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Priority Based Channel Searching Sequence Allocation for Rendezvous of Cognitive Radio

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Abstract

This paper proposes a scheme for a cognitive radio system that differentiates user rendezvous performance based on priority. We categorize users into primary CR users (PCUs) and secondary CR users (SCUs) and assign them distinct channel searching sequences. The proposed scheme is based on the method introduced by Paul, Choi, Jang, and Kim, where PCUs utilize a p-ary m-sequence of period $p^2 - 1$, and SCUs use a p-ary m-sequence of period $p^4 - 1$. A key advantage of this approach is its ability to transition a legacy system, which does not consider priority, into a priority-based system simply by adding a low-priority SCU group and assigning them a dedicated channel searching sequence. Furthermore, we demonstrate the effectiveness of the proposed scheme through computer simulations that show a clear difference in rendezvous performance between PCUs and SCUs. Additionally, we verify the distinction between our scheme and methods that restrict channel allocation with primary sequence for SCUs, also through simulation.

Keywords: cognitive radio; rendezvous; priority

1. Introduction

Cognitive Radio (CR) has emerged as a key technology to enhance spectral efficiency by allowing unlicensed users to opportunistically access licensed channels without causing harmful interference to Licensed users (LUs) [1–3]. A fundamental challenge in decentralized CR networks is the rendezvous, where unlicensed users must autonomously find a common available channel to establish a communication link [4,5]. Conventional rendezvous protocols typically aim to minimize the Time-to-Rendezvous (TTR) in a uniform manner for all users [6–8]. To this end, numerous studies have concentrated on the mathematical design of efficient channel-hopping (CH) sequences such as m-sequence [9,10] and MAC-level coordination [11]. However, such priority-agnostic approaches do not fully address scenarios involving heterogeneous service requirements, where certain users demand preferential access.

Early studies such as Jump-Stay [8,12], modular clock-based schemes, and Latin square-based constructions concentrated on sequence periodicity and deterministic coverage for homogeneous user scenarios. Subsequent works introduced more sophisticated stochastic or hybrid designs to reduce the Expected Time-to-Rendezvous (ETTR) and Maximum Time-to-Rendezvous (MTTR) under symmetric channel environments [11]. However, these approaches remain largely priority-agnostic, assuming identical service requirements and fairness among all unlicensed users.

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Academic Editors: Alessandro Lo Schiavo, Michel Kulhandjian and Hovannes Kulhandjian

Received: 17 October 2025
Revised: 27 November 2025
Accepted: 1 December 2025
Published: 23 December 2025

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In real-world CR applications—ranging from mission-critical Internet of Things (IoT) sensor networks and emergency response communications to vehicular ad hoc networks—users often exhibit heterogeneous Quality-of-Service (QoS) demands [13–16]. To address this, several priority-aware mechanisms have been proposed, mainly focusing on unequal channel allocation, virtual utility-based resource scheduling, or differentiated MAC-layer access probabilities. In [14], the authors addressed heterogeneous QoS demands by classifying traffic into multiple priority classes and assigning each class distinct channel selection and scheduling rules, thereby reducing delay and blocking for high-priority flows while maintaining overall spectrum utilization. In [15], the authors proposed priority and fairness by proposing a distributed utility/pricing-based resource allocation and MAC scheme, in which nodes with higher utility values effectively obtain more spectrum and relay resources, improving overall network throughput without centralized control. In [16], the authors addressed service differentiation by designing MAC-layer mechanisms that adjust sensing and access probabilities according to user or traffic priority, increasing channel access opportunities and reliability for high-priority cognitive users while still protecting licensed users. While these methods provide a level of priority control, they rely on modifying the spectral or control environment, which may lead to inefficient resource utilization and complex coordination overhead.

Consequently, the potential of using sequence design itself as the sole mechanism for priority differentiation—while all users operate on the same channel set—has remained largely unexplored. Most existing works based on channel searching pattern for rendezvous have aimed for optimal rendezvous performance under equal service conditions, rarely considering user-specific priorities, and instead relying on MAC-layer or resource allocation strategies to enforce differentiation. While MAC-based approaches can provide priority control, they are often accompanied by reduced spectral efficiency and increased network complexity.

In this work, we propose a fundamentally different approach: priority is directly embedded into the sequence allocation framework. High-priority (primary) users are assigned the classical p-ary m-sequence, securing best-in-class rendezvous performance, while secondary CR users(SCUs) are allocated sequences constructed to ensure practical access and fairness, but with intentionally differentiated performance. By assigning mathematically distinct sequences to different priority classes within the established m-sequence framework, our method provides controlled, hierarchical performance without explicit channel partitioning or centralized coordination.

It is important to emphasize that our approach presupposes the use of p-ary m-sequence as the optimal channel searching pattern, where direct comparison with methods based on alternative sequences (such as jump-stay, modular, or random schemes) is not applicable. Instead, we focus on enabling performance differentiation within the most efficient possible searching paradigm, thereby maximizing both fairness and priority effect. Moreover, the proposed scheme is compatible with supplementary MAC-layer priority mechanisms, allowing further flexibility and multi-dimensional prioritization if desired.

The key contributions of this work are summarized as follows:

1. We introduce a new design paradigm in which priority levels are embedded directly into the channel searching sequence itself, leveraging the algebraic structure of p-ary m-sequences to allocate optimal sequences to primary CR users(PCUs) and differentiated sequences to secondary CR users(SCUs), all while operating in a common unpartitioned channel environment.
2. We establish the theoretical foundation for sequence-based priority differentiation and show how mathematically distinct constructions yield controlled differences in expected time-to-rendezvous (ETTR) between user classes. This hierarchical perfor-

mance is obtained without requiring explicit resource allocation or additional network coordination mechanisms, thus maintaining spectral efficiency and system simplicity.
3. Through comprehensive simulations and analysis, we demonstrate that the proposed scheme achieves effective priority differentiation within the most efficient sequence paradigm (the p-ary m-sequence), and highlight that further enhancements are possible if combined with traditional MAC-layer priority mechanisms—offering a flexible and extensible framework for advanced cognitive radio rendezvous management.
4. We discuss the scope and boundaries of direct comparison with existing methods, clarifying that the proposed scheme is designed for systems where the p-ary m-sequence is a prerequisite, and that differentiation is achieved without resorting to alternative, less optimal channel searching sequences. This preserves both the fairness and practical applicability of our solution in real-world CR environments.

The remainder of this paper is organized as follows. Section 2 presents a few important preliminaries for this paper. In Section 3, we propose the new scheme of channel searching sequence for Rendezvous according to the user priority which can provide different performance according to the priority of user. Numerical Results via simulation are presented in Section 4, followed by the conclusion in Section 5.

2. Preliminaries

In this section, we introduce key definitions and notations related to the mathematical foundations underlying channel-searching sequence design for rendezvous in cognitive radio systems. These preliminaries are essential for understanding the construction and analysis of the channel-hopping sequences proposed in this work.

Let p be a prime, then the finite field F_p(or $GF(p)$) is defined as following definition.

Definition 1 (Finite Field [17]). *Let p be a prime number. The finite field F_p (also denoted as $GF(p)$) is defined as the set of integers*

$$F_p = \{0, 1, 2, \cdots, p-1\},$$

equipped with addition and multiplication operations performed modulo p. Under these operations, F_p forms a field, meaning every nonzero element has a multiplicative inverse, and the field contains exactly p elements.

A finite field F_{p^m} of degree m with p^m elements always contains the prime field F_p as its smallest subfield and inherits all field properties. More generally, a field F_{p^k} is a subfield. of F_{p^m} if $F_{p^k} \subseteq F_{p^m}$ and the field operations in F_{p^k} coincide with those of F_{p^m}. A subfield F_{p^k} exists if and only if k divides m (i.e., $k \mid m$). This divisibility condition completely characterizes the subfield structure of F_{p^m}.

Definition 2 (Extension Field [17]). *Let F_{p^m} and F_{p^k} be finite fields such that $k \mid m$. Then F_{p^m} is called an* extension field *of F_{p^k}, and the degree of the extension is defined as $[F_{p^m} : F_{p^k}] = m/k$. In particular, F_{p^m} is an extension field of the prime field F_p of degree m. The elements of F_{p^m} can be represented as polynomials of degree less than m with coefficients in F_p, where addition and multiplication are performed modulo an irreducible polynomial of degree m over F_p.*

Beyond its algebraic structure as a vector space over F_p, the extension field F_{p^m} also possesses a rich multiplicative structure. The nonzero elements of F_{p^m} form a finite abelian group under multiplication, denoted by $F_{p^m}^* = F_{p^m} \setminus \{0\}$, whose order is $p^m - 1$. It is a fundamental result in finite field theory that this multiplicative group is cyclic. This property implies the existence of at least one element that can generate all nonzero ele-

ments of the field through successive powers—a concept formalized by the notion of a primitive element.

Definition 3 (Primitive Element [17]). *A primitive element of a finite field F_{p^m} is a generator of the multiplicative group $F^*_{p^m}$. That is, an element $\alpha \in F_{p^m}$ is primitive if every nonzero element of F_{p^m} can be expressed as a power of α, i.e.,*

$$F^*_{p^m} = \{\alpha^0, \alpha^1, \ldots, \alpha^{p^m-2}\}.$$

The order of α is therefore $p^m - 1$, and the multiplicative group $F^*_{p^m}$ is cyclic.

This property enables the construction of p-ary m-sequences used in our proposed scheme. A finite field extension can be constructed explicitly by using a primitive polynomial. Let p be a prime and let F_p denote the corresponding prime field. Consider a monic irreducible (primitive) polynomial $f(x)$ of degree m over F_p. Then, an extension field F_{p^m} can be obtained as the quotient ring

$$F_{p^m} = F_p[x]/\langle f(x)\rangle,$$

where $\langle f(x)\rangle$ denotes the ideal generated by $f(x)$ in the polynomial ring $F_p[x]$. In this construction, the residue class of x modulo $f(x)$, denoted by $\alpha = x \bmod f(x)$, acts as a root of $f(x)$ and serves as a generator (primitive element) of the multiplicative group $F^*_{p^m}$. Thus, every element in F_{p^m} can be expressed uniquely as a polynomial in α of degree less than m with coefficients in F_p:

$$a_0 + a_1\alpha + a_2\alpha^2 + \cdots + a_{m-1}\alpha^{m-1}, \quad a_i \in F_p.$$

This establishes that the extension field F_{p^m} is generated from the base field F_p through the adjoining of a root of a primitive polynomial $f(x)$, linking the algebraic definition of extension fields to their constructive representation via primitive polynomials.

Every finite field F_{p^m} contains at least one primitive element, and in fact, there are $\varphi(p^m - 1)$ such elements, where $\varphi(\cdot)$ denotes Euler's totient function. If F_{p^k} is a subfield of F_{p^m} with $k \mid m$, then the multiplicative group $F^*_{p^k}$ is a subgroup of $F^*_{p^m}$ of order $p^k - 1$. Consequently, if α is a primitive element of F_{p^m}, then $\beta = \alpha^{(p^m-1)/(p^k-1)}$ generates the multiplicative group of the subfield $F^*_{p^k}$.

The primitive element provides a convenient exponential representation of field elements, enabling various algebraic operations to be expressed in terms of exponent arithmetic modulo $p^m - 1$. However, many practical applications—such as constructing binary or p-ary sequences, error-correcting codes, or mapping field elements to observable signals—require a mechanism to map or project elements of the extension field F_{p^m} back into the base field F_p while preserving linearity. Such a mapping is provided by the *trace function*, which connects the algebraic structure of the extension field with the additive structure of its base field.

Let p be a prime and n, and m be positive integer such that $m|n$. Let F_{p^n} be the finite field with p^n elements. Then, the trace function tr^n_m from F_{p^n} to F_{p^m} is defined as

$$\mathrm{tr}^n_m(x) = \sum_{i=0}^{\frac{n}{m}-1} x^{p^{mi}}$$

where $x \in F_{p^n}$. Then the trace function satisfies the following properties. The trace function has the following properties.

(i) $\mathrm{tr}_m^n(ax+by) = a\mathrm{tr}_m^n(x) + b\mathrm{tr}_m^n(y)$, for all $a, b \in F_{p^m}$, $x, y \in F_{p^n}$.
(ii) $\mathrm{tr}_m^n(x^{p^m}) = \mathrm{tr}_m^n(x)$, for all $x \in F_{p^m}$.

Using the definition of trace function, we can define the p-ary m-sequence $m(t)$ of the period $p^n - 1$ as follows:

$$m(t) = \mathrm{tr}_1^n(\alpha^t),\ 0 \le t < p^n - 1$$

where, α is a primitive element of F_{p^n}. Such sequences are widely used for their pseudo-random properties, distribution uniformity, and low collision probability, which are advantageous for distributed rendezvous in cognitive radio networks. Based on the property of trace function, we can rewrite p-ary m-sequence $m_{sub}(t)$ of period $p^m - 1$ as follows:

$$m_{sub}(t) = \mathrm{tr}_1^m(\beta^t) = \mathrm{tr}_1^m(\gamma\beta^t\mathrm{tr}_m^n(1)) = \mathrm{tr}_1^m(\mathrm{tr}_m^n(\gamma\beta^t)) = \mathrm{tr}_1^n(\gamma\beta^t)$$

where β is a primitive element of F_{p^m} and $\gamma \in F_p$ is the inverse of $\mathrm{tr}_m^n(1)$. According to the property of the finite field, it is clear that β can be replaced with the form α^T and $\gamma = \alpha^\delta$, the above equation can be rewritten as:

$$m_{sub}(t) = \mathrm{tr}_1^n(\alpha^{Tt+\delta})$$

In this paper, primary CR users utilize p-ary m-sequences of period $p^2 - 1$, while secondary CR users are assigned sequences with period $p^4 - 1$, leveraging different algebraic structures to realize distinct rendezvous performance.

3. Priority Based Channel Searching Sequence Allocation for Rendezvous of Cognitive Radio

In this section, we propose a new scheme that assigns distinct channel-hopping sequences for rendezvous based on user priority.

In practical cognitive radio (CR) networks, even among users employing CR technology, situations often arise where users differ in terms of criticality or urgency of their communication requests. This naturally leads to the need for supporting differentiated priorities among CR users, such that those with higher priority—by virtue of importance or emergency—should be able to establish initial communication more rapidly than others. From this motivation, it is desirable that the rendezvous process itself—the time required for two users to find a common channel and initiate communication—reflect such priority differences by granting differentiated rendezvous performance to users with distinct priority levels.

Building upon this motivation, this section proposes a priority-aware channel searching sequence allocation scheme in which user priority is directly embedded into the channel hopping sequence design. Specifically, recognizing that the p-ary m-sequence constitutes one of the most effective channel searching patterns for rendezvous [9], our approach assigns p-ary m-sequences of different periods to users of different priority. The primary CR (high-priority) users are allocated the most efficient sequences, while secondary CR users receive sequences of extended period, thereby achieving a clear and controllable differentiation in rendezvous performance based on user priority. This allows each user to have a distinct Expected Time-to-Rendezvous (ETTR) and Maximum Time-to-Rendezvous (MTTR) based on their priority while maintaining the same channel set. Unlike previous studies, we propose a scheme in which differences in rendezvous performance according to user priority arise solely from the distinct sequence assignments under an identical environment, without any adjustment of channel allocation or environmental parameters. This implies that traditional MAC protocols or channel allocation adjustment methods can be additionally applied to the newly proposed scheme, and through such integration, it

is possible to achieve further performance differentiation in rendezvous between primary and secondary CR users.

The conceptual architecture of the proposed system is shown in Figure 1. As shown on the left side of Figure 1, the newly proposed scheme in this paper is based on the system that employs the p-ary m-sequence as the channel searching pattern, as introduced by Paul, Choi, Jang, and Kim [9]. When there are two users with different priorities in a CR system, we refer to the user with higher priority as the primary CR user, and the user with lower priority as the secondary CR user. By adopting the newly proposed scheme, the system enables differentiated rendezvous performance between the two users, thereby increasing the likelihood that the primary CR user can establish communication more quickly than the secondary CR user. As illustrated in the right side of Figure 1, the primary CR user utilizes a p-ary m-sequence with a period of $p^2 - 1$ as its channel searching pattern, while the secondary CR user employs a p-ary m-sequence with a period of $p^4 - 1$. Furthermore, when a new user needs to be added to an existing CR system, the newcomer can be defined as a secondary CR user and be assigned a p-ary m-sequence with a longer period as its channel searching pattern. In this way, the priority of the existing users is preserved.

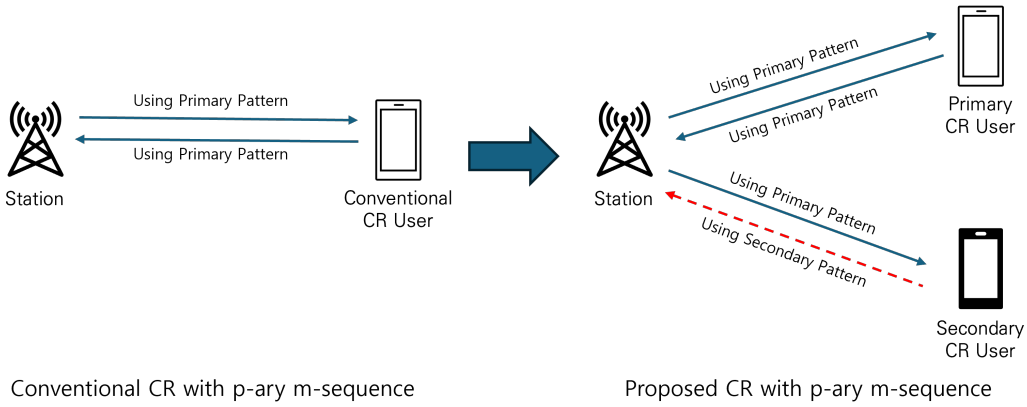


Figure 1. Conceptual Architecture of Proposed Scheme.

Paul, Choi, Jang, and Kim [9] proposed the channel searching pattern for rendezvous with symmetric channel as follows:

Theorem 1 ([9]). *For positive integers M and p such that p is the smallest prime bigger than or equla to M. Assume that there are M channels in the symmetric channel system. Let $m(t)$ be a p-ary m-sequence with period $p^2 - 1$. Using $m(t)$ as a channel-hopping sequence for the cognitive radio with M symmetric channels, the rendezvous occurs within $p + 1$ and ETTR is $(p + 1)/2$.*

Using the channel searching sequence in the above theorem as the channel searching sequence for primary CR user, we can define the channel searching sequence for secondary CR user as follows:

Definition 4 (Channel Searching Sequence for secondary CR user). *For positive integers M and p such that p is the smallest prime bigger than equal to M. Assume that there are M channels in the symmetric channel system. Let $m_p(t)$ be a p-ary m-sequence with period $p^2 - 1$ defined in Theorem 1. Then the channel searching sequence for secondary CR user is defined as $m_s(t) = tr_1^4(\alpha^t)$, where α is a primitive element of F_{p^4}.*

From Theorem 1 and Definition 4, it is clear that the condition for a secondary CR user to rendezvous with the station in Figure 1 under the proposed scheme is as follows:

$$\mathrm{tr}_1^4(\alpha^t) = \mathrm{tr}_1^2(\beta^{t+\tau})$$

where α is a primitive element of F_{p^2}, β is a primitive element of F_{p^2}, and $0 \le \tau < p^4 - 1$. The above equation can be rewritten as

$$\mathrm{tr}_1^4(\alpha^t) - \mathrm{tr}_1^2(\beta^{t+\tau}) = 0 \tag{1}$$

To calculate the ETTR, we must first examine the following theorem.

Theorem 2 (Nonbinary Kasami Sequence Sets [18]). *Let n and m be positive integers such that $n = 2m$ and p be a prime. Then the set of nonbinary Kasami sequence is defined as*

$$S = \{s_i(t) | 0 \le i \le p^m\}$$

where $s_i(t)$ is given

$$s_i(t) = \begin{cases} tr_1^4(\alpha^t), & i = 0 \\ tr_1^4(\alpha^t) + tr_1^2(\beta^{t+i}), & \text{otherwise} \end{cases}$$

where $\beta = \alpha^T$ is a primitive element of F_{p^2}.

The correlation values of the set of nonbinary Kasami sequence in the above equation have the following distribution:

$-1 + p^n$,	occurs p^m times
-1,	occurs $(p^n - 2)p^m$ times
$-1 - p^m$,	occurs $p^m(p^m - 1) + (p^n - 2)p^m(p^{m-1} - 1)$ times
$-1 - \omega^k p^m$,	occurs $(p^n - 2)p^{n-1}$ times for $k = 1, 2, \cdots, p - 1$.

From the definitnion of nonbinary Kasami sequence in Theorem 2 and (1), we can infer that the probability of t in $0 \le t < p^n - 1$ those satisfy (1) is the same as the probability of t in $0 \le t < p^n - 1$ those satisfy $s_i(t) - s_j(t + \tau) = 0$ except for $\tau = 0$ and $i = j + \tau$.

From the correlation value distribution of Theorem 2, the approximated value of the probability of t in $0 \le t < p^n - 1$ those satisfy $s_i(t) - s_j(t + \tau) = 0$ except for $\tau = 0$ and $i = j + \tau$ is $1/p$.

With the assumption that rendezvous occures within $p^2 + 1$, we can calculate the approximated ETTR of channel searching sequence for secondary CR user to rendezvous the station as follows

Theorem 3 (ETTR of channel searching sequence for secondary CR user). *The approximated ETTR of channel searching sequence for secondary CR user to rendezvous the station $ETTR_{sec}$ is calcuated as follows.*

$$ETTR_{sec} \approx \frac{(p-1)^2}{p} \approx p.$$

Proof. Since the probability of appearance 0 is $1/p$, the probability of rendevous occures at ith search is given as

$$a_i = (\frac{p-1}{p})^{i-1} \cdot \frac{1}{p}.$$

Therefore, the $ETTR_{sec}$ can be calculated as

$$\begin{aligned} ETTR_{sec} &= \sum_{i=1}^{p^2+1} i \cdot (\frac{p-1}{p})^{i-1} \cdot \frac{1}{p} \\ &= \sum_{i=1}^{p^2+1} i \cdot (\frac{p-1}{p})^{i} \cdot \frac{1}{p-1} = \frac{1}{p-1} \sum_{i=1}^{p^2+1} i \cdot (\frac{p-1}{p})^{i} \\ &= \frac{1}{p-1} \cdot \frac{p-1}{p} \cdot \frac{1-(p^2+2)(\frac{p-1}{p})^{p^2+1}+(p^2+1)(\frac{p-1}{p})^{p^2+2}}{(1/p)^2} \\ &= p \cdot (1-(p^2+2)(\frac{p-1}{p})^{p^2+1}+(p^2+1)(\frac{p-1}{p})^{p^2+2}(1/p)^2). \end{aligned}$$

For the case of large p, the values of $(p^2+2)(\frac{p-1}{p})^{p^2+1}$ and $(p^2+1)(\frac{p-1}{p})^{p^2+2}$ become negligible. You can see the values for each p in Table 1. So the value of the above equation can be approximated as

$$ETTR_{sec} \approx p.$$

□

Table 1. Values of $(p^2+2)(\frac{p-1}{p})^{p^2+1}$ and $(p^2+1)(\frac{p-1}{p})^{p^2+2}$ according to p.

p	$(p^2+2)(\frac{p-1}{p})^{p^2+1}$	$(p^2+1)(\frac{p-1}{p})^{p^2+2}$
11	0.001096	0.000997
17	6.74×10^{-6}	6.34×10^{-6}
23	3.11×10^{-8}	2.98×10^{-8}
29	1.24×10^{-10}	1.2×10^{-10}
31	1.92×10^{-11}	1.86×10^{-11}
37	6.84×10^{-14}	6.66×10^{-14}
41	1.54×10^{-15}	1.51×10^{-15}
47	5.05×10^{-18}	4.94×10^{-18}
53	1.6×10^{-20}	1.57×10^{-20}

As we mentioned before Theorem 3, we assume that rendezvous occurs within p^2+1 between primary sequence and second sequence. According to our simulation results in the Section 4, the maximum rendezvous value did not exceed p^2+1 over 10,000 trials. Thus, we are confident this assumption is valid. However, the mathematical calculation of the maximum rendezvous between the primary and secondary sequences remains a subject for future work.

4. Numerical Results

In this section, we present detailed simulation results to evaluate the performance of the proposed priority-driven rendezvous scheme. The simulation program was written in C, and the simulations were conducted on a PC equipped with 32 GB of RAM and an AMD Ryzen 9 CPU using the Dev-C++ compiler. All experiments were tested over 10,000 independent Monte Carlo trials to obtain statistically stable averages of both Expected Time-to-Rendezvous (ETTR) and Maximum Time-to-Rendezvous (MTTR).

The symmetric channel environment was assumed with M available channels, and p was selected as the smallest prime greater than M. Unless otherwise stated, $M = 17$ and

$p = 19$ were used for baseline experiments. The number of channel(M) and the value of prime(p) used in the simulation are summarized in Table 2.

Table 2. Values of M and p in simulation.

M	10	15	20	25	30	35	40	45	50
p	11	17	23	29	31	37	41	47	53

Two user groups were considered:

- Primary CR User (PCU)—adopts a p-ary m-sequence of period $p^2 - 1$ as its channel-hopping sequence.
- Secondary CR user (SCU)—adopts a p-ary m-sequence of period $p^4 - 1$, thereby producing a longer cycle and statistically delayed rendezvous opportunity.

All users share the same channel pool, and no additional channel reservation or resource partitioning was introduced.

For comparison, a conventional Reduced Channel Allocation (RCA) baseline was implemented, where SCUs were permitted to access only a subset (50–80%) of channels. This allows direct comparison between sequence-based and resource-based priority differentiation.

The primary performance metrics are defined as follows:

$$\text{ETTR} = \mathbb{E}[TTR], \quad \text{MTTR} = \max(TTR).$$

Figure 2 presents the ETTR performance for PCUs and SCUs using the proposed scheme. The PCU's sequence of period $p^2 - 1$ yields an average ETTR approximately half that of the SCU's sequence of period $p^4 - 1$. As shown in Figure 2, the ETTR of the primary CR user is approximately half that of the secondary CR user. This indicates that a distinct difference in ETTR performance is observed between the primary and secondary CR users, even without requiring specific adjustments such as resource allocation.

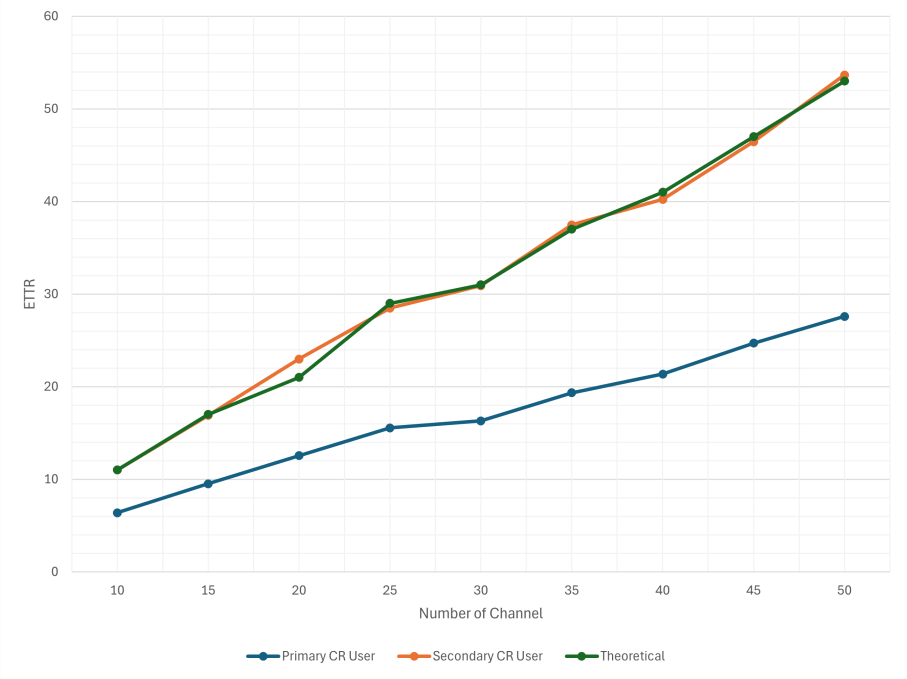


Figure 2. ETTR Performance of Primary CR User vs. secondary CR user.

Figure 3 illustrates the simulation results with MTTR of the proposed scheme. The sequence allocation for primary and secondary CR user is the same as ETTR comparison. As shown in Figure 3, the MTTR value of the secondary CR user is approximately nine times that of the primary CR user. This also indicates that a distinct difference in MTTR performance is observed between the primary and secondary CR users, even without requiring specific adjustments such as resource allocation.

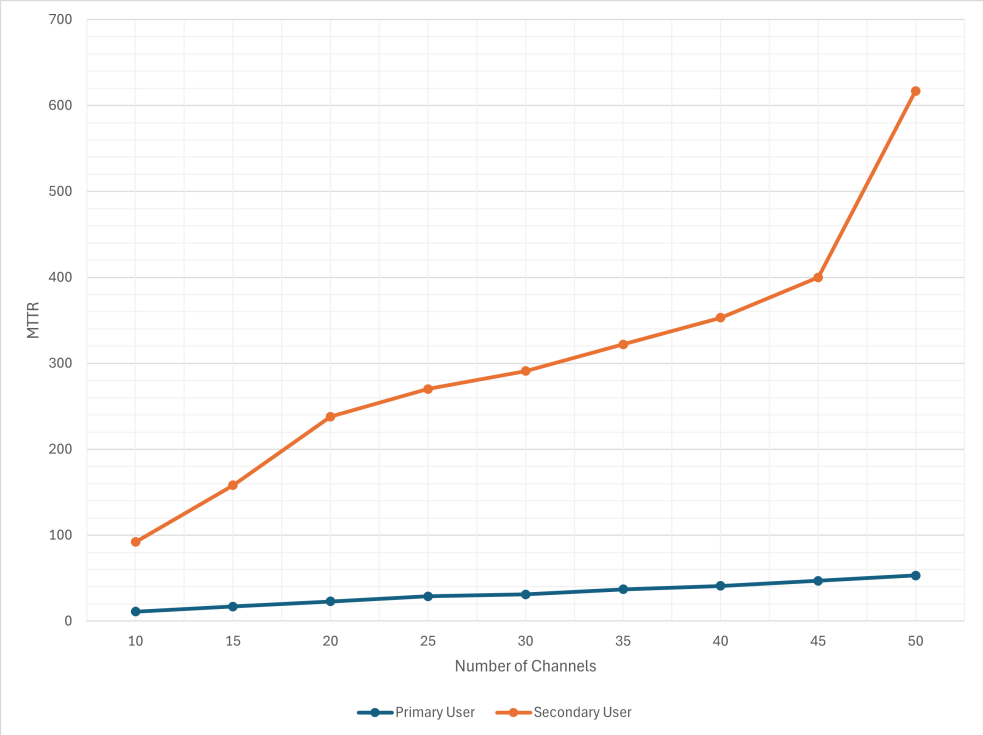


Figure 3. MTTR Performance of Primary CR User vs. secondary CR user.

To further verify the fairness–efficiency trade-off, Figure 4 compares the ETTR of the proposed scheme with that of the RCA baseline, where SCU access ratios vary from 50% to 80%. The proposed method achieves ETTR performance intermediate between 60% and 70% channel-allocation cases, despite operating without any channel restrictions. This indicates that the proposed priority mechanism achieves comparable differentiation purely through sequence design, eliminating the need for explicit spectrum segmentation.

From the simulation results, we can find three major findings:

1. The proposed scheme provides predictable hierarchical performance: PCUs consistently achieve shorter ETTR (about a half) and MTTR (approximately 1/9) without degrading SCU access probability.
2. Priority differentiation arises entirely from algebraic sequence properties, not from external control or allocation mechanisms, thus preserving spectral efficiency and implementation simplicity.
3. Simulation results align closely with analytical approximations (e.g., $\mathrm{ETTR}_{SCU} \approx p - 1$ for large p), confirming the accuracy of the theoretical model.

Overall, these findings demonstrate that the proposed sequence-based priority framework achieves a tunable and mathematically tractable method of user differentiation in cognitive-radio rendezvous without modification of the underlying channel environment.

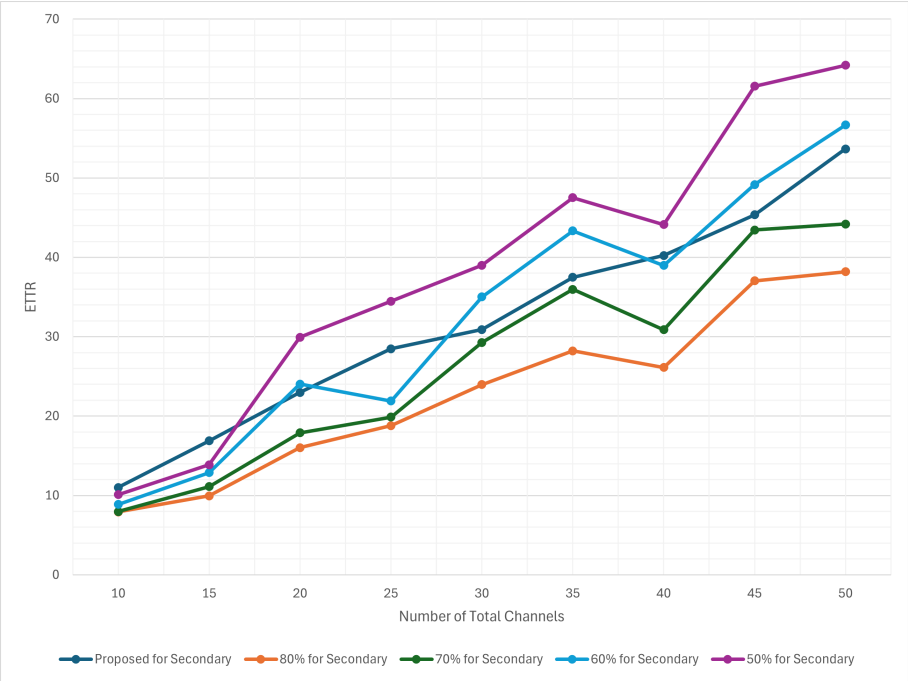


Figure 4. ETTR Performance Comparison for secondary CR user of reduced channel allocation and proposed scheme.

5. Conclusions

In summary, this paper introduced a priority-based rendezvous framework that assigns channel-searching sequences according to user priority, enabling differentiated performance without modifying the shared channel environment. Simulation results verified that the proposed approach ensures predictable performance tiers between users. To further advance this study, future work will focus on analytically deriving ETTR bounds and extending the scheme to multi-level priority hierarchies.

Author Contributions: Conceptualization, J.-W.J.; Methodology, D.J. and J.-W.J.; Formal analysis, D.J. and J.-W.J.; Writing—original draft, J.-W.J. All authors have read and agreed to the published version of the manuscript.

Funding: This result was supported by the "Regional Innovation System & Education (RISE)" through the Ulsan RISE Center, funded by the Ministry of Education (MOE) and the Ulsan Metropolitan City, Republic of Korea (2025-RISE-07-001).

Data Availability Statement: The data will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CR	Cognitive Radio
PCU	Primary CR User
SCU	secondary CR user
TTR	Time-to-Rendezvous
ETTR	Expected Time-to-Rendezvous
MTTR	Maximum Time-to-Rendezvous

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