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Research Article

Capacity Optimization of MISO System in Intercell Interference of Visible Light Communication System

Agha Yasir Ali,[1] **Abdeldime M. S. Abdelgader**,[2] **Lubna Farhi**,[1] **Umm E. Laila**,[1] **and Shujun Wang**[3]

[1]*Sir Syed University of Engineering and Technology Karachi, Pakistan*
[2]*Karary University, 12304, Sudan*
[3]*West Anhui University, Nanjing, China*

Correspondence should be addressed to Abdeldime M. S. Abdelgader; abdeldime@karary.edu.sd

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The capacity of multiple input and single out (MISO) system is investigated in intercell interference environment of a visible light communication (VLC) system. The interference is dominating in cell edges and the center of the room due to overlapping of light signals from neighbor cell. The footprint of one cell extends at high SNR, and consequently, this increases the intercell interference regions. Therefore, the channel capacity is greatly deteriorated due to interference power. In this paper, the channel capacity can be improved using diversity gain of MISO-based VLC system. The light-emitting diode (LEDs) of MISO system in a cell can use the same data to improve the diversity gain of the system. The MISO array is derived as per SNR requirements in interference region of the room. The capacity of the MISO system is examined and compared with that of the single input and single output (SISO). A trade-off of the MISO array is obtained at different SNRs to achieve the interference free capacity system. Theoretical and simulation capacity response show that the interference is considerably minimized by using diversity gain of MISO system. The interference free capacity is achieved at 44 dB, 49.5 dB, and 51.7 dB SNR using 4X1, 9X1 and 16X MISO system, respectively.

1. Introduction

The VLC MIMO system emerge as the promising technology used to support high performance in communication systems [1]. MISO-VLC system is generalized into two types, i.e., the imaging and nonimaging MISO system. The most usage in MISO equipment system is imaging in which the channel matrix is guaranteed to be with full-rank, and the multiplexing gain is extremely high [2]. There are lot of challenges in VLC system. The cell interference is one of the important issues need to be investigated and solved. The cell interference is initiated when the different neighbor cells attempt to use the identical resource at the same time. The cell interference deteriorates the system performance especially channel capacity, bit error rate, and data rate. The MISO system can increase the channel capacity without consuming extra bandwidth and SNR. The high-order MISO is commonly applied in VLC system and for further exploiting of the multipath channel capacity [3–5]. However, increasing the number of light-emitting diode (LED) and other hardware of the transmitter in a limited space is also a challenge. Therefore, it is important to find an optimized topology for the high-order MISO array system in mobile receivers which can maximize the system performance of MISO-VLC.

Several interference mitigation methods have been studied in the literature under various conditions and network infrastructures. The distribution of multicolor, time division, frequency reuse, and cell coordination is commonly used to eliminate the interference. The utilization of bandwidth, power, and blanking resources are utilized to overcome the cell interference effects. In [6], the dynamic and static allocation of frequency resources, time slots, and the power distribution is controlled at the receiver to ensure that the cell

interference remains within acceptable limits. The signal-to-noise ratio (SNR), signal-to-interference-noise ratio (SINR), and optical channel constraints relation is investigated in [7] to provide fair comparison across optical wireless communication. A phase predistorted joint detection technique is investigated in [8] to improve the system performance of uplink nonorthogonal multiple access (NOMA). This scheme outperforms the previously proposed successive interference cancellation-based NOMA with or without predistortion. The fix power allocation to successive interference cancellation algorithms is examined. These schemes increase the complexity at transmitter side. The proposed scheme in [9] is comprised of a two-level algorithm—one at the base station level, and the other at a central controller to which a group of neighboring base stations are connected. The frequency share and reuse combined method is investigated in [10], in which the two resource allocation algorithms are used to minimize interference and maximize the system throughput. This technique utilizes more resources by increasing the number of cells. A static scheduler technique is offered to achieve high signal-to-interference-noise ratio (SINR) in [11]. Two approaches are proposed, one for the centralized part, and the other is based on the greedy color allocation. Both approaches improve the performance of cell-edge users but they increase the complexity of the system. A polynomial time distributed algorithm is proposed in [12] to minimize the cell interference, while the resource allocations has been tackled with blanking. However, the excessive use of blanking may deteriorate the performance. The pilot-based interference estimation scheme proposed in [13] is a crucial step to control power and band resources for cell–edges users. However, the pilot-based schemes are not accurate, and it utilizes extraband resources. An orthogonal frequency division multiplexing (OFDM), based load balancing algorithm is proposed in [14] for managing the resources of the resulting hybrid VLC/RF network and determining the user association to each system. The complexity of this optimization problem is excessively high for practical VLC/RF networks. The coverage analysis of multi-user VLC networks is presented in [15]. This work employed a dynamic cell formation method for grouping the optical access points in multiple optical cells that cover a footprint to minimize the intercell interference. Then, the transmission based on blind interference alignment in each optical cell is utilized to minimize the interference.

This paper investigates the channel capacity in cell interference area by using the MISO system. The interference power is different in different areas of the room due to interference and distance. The channel capacity is deteriorated due to signal-to-interference-noise ratio (SNIR). Therefore, the formulation to find the number of MISO array is utilized which minimize the intercell interference effect. The cell interference free channel capacity is derived by using a high-order MISO array at different levels of SNR. This technique secures the power, bandwidth, transmitter, and receiver complexity and many other complex algorithm used in transmitter and receivers. The high SNR produces high SNIR and decrease the channel capacity especially in the intercell interference regions. The deterioration of channel capacity is compensated by the high order of MISO array. The MISO system is optimized for high interference area of the room which is more depending upon the placement of LEDs and distance between them and transmitted power.

This paper is structured as follows. Section 2 describes the proposed schemes. The analyses are shown in Section 3. Section 4 represents the simulation results. Section 5 concludes this paper.

2. System Model

The higher-order MISO array is used to improve the capacity at high SNR of the system in cell interference environment. The LED array for brightness and data transmission are used for multiple receivers simultaneously. In this paper, four cells of N_T number of LEDs are installed at the same distances. We consider same number of LEDs in each cell.

The signal $x_i(t)$ is transmitted at time t from LEDs $i = 1, 2, 3, ..N_T$, and $y_j(t)$ is received at time t.

$$y_R(t) = \sum_{i=1}^{N_t} Rh_{ij}(t)x_i(t) + n_j(t), \tag{1}$$

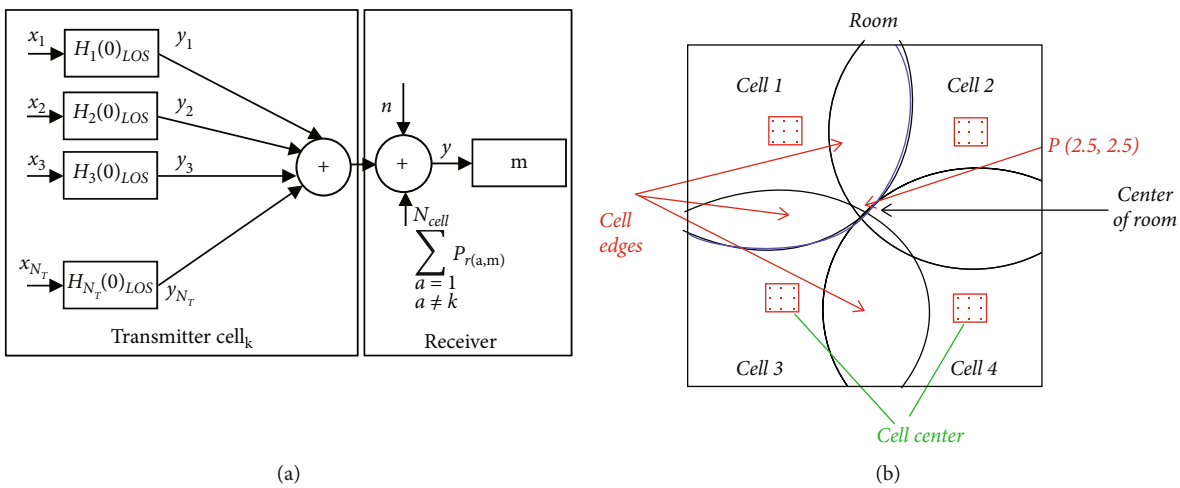
where $h_i(t)$ is the complex channel gain with $E[h_i(t)]^2 = 1$ and R represents the responsiveness of the photo-detector (in A/W) and $x(t) = [x_1(t)x_2(t)x_3(t) \cdots ..x_{N_T}(t)]^{\mathrm{T}}$ and $y_R(t) = [y_1(t)y_2(t)y_3(t) \cdots ..y_{N_T}(t)]^{\mathrm{T}}$. The VLC channel matrix H_o with $1XN_T$ dimension as shown in Figure 1.

The direct signal or line of sight (LOS) is considered; however, signals from non-LOS (NLOS) are negligible. The distance between the transmitter and receiver is d, A_{PD} is the receiving area, p is the refractive index, ψ is the angle of incidence, φ is the irradiance angle, γ is the reflectance factor, l is the order of Lambertian emission, ψ_c is the field of view (FOV), and $T(\psi)_{\mathrm{cof}}$ is the signal transmission coefficient of an optical filter. The $g(\psi)$ is the gain of the optical concentrator which is expressed in [16]

$$g(\psi) = \begin{cases} \dfrac{p^2}{\sin^2\psi_c}, & 0 \le \psi \le \psi_c, \\ 0, & 0 \ge \psi_c, \end{cases} \tag{2}$$

where A_{eff} is effecting area of photodiode and A_r is the surface area of the photodiode, which can be write mathematically as

$$A_{\mathrm{eff}}(\psi) = \begin{cases} N_r A_r \cos\psi, & 0 \le \psi \le \dfrac{\pi}{2}, \\ 0, & \psi > \dfrac{\pi}{2}, \end{cases}$$
$$A_{\mathrm{eff}}(\psi) = \begin{cases} N_r A_r \cos\psi T_s(\psi) g(\psi), & 0 \le \psi \le \psi_c, \\ 0, & \psi > \psi_c. \end{cases} \tag{3}$$



(a) (b)

Figure 1: Top view of VLC MISO system. (a) MISO system. (b) Footprint of four cells.

The transmitted and received power can be expressed as

$$P_r = \sum_{i=1}^{N_T} P_{t(i)} H_d(t). \tag{4}$$

However, the transmitted power is divided equally between all number of LEDs and received power in the room is shown in Figure 2, where transmitted power is

$$P_t = \frac{I(\varnothing)}{R(\varnothing)}, \tag{5}$$

where $R(\varnothing)$ is radiant Lambertian.

Received power is a product of received intensity $I_t(\varnothing)$ and the effective area $A_{\text{eff}}(\psi)$. Therefore, the received power can be defined as [17]

$$P_r = \frac{I(\varnothing)}{d^2} A_{\text{eff}}(\psi), \tag{6}$$

$$H_d(0)_{\text{LOS}} = \left\{ \begin{array}{c} \dfrac{(l+1) N_r A_r \gamma \cos^{l}(\varphi) g(\psi) T(\psi)_{cof} \cos(\psi)}{2\pi d^2}, \\ 0 \le \psi \le \psi_c, \\ 0, \text{elsewhere.} \end{array} \right\} \tag{7}$$

Equation (7) represents the DC gain $H_d(0)$ in LOS in frequency domain. The average transmitted optical power is given in

$$P_t = \lim_{T \longrightarrow \infty} \frac{1}{2T} \int_{-T}^{T} x(t) dt. \tag{8}$$

The different MISO cells are transmitting different bit streams data. Therefore, the m is nearby receiver to the kth cell as shown in Figure 1(a). Thus, the maximum SNR is received from the kth cell. The powers from neighbor cells which are using the same signal shape but different bit streams are considered interference $\sum_{\substack{a=1 \\ a\neq k}}^{A} P_{r(a,m)}$ as given in

$$P_{r(m)} = P_{r(k,m)} + \sum_{\substack{a=1 \\ a\neq k}}^{N_{\text{cell}}} P_{r(a,m)} \tag{9}$$

The footprint of four cells are shown in Figure 1(b), and the illumination of every cells is overlapping the neighbor cell which cause the interference. However, the interference area and cell edges are clearly mentioned in Figure 1(b). The highest interference area is located at the center of the room.

3. Analysis

In this paper, the channel information of the VLC system is known at both the side receiver and transmitter. The [18, 19] multiple independent data streams are simultaneously transmitted from different cells to achieve higher transmission data rate. The diversity gain of MISO transmission technique is transmitting same bit streams within a cell. The diversity gain increases the SNR within the cell and improves the channel capacity of the system. In this paper, the diversity gain is analyzed within the cells of a VLC system. The cell interference of the neighbor is analyzed between cells which dominant at the boundaries of the cell as shown in Figure 1(b). The cell interference is compensated through number of LEDs N_T at transmitter. The interference signals are dominant in cell edges and center of the room; therefore, the channel capacity performance are affected in interference regions. The cell interference effect is mitigated by increasing the number of LEDs at the transmitter. The higher-order MISO transmitter can be utilized only in high interference areas if receivers are static.

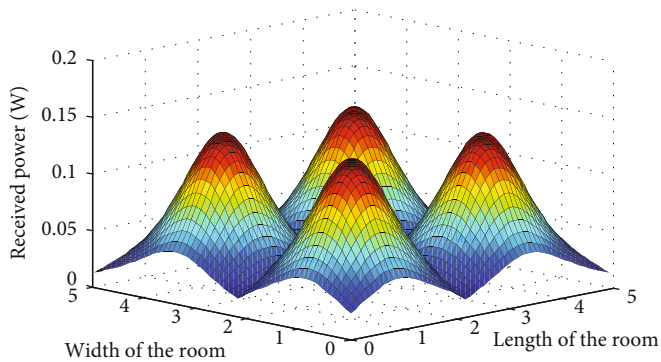


Figure 2: Received power of four cells' constrain.

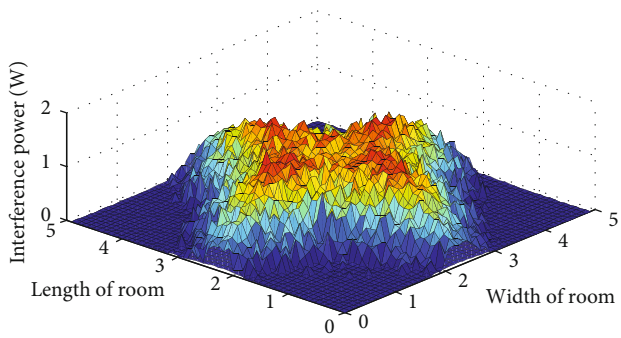


Figure 3: Interference power of four cells' indoor room.

The capacity of MISO AWGN channel:

$$C_{\mathrm{MISO}} \leq \sum_{i=1}^{N_T} \log(1+\mathrm{SNR}),$$
$$\gamma = \frac{P_{r(k)}^2}{n^2 W} N_T, \tag{10}$$

with cell interference $\mathrm{SNIR} = \mathrm{SNR}_{\mathrm{ICI}} \leq (P_{r(k)}^2/(n + \sum_{\substack{a=1\\a\neq k}}^{N_{\mathrm{cell}}} P_{r(a,m)})W)N_T$, the $\sum_{\substack{a=1\\a\neq k}}^{N_{\mathrm{cell}}} P_{r(a,m)}$ is cell interference power from neighbor cells as shown in Figure 3.

The channel capacity per band for single input and single output (SISO) in interference environments is given below:

$$\frac{C}{W} \leq \frac{1}{2} \log \left(1 + \frac{\left(P_{r(k)}\right)^2}{\left(n + \left(\sum_{\substack{a=1\\a\neq k}}^{N_{\mathrm{cell}}} P_{r(a,m)}\right)^2\right) W} \right). \tag{11}$$

The approximation of noise at high interference is negligible. The MISO capacity is compared with capacity of SISO system without interference (SISOWI) as shown in Figure 4 to estimate the number of N_T

$$\frac{1}{2} \log \left(\frac{P_{r(k)}^2}{nW}\right) \geq \frac{1}{2} \log \left(\frac{P_{r(k)}^2}{\left(n + \sum_{\substack{a=1\\a\neq k}}^{N_{\mathrm{cell}}} P_{r(a,m)}\right) W} N_T \right),$$
$$\left(\frac{P_{r(k)}^2}{nW}\right) \geq \frac{P_{r(k)}^2}{\left(n + \sum_{\substack{a=1\\a\neq k}}^{N_{\mathrm{cell}}} P_{r(a,m)}\right) W} N_T,$$
$$\sum_{\substack{a=1\\a\neq k}}^{N_{\mathrm{cell}}} P_{r(a,m)} \geq \frac{P_{r(k)}^2}{P_{r(k)}^2} n N_T W - n,$$
$$\sum_{\substack{a=1\\a\neq k}}^{N_{\mathrm{cell}}} P_{r(a,m)} \geq n N_T W - n,$$
$$N_T \geq \left(\frac{\sum_{\substack{a=1\\a\neq k}}^{N_{\mathrm{cell}}} P_{r(a,m)} + n}{Wn} \right), \tag{12}$$

Equation (12) defines the required number of N_T to compensate the cell interference power in MISO systems. However, the SNR can be define as in

$$\left(\frac{P_{r(k,m)} + \sum_{a=1}^{N_{\mathrm{cell}}} P_{r(a,m)}}{n} \right) \geq N_T W - 1,$$
$$\left(\frac{P_{r(k,m)}}{n} \right) \geq \left[(N_T W - 1) - \frac{\sum_{a=1}^{N_{\mathrm{cell}}} P_{r(a,m)}}{n} \right]. \tag{13}$$

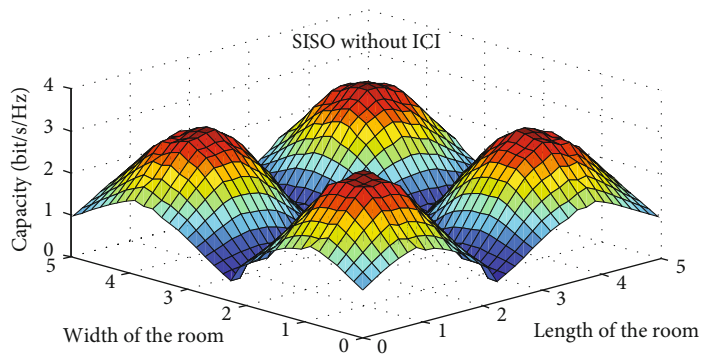


Figure 4: Channel capacity of SISO without considering interference.

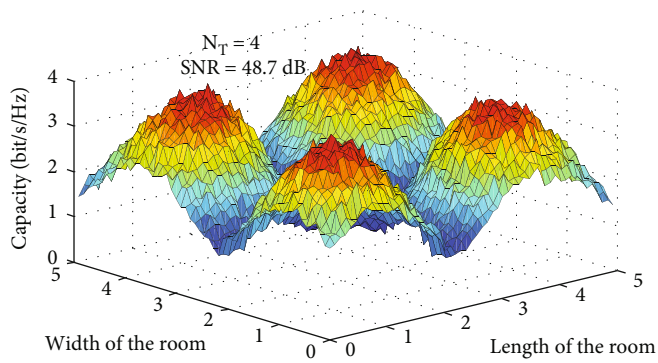


Figure 5: Channel capacity of four cells and each cell contain $N_T = 4$ MISO system.

The MISO system is optimized at highest interference area which is the center of the room. The center of the room is at $P(x - \text{axis} = 2.5, y - \text{axis} = 2.5)$ as shown in Figure 1(b), the light from all cell received equally. Therefore, the interference power is three time greater then principle cell as shown in

$$\left(\frac{P_{r(k,m)}}{n}\right)_{(2.5,2.5)} \geq \left[(N_T W - 1) - 3 * \frac{P_{r(k,m)}}{n}\right]. \quad (14)$$

The condition for optimization is the difference between $(N_T W - 1)$ and $(3 * (P_{r(k,m)}/n))$ should be high enough to achieve the high SNR. Therefore, analytically the high SNR requires high MISO array system in interference areas of the room. Hence, the MISO system is optimized as per high interference to achieve the required SNR.

The overall capacity of whole indoor cellular system is equal to the combination of all cell's capacity. However, every cell is transmitting different bit stream which creates the cell interference in neighboring cells. Every cell utilizes the MISO system with diversity gain and get an improved capacity in that particular cell. The overall capacity

$$C = \sum_{\text{cell}(i)=1}^{Y} C_{\text{cell}(i)}, \quad (15)$$

where Y represents the number of cells and every cell (i) utilizes diversity gain with N_T order of MISO system to minimize the cell interference from neighbor cell. The distance between cells decreases the SNIR at the boundaries of every cell. However, the less distance between cell increases the cell interference which requires the higher order of MISO system. Therefore, we have trade-off between cell interference, distance between LEDs within cell, SNR and order of MISO system within one cell. The cell interference varies due to two factors one is distance between cells and SNR. However, distance between LEDs and SNR increase the interference at boundaries of the cell. The distance between LEDs improves the illumination distribution in the room, and interference power is compensated via MISO system.

4. Simulation Result and Discussion

The simulation of this indoor VLC MISO system is performed by using four cells installed in a 270 sq. ft. room. MISO LEDs are placed at same distances inside every cell, and the room is covered by four cells. Every cell has fixed number of N_T or LEDs. The receiving surface is 2 meter away from ceiling. This paper examined the simulation and analytical channel capacity which is deteriorated due to cell interference. The VLC is a high SNR communication; however, the high SNR is a big challenge to be achieved in intercell interference environments, because the intercell interference increases in high SNR.

Figure 5 is simulated at $N_T = 4$ MISO system for every cell. Figures 5–7 show that the higher-order MISO systems increase the channel capacity specially at high SNR in cell

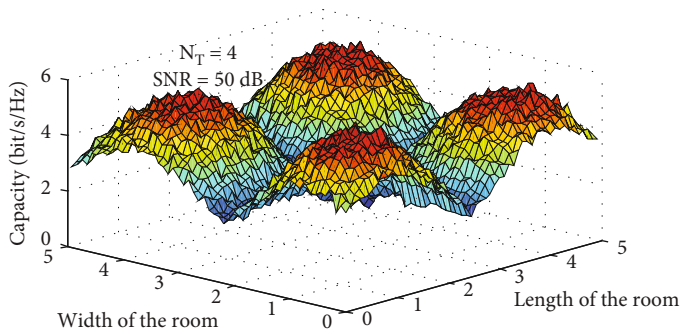


Figure 6: Channel capacity of four cells and each cell contain nine LEDs.

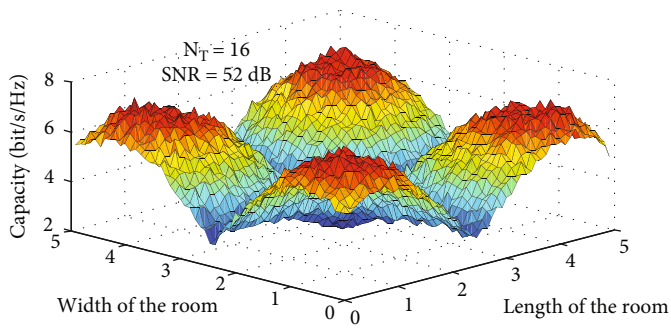


Figure 7: Channel capacity of four cells and each cell contain $N_T = 16$ MISO system.

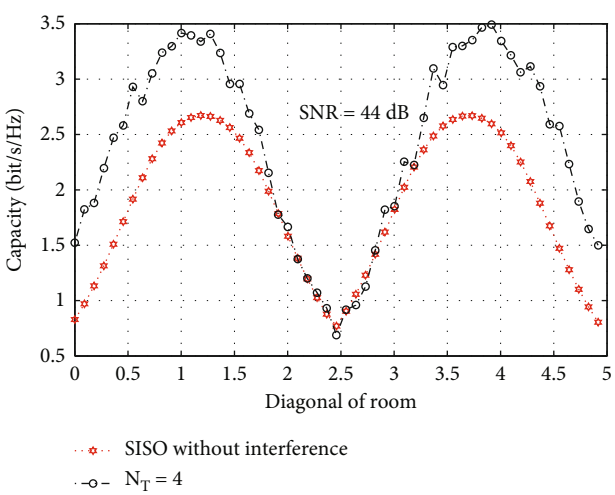


Figure 8: Channel capacity comparison of SISOWI and MISO $N_T = 4$ at 44 dB SNR.

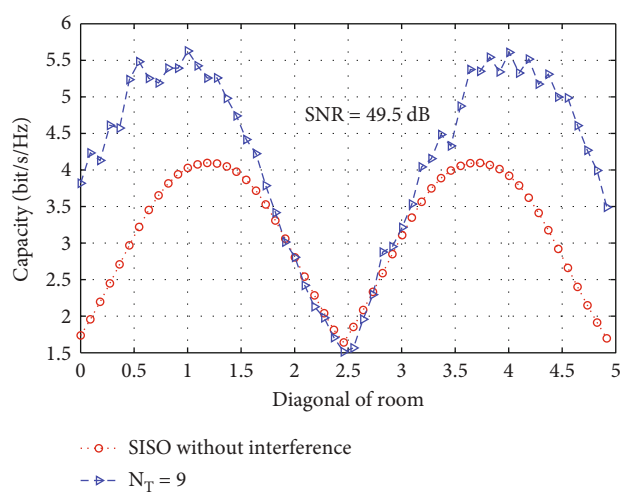


Figure 9: Channel capacity comparison of SISOWI and MISO $N_T = 4$ at 49.5 dB SNR.

interference regions. The center of the room is more affected with interference because the all four cells signals are combined at the center (signal overlapping). The minmum and maximum channel capacity is observed as 3.5 bit/s/Hz and 0.75 bit/s/Hz respectively which is much higher than channel capacity of SISO system as shown in Figure 5.

Similarly, Figures 6 and 7 is, respectively, simulated for $N_T = 9$ and $N_T = 16$ MISO system, and it is observed that the capacity is improved at high interference and low interference regions of the room. The SNR used in SISO are $N_T = 4$, $N_T = 9$, while $N_T = 16$ is used in the MISO system. The high capacity is noted as N_T increases. Hence, the higher N_T, MISO system reduces the effects of cell interference, particularly in high interference areas.

Moreover, this paper achieves the high SNR in cell interference environments. The MISO system is utilized to compensate the channel capacity in high-interference regions.

Figures 8–10 are simulated at the diagonal of the room by comparing the channel capacity of the MISO and SISOWI systems. Figures 8–10 depicted that the optimum capacity is achieved by using the MISO system. Higher-order MISO systems are simulated by including interference of neighbor cells. The MISO capacity is compared with SISOWI.

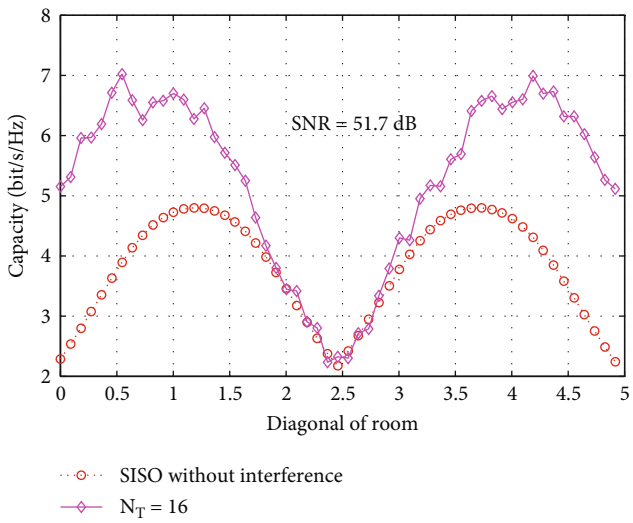


Figure 10: Channel capacity comparison of SISOWI and MISO $N_T = 16$ at 51.7 dB SNR.

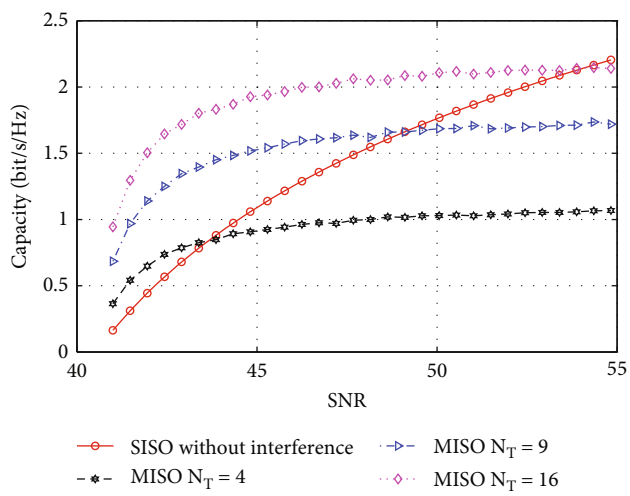


Figure 11: Channel capacity at high-interference area (1.5,1.5) location

Figure 8 shows that the in high-interference regions the SISOWI is achieved by $N_T = 4$ MISO system at 44 dB SNR. As the SNR increases the interference power increases, therefore, Figure 9 shows $N_T = 9$ MISO system is used at 49.5 dB SNR for high-interference area to achieve the SISOWI. Similarly, Figure 10 shows that the 51.7 dB SNR required $N_T = 16$ MISO system to achieve similar capacity response to that of SISOWI at the high-interference area.

Figure 11 shows the channel capacity at $(1.75, 1.75)$ location and the simulation at different SNRs using the SISOWI and MISO systems with interference. The results show that the highest channel capacity is achieved at $N_T = 16$ MISO system. The cell interference power increases with increasing of SNR, however, the SNR of $N_T = 4$, $N_T = 9$, and $N_T = 16$ MISO system become constant after getting certain level due to interference. The SISOWI increases with the increasing of SNR.

5. Conclusion

The proposed method in this paper attained the required capacity at high SNR by using the MISO system. The effect of intercell interference is high at high SNR especially at the overlapping regions. Therefore, a trade-off of the order of MISO array is investigated at different SNRs to achieve the interference free capacity system. The interference free capacity is achieved at 44 dB, 49.5 dB, and 51.7 dB SNR in cell interference environment at $N_T = 4$, $N_T = 9$, and $N_T = 16$, MISO system, respectively. Theoretical and simulation capacity show that the interference is eliminated and high SNR is achieved by using the high order of the MISO system. The mitigation of intercell interference at high SNR by using the MISO system outperforms the existing technique due to the less complexity of transmitter and receiver and cell planning.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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References

[1] C. Chen, W. D. Zhong, H. Yang, and P. du, "On the performance of MIMO-NOMA-based visible light communication systems," *IEEE Photonics Technology Letters*, vol. 30, no. 4, pp. 307–310, 2018.

[2] L. Wei, H. Zhang, and J. Song, "Experimental demonstration of a cubic-receiver-based MIMO visible light communication system," *IEEE Photonics Journal*, vol. 9, no. 1, pp. 1–7, 2016.

[3] T.-A. Tran and D. C. O'Brien, "Performance Metrics for Multi-Input Multi-Output (MIMO) Visible Light Communications," in *2012 International Workshop on Optical Wireless Communications (IWOW)*, Pisa, Italy, 2012.

[4] S. Deepthi and P. Visalakshi, "Enhanced optical OFDM: a novel approach for SISO and MIMO visible light communication system in indoor environment," *Optical and Quantum ElectronicsElectronics*, vol. 53, no. 9, pp. 1–24, 2021.

[5] K. Xu, H. Yu, and Y.-J. Zhu, "Channel-adapted spatial modulation for massive MIMO visible light communications," *IEEE Photonics Technology Letters*, vol. 28, no. 23, pp. 2693–2696, 2016.

[6] A. S. Hamza, S. S. Khalifa, H. S. Hamza, and K. Elsayed, "A survey on inter-cell interference coordination techniques in OFDMA-based cellular networks," *IEEE Communications Surveys & Tutorials*, vol. 15, no. 4, pp. 1642–1670, 2013.

[7] M. Rahaim and T. D. Little, "Interference in IM/DD optical wireless communication networks," *Journal of Optical Communications and Networking*, vol. 9, no. 9, pp. D51–D63, 2017.

[8] X. Guan, Q. Yang, and C.-K. Chan, "Joint detection of visible light communication signals under non-orthogonal multiple access," *IEEE Photonics Technology Letters*, vol. 29, no. 4, pp. 377–380, 2017.

[9] M. Rahman and H. Yanikomeroglu, "Enhancing cell-edge performance: a downlink dynamic interference avoidance scheme with inter-cell coordination," *IEEE Transactions on Wireless Communications*, vol. 9, no. 4, pp. 1414–1425, 2010.

[10] A. Ibrahim, T. Ismail, K. F. Elsayed, M. S. Darweesh, and J. Prat, "Resource allocation and interference management techniques for OFDM-based VLC atto-cells," *IEEE access*, vol. 8, pp. 127431–127439, 2020.

[11] K. Zhou, C. Gong, and Z. Xu, "Color planning and intercell interference coordination for multicolor visible light communication networks," *Journal of Lightwave Technology*, vol. 35, no. 22, pp. 4980–4993, 2017.

[12] A. Bin Sediq, R. Schoenen, H. Yanikomeroglu, and G. Senarath, "Optimized distributed inter-cell interference coordination (ICIC) scheme using projected subgradient and network flow optimization," *IEEE Transactions on Communications*, vol. 63, no. 1, pp. 107–124, 2015.

[13] V. P. Mhatre and C. P. Rosenberg, "Impact of network load on forward link inter-cell interference in cellular data networks," *IEEE transactions on wireless communications*, vol. 5, no. 12, pp. 3651–3661, 2006.

[14] A. Adnan-Qidan, M. Morales-Céspedes, and A. G. Armada, "Load balancing in hybrid VLC and RF networks based on blind interference alignment," *IEEE Access*, vol. 8, pp. 72512–72527, 2020.

[15] L. Yin and H. Haas, "A tractable approach to joint transmission in multiuser visible light communication networks," *IEEE Transactions on Mobile Computing*, vol. 18, no. 10, pp. 2231–2242, 2019.

[16] T. Komine and M. Nakagawa, "Fundamental analysis for visible-light communication system using LED lights," *IEEE transactions on Consumer Electronics*, vol. 50, no. 1, pp. 100–107, 2004.

[17] S. Fuada, A. P. Putra, and T. Adiono, *Analysis of received power characteristics of commercial photodiodes in indoor LoS channel visible light communication*, 2017, Unpublished.

[18] J. Lian and M. Brandt-Pearce, "Multiuser MIMO indoor visible light communication system using spatial multiplexing," *Journal of Lightwave Technology*, vol. 35, no. 23, pp. 5024–5033, 2017.

[19] C. Xu, S. Sugiura, S. X. Ng, P. Zhang, L. Wang, and L. Hanzo, "Two decades of MIMO design tradeoffs and reduced-complexity MIMO detection in near-capacity systems," *IEEE Access*, vol. 5, pp. 18564–18632, 2017.