Spectral Efficiency Enhancement using Hybrid Pre-Coder Based Spectrum Handover Mechanism

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Article Info

Article history:

Received Jan 31, 2022
Revised Jul 15, 2022
Accepted Jul 28, 2022

Keyword:

Spectrum Handover Process
Hybrid Pre-Coder Design based Spectrum Handoff (HPDSH)
Millimeter Wave (mm-wave) System
Cognitive Radio Networks (CRNs)
Fully Connected Structure

ABSTRACT

The use of Millimeter-wave (mm-Wave) has recently immensely enhanced in various communication applications due to massive technological developments in wireless communications. Furthermore, mm-Wave consists of a high bandwidth spectrum that can handle large demands of data transmission and internet services. However, high interference is observed in previous research at the time of spectrum handover from secondary (unlicensed) users to primary (licensed) users. Thus, interference reduction by achieving high spectral efficiency and an easy spectrum handoff process with minimum delay is an important research area. Therefore, a Hybrid Pre-coder Design based Spectrum Handoff (HPDSH) Algorithm is proposed in this article to increase spectrum efficiency in Cognitive Radio Networks (CRNs) and to access the large bandwidth spectrum of mm-Wave systems to meet the high data rate demands of current cellular networks. Moreover, a HPDSH Algorithm is presented to enhance spectral efficiency and this algorithm is utilized to take handover decisions and select backup channels. Here, different scenarios and parameters are considered to evaluate the performance efficiency of the proposed HPDSH Algorithm in terms of spectral efficiency and Signal to Noise (SNR) ratio. The proposed HPDSH Algorithm is compared against precoding methods like the OMP algorithm and SIC based methods.

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1. INTRODUCTION

Recently, the demand for high data rates and Quality of Services\ (QoS) in telecommunication and broadband services has immensely enhanced due to the massive advancements in internet-enabled services and devices. As a result, high bandwidth and are spectrum utilized and the use of 5G systems becomes compulsory to meet these heavy bandwidth demands [1-2]. Thus, 5G cellular networks can be heavily utilized in near future to satisfy the high data rates of end-users. Therefore, CRNs can be considered to play an important role in achieving 5G cellular networks' requirements and can provide great\ QoS and can efficiently handle spectrum utilization. Moreover, CRNs have a high potential to enhance spectral efficiency at a lower cost [3]. The main intention behind the utilization of CRNs is to provide access to secondary users so that the temporarily available unused spectrum of licensed users can be utilized efficiently [4-5]. Further, CRNs can efficiently handle spectrum capacity challenges. In other words, CRNs are a type of wireless communication that can be utilized to smartly differentiate between vacant and non-vacant channels. Moreover, this technique utilizes unused bandwidth spectrum while avoiding occupied spectrum so that interference remains minimum between licensed and unlicensed users. Thus, the main purpose of forming CRNs is to share the licensed spectrum between licensed and unlicensed users.

Moreover, CRNs have several facilities like this networks can be reconfigured by themselves in order to provide access to the licensed spectrum and continuously observes the environment, and take suitable decisions based on the observations made. Moreover, CRNs always remain aware of the environment in which they operate and usually learn from the experience [6]. Here, many factors remain associated with the efficiency of CRNs such as routing plan, bandwidth selection, frequency and time slot fixing, frame size, and interference minimization. Moreover, the efficiency of spectrum sharing access can be improved by minimizing interference between licensed and unlicensed users. The main functions of CRNs are spectrum detection, spectrum decisions based on the observations made, spectrum access, and spectrum handoff. Here, the first three operations describe the vacant channel detection from the available spectrum and then idle channels are selected while occupied channels remain undisturbed. Finally, the spectrum mobility (Handoff) function is utilized to switch from the primary user's occupied channel when the primary user reappears to another unused channel in the spectrum with the help of mentioned three functions [7]. Additionally, spectrum detection, the arrival of the licensed user, and data packet transmission can cause extra interference in the spectrum handoff process which can heavily affect the efficiency of CRNs. However, effective management of the spectrum handoff process can improve the bandwidth accessibility of CRNs. Moreover, spectrum handoff schemes can be segregated into two types such as proactive and reactive schemes [8]. In a proactive spectrum handoff scheme, fewer bandwidth channels of licensed users are accessed while in a reactive spectrum handoff scheme, usually all the bandwidth channels of licensed users are accessed. In this way, CRNs are a great option to handle diverse and random traffic demands of 5G cellular networks at minimum operational cost with the help of their ubiquitous accessibility feature. Moreover, several researchers have shown great interest in forming CRNs to access large bandwidth spectrum efficiently. Some of the significant research regarding CRNs are discussed below.

In [9], an energy-aware and secure method are adopted for CRNs to reduce power consumption and enhance the security of data packet transmission. This method discusses the varied problems that arise in CRNs such as power consumption, data security, detection of unutilized bands and vulnerability level, etc. In [10], Cognitive D2D Communication System is formed to access the spectrum and improve QoS Provisioning. This technique works upon non-switching spectrum hand-off for multi-class D2D Communication Systems. Here, Continuous-Time Markov Chain (CTMC) has been adopted to improve the performance efficiency of the Cognitive D2D system. In [11], a cognitive radio sensing technique is adopted to handle broadband and broadcast services and to improve CR spectrum efficiency. This scheme supports low latency communications with high reliability. Additionally, a strong correlation is formed between spectrum blocks to achieve high data rates. In [12], a Network Coding Technique is adopted to generate effective coordination between licensed and unlicensed users in Cognitive Radio Networks. This technique provides the overall performance efficiency of CRNs. This technique provide high throughput in terms of data packet transmission.

However, problems such as spectrum handoff performance efficiency enhancement, data packet transmission interference, and spectrum interference remain undiscussed which can heavily impact the spectrum efficiency of CRNs. Therefore, a Hybrid Pre-coder Design based Spectrum Handoff (HPDSH) Algorithm is proposed in this article to enhance spectrum efficiency in CRNs. In addition, mm-Wave communication is adopted which can provide a large bandwidth spectrum to meet the demands of high data rates in current cellular services.

1.1 Research Significance:

Here, the focus of the research remains on the efficiency improvement in the spectrum handoff process between primary and secondary users. The use of mm-wave bands offers greater bandwidth than the current cellular bands and the proposed hybrid precoding mechanism is cost-effective and improves high spectral efficiency. In a CRN, spectrum handover is achieved by accomplishing different phases where the first phase is spectrum access for the analysis of large spectrum bandwidths, the second phase is spectrum sensing that distinguishes between occupied and vacant frequency bands, the last phse is spectrum handover whenever a primary user wants to have their licensed users. Thus, this research work is mainly focused on spectrum access through HPDSH) Algorithm. Hybrid precoding, a combination of analog and digital precoding, is an attempt to reach a compromise between complexity and performance. By exploiting more than one radio frequency chain, hybrid precoding enables a millimeter wave (mmWave) system to take advantage of both spatial multiplexing and beamforming gain. Channel estimation for the millimeter-wave (mmWave) MIMO systems with hybrid precoding can be performed by estimating the path directions of the channel and corresponding beamforming gains. Thus, hybrid precoding is useful for efficient channel estimation and spectrum access. The proposed HPDSH algorithm provides spectrum handover with minimum delay and reduced interference. Moreover, energy consumption in this process remains minimum for CRNs. Besides, the performance of the proposed HPDSH algorithm in CRNs is compared with conventional algorithms in terms of power consumption, NMSE and spectral efficiency.

This paper is arranged in the following manner which is described below. Section 2, discusses about the related work regarding CRNs, their problems, and how these problems can be avoided with the help of the proposed technique. Section 3, discusses about the methodology used in the proposed technique. Section 4 describes potential results and their comparison with state-of-arts-techniques and section 5 concludes the paper.

2. RELATED WORK

Several research papers have shown that future cellular networks may require data speed up to some GHz. Thus, a large bandwidth spectrum and its efficient spectrum utilization become a necessity. Besides, the high bandwidth requirements in future cellular networks, cannot be met using present bandwidth spectrums. Thus, MM-Wave is adopted to handle high bandwidth requirements and CRNs can be used to efficiently utilize the high bandwidth spectrum of the MM-Wave system which ranges from 30 GHz to 300 GHz. However, spectrum handoff with immediate effect and minimum interference is a challenge in CRNs. Therefore, many researchers have discussed the high potential of CRNs and MM-Wave communication systems. Some of the research articles are discussed in the next paragraph.

In [13], a cross layer resource allocation technique is adopted to implement CRNs and handle the high bandwidth spectrum. In addition, Software Defined Radio (SDR) technology is introduced to realize a distributed cross-layer computation. The functions like spectrum sensing and spectrum detection can be handled using Markov Random Field (MRF) framework. In [14], a clustering technique is presented to provide network stability, and a cognitive radio communication system is used to improve spectrum efficiency. This technique has the potential to provide stability and reliability in handling excessive demand for wireless communications. In [15], the Spectrum Handoff Mechanism is presented to enhance spectrum efficiency in CRNs. In addition, novel cognitive user emulation attack is adopted to provide security from spectrum intruders. Here, MATLAB simulations are utilized to validate the performance of spectrum utilization. In [16], the two-way simultaneous wireless information and power transfer (SWIPT) technique is introduced to investigate the relay selection problem. This technique works upon Neural Network Architecture (NNA) and CRNs is utilized to enhance spectrum efficiency. In this technique, a pair of primary users and multiple secondary user are considered to perform transmission. In [17], a Q-learning method is introduced to access spectrum bandwidth and handle multimedia transmission in CRNSs. This technique allocates multimedia data and reduces delay so that performance efficiency can be improved. Simulation results are demonstrated in terms of power efficiency, throughput and delay. In [18], a Spectrum Access Architecture is introduced to analyze on-demand CRNs so that citizens broadband radio service (CBRS) can be enabled. This technique is used to estimate spectrum probability based on the priority access license users. This technique provides high-performance result. In [19], a *k*-hop Clustering method is presented to enhance the energy efficiency of CRNs. Here, spectrum scarcity problem is handled by CRNs and clustering is performed to optimize energy. Additionally, a neighbour discovery algorithm is introduced to perform constant intra-cluster and inter-cluster communications. In [20], an Energy Harvesting technique is presented to improve Bit Error Ratio (BER) Performance in Cognitive Radio Networks based on Primary Users and Secondary Relays. Here, node selection is performed based on relay selection criteria. Performance results are estimated considering parameters like energy and power consumption in CRNs.

However, there are a few challenges that can be encountered in CRNs and their practical implementation becomes difficult. Therefore, an improved HPDSH Algorithm in CRNs is introduced in this article to minimize delay and reduce interference while spectrum switching from one to another when the primary user reappears. So that spectral efficiency and utilization of CRNs can be enhanced. The proposed HPDSH algorithm reduces channel interference. Detailed mathematical modeling of the improved spectrum handoff algorithm is presented in the following section.

3. MODELING FOR PROPOSED HYBRID PRE-CODER DESIGN BASED SPECTRUM HANDOFF (HPDSH) ALGORITHM

In this section, a comprehensive mathematical modelling for proposed HPDSH Algorithm is discussed to enhance spectrum efficiency in CRNs. Millimeter-wave (MM-Wave) MIMO communication is a key technology to meet the high capacity and high throughput requirements of 5G wireless communication systems, it also achieves a Gigabit per second data transmission rate in an indoor and outdoor communication system. Fortunately, the shorter wavelength of MM-Wave signals enables the facility to put large antenna arrays into a much smaller space and make massive MIMO practical in wireless communications systems. The large antenna arrays could also provide sufficient antenna gains by precoding to compensate for the high path loss. Therefore, MM-Wave MIMO system have been a promising candidate for future cellular networks.

For a massive MM-Wave MIMO communication systems, in order to cancel the interferences between different data streams and decrease the complexity of the receiver, signals should be pre-coded before transmission. At present, the fully digital precoding at the MM-Wave systems can achieve optimal performance. However, an individual radio frequency (RF) chain is required for each antenna and a large number of RF chains will cause high cost and energy consumption. Thus, analog precoding is required to reduce the number of RF chains, so the cost of hardware and power consumption can be reduced greatly. Precoding is typically accomplished at baseband through digital precoders, which can adjust both the magnitude and phase of the signals. However, fully digital precoding demands radio frequency (RF) chains, including signal mixers and analog-to-digital converters (ADCs), comparable in number to the antenna elements. While the small wavelengths of mmWave frequencies facilitate the use of a large number of antenna elements, the prohibitive cost and power consumption of RF chains make digital precoding infeasible. Thus, it is mainly realized in both the digital domain and an analog domain, the digital precoding is realized through baseband signal processing in the digital domain, while analog precoding is usually realized by an analog phase shifter in the analog domain. Thus, hybrid precoding improves spectral efficiency.

In addition, the MM-Wave system is adopted to effectively utilize the high bandwidth spectrum. Here, spectrum efficiency is improved by reducing computational complexity and designing a hybrid pre-coder to optimize objective functions. The main focus of CRNs is to provide access to the idle bandwidth spectrum in order to have communication. However, spectrum handover in CRNs is a quite challenging task. Generally, CRNs consist of both primary and secondary users. Further, primary users have complete access to the available bandwidth spectrum as they have legacy rights for the spectrum access whereas secondary users have the opportunity to access the bandwidth spectrum when primary users are not using the spectrum. However, secondary users need to switch the spectrum when primary users want to access their spectrum. Thus, switch of spectrum may cause a large delay and high interference. Therefore, in this article, spectrum switching delay and interference is reduced using HPDSH algorithm and spectrum efficiency is also improved. Then, the mathematical modeling of the proposed HPDSH algorithm is presented in the next section.

Here, HPDSH algorithm is formulated using system and channel model in the considered CRNs to support mm-Wave bandwidth spectrum and spectrum handover scenarios. Here, a mm-Wave system is considered for a single user in which M_t data is transmitted and received by transmitting and receiver antennas, respectively. Here, the transmitter antennas are denoted by M_r and receiver antennas are denoted by M_s. Here, the number of Radio Frequency (RF) chains are denoted by $M_\aleph^r$ at the transmitter side and by $M_\aleph^s$ at the receiver side. Then, transmitted signal is given by $y = K_\aleph K_g t$, where t is a vector quantity of the dimension $M_t \times 1$ such that $F[tt^N] = (M_t)^{-1} D_{M_t}$. A hybrid pre-coder contains a digital and analog pre-coder. Here, digital pre-coder K_g is represented by $M_\aleph^r \times M_t$ and analog pre-coder $K_\aleph$ is represented by $M_r \times M_\aleph^r$. Then, the optimized transmitted power is given by $\|K_\aleph K_g\|_K^2 = M_t$. Then, the decoded signal at the received end is given by the following equation,

$$x = (\delta)^{\frac{1}{2}} A_g^N A_\aleph^N N K_\aleph K_g t + A_g^N A_\aleph^N m \tag{1}$$

Where the average received power is denoted by δ and A_g is represented as the $M_\aleph^s \times M_t$ digital decoder, channel matrix is represented by N, m is represented as the noise vector which has $\Psi\left(0, \beta_\gamma^2\right)$ elements, and $A_\aleph$ is represented as the $M_w \times M_\aleph^s$ analog decoder at the receiver sides. Here, it is considered that Channel State Information (CSI) is obtained both at the transmitter and receiver side efficiently. Here, transmitted data follows a Gaussian distribution model. Then, spectral efficiency is given by the following equation,

$$S = \log\det\left(D_{M_t} + \delta\left(\beta_\gamma^2 M_t\right)^{-1}\left(A_\aleph A_g\right)^T N K_\aleph K_g \times K_g^N K_\aleph^N N^N \left(A_\aleph A_g\right)\right) \tag{2}$$

Moreover, analog pre-coders are implemented with phase shifters to adjust phase of the signals. Further, non-zero elements $K_\aleph$ and $A_\aleph$ should satisfy the condition $\left|(K_\aleph)_{d,c}\right| = \left|(A_\aleph)_{d,c}\right| = 1$. Here, a fully connected structure is utilized to transmit signals from RF chains to antennas. In this structure, output signals are sent from each RF chain to all the antennas with the help of phase shifters. Therefore, high beamforming gain is achieved in a fully-connected structures using RF chains and antennas. Here, the channel matrix in mm-Wave system for a clustered model is given by following the equation,

$$N = [M_r M_s . (M_e M_l)^{-1}]^{1/2} . \sum_{d=1}^{M_e} \sum_{z=1}^{M_l} \varphi_{dz} \mu_s (\psi_{dz}^s, \Theta_{dz}^s) \, \mu_r (\psi_{dz}^r, \Theta_{dz}^r)^N \tag{3}$$

Where, total number of rays in a cluster is defined by M_l and total number of clusters are defined by M_e and gain of z^{th} ray in the mm-Wave system is given by φ_{dz}. Besides, consider that φ_{dz} satisfy the condition $F[\|N\|_K^2] = M_r M_s$ and follows distribution model $\Psi(0, \beta_\gamma^2)$. Additionally, $\mu_s(\psi_{dz}^s, \Theta_{dz}^s)$ represents response vector at receiver side and $\mu_r(\psi_{dz}^r, \Theta_{dz}^r)$ represents response vector at transmitter side. Thus, response vector of $z - th$ ray in a $d - th$ cluster is defined by following equation,

$$\mu(\psi_{dz}, \Theta_{dz}) = \sqrt{M}^{-1}\left[1, \dots\dots, e^{c\frac{2\pi}{\xi}v(q sin\,\psi_{dz}.\sin\Theta_{dz} + q\cos\Theta_{dz}),\dots,} e^{c\frac{2\pi}{\xi}v((\sqrt{M}-1)sin\,\psi_{dz}.\sin\Theta_{dz} + (\sqrt{M}-1)\cos\Theta_{dz})}\right]^T \quad (4)$$

Where, wavelength of the signal is denoted by ξ and antenna spacing is represented by v. Furthermore, the design structure of pre-coder and decoder is almost similar. However, pre-coder design requires more power than decoder design. Here, the focus of this paper remains on spectrum handover in CRNs to access high bandwidth spectrum of mm-Wave system and reduce delay while spectrum switching from one to another. Moreover, the optimization of following equation (5) can provide high spectral efficiency. This can be achieved by minimizing the objective function of equation (5). Then, equation (5) is given by,

$$\min_{F_\aleph, F_g} \left\|K_{opt} - K_\aleph K_g\right\|_K \quad subject\ to \begin{cases} F_\aleph \in U \\ \left\|K_\aleph K_g\right\|_K^2 = M_t \end{cases} \quad (5)$$

Where, optimized fully digital pre-coder is denoted by K_{opt} and $K_\aleph$ denotes analog precoder and K_g represents digital precoder which need to be optimized. Besides, U is a constant set of analog pre-coder and represented by $U \in \{U_q, U_k\}$. Here, two objective functions $K_\aleph$ and K_g are optimized by decoupling both variables

3.1. Pre-coder Design Based Spectrum Handoff Considering Fully Connected Structure

The fully connected structure for hybrid precoding is regularly used in the mm-Wave systems in which every RF chain is linked to all the antenna elements. This section discusses about the optimization of pre-coder design problem and provide solution to minimize objective functions of equation (5) so that performance to access high bandwidth spectrum of mm-wave system can be enhanced as well as spectral efficiency can be increased. Here, pre-coder design based spectrum handoff process is distributed into three parts in which first part discusses about the digital pre-coder design based spectrum handoff, second part describes about the analog pre-coder design based spectrum handoff and last part discusses about the hybrid pre-coder design based spectrum handoff.

i. Digital Pre-coder Design based Spectrum Handoff Considering Fully Connected Structure:

In this section, digital pre-coder design K_g is considered while analog pre-coder $K_\aleph$ is kept at fixed place. Therefore, equation (5) can be re-written as,

$$\min_{K_g} \left\|K_{opt} - K_\aleph K_g\right\|_K \quad (6)$$

Then, the optimal solution for digital pre-coder design K_g is given by following equation,

$$K_g = K_\aleph^T K_{opt} \quad (7)$$

ii. Analog Pre-coder Design based Spectrum Handoff Considering Fully Connected Structure:

In a fully connected structure for an analog pre-coder, every RF chain is linked to all the antennas. Then, the set U_k of analog pre-coder can be evaluated as $\left|(K_\aleph)_{d,c}\right| = 1$. Here, digital pre-coder design K_g is kept at fixed place and analog pre-coder $K_\aleph$ is optimized to minimize objective functions of equation (5),

$$\min_{K_\aleph} \left\|K_{opt} - K_\aleph K_g\right\|_K^2 \quad subject\ to \left|(K_\aleph)_{d,c}\right| = 1, \forall d, c. \quad (8)$$

Thus, an effective optimum solution is presented to optimize analog pre-coder problem of equation (8). Then, Euclidean metric with the complex plane $\mathbb{P}$ is evaluated by following equation,

$$\langle y_1, y_2 \rangle = \partial\{y_1^*, y_2\}, \quad (9)$$

Then, complex plane $\mathbb{P}$ can be equivalent to Ω^2 so that complex circle can be evaluated as,

$$\Gamma_{ww} = \{y \epsilon \mathbb{P}: y^* y = 1\} \tag{10}$$

For a specific point y on complex circle Γ_{ww}, the direction of point is determined using tangent vectors. Then, evaluate tangent space for the point $y \in \Gamma_{ww}$ as,

$$R_y \Gamma_{ww} = \{b \in \mathbb{P}: b^* y + y^* b = 2\langle y, b\rangle = 0\} \tag{11}$$

Here, a complex circle Γ_{ww}^{ϖ} is formed by the tangent vector $y = vec\ (K_{\aleph})$ where $\varpi = M_r M_{\aleph}^r$. Then, tangent space to sort optimization problem for a given specified point $y \in \Gamma_{ww}^{\varpi}$ as,

$$R_y \Gamma_{ww}^{\varpi} = \{b \in \mathbb{P}^{\varpi}: \partial\{b\ o\ y^*\} = \chi_{\varpi}\} \tag{12}$$

Here, complex circle Γ_{ww}^{ϖ} is determined as the subspace of $\mathbb{P}^{\varpi}$ and tangent vector $\mathbb{G}\mathbb{f}(y)$ is known as the gradient at point y and determined as Euclidean gradient projection $\nabla \mathbb{f}(y)$ over tangent space $R_y \Gamma_{ww}^{\varpi}$ as,

$$\mathbb{G}\mathbb{f}(y) = Proj_y \nabla \mathbb{f}(y) = \nabla \mathbb{f}(y) - \partial\{\nabla \mathbb{f}(y) o\ y^*\}\ o\ y \tag{13}$$

Then, the cost function of Euclidean gradient is given by following equation,

$$\nabla \mathbb{f}(y) = -2\left(K_g^* \otimes D_{M_r}\right)\left[vec\left(K_{opt}\right) - \left(K_g^R \otimes D_{M_r}\right) y\right] \tag{14}$$

Here, retraction is an important factor to evaluate destination of a tangent vector. Then, at point $y \in \Gamma_{ww}^{\varpi}$, the tangent vector retraction φv is given by,

$$\mathfrak{R}_y: R_y \Gamma_{ww}^{\varpi} \to \Gamma_{ww}^{\varpi}: \varphi v \to \mathfrak{R}_y(\varphi v) = vec\ [(y + \varphi v)_d . ((y + \varphi v)_d)^{-1}] \tag{15}$$

Here, two tangent vectors are mapped together which are placed in two different tangent spaces $R_{y_ℶ} \Gamma_{ww}^{\varpi}$ and $R_{y_{ℶ+1}} \Gamma_{ww}^{\varpi}$. The distance of tangent vector v from $y_ℶ$ to $y_{ℶ+1}$ is determined as follows,

$$Dist_{y_ℶ \to y_{ℶ+1}}: R_{y_ℶ} \Gamma_{ww}^{\varpi} \to R_{y_{ℶ+1}} \Gamma_{ww}^{\varpi} : v \to v - \partial\{v\ o\ y_{ℶ+1}^*\} o\ y_{ℶ+1} \tag{16}$$

iii. Hybrid Pre-coder Design based Spectrum Handoff Considering Fully Connected Structure:

Here, objective functions can be optimized using HPDSH algorithm to enhance spectral efficiency to access the mm-Wave bandwidth spectrum by solving problems of equation (6) and equation (8).

Algorithm 1: HPDSH algorithm Considering Fully Connected Structure	
Step 1: Input: K_{opt}	
Step 2: Form $K_{\aleph}^{(0)}$ with different phases and set $ℶ = 0$	
Step 3: Repeat	
Step 4:	Fix $K_{\aleph}^{(ℶ)}$
Step 5:	$K_g^{(ℶ)} = \left(K_{\aleph}^{(ℶ)}\right)^T K_{opt}$
Step 6:	Evaluate $K_g^{(ℶ+1)}$ while $K_g^{(ℶ)}$ is kept at fixed position
Step 7:	$ℶ \leftarrow ℶ + 1$
Step 8: Until a criteria triggers to stop the process	
Step 9: Normalize $\widehat{K}_g = \sqrt{M_t} . \left(\left\|K_{\aleph} K_g\right\|_K\right)^{-1}$	

In this way, this algorithm helps to enhance spectral efficiency considering fully connected structure to access high bandwidth spectrum of mm-wave system. This algorithm helps to minimize objective functions of equation (5), (6) and (8). Although, computational complexity in fully connected structure is relatively higher than partially connected structure. However, with the help of proposed HPDSH algorithm, the spectral efficiency can be massively improved.

Here, switching delay and interference reduction are two important factors in improving spectral efficiency of spectrum handoff process with the help of proposed HPDSH algorithm. Usually, spectrum handover is a process of switching bandwidth spectrum from one to another available spectrum, whenever primary user wants to occupy their spectrum. At the time of spectrum handover process, the number of Base Stations (BSs) are remain available which can link to the User Equipment (UE). However, channel quality may get affected due to the switching of spectrums and obstacles come across due to the blockages. Thus, searching of new BS and beamforming may enhance overhead and can heavily impact UE performance. This process may enhance computational complexity of entire spectrum handover process. This challenges can be addressed using the proposed HPDSH Algorithm. When quality of a serving BS is reduced below pre-defined handover threshold, then a new backup BS is selected and a link is established from the BS to the UE. Furthermore, UE switches to the selected BS whenever channel quality get lowered to the pre-defined handover threshold. The proposed HPDSH Algorithm depends upon three main components which massively helps in spectrum handover process. Those three components are channel estimation using HPDSH Algorithm, mobility estimation and spectrum handoff. Here, channel estimation efficiency is evaluated using HPDSH Algorithm. Here, handover decisions and backup channel selection can be made with the help of proposed HPDSH Algorithm. Two varied slots are utilized to determine transmission durations of pilot signals for channel estimation towards serving BS and backup BS, respectively. The phase related to serving BS notifies about the backup BS selection whereas the phase related to backup BS notifies about the handover execution process. The HPDSH algorithm is a cost effective approach. However, mobility behaviour in handover process is a key challenge which is carefully handled. Further, a precise mobility estimation can heavily enhance performance efficiency of handover process by reducing channel overhead. Furthermore, HPDSH algorithm provides better quality of service as well as frequent connections. Algorithm 2 provides all the details regarding the working mechanism of proposed HPDSH Algorithm.

Algorithm 2: Proposed HPDSH Algorithm for Spectrum Handover

Step 1: **Input:** Pre-defined handover threshold, Total number of BSs in UE region, trajectory location and mobility data
Step 2: **Initialization:** set $BS_{\mathbb{S}}^{1} = BS_1$ while $\mathbb{k} = 1$
Step 3: $\mathbb{t}_{log}(BS_{\mathbb{i}}) = +\infty$, for all $\mathbb{i} \epsilon [\mathbb{M}]$
Step 4: **for** $\mathbb{j} = 1, \ldots \ldots, \mathbb{N}$
Step 5: $\mathbb{k} \leftarrow current\ interval$
// At the time of first small slot
Step 6: Predict channel from $BS_{\mathbb{S}}^{\mathbb{k}}$ towards location $\mathbb{j}$
Step 7: Evaluate SNR $\left(BS_{\mathbb{S}}^{\mathbb{k}}, \mathbb{j}\right)$
Step 8: Set $\mathbb{t}_{log}\left(BS_{\mathbb{S}}^{\mathbb{k}}\right) = 0$
// At the time of second small slot
Step 9: Select $BS_{\mathbb{C}}^{\mathbb{k}} = BS_{\mathbb{i}}, i \in [\mathbb{M}]$ based on phase related to serving BS
Step 10: Predict channel from $BS_{\mathbb{C}}^{\mathbb{k}}$ to the location $\mathbb{j}$
Step 11: Evaluate SNR $\left(BS_{\mathbb{C}}^{\mathbb{k}}, \mathbb{j}\right)$
Step 12: Set $\mathbb{t}_{log}\left(BS_{\mathbb{C}}^{\mathbb{k}}\right) = 0$
Step 13: ***if*** $SNR^{\mathbb{L}}\left(BS_{\mathbb{S}}^{\mathbb{k}}, \mathbb{j}\right) > \mathbb{T}_{\mathbb{h}}$ ***then***
Step 14: $BS_{\mathbb{S}}^{\mathbb{k}+1} = BS_{\mathbb{S}}^{\mathbb{k}}$
Step 15: **else**
// Perform Handover process
Step 17: ***if*** $SNR^{\mathbb{L}}\left(BS_{\mathbb{C}}^{\mathbb{k}}, \mathbb{j}\right) > \mathbb{T}_{\mathbb{h}}$ ***then***
Step 18: $BS_{\mathbb{S}}^{\mathbb{k}+1} = BS_{\mathbb{C}}^{\mathbb{k}}$
Step 19: **else**
Step 20: $BS_{\mathbb{S}}^{\mathbb{k}+1} = BS_{\mathbb{i}}$
Step 21: $i = \arg\min_{\mathbb{i}} \mathbb{t}_{log}(BS_{\mathbb{i}}) \quad s.t. SNR^{\mathbb{L}}(\mathbb{i}, \mathbb{j}) > \mathbb{T}_{\mathbb{h}}$
Step 22: ***end if***
Step 23: ***end if***
Step 24: $\mathbb{t}_{\mathrm{log}}(\mathrm{BS}_{\mathbb{i}}) = \mathbb{t}_{\mathrm{log}}(\mathrm{BS}_{\mathbb{i}}) + 1$, for all $\mathbb{i} \epsilon [\mathbb{M}]$
Step 25: ***end for***
Step 26: **Output:** $BS_{\mathbb{S}}$ and $\mathbb{R}_{\mathbb{j}}$ for all j ϵ $[\mathbb{N}]$

4. RESULTS AND DISCUSSION

In this section, the performance analysis of the proposed HPDSH algorithm is discussed and compared against various state-of-art channel estimation algorithms in terms of spectral efficiency against the SNR ratio. A detailed investigation is carried out on performance results. Further, MM-Wave communication is adapted to provide a large bandwidth spectrum to meet the demands of high data rates in current cellular services. The main focus of this article is to design an efficient HPDSH algorithm to access the high bandwidth spectrum of mm-wave and enhance spectral efficiency of CRNs and handover spectrum to primary users from secondary unlicensed users. The performance of the proposed HPDSH algorithm provides high spectrum efficiency and lower switching delay. Another focus of this research is to keep minimum interference as well as spectrum handover process is conducted with lower computational complexity. Significant mitigation in computational complexity and enhancement in spectral efficiency is observed using the proposed HPDSH algorithm in contrast to conventional methods as demonstrated in the below results. This algorithm handles the objective function optimization problems of analog and digital pre-coder efficiently. Here, minimum switching delay and high spectral efficiency is observed using the proposed HPDSH algorithm. All the performance results are simulated using $MATLAB^{TM}$. Here, the performance of this algorithm is numerally measured and data streams are transmitted from the transmitter to the receiver antennas.

Here, Table 1 demonstrates the basic simulation parameters utilized in analyzing the performance of the proposed HPDSH algorithm considering a fully connected structure. Different scenarios are taken by using different values of these parameters. The proposed HPDSH algorithm evaluates the performance of the spectrum handover process in terms of spectral efficiency and SNR ratio. Moreover, the proposed HPDSH algorithm is compared with various traditional channel estimation and spectrum handover methods like the SIC-Based method [22] and OMP Algorithm [21] considering different scenarios and parameters as shown in Figures 1 to Figure 5. Here, all the results are computed by keeping SNR initially at 0 dB and data packet transmission frequency at 50 GHz.

Here, Figure 1 shows comparison of Spectral efficiency against SNR Ratio. Moreover, SNR ranges from -15 dB to 10 dB in this simulation. It can be evident from Figure 1 that the spectral efficiency is always higher in case of proposed HPDSH algorithm in contrast to OMP Algorithm [21] and SIC-Based method [22] under varied system parameters. Here, spectral efficiency increases in case of HPDSH algorithm with increase in SNR value whereas spectral efficiency remains comparatively lower in other two methods. Additionally, Figure 2 shows the performance of proposed HPDSH algorithm against different spectrum handoff schemes for different values of $M_{\aleph}$. It can be evident from Figure 2 that the performance of proposed HPDSH algorithm is higher in contrast to OMP Algorithm [21] and SIC-Based method [22].

Here, Figure 3 shows comparison of Spectral efficiency against Signal to Noise (SNR) Ratio with the help of Proposed HPDSH algorithm against different spectrum handoff schemes by keeping similar values for many parameters like $\mathrm{M}_{\aleph}^{\mathrm{r}} = \mathrm{M}_{\aleph}^{\mathrm{s}} = \mathrm{M}_{\aleph} = \mathrm{M}_{\mathrm{t}}$. Moreover, SNR ranges from -35 dB to 5 dB in this simulation. It can be evident from Figure 3 that the spectral efficiency is always higher in case of proposed HPDSH algorithm in contrast to OMP Algorithm [21] and SIC-Based method [22] considering varied system parameters. Here, spectral efficiency remains lower for some time and then gradually increases in case of proposed HPDSH algorithm with increase in SNR value whereas spectral efficiency remains comparatively much lower in other two methods. Additionally, Figure 4 shows the performance of proposed HPDSH algorithm against different spectrum handoff schemes for different values of $M_{\aleph}$. It can be evident from Figure 4 that the performance of HPDSH algorithm is relatively higher in contrast to OMP Algorithm [21] and SIC-Based method [22]. Figure 5 shows comparison of Spectral efficiency against Signal to Noise (SNR) Ratio with the help of Proposed HPDSH algorithm against different spectrum handoff schemes by keeping parameters as $\mathrm{M}_{\aleph}^{\mathrm{r}} = \mathrm{M}_{\aleph}^{\mathrm{s}}$. Moreover, SNR ranges from -25 dB to 15 dB in this simulation. It can be evident from Figure 5 that the spectral efficiency is much higher in case of proposed HPDSH algorithm in contrast to OMP Algorithm [21] and SIC-Based method [22]. Here, spectral efficiency remains lower for some time and then gradually increases in case of proposed HPDSH algorithm with increase in SNR value whereas spectral efficiency remains comparatively much lower in other two methods. Table 2 demonstraes performance comparison of proposed HPDSH algorithm against traditional hybrid precoding methods. From Table 2 results it is evident that proposed algorithm generates higher spectral efficieny at varied SNR values than classical methods.

Table 1. Simulation Parameters for Performance Evaluation

Simulation Parameter	Parameter Value
Number of Transmitter Antennas	144
Number of Receiver Antennas	36
Signal To Noise Ratio (SNR) (dB)	0
Number of Clusters	5
Number of Rays in each cluster	10
Channel Realization	100
Transmission Frequency	50 GHz

Table 2 Performance analyis of proposed HPDSH algorithm against classical hybrid precoding methods

SNR (dB)	OMP (bits/s/Hz)	SIC BASED(bits/s/Hz)	HPDSH(bits/s/Hz)
-15	9.5692	10.7418	12.1707
-10	14.9086	16.5558	18.2662
-5	20.8790	22.8937	24.7236
0	27.2017	29.4350	31.3071
5	33.7122	36.0457	37.9317
10	40.3078	42.6791	44.5694

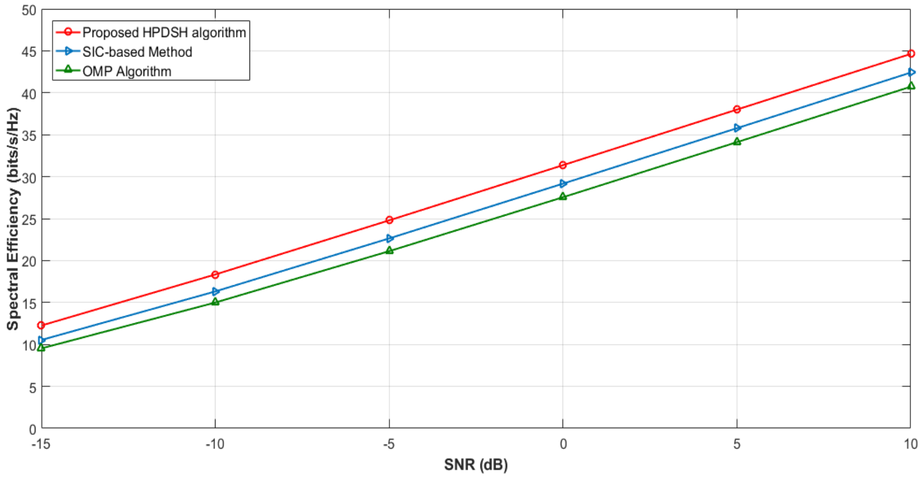

Figure 1. Spectral efficiency achieved by Proposed HPDSH algorithm against different spectrum handoff schemes

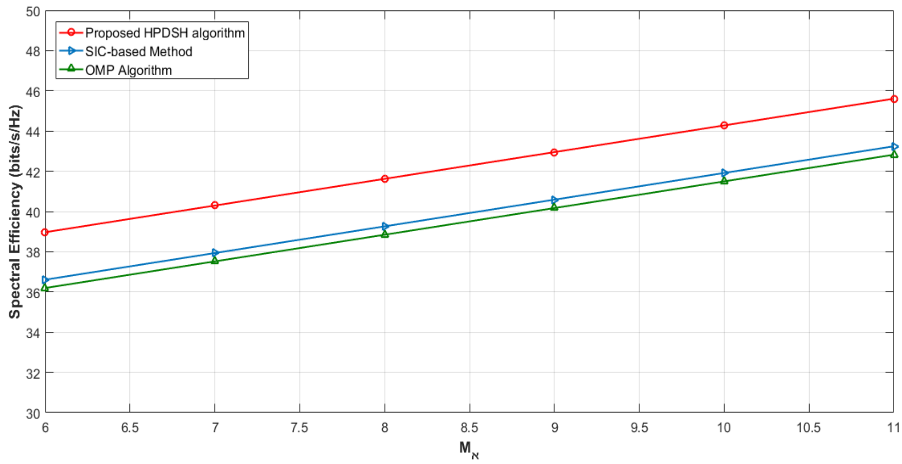

Figure 2. Spectral efficiency achieved by HPDSH algorithm against varied values of $M_{\aleph}$.

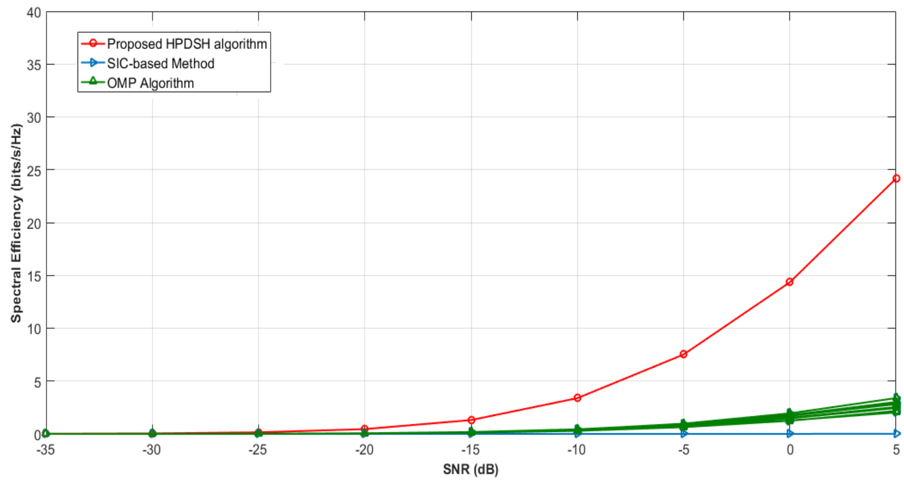

Figure 3. Spectral efficiency achieved by Proposed HPDSH algorithm against different spectrum handoff schemes considering $M_{\aleph}^{r} = M_{\aleph}^{s} = M_{\aleph} = M_{t}$

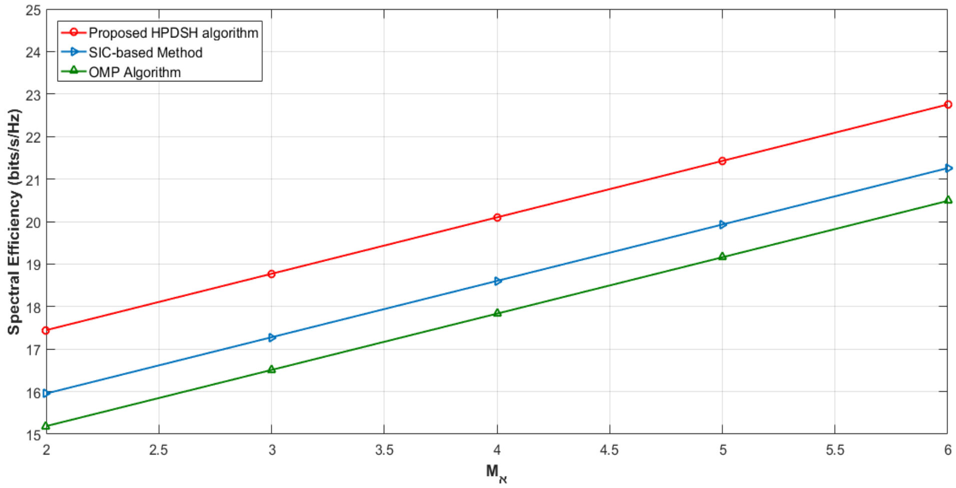

Figure 4. Spectral efficiency achieved by Proposed HPDSH algorithm against different values of $M_{\aleph}$ considering $M_{\aleph}^{r} = M_{\aleph}^{s} = M_{\aleph}\ and\ M_t = 2$

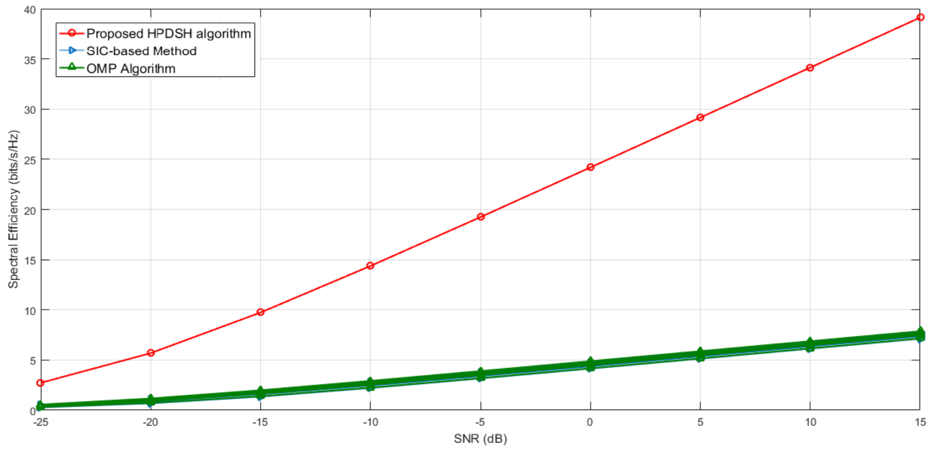

Figure 5. Spectral efficiency achieved Proposed HPDSH algorithm against different values of $M_{\aleph}$ considering $M_{\aleph}^{r} = M_{\aleph}^{s} = 64\ and\ M_t = 3$

5. CONCLUSION

The significance of channel estimation and interference reduction in a spectrum handover process is quite high. However, in traditional spectrum handoff and channel estimation methods various problems like beam selection, high computational complexity, lower spectral efficiency and objective function optimization exist. Therefore, in this article, a HPDSH algorithm is proposed to enhance spectrum efficiency in CRNs and to efficiently access large bandwidth spectrum of mm-Wave system so that demands of high data rate in current cellular services can be handled. First of all, system and channel parameters are considered to model spectrum handover. Next, the optimization and objective function minimization solutions for spectrum handover problems are discussed and handled considering HPDSH algorithm. In the last phase, handover and interference minimization process is discussed based on proposed HPDSH algorithm. This algorithm mainly depends upon three main components which are channel estimation using HPDSH Algorithm, mobility estimation and spectrum handover. From the experimental results it can be evident that the proposed HPDSH Algorithm reduces computational complexity and enhances spectral efficiency. The proposed HPDSH Algorithm is compared with various traditional spectrum handoff schemes considering different scenarios and parameters as shown in Figure 1 to Figure 5. The scenarios are spectral efficiency versus SNR values and different values of $M_{\aleph}$ respectively. This concludes that the spectral efficiency remains higher using proposed HPDSH Algorithm compare to other traditional methods.

ACKNOWLEDGMENTS

The authors would like to thank everyone, just everyone!

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