \quad (3)$$

Blind detection is the simple technique, because of its low reckoning and execution complications, it is widely used to sense the spectrum. In this method receiver does not require any awareness about the primary user information. Presence of user is determined by matching the output of the blind detector with a known threshold value which depends on the typical interference power[10,11]. The mathematical expression for blind detector is given as:

$$T_{BD} = \frac{1}{N}\sum_{n=1}^{N} |Y(N)|^2 \underset{>}{\overset{<}{}} \lambda \quad \begin{matrix} H0 \\ H1 \end{matrix} \quad (4)$$

Mathematical hypothesis is:

$$y(t) = \begin{cases} n(t),\ H0 \\ hx(t0 + n(t),\ H1 \end{cases} \quad (5)$$

where, N is the length of the observation, under hypothesis H_0 the received signal consists of only the white noise component which is assumed to be scattered generally with zero mean and variance equal to σ_s^2:

$$E\ [|T(N)|^2] = \mu s$$

$$E\ [(|Y(N)|^2 - \mu_s)^2] = \sigma_s^2 \quad (6)$$

where, E denotes the expectation operator.

After sensing the idle spectrum for adaptive length N the channel will be allocated to the group of secondary users and the block diagram of batch management is shown in Fig. 3.

Adaptive length algorithm:

- Get adaptive length N
- Let the number of channels to be sensed is D
- Perform sensing for N number of channels
- If all N number of channels is idle then the entire channels are allocated to the N numbers of secondary users
- Else it verifies the sub-batches to find the occupancy of primary users, by dividing N in to two halves, one half is round-off of N/2 and the other half is (N minus (round-off (N/2))). The process will be repeated until N becomes 1
- All the sensed idle channels are allocated to the secondary users depends on the requirement
- All the above process will be repeated up to D/N

Batch management: Depending on the specified length the batch sensing and management will be processed. In Fig. 4 the given group is divided into subgroup and then sensing is done for this particular sub-groups if all the slots are free then immediately FIS decides best available channel and allocate it's to the secondary users depending upon their requirements, this greatly reduces the average sensing time and management time when compared to a conventional slot by slot sensing method, else this sub-group is divided into co-sub groups and the same process will be repeated until the end of the slot.

Figure 4 provides the explanation how the spectrum is batch wise sensed and managed for N number of groups in cognitive radio with various sub-groups and co-groups.

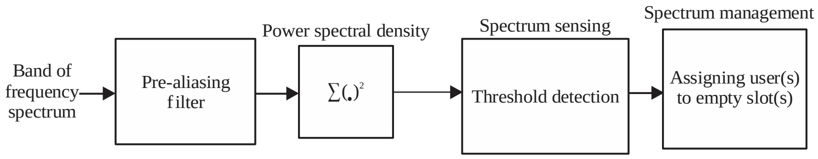

Fig. 3: Block diagram of batch management

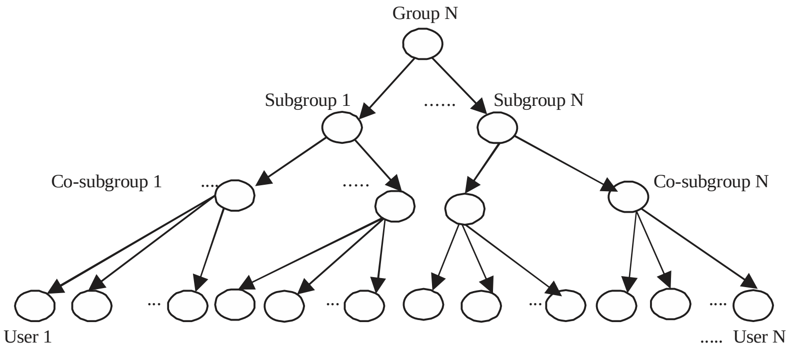

Fig. 4: Process of spectrum sensing and batch management

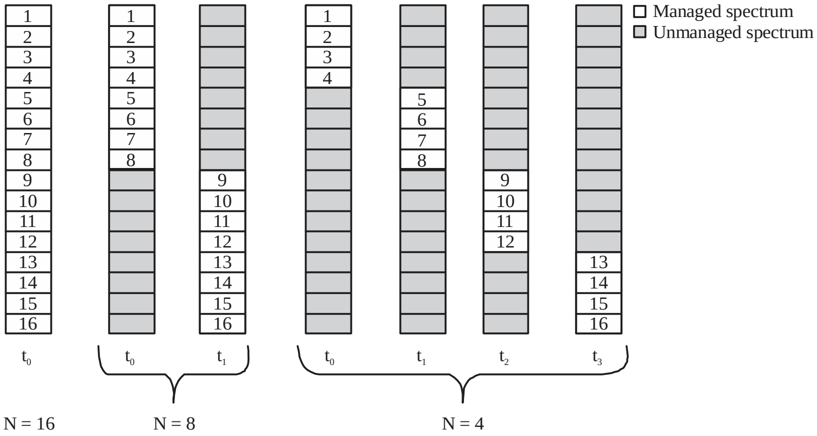

Fig. 5: Spectrum sensing and management when N numbers of users were free

When N number of channels were free all the secondary are managed at same time t = t_0. If batch length decreases then the process will be repeated for t_m times, it increases the delay where, m = 0, 1, 2, 3...

The basic idea as shown in Fig. 5, is to search for spectrum space of diverse set of band by building many passes of hunt on a specified wideband. With every consecutive pass, the width of the space being searched for is halved and only the parts of the wideband that have been confirmed occupied in the earlier stages are considered in the search.

Figure 6 presented a part of 81 rules for 4 input parameters with 3 membership functions with corresponding decision. The FIS surface viewer the decision surface for the 81 rule base keeping two parameters (signal power vs. speed) constant is shown in Fig. 7.

RESULTS AND DISCUSSION

From Fig. 8-13 simulation results present is as follows; in Fig. 8, proved the probability detection of this system is very high when the batch length increases (optimum n = 32), Fig. 9 explains how the management time is decreases with respect to the number of users (optimum n = 16), Fig. 10 shows the sensing time is reduced when the batch length is high (optimum (n = 32), Fig. 11 gives the management time for various length size (optimum n = 16), Fig. 12 proves the system efficiency is very high (optimum n = 16) for various batch length. Figure 13 proves the sensing time is greatly reduced when more number of users is used to sense the spectrum.

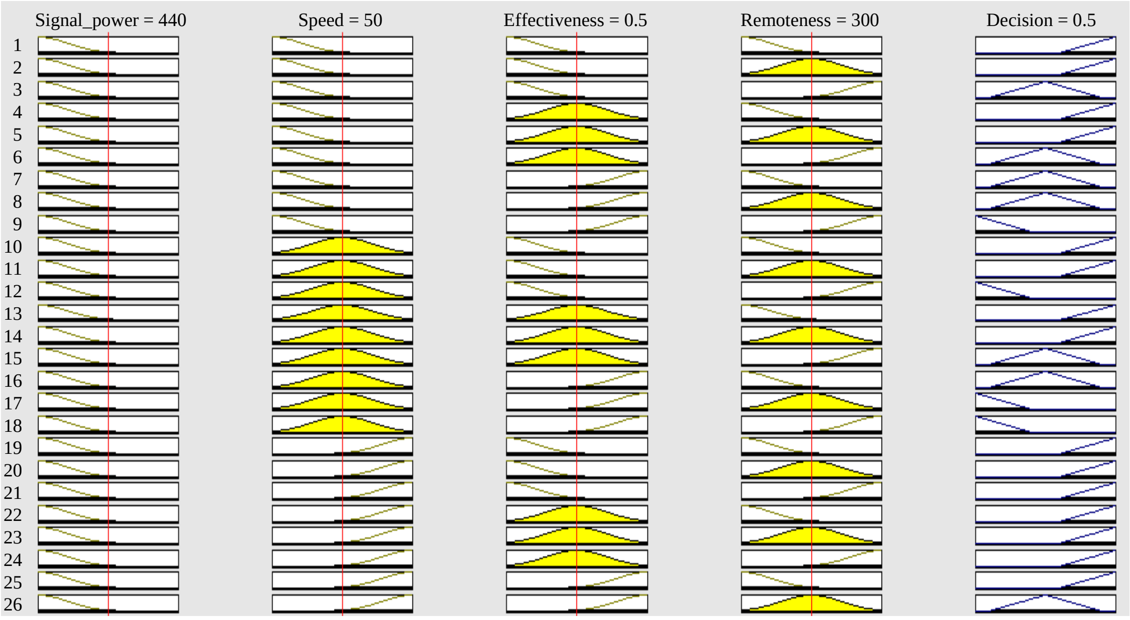

Fig. 6: Part of 81 rules for 4 input parameters with 3 membership functions with corresponding decision

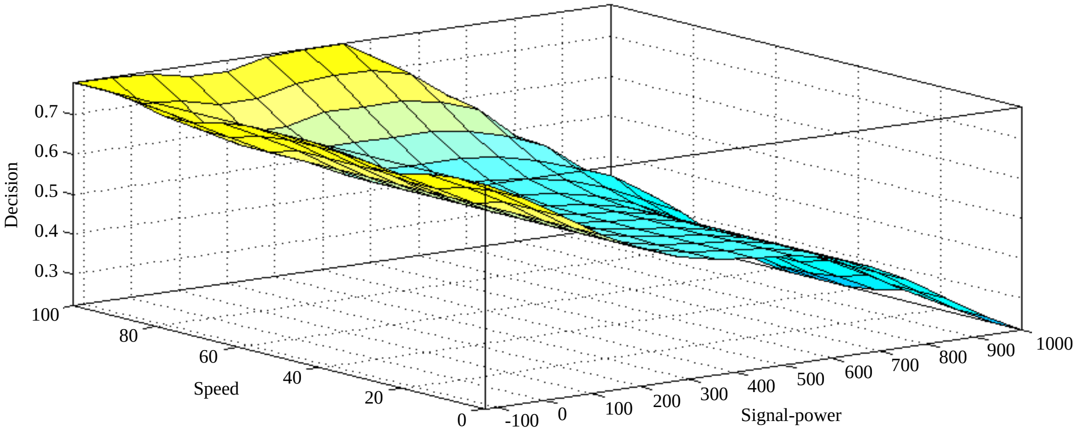

Fig. 7: FIS surface viewer the decision surface for the 81 rule base keeping two parameters (signal power vs. speed) constant

Figure 8 explains how the probability of detection is increased when the SNR is increased from 5-20 dB for different batch length. When N = 1 the Pd is 0.2 and it is increased to 0.37 when N = 2. Similarly if the batch length increases then the probability of detection Pd reaches it maximum value 1 even in the low SNR also. This is done for various batch length like N = 1, 2, 4, 8 and 32, the optimum value is N = 32 since its Pd is very high at low SNR.

Figure 9 explains the management time, how the spectrum is allocated with respect to the number of users. The channel allocating time is very high when single user is allocated one by one in an array. When 16 users are allocated one by one to the channel then the management time is 4 sec at the same time if all 16 users are allocated at the same time when all 16 slots are free then the time is 0.2 sec only. Here the optimum value is 16.

Figure 10 depicts the average sensing time as a function of SNR for various string lengths N. In all cases the sensing time is greatly reduced when SNR is increased. At the same time the sensing time is grammatically reduced when the batch length is increased, here the optimum is N = 32.

Figure 11 gives the details about management duration vs. SNR over the AWGN channels for various lengths N. Allocating each user by-bin-by-bin in a 16 length string increases the management time as discussed by Singh and Saxena[17], but allocating all the 16 users in all the slots at a time greatly reduces the management duration[18]. Here the optimum value is N = 16.

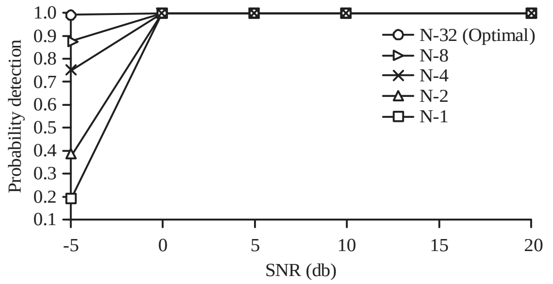

Fig. 8: Probability of detection curve as a function of SNR with various batch lengths (N)

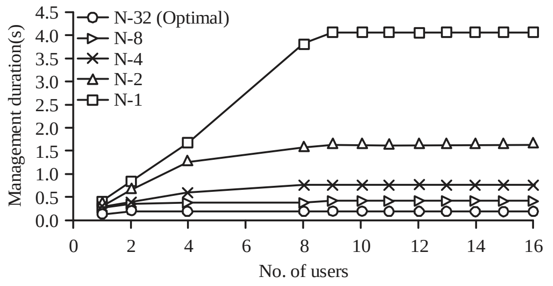

Fig. 9: Comparison of average management duration for different batch length (N) when 'k' numbers of user

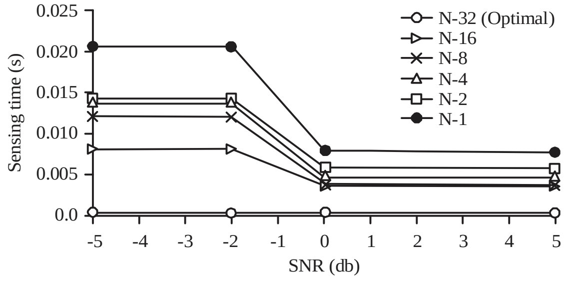

Fig. 10: Estimation of average sensing time as a function of SNR with various batch lengths (N)

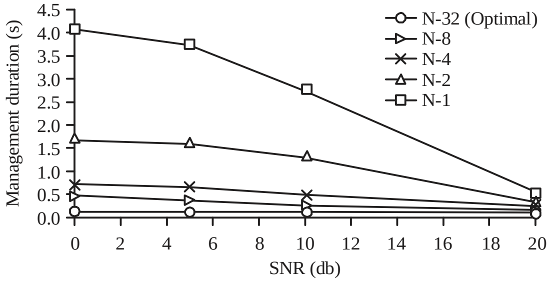

Fig. 11: Comparison of average management duration vs. SNR in the AWGN with various batch lengths N

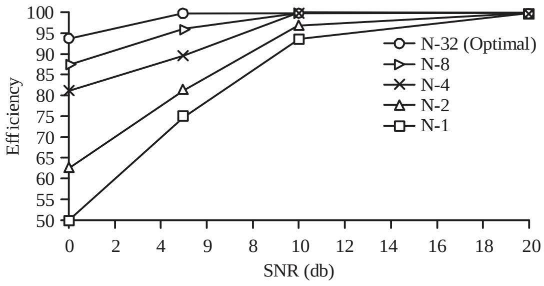

Fig. 12: Efficiency versus SNR for various batch lengths N

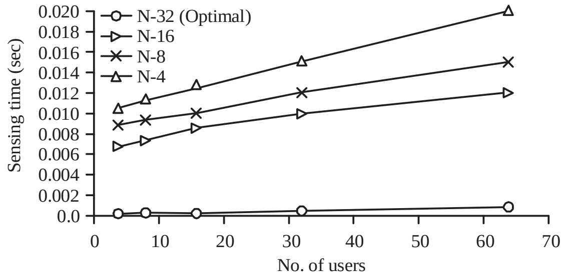

Fig. 13: Sensing time versus 'k' numbers of users for various batch lengths N

Figure 12 explains how the spectrum efficiency is improved when batch sensing is executed for various group lengths N = 1, 2, 4, 8 and 16. Allocating all the 16 users at a time increases the efficiency and it reaches nearly 94% even in the low SNR but bin-by-bin allocations reaches 50% only. Here efficiency increases with high SNR as compared with Trigui *et al.*[9] and Suseela and Sivakumar[15], if batch length N increases then the efficiency increases (when compared to bin-by-bin) even in low SNR.

Figure 13 gives the channel sensing time interval when K number of users are used to sense the spectrum. Sensing was done for various N = 4, 8, 16 and 32. Here sensing time decreases as recommended by Axell *et al.*[1] and Christian *et al.*[3], when the batch length is high. The sensing time reduced when several users are senses the spectrum, the optimum value of N = 32 as recommended by Axell *et al.*[1].

During calamity and disaster conditions conventional wireless system cannot respond to heavy congestion and overload conditions to provide the network capacity and coverage. In order to serve during emergency conditions, an intelligent network should serve the demand. Cognitive is one such network which facilitates the usage of spectrum in efficient and effective manner during demand and emergency conditions[24,25]. It can be used in various applications in providing inter-operability between public safety services like police, ambulance, fire service and medical assistance. Similarly, it can be operated while providing rescue using various emergency working conditions. Each application will have their own hardware configurations and will not be compatible with all other applications. The CR take care of this inter-operability problem that exists between all the application providers. Even using CR whit spaces in the frequency spectrum can even be utilized to provide services under disaster conditions. It can be used to provide localization, communication and integration of various services. With cognitive, secured emergency based robust services can be provided by applying various encryption algorithms and keys.

CONCLUSION

This study has scrutinized the use of adaptive batch testing and management techniques for spectrum crack hunt in CR's. The designed batch testing based algorithm to seek out proximate spectrum holes while assuring a given level of guard to the primary network. This study suggests the following procedure to carry broaden the batch tests to a multistage sensing algorithm that looks for nearby holes of different widths at each stage. Based on the theoretical analysis of batch tests, a computational procedure to obtain an optimum batch size, number of samples and detection threshold values were arrived, which minimizes the time average. The 81 rule based FIS is proposed in this study can compute the risk factor of the decision surface for opportunistic spectrum arrangement by cognitive users. The effect of CR factors like spectrum utilization effectiveness, speed, power of signal received and remoteness to the primary user have been utilized as a fuzzy logic inputs on the basis of which the cognitive users can be scheduled as per the ruling base of spectrum management. This study proved the proposed system reduces the average sensing time, management time as a function of SNR. Number of users and the efficiency is also high when more number of users were managed at same time.

SIGNIFICANCE STATEMENTS

- Adaptive batch testing methodology to identify the spectrum holes using cognitive radio technology
- Reduces the average sensing and management time in CR networks
- Fuzzy inference system is used to estimate the channel conditions
- Parameters like signal power, speed, remoteness and effectiveness have been analyzed
- Effective spectrum sensing has been carried out during emergency conditions

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