MOBILITY AND ROUTING BASED CHANNEL ESTIMATION FOR HYBRID MILLIMETER-WAVE MIMO WSNS

Geeta[1] and A.M. Bhavikatti[2]

[1]Department of Computer Science Engineering,
Bheemanna Khandre Institute of Technology, Bhalki, India
[2]Department of Electronics and Communications Engineering,
Bheemanna Khandre Institute of Technology, Bhalki, India

ABSTRACT

Recently, technological developments have enhanced, the use of Millimeter-wave (mm-Wave) Multiple Input Multiple Output (MIMO) system in various communication applications and wireless sensor networks as channel estimation efficiency can be immensely improved with the help of this technological developments in Millimeter-wave MIMO system and wireless sensor network as well. Moreover, they can improve quality of communication services to a great extent. However, cell interference in Millimeter-wave (mm-Wave) MIMO system can produce a massive impact on spectral efficiency. Therefore, a Routing Enabled Channel Estimation (RECE) technique is presented in this article to minimize interference between cells. The proposed Channel Estimation technique improves channel capacity as well as spectral efficiency. Moreover, Normalized Mean Square Error (NMSE) is minimized heavily using proposed RECE technique. Here, main aim of this article is to reduce cell interference and channel estimation inside a cell by using route selection, beam selection, and spatial frequency estimation. Here, different scenarios and parameters are considered to evaluate performance efficiency of proposed RECE technique in terms of spectral efficiency, NMSE and SNR and compared against varied traditional channel estimation techniques. Moreover, it is clearly evident from performance results that the proposed channel estimation technique performs better than the other two methods.

KEYWORDS

Millimeter-Wave MIMO Systems, Interference Reduction, Beam Selection, Channel Estimation Technique, Spectral Efficiency.

1. INTRODUCTION

Sectors such as Manufacturing, Telecom, Healthcare, Information Technology and Communication industries have immensely profited by modern and advance technological developments in their fields. Especially, fields like Wireless sensor network, Telecom and Communication industries require relentless technology advancements in order to get maximum yield. These powerful and exceptional technological advancements has made Telecom and Communication industries very influential and effective in highly competitive market as well as daily human life. However, the ever-lasting demand of spectral efficiency and the capacity in wireless sensor network and future 5G applications is getting heavily increased by each passing day [1], [2]. Although, potential candidate to handle these large demands is mm-wave-MIMO technology [3] which has the ability to handle high demands of spectral efficiency and the capacity and can be used in WSN to access high bandwidth so that data packets can be transferred with a ultra-high speed. Moreover, mm-wave communication technology is a prime

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solution to provide high spectral efficiency and capacity due to their high bandwidth availability in millimetre-wave (mm-wave) frequency for vehicle communication [4], [5] and fifth-generation (5G) Wireless Sensors Network (WSN) [6], [7].

Furthermore, multiple studies have discussed that fifth-generation (5G) cellular networks are a probable solution for high data transmission. Moreover, use of 5G spectrum in wireless sensor networks provide exceptional coverage with low and high frequencies and enhances mobility as well. 5G cellular networks have extraordinary information rates up to multiple gigabits, and provide highly reliable services. According to a recent survey, traffic load in mobile apps would increase 1000 times with the upcoming 5G network compared to the existing 4G network. To sustain high data rates and high mobility, future 5G networks would require at least a 100 MHz bandwidth, the use of numerous antennas, and ultra-densely placed Source Stations (SS), which can be a difficult and demanding task. As a result, numerous experts and academics have highlighted the use of Millimeter-wave (mm-Wave) frequency in future cellular networks as a possible option for ensuring high-frequency, high-bandwidth spectrum. Future 5G cellular communication will be more strong and effective with millimeter-wave (mm-Wave) technology [8]. High data speeds, like gigabits per second, are possible with mm-Wave communication because of the large bandwidth available at mm-Wave frequencies. The bandwidth spectrum used by mm-Wave technology is 200 times more than that used by contemporary cellular networks.

MIMO technology may be used in conjunction with mm-Wave communication to assure high data speeds, low latency, high mobility, better traffic load handling and more spectrum efficiency. However, substantial attenuation and signal absorption in mm-Wave communication is a cause for concern [9]. Although, use of numerous cell array components in mm-Wave communication can decrease attenuation and signal absorption significantly. Furthermore, channel properties of any communication system is represented as Channel State Information (CSI). The channel state information is heavily affected by the factors like power consumption, mutual signal scattering and signal fading.Furthermore, in mm-WAVE communication technology, CSI estimation is critical to achieve high data transmission under several channel conditions [10-11]. The efficacy of mm-WAVE communication technology is directly dependent on the source station's and receiver's CSI. The CSI heavily affect efficiency of mm-WAVE communication technology. Numerous researchers have contributed to the advancement of MIMO and mm-Wave communication technologies, and some of the research paradigms are discussed in the paragraph below.

In [12], a channel estimation technique with beam squint is adopted to achieve high channel capacity and mitigate NMSE for Millimeter-Wave Systems considering hybrid beamforming. Moreover, effectiveness of this channel estimation technique is compared with several channel estimation methods. In [13], a channel estimation technique is designed for mm-Wave multiuser MIMO communications to enhance channel quality and reduce channel overhead. Here, channel estimation methods are designed using deep learning methods. A transmission frame structure is also designed to evaluate angle of arrival and departure and medium gain. In [14], a machine learning based scheme is presented to examine a joint optimization problem in Millimeter-Wave Systems. Additionally, hybrid beamforming technique is presented for beam steering and beamforming optimization. And a mean field game (MFG) is utilized to optimize mm-Wave channel conditions. In [15], a Sequential Subspace scheme is adopted to generate precise CSI in hybrid beamforming based Millimeter-Wave communication. Here, Sequential Subspace scheme is utilized to resolve the overhead issues and provide accurate subspace information. However, there are a number of issues in mm-wave communication technology that need to be addressed in depth in order to improve spectrum efficiency which can be heavily affected by multiple factors like high attenuation, severe route loss, low mobility, low data packet delivery ratio, data packet propagation delay, high power consumption. This problems can arise due to the use of multiple cell components, inaccurate prediction of channel state information and spectral efficiency loss in existing methods.

Therefore, a Routing Enabled Channel Estimation (RECE) technique with hybrid beamforming is proposed in this article to reduce interference between cells so that spectral efficiency and capacity of mm-WAVE MIMO communication system in Wireless Sensor Networks (WSN) is heavily improved and future 5G cellular networks can be utilized efficiently. Moreover, CSI can be achieved effectively using proposed RECE technique. Additionaly, Routing Enabled Channel Estimation technique is used to evaluate information like beam position, beam direction etc. Further, this method is used to evaluate beams present in all the stations. Then, in the next stage, those beams are selected between multiple cells whose positional status is clearly known. Further, spatial frequencies are predicted for all the stations and this frequencies are matched with the selected beams to predict channels. Finally, beam interference and route losses are evaluated. The proposed RECE technique make their efforts for avoiding optimization problem and reducing channel overhead and enhances mobility and data packet delivery ratio finding best route for data packet transmission. The performance of proposed RECE technique is compared with conventional algorithms in terms of SNR, NMSE and spectral efficiency of the mm-Wave MIMO systems.

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

2. RELATED WORK

Several research papers have shown that the 5G cellular networks can collaborate with mm-WAVE MIMO technology. Further, in these 5G cellular networks, high bandwidth is required up to several GBPS which cannot be met using present bandwidth spectrums. Although, these high bandwidth spectrums can be easily achieved using mm-WAVE MIMO communication networks for effective implementation of 5G systems inside a WSN. However, a significant research is require to effectively utilize mm-Wave communication frequency bands. Moreover, many problems are associated with mm-Wave communication systems, especially channel interference and lower spectral efficiency which can affect high speed of 5G systems. Therefore, these challenges need to be discussed in detail. Therefore, several researchers are making efforts to formulate these issues and improve spectrum efficiency. Some of the related works are discussed below in the following paragraph.

In [16], a user tracking mechanism is adopted to identify users in multi-user scenarios for millimeter-wave networks and reduce route loss with the help of directional beamforming method. The network overhead can be reduced by tracking the user one by one. Additionaly, an iterative method is utilized to evaluate angle of arrival and departure and medium gain. In [17], a deep learning based channel estimation technique is adopted in mm-Wave MIMO systems for channel reconstruction and amplitude prediction. An offline mechanism is utilized to train the network in mm-Wave MIMO systems and correlation between data packets is identified base on the measurement matrix. In [18], a hybrid beamforming mechanism is introduced to mitigate interference in mm-Wave MIMO systems. Several channel conditions and parameters are considered to note own the effect of these parameters on mm-Wave MIMO systems. Additionaly, a data packet detection scheme is adopted to mitigate computational complexity and improve error performance. In [19], an enhanced compression sensing method is used to estimate channel capacity and sparsity in mm-Wave MIMO systems. Furthermore, threshold selection scheme is presented to constitute more relevant atoms so that data packet reconstruction can be improved. In [20], deep learning base sparse channel estimation technique is presented to estimate beam-space channel amplitude for multi-user mm-wave MIMO systems. Further, channel reconstruction efficiency can be improved using quantized phase hybrid decoder. In [21], a channel estimation technique is adopted with Lens Cell Array in mm-Wave MIMO systems based on the Quasi-Orthogonal Pilots. This technique mitigate high utilization of radio-frequency chains. Simulation results discusses about the channel errors. In [22], a channel estimation technique is presented in angular domain with a single bit analog-to-digital converters (ADCs) and digital-to-analog converters (DACs) in mm-Wave MIMO systems. Then, channel estimation for uplink and downlink medium can be handled using pre-coding techniques. In [23], a Gradual Channel Estimation method is adopted to enhance reliability and mitigate error efficiency considering NAND flash memory. This method improves predicted time using data sensing operations. High accuracy and lower time complexity is achieved using this method.

However, there are few challenges which can be encountered and their practical implementation becomes difficult. Therefore, a RECE technique with hybrid beamforming is proposed in this article to reduce interference between cells so that spectral efficiency, network throughput and capacity of mm-WAVE MIMO communication system can be enhanced. The propose RECE technique and reduce channel overhead an interference. A detailed mathematical modelling of the proposed RECE technique is presented in the following section.

3. MODELLING FOR PROPOSED ROUTING ENABLED CHANNEL ESTIMATION TECHNIQUE

In this section, a comprehensive mathematical modelling for proposed (RECE) technique is discussed to reduce interference between cells to improve network throughput and mobility. The proposed RECE method works in coordination with mm-Wave MIMO communication system to enhance spectral efficiency and network capacity. The proposed RECE method mitigates computational complexity by using few training samples. Moreover, the proposed RECE technique mitigates cell interference and phase disturbances. Furthermore, this method ensure data packet reconstruction, compression and resource reduction.

Assume that there are M number of cells in mm-WAVE MIMO communication system. In every cell, a Source Station (SS) is present which can handle N number of mobile stations. Further, SS consists of a rectangular array which is uniformly distributed. This uniform rectangular array can efficiently handle mobile stations present ahead of array. Every mobile station consists of an antenna and all the M number of cells must be enclosed by source station. The proposed RECE technique works in Time Duplex Division (TDD) and it can be assumed that both uplink and downlink mediums remain opposite to each other. Consider that, channel remains constant in one of the coherent interval. Thus, data packet transmission process is sub-divided into three parts in which first part is uplink channel prediction, second part represents transmission of uplink data and third part represents transmission of downlink data. Further, SS receives several data symbols from different mobile stations. Then, received data packet matrix at $k-th$ SS can be given by following equation,

$$Z_k^q = \sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{t=0}^{T}\left(\sqrt{A}\right)^{-1}.\,\beta_{k,m_n,t,}.\,C\left(\phi_{k,m_n,t},\theta_{k,m_n,t}\right)T_{m,n}^q + A_k^q \in \mathbb{E}^{A\times A_q} \qquad (1)$$

And,

$$Z_k^{hv} = \sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{t=0}^{T}\left(\sqrt{A}\right)^{-1}.\beta_{k,m_n,t}.C\left(\phi_{k,m_n,t},\theta_{k,m_n,t}\right)T_{m,n}^{hv} + A_k^{hv} \in \mathbb{E}^{A\times A_{hv}} \qquad (2)$$

Where, total number of antennas present at the SS are denoted by A and route loss of uplink medium is represented byβ_k, m_n, t. Furthermore, the route for the loss is estimated from the $n-th$ Mobile Station (MS) of $m-th$ cell to the SS in the $k-th$ cell. Here, array is represented by $\left(\phi_{k,m_n,t},\theta_{k,m_n,t}\right) \in \mathbb{E}^{A\times 1}$. Moreover, both angles $\phi_{k,m_n,t}$ and $\theta_{k,m_n,t}$ represents angle of arrival. The communicated vector symbols present in the $n-th$ MS of the $m-th$ cell are represented by$T_{m,n}^{q} \in \mathbb{E}^{1\times A_q}$. Then,

$$T_{m',n'}^{q}\left(T_{m,n}^{q}\right)^{I} = \rho_{m,n}\rho_{m',n'}A_q\gamma(n-n') \qquad (3)$$

Where, for the $n-th$ MS of $k-th$ cell, the power coefficients are denoted as$\rho_{m,n}$. Then, data symbols which are communicated from the $n-th$ MS of $m-th$ cell is represented by $T_{m,n}^{hv} = \rho_{m,n}\tilde{T}_{m,n}^{hv}$ and where $T_{m,n}^{hv}$ is identically represented and distributed with variance = 1 and mean = 0 by$T_{m,n}^{hv} \in \mathbb{E}^{1\times A_{hv}}$. Further, the noise matrices are represented by $A_k^{q} \in \mathbb{E}^{A\times A_q}$ and $A_k^{hv} \in \mathbb{E}^{A\times A_{hv}}$. In the same way, data symbols which are received by the $n-th$ MS of $k-th$ cell is represented by,

$$z_{k,n}^{hh} = \sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{s=0}^{S}\left(\sqrt{A}\right)^{-1}.\beta_{m,k_n,t}^{*}.C^{I}\left(\phi_{m,k_n,t},\theta_{m,k_n,t}\right)T_m^{hh}.D_m^{hh} + a_{k,n}^{hh} \in \mathbb{E}^{1\times A_{hh}} \qquad (4)$$

Where, data symbols which are communicated from the $m-th$ Source Station (MS) of $m-th$ cell to the MS in the $m-th$ cell is represented by $T_m^{hh} \in \mathbb{E}^{N\times A_{hh}}$ and expressed by$T_m^{hh} = F_m\tilde{T}_m^{hh}$. Here, diagonal matrix is represented by $F_m \in \mathbb{P}^{N\times N}$ and $\tilde{T}_m^{hh}$ contains variables with variance = 1 and mean = 0. Then, from equation (1) and (2), it is clearly evident that the medium between $n-th$ mobile stations of$m-th$ cell to the source station in the $k-th$ cell is defined by following equation,

$$i_{k,m_n} \triangleq \sum_{t=0}^{T}\left(\sqrt{A}\right)^{-1}.\beta_{k,m_n,t}.C\left(\phi_{k,m_n,t},\theta_{k,m_n,t}\right) \in \mathbb{E}^{A\times 1} \qquad (5)$$

Where, t represents data packet transmission route and $t = 0,1,2\ldots.T$ represents multiple number of routes. Then, route loss is defined by following equation,

$$\beta_{k,m_n,t} = \aleph_{k,m_n,t}.H\left(\phi_{k,m_n,t},\theta_{k,m_n,t}\right)\vartheta^{2}.e^{g\omega_{k,m_n,t}}.\left(16\pi^{2}h_{k,m_n,t}^{2}\right)^{-1} \qquad (6)$$

Here, $H\left(\phi_{k,m_n,t},\theta_{k,m_n,t}\right)$ is the array and wavelength is denoted by ϑ and length of the route is given by $h_{k,m_n,t}$ and phase is given by$\omega_{k,m_n,t}$. Here, $\aleph_{k,m_n,t}$ is a constant coefficient for route loss. Then, the best route can be selected to predict the beam-space channel given by following equation,

$$\beta_{k,k_n,\tilde{t}_{k,k_n}}.\left[\sqrt{A}\tilde{V}_k^{I}y\left(cos\theta_{k,k_n,\tilde{t}_{k,k_n}}.\sin\phi_{k,k_n,\tilde{t}_{k,k_n}},sin\,\theta_{k,k_n,\tilde{t}_{k,k_n}}\right)\right]^{-1} \qquad (7)$$
$$\forall\, k = 1,2,\ldots\ldots,M,\forall\, n = 1,2,\ldots\ldots,K$$

Where, the strongest route considered between the $n-th$ MS of $m-th$ cell to the $k-th$ SS is represented by$\tilde{t}_{k,m_n} = \arg\max_t\{|\beta_{k,m_n,t}|, t = 0,1,\dots\dots,T\}$.

Besides, the state-of-art-channel estimation techniques suffers high interference while using mm-wave MIMO systems with multiple cells in a WSN. Thus, it is required to propose a highly efficient channel estimation technique with beam-space approach to reduce interference in mm-wave MIMO systems. Generally, interference is reduced at receiver side in mm-wave MIMO systems with multiple cells. However, in this article, in-cell channel estimation and interference estimation between cells is evaluated together. So that, maximum amount of interference can be reduced. And the rate at which data packets transmit is called as mobility which is very high in this WSN as data packets get transmitted at very high speed due to large bandwidth. Therefore, proposed RECE technique provides best routing mechanism and high mobility. Furthermore, the proposed RECE technique is sub-divided into two stages.

3.1. Selection of Beam for the Enhancement of Routing Enabled Channel Estimation Efficiency

Here, first stage focuses on the selection of beam for the MS present inside a particular cell and remaining other cells in a multi-cell mm-wave MIMO system. The configuration and design remain similar for all the MS in these multi-cell environment. Then, a beam for N and M MS is considered for each cell. Then, the received data packet matrix Z_k^qin equation (1) can be further processed as,

$$E_n = (A_q)^{-1} V^I Z_k^q (t_{k,n}^q)^I = \sum_{m=1}^{M}\sum_{t=0}^{T} (\sqrt{A})^{-1} . \beta_{k,m_n,t} \cdot \rho_{m,n}\rho_{k,n} V^I y$$
$$. (cos\theta_{k,m_n,t} . sin\,\phi_{k,m_n,t}, sin\,\theta_{k,m_n,t}) + (A_q)^{-1} V^I A_k^q (t_{k,n}^q)^I \tag{8}$$

$$E_n = \sum_{m=1}^{M} (\sqrt{A})^{-1} \beta_{k,m_n,\tilde{t}_{k,m_n}} \cdot \rho_{m,n}\rho_{k,n} V^I y$$
$$. \left(cos\theta_{k,m_n,\tilde{t}_{k,m_n}} . sin\,\phi_{k,m_n,\tilde{t}_{k,m_n}}, sin\,\theta_{k,m_n,\tilde{t}_{k,m_n}}\right) + (A_q)^{-1} V^I A_k^q (t_{k,n}^q)^I \in \mathbb{E}^{A\times 1} \tag{9}$$

Where, equation (9) is derived based on the assumption that the considered best route for a multi-cell mm-wave MIMO system as shown in equation (7) is the strongest route possible in all the available data packet transmission route from a mobile station to a source station, evaluated using the proposed RECE technique.

Here, a two-dimensional plane $(X_j - X_z)$ is considered where $X = 1,2,3,\dots\dots\dots,A$ and X value is putted into an expression $|[E_n]_X|$ to get M largest non-adjacent elements and an expression $X = (X_z - 1)A_j + X_j$ is used to get M beams of corresponding M largest non-adjacent elements. Furthermore, for M MS, this M beams are selected. However, in the multi-cell mm-wave MIMO system, all the M Mobile Stations (MS), comes very close to each other in a X_j plane. Due to which, all the M largest non-adjacent elements present in the two-dimensional plane $(X_j - X_z)$ which are evaluated using the expression, $|[E_n]_X|, X = 1,2,3,\dots\dots\dots,A$ comes in a close contact with each other. Thus, there will not be a clarity in selection of these M elements. This problem can be handled by placing all the MMSs at different places and a specific distance is maintained between each other inside M cells in the mm-wave MIMO system. This can be achieved using an advanced allocation strategy in which spatial frequency data of MMS are utilized to get the distance from $n-th$ MS placed inside $k-th$ cell to the remaining $M-1$MSs placed inside $M-1$ cells. Each cell consists of a MS in a two-dimensional plane$(X_j - X_z)$. Here, both spatial frequencies and positions are remain co-related to each other in a linear basis. Moreover, spatial frequencies are denoted by d_l, r_l whereas positions are denoted byl_j, l_z. Therefore, spatial frequency for a particular MS is expressed by f_1, p_1 and for another MS is expressed by f_2, p_2 and the positions for both the MSs are given by $\left(\frac{1}{2}(f_1+1)A_j, \frac{1}{2}(p_1+1)A_z\right)$ and $\left(\frac{1}{2}(f_2+1)A_j, \frac{1}{2}(p_2+1)A_z\right)$ respectively. Then, the distance from one mobile station to the other mobile station is given by,

$$\frac{1}{2}\left[(f_1-f_2)^2.A_j^2 + (p_1-p_2)^2.A_z^2\right]^{1/2} \tag{10}$$

Here, total number of N^{M-1} cases are possible for finding out distances between mobile stations. However, only the distances which are quite higher than the threshold distances are selected so that efficient beam selection can be achieved and ambiguity problem can be avoided. Then, for a particular mobile station, correlation with spatial frequency f_1, p_1 in a beam is evaluated by following equation,

$$A^{-1}|y^I(f_1, p_1)y(d_{l'}, r_{l'})| = A^{-1}\sum_{X_j=1}^{A_j} e^{i\pi X_j(d_{l'}-f_1)} \sum_{X_z=1}^{A_z} e^{i\pi X_z(r_{l'}-p_1)} \tag{11}$$

Equation (11) is further processed as,

$$\begin{aligned} A^{-1}|y^I(f_1, p_1)y(d_{l'}, r_{l'})| &= A^{-1}\left|\sin\left(\frac{1}{2}\pi(d_{l'}-f_1)A_j\right).\sin\left(\frac{1}{2}\pi(d_{l'}-f_1)\right)^{-1}\right|.\left|\sin\left(\frac{1}{2}\pi(r_{l'}\right.\right. \\ &\left.\left.-p_1)A_z\right).\sin\left(\frac{1}{2}\pi(r_{l'}-p_1)\right)^{-1}\right| \end{aligned} \tag{12}$$

Where, $(d_{l'}-f_1)$ lies in the range of $12\left(A_j\right)^{-1} < |(d_{l'}-f_1)| < 1$. Thus, correlation can be determined easily as a function of f_1 or p_1. Then,

$$\begin{aligned} A^{-1}|y^I(f_1, p_1)y(d_{l'}, r_{l'})| & \\ < \max_{12(A_j)^{-1}<|(d_{l'}-f_1)|<14(A_j)^{-1}} & A^{-1}\left|sin\left(\frac{1}{2}\pi(d_{l'}\right.\right. \\ \left.\left.-f_1)A_j\right).sin\left(\frac{1}{2}\pi(d_{l'}-f_1)\right)^{-1}\right| & .\left|sin\left(\frac{1}{2}\pi(r_{l'}\right.\right. \\ \left.\left.-p_1)A_z\right).sin\left(\frac{1}{2}\pi(r_{l'}-p_1)\right)^{-1}\right| & \end{aligned} \tag{13}$$

Here, equation (13) is further processed for $|(d_{l'}-f_1)| = 0$ and $A_j \rightarrow \infty$ as,

$$A^{-1}|y^{I}(f_1,p_1)y(d_{l'},r_{l'})| = A^{-1}.(13\pi)^{-1}.2A_j \left| sin\left(\frac{1}{2}\pi(r_{l'} - p_1)A_z\right).sin\left(\frac{1}{2}\pi(r_{l'} - p_1)\right)^{-1} \right| \tag{14}$$

$$A^{-1}|y^{I}(f_1,p_1)y(d_{l'},r_{l'})| = A_j.A^{-1} \left| sin\left(\frac{1}{2}\pi(r_{l'} - p_1)A_z\right).sin\left(\frac{1}{2}\pi(r_{l'} - p_1)\right)^{-1} \right| \tag{15}$$

It is clearly evident from the equation (15) that the value of correlation function remains lower than 1 and which lies in the range of$6\left(A_j\right)^{-1} < |(d_{l'} - f_1)| < 1$. This shows the effect of correlation function are minimum on the distances measured higher than threshold and can be avoided. Thus, the ambiguity problem have zero impact on beam selection process. Finally, evaluate all the cases for distances between two MSs and select the case with largest distance. Then, select adjacent $(A_{MS} - 1)$beams which have the largest value from the expression $|[E_n]_X|$ for every M considered beam. Therefore, total A_{MS} beams are obtained for $n - th$ Mobile Station in the $k - th$ cell. Similarly, $A_{MS}M$ beams are obtained for M Mobile Stations in the M cell. This whole process is computed by considering $n = 1,2,3, \dots \dots .N$. Furthermore, once beam selection process is completed, beamforming matrix can be obtained in the SS of $k - th$ cell considering all M and N MSs and given by following equation,

$$\bar{V}_k^I \bar{V}_k = G_{A_{cell}M}, \ \forall k = 1,2, \dots \dots \dots M \tag{16}$$

Where, $\bar{V}_k$ is expressed as $\bar{V}_k \in \mathbb{E}^{A \times A_{cell}M}$ and beamforming matrix in the SS of $k - th$ cell are formed using the beams for NMSs in the $k - th$ cell. Then, repeat the following steps for each MS in a particular cell to get beamforming matrix in the SS,

1. Process the received data packet matrix Z_k^q as demonstrated in equation (8).
2. Consider two-dimensional plane $\left(X_j - X_z\right)$ and put $X = 1,2,3, \dots \dots \dots, A$ in the expression $|[E_n]_X|$ get M largest non-adjacent elements.
3. After evaluation of non-adjacent elements from the expression$|[E_n]_X|, where\ X = 1,2,3, \dots \dots \dots, A$, select the desired M largest non-adjacent elements in a two-dimensional plane$\left(X_j - X_z\right)$.
4. Determine their corresponding M beams for the M MSs.
5. Select the case with largest distance between two MSs.
6. Select the beam which is positioned nearest to the $k - th$ Source Station similar to the beam positioned for $n - th$ Mobile Station in the $k - th$ cell.
7. Select those adjacent beams $(A_{MS} - 1)$ which have the largest value for the expression $|[E_n]_X|$with respect to M beam.

Construct beamforming matrix in the SS with the help of $n - th$ Mobile Station in the $k - th$ cell.

3.2. Estimation of Spatial Frequencies to Reduce Cell Interference

In this second phase, spatial frequencies are estimated for cell interference reduction which are important factor for the purpose of routing enabled channel estimation efficiency enhancement.

The dimension of received data packets can be reduced using the beam selection process carried out in first stage. Thus, spatial frequency estimation can be achieved using low-dimensional received data packets and beam selection process. The obtained frequencies are estimated with high accuracy and low computational complexity. Then, the received data packet matrix obtained in equation (2) can be rewritten as,

$$\begin{aligned} Z_k^{hv} &= \sum_{m=1}^{M}\sum_{n=1}^{N}\left(\sqrt{A}\right)^{-1}.\beta_{k,m_n,\tilde{t}_{k,m_n}}.C\left(\phi_{k,m_n,\tilde{t}_{k,m_n}},\theta_{k,m_n,\tilde{t}_{k,m_n}}\right)T_{m,n}^{hv} \\ &= \left(\sqrt{A}\right)^{-1}H_kTS_k + A_k^{hv} \end{aligned} \tag{17}$$

Where, H_k is a diagonal matrix and expressed by $H_k \in \mathbb{E}^{NM\times NM}$ whereas T is expressed as $T \in \mathbb{E}^{NM\times A_{hv}}$. Then, the respective rows are expressed as $T_{m,n}^{hv}$ in which $m = 1,2,3\ldots\ldots\ldots\ldots,M$ and $n = 1,2,\ldots\ldots\ldots,N$. Then, the received data packet matrix Z_k^{hv} is beam-formed with $\bar{V}_k$ so that received data packet Z_k^{hv} is processed as,

$$\bar{Z}_k^{hv} = Z_k^{hv}\bar{V}_k^I \approx \left(\sqrt{A}\right)^{-1}\bar{V}_k^IH_kTS_k + \bar{V}_k^IA_k^{hv} \in \mathbb{E}^{A_{hv}\times A_{cell}M} \tag{18}$$

Then, covariance matrix is determined for every column of received data packet $\bar{Z}_k^{hv}$ is,

$$\begin{aligned} P_k = (A_{hv})^{-1}\varphi\left\{\bar{Z}_k^{hv}\left(\bar{Z}_k^{hv}\right)^I\right\} \approx A^{-1}\rho_t^2\bar{V}_k^IH_kS_k\partial_kH_k^IS_k^I\bar{V}_k + G_{A_{cell}M} \\ \in \mathbb{E}^{A_{cell}M\times A_{cell}M} \end{aligned} \tag{19}$$

Where, $\partial_k$is a diagonal matrix and expressed by$\partial_k \in \mathbb{E}^{N\times N}$. Here, three partial rows from different parameters $Z_k^{hv}, S_k\ and\ A_k^q$are selected to obtain three new matrices $J_k^{(1)}, J_k^{(2)} and\, J_k^{(3)}$as respectively. Then, the combination of these three new matrices $J_k^{(1)}, J_k^{(2)} and\, J_k^{(3)}$can be determined as,

$$J_k^{(m)} \approx \left(\sqrt{A}\right)^{-1}Y_k^{(m)}H_kT + L_k^{(m)}, m = 1,2,3. \tag{20}$$

Then, $J_k^{(m)}$ is further processed into following equation,

$$\bar{J}_k^{(m)} = \xi_k^IJ_k^{(m)} \approx \left(\sqrt{A}\right)^{-1}\xi_k^IY_k^{(l)}H_kT + \xi_k^IL_k^{(l)} \in \mathbb{E}^{A_{cell}M\times A_{hv}}, l = 1,2,3. \tag{21}$$

Finally, covariance matrix for the column of $\bar{J}_k^{(m)}$ against the column of $J_k^{(1)}$ is expressed by following equation,

$$\begin{aligned} P_k^{(l)} = (A_{hv})^{-1}\varphi\left\{\bar{J}_k^{(l)}\left(\bar{J}_k^{(1)}\right)^I\right\} \approx A^{-1}\xi_k^IY_k^{(l)}H_k\partial_kH_k^I\left(Y_k^{(1)}\right)^I\xi_k + \xi_k^I\xi_k \\ \in \mathbb{E}^{A_{cell}M\times A_{cell}M}, \forall l = 1,2,3. \end{aligned} \tag{22}$$

Here, two facts are evident from equation (22) that the spatial frequencies obtained considering a MS of a particular cell in the proposed RECE process remains similar considering MSs positioned in the other cells. This shows that the channel estimation efficiency in cells and cell interference are evaluated together. Therefore, the impact of cell interference on the channel estimation efficiency remains minimum. Another conclusion is that the proposed RECE technique reduces dimensionality of covariance matrix $P_k^{(l)}$ with high precision and lower computational complexity. And this concludes that the channel vectors are estimated with lower path loss, higher efficiency and with higher mobility using proposed channel estimation process.

4. RESULT AND DISCUSSION

In this section, performance analysis of proposed routing enabled channel estimation technique is discussed and compared against various state-of-art channel estimation methods in terms of spectral efficiency, Signal to Noise (SNR) and NMSE. Here, the hybrid mm-Wave massive MIMO system with multiple cell is adopted to improve wireless sensor network capacity and spectral efficiency. A detailed investigation is carried out on performance results. Here, main aim of this article is to reduce cell interference and channel estimation inside a cell due to which efficiency of the mm-Wave massive MIMO system and network throughput can be heavily improved. The proposed RECE technique enhances efficiency by selecting strongest data packet transmission route and selecting beam for a Mobile Station inside a cell. Then, spatial frequencies are selected to reduce channel interference in a cell. The proposed RECE technique utilizes minimum training samples and improves capacity by reducing antenna disturbances and antenna coupling errors. The existing channel estimation techniques have varied problems like cell interference and optimization problem. However, proposed RECE technique handles these mentioned problems efficiently. All the performance results are simulated using$MATLAB^{TM}$. A significant mitigation in computational complexity is observed using the proposed RECE technique in contrast to conventional methods as demonstrated in below results.

Here, Table 1 demonstrates the basic simulation parameters utilized in analysing performance of proposed RECE technique for a multi-cell mm-Wave massive MIMO system in a WSN. Many scenarios are taken by using different values of this parameters. The proposed RECE technique evaluates performance of the mm-Wave massive MIMO system in terms of spectral efficiency, SNR ratio and NMSE. Moreover, the proposed RECE technique is compared with various traditional channel estimation methods like Beam-space based method [24] and Pilot based Method [25] considering different scenarios and parameters as shown in in Figure 1 to Figure 6. 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 versus the number of MSs in each cell. Moreover, the number of MSs changes from 10 to 50 in this simulation. It can be evident from Figure 1 that the spectral efficiency is much higher in case of proposed RECE technique in contrast to Beam-space based method [24] and Pilot based Method [25]. Here, spectral efficiency increases in case of proposed RECE technique with increase in number of MSs whereas spectral efficiency remains lower in other two methods. Additionally, Figure 2 shows comparison of NMSE versus the number of MSs in each cell. It can be evident from Figure 2 that the NMSE is much lower in case of proposed RECE technique in contrast to Beam-space based method [24] and Pilot based Method [25]. Besides, NMSE results of all three methods enhances with increase in the number of MSs in each cell as demonstrated in Figure 2.

Table 1. Simulation Parameters for Performance Evaluation

Simulation Parameter	**Parameter Value**
Number of MSs Present in Every Cell (N)	10
Number of Cells (M)	3
Signal To Noise Ratio (SNR) (dB)	0
Number of Selected beams for Every MS (A_{MS})	2
Number of Horizontal Antennas $\left(A_j\right)$	32
Number of Vertical Antennas (A_z)	151
Height of Source Station (SS)	10 m
Transmission Frequency	50 GHz
Channel Coherence Interval	300 slots
Minimum Distance from MS to SS	5 m
Maximum Distance from MS to SS	50 m

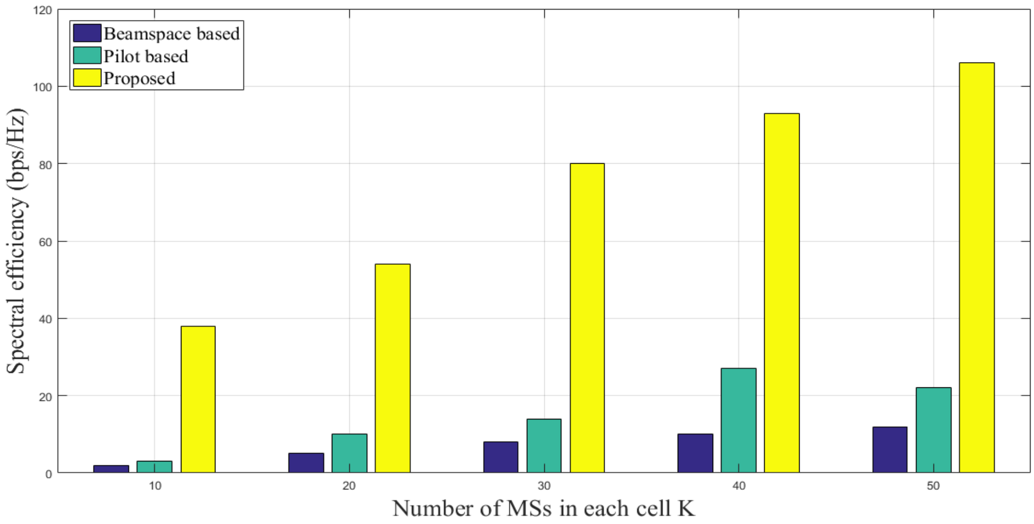

Figure 1. Comparison of Spectral efficiency versus the number of MSs in each cell.

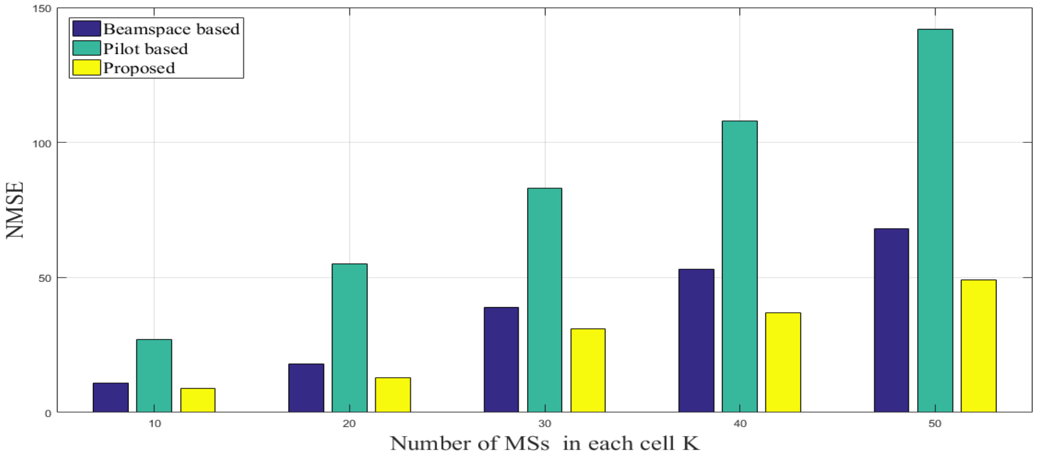

Figure 2. Comparison of NMSE vs versus the number of MSs in each cell.

Here, Figure 3 shows comparison of Spectral efficiency versus the transmission SNR (dB). Moreover, SNR changes from -40 dB to 40 dB in this simulation. It can be evident from Figure 3 that the spectral efficiency is much higher in case of proposed RECE technique in contrast to Beam-space based method [24] and Pilot based Method [25]. Here, spectral efficiency increases in case of proposed RECE technique with increase in the transmission SNR (dB). Additionally, Figure 4 shows comparison of NMSE versus the transmission SNR (dB). It can be evident from Figure 4 that the NMSE is much lower in case of proposed RECE technique in contrast to Beam-space based method [24] and Pilot based Method [25]. Moreover, it can be concluded that the proposed approach has reduced more cell interference in the channel estimation than the other two methods.

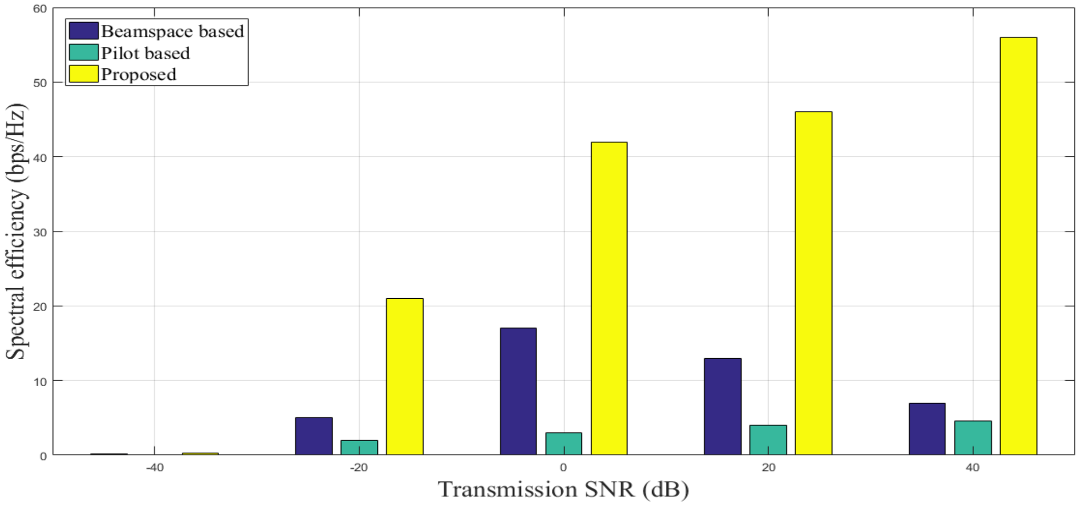

Figure 3. Comparison of Spectral efficiency versus the transmission SNR.

Here, Table 2 shows simulation results considering NMSE against transmission SNR (dB) using proposed model in comparison with Beam-space based Method and Pilot based method. Table 2 represents numerical data of obtained NMSE results for varied values of SNR in dB and Figure 4 is the graphical comparison of Table 2.

Table 2. Simulation results for NMSE against transmission SNR (dB)

SNR(dB)	Beam-space based Method(10^4)	Pilot based Method (10^4)	Proposed Model (10^4)
-40	0.2	9.2	0.1
-20	0.1	0.3	0.05
0	0.1	0.1	0.05
20	0.1	0.1	0.05
40	0.1	0.1	0.05

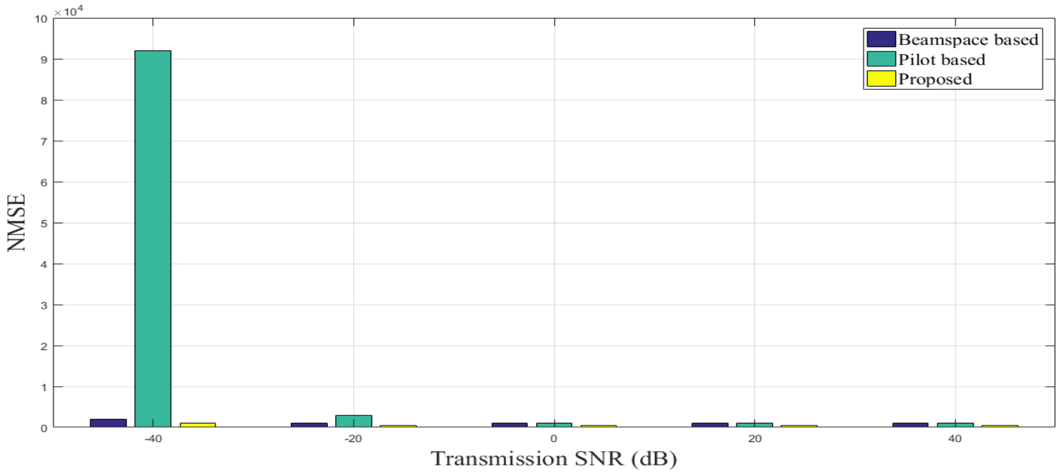

Figure 4. Comparison of NMSE versus the transmission SNR.

Here, Figure 5 shows comparison of Spectral efficiency versus the channel coherence interval. In this simulation, the channel coherence interval changes from 50 to 250. It can be evident from Figure 5 that the spectral efficiency is higher in case of proposed RECE technique in contrast to Beam-space based method [24] and Pilot based Method [25]. Additionally, Figure 6 shows relationship between NMSE and the channel coherence interval. It can be evident from Figure 6 that the NMSE is higher in both Beam-space based method [24] and Pilot based Method [25] than proposed RECE technique. Moreover, it can be concluded that the proposed RECE technique performs better than the other two methods.

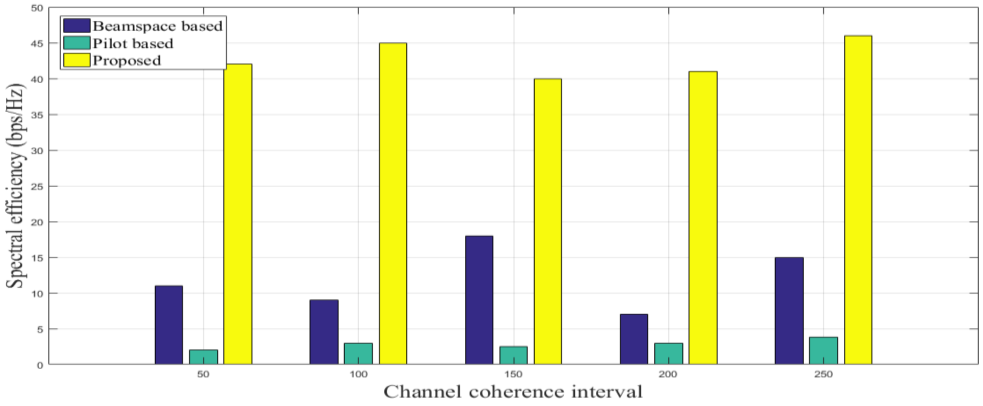

Figure 5. Spectral efficiency versus the channel coherence interval

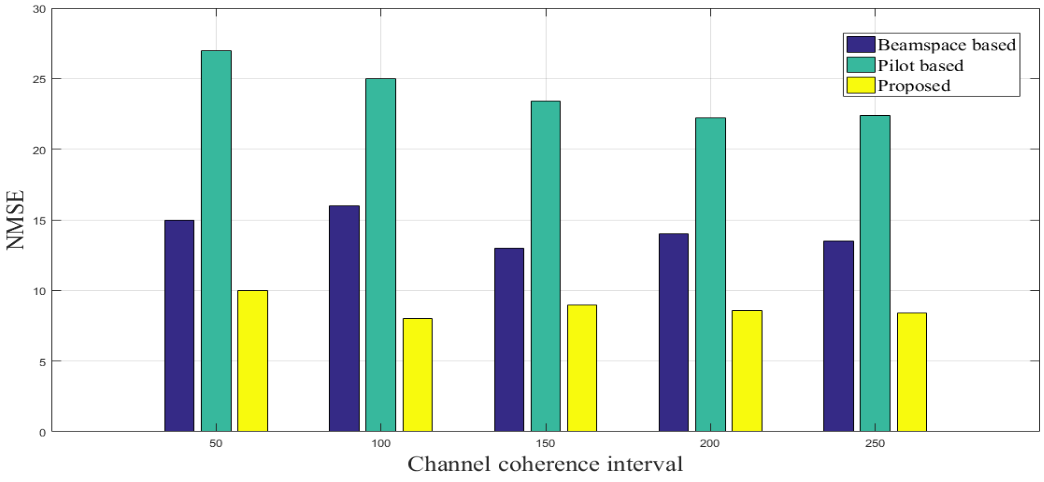

Figure 6. NMSE versus the channel coherence interval

5. CONCLUSIONS

The significance of channel estimation and cell interference reduction in a multi-cell mm-Wave massive MIMO system is quite high. Moreover, in traditional channel estimation methods, transmission route selection, beam selection and cell interference problems exist. Therefore, in this article, a Routing Enabled Channel Estimation technique with hybrid beamforming is proposed to reduce interference between cells so that spectral efficiency and capacity of mm-WAVE MIMO communication system in a WSN get enhanced. First of all, an in-cell channel estimation and interference estimation between cells is evaluated together by finding out the strongest route possible in all the available data packet transmission routes from a mobile station to a source station. Then, beams are selected for a particular Mobile Station in a cell so that beamforming matrix is constructed in the source station. Finally, spatial frequency estimation can be achieved using low-dimensional received data packets and the impact of cell interference on the channel estimation efficiency remains minimum. From the experimental results it can be evident that the proposed RECE technique reduces dimensionality and lower computational complexity. The proposed RECE technique is compared with various traditional channel estimation methods considering different scenarios and parameters as shown in in Figure 1 to Figure 6. The scenarios are spectral efficiency and NMSE versus number of MSs, transmission SNR and channel coherence interval respectively. This concludes that the channel vectors are estimated with lower route loss and spectral efficiency remains higher using proposed RECE process with minimum cell interference.

CONFLICTS OF INTEREST

The authors whose names are listed above certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies and stock ownership), or non-financial interest in the subject matter or materials discussed in this manuscript.

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AUTHORS

Geeta currently work in as Assistant Professor at Bheemanna Kandre Institute of Technology, Bhalki. Perusing Ph.D from Visveswaraiah Technological University, Belgaum Karnataka. Research work at wireless sensor networks. Interest of area wireless communication, digital processing etc

Dr. A. M. Bhavikatt has a teaching experience of 36 yrs at BKIT, Bhalki .He is having 77 publications in various journals and conferences with 94 Citations to his credit. So far, he has produced 3 PhDs under VTU, Belagavi and three research scholars are actively pursuing PhD. He has worked as External examiner for PhD for other universities also. He has worked as member of BOS, BOE of ECE board for Gulbarga University, Gulbarga and VTU, Belgavi. Attended many workshops and conferences in various institutions. He has also worked as Chair/Co-chair of many conferences at his institute and other institutions. He has delivered talks at various workshops/FDPs. He is a fellow of IETE and life member of ISTE.