THE HANDOFF OF SPECTRUM IN COGNITIVE RADIO NETWORKS

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ABSTRACT: Because wireless networking technology is rapidly evolving, spectrum band is in high demand. Cognitive radio networks (CRNs) can address the issue of spectrum scarcity since they use flexible spectrum access. Cognitive radio technology would allow a number of secondary users (SU) to use spectrum that is normally reserved for a primary user (PU). This would aid in the reduction of spectrum scarcity and waste. However, because the range is constantly shifting, SUs must cope with a number of issues. Spectrum handoff occurs when a PU joins a specific frequency band. Any SUs who are currently using that band must relinquish their channels so that PUs can utilize them. It is a significant occurrence that has yet to be discovered in the network of cognitive radios. This section provides a brief explanation of why spectrum handoff occurs, how it works, what problems it causes, and how it can be resolved.

***Keywords*:** cognitive radio, spectrum handoff, spectrum mobility queuing theory, PRP M/G/1 queueing model.

1. INTRODUCTION

The need for new wireless applications and services is continuously increasing, but spectrum is nonrenewable. Significant research has been conducted to optimize spectrum utilization in response to this need. According to the Federal Communications Commission (FCC), inefficient fixed spectrum distribution underutilizes spectrum. Due to spectrum scarcity and inefficiency, a novel communication mechanism is required to opportunistically exploit wireless spectrum by entering licensed bands without interfering with the primary user. Dynamic Spectrum Access (DSA) or cognitive radio networks are new networking paradigms. Primary and secondary users are both licensed and unauthorized.Secondary users or cognitive users can temporarily access vacant licensed airwaves using cognitive radio, reducing spectrum scarcity. Secondary users can use spectrum sensing to determine which spectrum is available and to detect a primary user in a licensed band. In addition to spectrum management, the best channel must be chosen. If a primary user fills the band, CR users can escape interference by switching channels or spectrum holes. This is called spectrum handoff. Cognitive radio networks use cognitive capabilities and reconfigurability to identify the optimum channel. Cognitive radio (CR) allows secondary or cognitive users to temporarily borrow unused licensed spectrum from primary users, enhancing spectrum efficiency. Cognitive radio (CR) systems require four characteristics:

- Spectrum sensing
- Spectrum management
- Spectrum sharing
- Spectrum handoff

This research looks at spectrum handoff, a little-discussed CR network spectrum issue. When a high-priority main user lands on a licensed channel used by secondary users, spectrum handoff happens. In this case, secondary users must clear licensed spectrum. Secondary users can employ spectrum handoff mechanisms to discover target channels to resume stopped transmissions.

2. SPECTRUM HANDOFF

Cognitive radio technology allows cognitive users to temporarily use dormant spectrum resources without interfering with the communication of licensed users. The cognitive user's spectrum sensing, access, and handoff are required for the procedure to be completed successfully. This is called spectrum handoff. Cognitive users must leave a licensed band occupied by a cognitive user or secondary user and establish a communication link on another unoccupied channel or spectrum to avoid interfering with primary users.

The secondary user's communication is moved to a free channel by spectrum handoff. This causes communication with SU to be delayed, reducing performance. CRN spectrum handoffs can be triggered by two PU events. When the PU enters the licensed channel of the secondary user, the SU must exit the spectrum. Spectrum handoff #2 is caused by cognitive user movement. As CR users move spatially, the broadcast coverage of the secondary user may overlap with that of a primary user using the same channel band. Because secondary users are opportunistic in licensed bands, their behavior in legacy networks must adhere to the following rule: primary users always use the licensed band first. As a result, if the secondary user's presence interferes with the primary user's data transmission, the secondary user must leave the licensed channel. Spectrum might be handed off by SUs due to poor link quality. Because the radio spectrum of cognitive radio networks is occupied by main users who are not controlled by secondary users, the quality of their communication channels may vary over time and space.

Secondary users must examine and analyze the communication or data transmission channel's integrity on a regular basis. If channel quality deteriorates, spectrum handoff will be required to maintain secondary user quality of service. The transfer of spectrum is cyclical. It consists of link evaluation and maintenance. During evaluation, the secondary user monitors the environment for handoff-triggering events. When SU turns off the spectrum, link maintenance begins. The Secondary user suspends communication at the start of this phase. The secondary user reclaims the reclaimed channel and resumes data transmission on another channel. Following link maintenance, SU repeats the cycle. The most important phase in spectrum mobility is handoff.

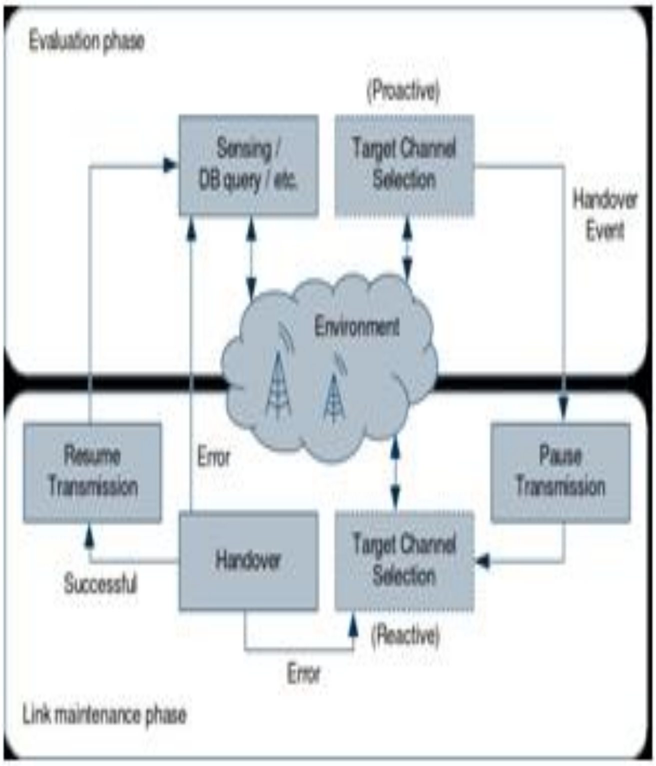
Secondary users can employ spectrum handoff mechanisms to discover target channels to resume stopped transmissions.

Spectrum handoff systems are classified into two types based on target channel selection methods:

proactive spectrum detection and handoff

Handoff of the reactive-sensing spectrum

Secondary users watch all channels on a regular basis to collect channel usage statistics and to choose a group of target channels for proactive-sensing spectrum handoff based on long-term observation. Prior to transmission, secondary users prepare target channels for spectrum handoff.Spectrum handoffs for reactive sensing seek target channels on demand. When a spectrum handoff is requested, the target channel is determined using immediate wideband sensing findings.



The reactive spectrum sensing and reactive handoff action approach are used by the second user. After a handoff, spectrum sensing by the secondary user detects the intended fallback channel. After that, link communication is moved to the new destination channel. A trigger event causes the target channel to be selected and the handoff action to be performed.

Spectrum sensing in the optimal spectrum environment provides an accurate target channel to the secondary user. On-demand spectrum sensing enhances handoff latency while improving accuracy. Because the secondary user does so after detecting the handoff event, spectrum sensing accounts for the majority of the handoff delay.

Reactive Handoff: The secondary user employs proactive spectrum sensing and handoff action. Before the handoff, the secondary user uses spectrum sensing to identify an alternate target channel. Because the secondary user is aware of the primary user's traffic model, the secondary user can exit the channel before the primary user arrives. Prior to handoff triggering, target channel selection and handoff are proactive.

Proactive Handoff: There are numerous advantages of proactive spectrum handoff. Because everything is preplanned, the handoff delay is minimal. Second, by selecting fallback target channel sequences with future target channel utilization in mind, spectrum handoffs are reduced. With this handoff method, the secondary target channel may become obsolete. During handoff, the primary user or another secondary user may be using the prepared backup channel. This handoff also necessitates a precise primary user traffic model. Spectrum mobility may be hampered by incorrect primary user traffic model estimates.

3. STEPS OF SPECTRUM HANDOFF

When a PU occurs in CR systems, the cognitive user swiftly abandons a band inhabited by an SU. The SU would next attempt one of three recovery methods:

The SU will remain on the original channel and defer broadcast until the PU has completed.

(Predetermined spectrum handoff) Select a channel from a list of observed channels.

Switching to a channel after instant sensing (sensing-based spectrum handoff); if SU is unable to recoup spectrum, the session terminates.

Secondary users SU1 and SU2 use channel Ch1 in Figure 1(a). When the primary user appears on Channel 1, SUs should stop communicating, as seen in Figure 1(b). SU1 and SU2 can restart transmission on the specified target channel, as shown in Fig. SU1 and SU2 can switch channels in 1(c) or ii).

It can stay on the same channel and resume transmission after PU action, as demonstrated in figure 1(d). When PU activity is minimal, this lowers handoffs and is preferable. The transmission of a frame may be interrupted several times, necessitating multiple spectrum handoffs.Communication among SUs

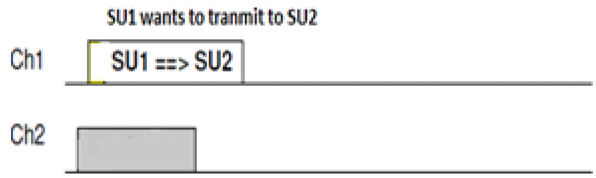


Fig 1(a): Communication among Sus

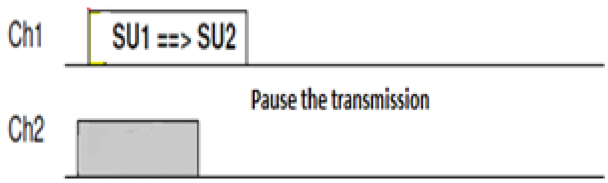


Fig 1(b): The letter PU occurs

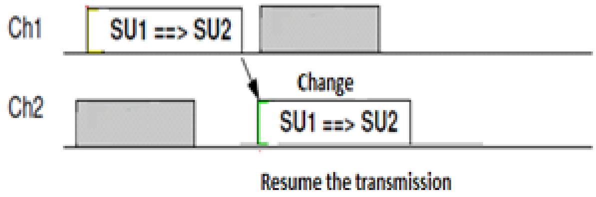


Fig 1(c): Restart broadcasting on the designated frequency.

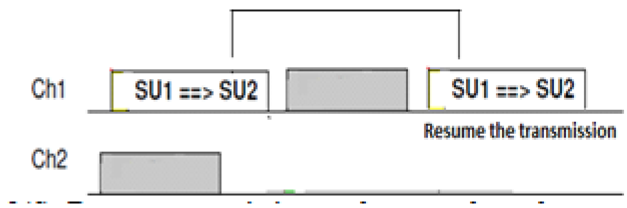


Fig 1(d): Repeat the transmission on the same channel.

4.DESIGNING STRATEGY OF SPECTRUM HANDOFF

Openness is required for DSA design, analysis, and optimization. Wireless communication and networking, signal processing (to estimate parameters), filtering and prediction (to understand the radio environment), machine learning (to learn, plan, and optimize the DSA choice), and optimization are all part of this process. Intelligent techniques based on fuzzy logic and decision theory are also included.

Spectrum sensing provides insufficient and imprecise information to the secondary user for spectrum handoff decisions. Fuzzy logic can perform spectrum handoff decisions with incomplete, ambiguous, or heterogeneous input. For cognitive users, a fuzzy logic system (FLS)-controlled spectrum access approach identifies cognitive radio (CR) spectrum access. Channel selection and estimation based on secondary user spectrum sensing information were examined in a decentralized architecture for spectrum handoff decision. A simple fuzzy-based spectrum handoff method allows for quick decisions, allowing the secondary user to instantaneously move its frequency channel. Although fuzzy logic is a simple method for drawing conclusions from ambiguous and missing input data, it requires extensive testing and cannot learn and adapt like expert systems.

Secondary users can use spectrum handoff to discover target channels to restart transmissions. Spectrum handoff systems are either proactive or reactive based on target channel selection methodologies. Secondary users select the target channels before transmission in proactive-sensing spectrum handoff. Secondary users scan all channels and collect usage information on a regular basis to select spectrum handoff channels. On-demand spectrum handoff with reactive sensing searches for target channels. In this situation, wideband sensing will choose the spectrum handoff channel. Because no wideband sensing is required, the proactive-decision spectrum handoff has a lower latency than the reactive-decision spectrum handoff, even if the target channel is unavailable. Although reactive spectrum handoffs enable more exact target channel selection, they need greater sensing time.

For modeling and analysis, use the pre-emptive resume priority (PRP) M/G/1 queue model. Priority determines channel allocation to primary and secondary users in CRN. In comparison to the proposed PRP M/G/1 queue network paradigm, compare reactive and proactive. The frame transmission time in single and multiple handoffs determines the transmission delay for reactive and proactive systems. The author independently developed and investigated proactive and reactive spectrum handoff. In a pre-emptive resume priority (PRP) network, M/G/1 queuing is recommended for proactive use. This model allows us to compute total service time for several target channel sequences and select the best one. As previously stated, preset channel unavailability restricts proactive handoff. To locate the best target channels and simplify target channel finding, a suboptimal greedy target channel selection technique is proposed. Because spectrum sensing can precisely find an idle channel but takes more time, the reactive decision spectrum handoff latency may be reduced. To continue data transmission, the secondary user can select the spectrum handoff channel reactively. To characterize the effects of sensing time, channel switching time, and handoff time on CR network handoff delay, a Markov transition model is integrated with the pre-emptive resume priority (PRP) M/G/1 queuing network.

Primary-secondary collisions are better avoided by being proactive rather than reactive. It improves primary and secondary user throughput, but its implementation necessitates the employment of a complex algorithm. Secondary user collisions are avoided by using an active spectrum handoff technique based on Greedy Channel Selection (GCS). Channel selection distribution improves throughput while decreasing average service time. The entrance of licensed users at random may impede throughput for both licensed and unlicensed users. We propose a proactive spectrum handoff paradigm for CR ad hoc networks. Channel switching policies and a proactive spectrum handoff protocol are offered to remove unlicensed users from a channel before licensed users arrive to avoid interference. Spectrum band inactivity can be predicted by cognitive users with prediction abilities. As a result, harmful SU-PU interference can be avoided, and SU throughput can be maximized.

Secondary users use spectrum handoff to free up the licensed band and locate a target channel to resume broadcasting. Proactive decisions are based on historical channel utilization, estimates for the future, and channel inactivity. Because of predictive and probabilistic techniques, this scenario is unstable.

5.CHALLENGES AND SOLUTIONS INSPECTRUM HANDOFF

In cognitive circumstances, spectrum handoff is critical and must be managed correctly. Many difficulties arise during spectrum handoff, such as reducing handoff time, locating the appropriate channels to complete the transmission, and guaranteeing service quality.

Secondary users' power consumption will alter if they work together to detect prime users. Power management is required for CR networks, and it is difficult to establish when a secondary user must hand up the spectrum to the primary user. Broad spectrum availability, fluctuating spectrum availability, and heterogeneous mobility events all impede smooth communication.

Evaluating a new spectrum band and selecting the optimal channel among the available channels might be challenging as well. Before making a selection, the channel's width, bandwidth, rate, etc. must be examined, which can be challenging. CR is assumed in cellular architecture, and spectrum-aware mobility management is proposed. A spectrum pooling-based network architecture lowers diversified spectrum availability. When a PU tries to abandon the channel, an SU's transport layer protocols may suffer. TCP indicates congestion causes packet loss, yet mobility causes most packet losses. Therefore, TCP will call congestion management algorithms for packet loss caused by route failures, resulting in lower throughput. This research addresses the problem by examining the differences between TCP implementation in CR and regular wireless networks. The proposed TCP rate-adapting technique ensures a smooth spectrum handoff when PU emerges.

New mobility and connection management methods are needed to reduce spectrum handoff delays and data loss. Application performance must be preserved when shifted to another frequency band owing to a primary user's presence. New algorithms are needed. Maintaining links is crucial to transmission quality because damaged links can cause performance degradation. Reduce radio sensing time, erroneous channel selection probability, and handoffs to boost connection maintenance likelihood. The session is forced to end if SU does not receive the transmission channel. To avoid this in virtual reservation, a new connection maintenance method decreases SU forced termination. This unique link maintenance technique maximizes spectrum consumption to boost cognitive network throughput. Multiple handoffs can lower service quality for interrupted users. A PU interrupts an SU utilizing a licensed band, forcing it to suspend its transmission and change its operating channel.

Spectrum handoff must be efficient for SUs to sustain QoS. Interrupted users take precedence over fresh uninterrupted users in the suggested paradigm. This paradigm compels interrupted users to wait in a queue until all primary and secondary users receive services. This delay will lengthen their handoff and service time. By keeping a queue, we can easily identify the interrupted user and prioritize them above the others. This reduces handoff delay while maintaining QoS. Pre-emptive resume priority (PRP) M/G/1 queue models model the suggested task. The spectrum handoff delay is a long switching latency caused by SUs searching for available spectrum and reconfiguring their operating frequency at the RF front-ends dynamically and abruptly when spectrum availability changes. Spectrum sensing, analysis, decision-making, and switching time are included. Therefore, reducing unnecessary spectrum handoffs is best. Rather than switching to an empty channel, the SU waits in silence until the PU leaves. This option benefits the secondary user if the returned primary user stays on the channel briefly. We establish a maximal waiting time expression for secondary users where the distribution of primary users is known or unknown. Spectrum handoff can cause service outages or delays that lower secondary user quality.

Spectrum handoff delays can be reduced while transmission quality is maintained using a unique way. Choosing the best routes is essential for SU's excellent service level. Initial calculation of application packet latency is based on channel queue. This delay determines the delay violation ratio, which guides spectrum handoff and selection.

A backup channel list allows the SU to quickly switch to a channel during a handoff to reduce handoff latency. A fallback channel list is maintained in IEEE 802.22, the first CR network standard, to enhance the likelihood of finding a spectrum band quickly. More idle channels in the backup channels list reduce switching delay. Using additional backup channels during handoff to prevent quick sequential handoffs has been considered, however maintaining a list is difficult.

4. CONCLUSION

Given increased demand for radio spectrum from new wireless applications and inefficient licensed spectrum band use, a spectrum access policy change seems likely. Opportunistic spectrum access allows unlicensed or secondary users to dynamically use spectrum holes or white space throughout the licensed spectrum without interference to solve spectrum scarcity. Cognitive radio (CR) may alleviate wireless spectrum shortages. Spectrum handoff is vital but understudied in cognitive radio networks. Spectrum handoff study relies on prediction and probabilistic methods due to Primary user behavior's unpredictability. Primary goal of handoff is flawless and fast transmission for secondary users. New mobility and connection management solutions are needed to reduce spectrum handoff delays and data loss. To reduce spectrum handoff latency, a list of fallback channels is maintained, although maintaining it is difficult. Future work will include building a spectrum handoff framework that relies less on probability and prediction and understanding the fallback channel list and how to use it to ensure smooth and fast transmission.

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