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A Novel Algorithm for Network Enhancement JUP and Rate Scheduling in mmWave for 5 G Networks

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Abstract: ***Because of the open nature of the wireless medium, which renders wireless transmission subject to eavesdropping and hostile attacks, security and privacy have become increasingly important aspects in wireless communication networks. The introduction and development of decentralised and ad-hoc wireless networks has posed significant obstacles for implementing higher-layer key distribution and management in practise. As a result, physical layer security has emerged as a feasible method for enabling safe transmission while keeping complexity to a minimum. We might use this technique to focus on physical layer security design and enhancement in wireless networks.***

Keywords: ***Communication security can be described using concepts such as millimetre wave, ad hoc network, wireless network, self-backhaul, mmWave communications, multi-hop scheduling, ultra-dense small cells, stochastic optimization, and reinforcement learning.***

I. INTRODUCTION

Because of the significant bandwidth availability and low interference nature of the mmWave spectrum, millimetre wave (mmWave) communication is particularly appealing for industrial wireless applications. In recent years, novel industrial applications such as machinery precision motion control, collaborative mobile robots, and real-time visible monitoring have arisen. These applications necessitate the transmission of real-time data, video, and control signals, which necessitates tremendous throughput, ultra-fast response, and excellent dependability. According to a recent study, connectivity needs for industrial control applications may necessitate data speeds in excess of 500 Mbps while requiring single-digit millisecond latency. Existing industrial wireless technologies, which are primarily based on and operate in unlicensed 2.4 GHz or 5 GHz frequency bands, are not suitable for new industrial applications. mmWave communication, on the other hand, is vulnerable in wireless environments, particularly in scatter-rich industrial scenarios such as factories. In non-line-of-sight (NLOS) channels, small wavelength produces significant pass loss and excessive signal strength variability, resulting in severe blockage and coverage issues. A packet's overall transmission latency (denoted by TLatency) is determined by a variety of factors and can be calculated as

$T_{Latency} = P_{ropagate} + T_{ransmit} + T_{PHY} + T_{Queue}$

where TPropagate is the time for electromagnetic waves to propagate over the air, TTransmit is the time to position frames to the transmission time interval (TTI) at the link layer, which is a discrete value of one or multiple TTI times depending on packet size and modulation scheme, TPHY is the processing time in the physical (PHY) layer, which is typically a fixed delay, and TQueue is the queuing delay for buffered packets until they are allocated channel resources for. It should be noted that TQueue is a variable delay controlled mostly by the wireless medium access control (MAC) layer scheduler. Some packets must wait for an unusually lengthy period of time before being allotted channel resources. Because of the use of ultra-high carrier frequencies in mmWave communication, TTI values have a short duration. As a result, TQueue is the most important element in overall delay. Higher latency and buffer overflows can result in high transmission failures, which are unacceptably high for industrial applications. The key to enhancing the performance of mmWave communication is MAC layer scheduling. The full potential of mmWave communication can be realised with an efficient MAC layer scheduling method. To that aim, the primary contribution of this study is the development of a high-performance, fairness-centric MAC scheduler for scatter-rich industrial mmWave communication that can meet the rigorous requirements of dependability and real-time delivery for industrial applications.

5G Networks

Fifth generation (5G) wireless networks have sparked a lot of research interest in recent years. According to the 3GPP, 5G networks should enable three primary families of applications: enhanced mobile broadband (eMBB), massive machine type communications (mMTC), and ultra-reliable and low-latency communications (URLLC). Furthermore, improved vehicle-to-everything (eV2X) communications are regarded as a key service that should be offered by 5G networks. These possibilities necessitate huge connectivity with high system throughput and higher spectral efficiency (SE), posing considerable hurdles to universal 5G network design. Additional modulation and multiple access (MA) techniques are being investigated in order to meet these new criteria.

Fourth generation (4G) networks have employed orthogonal frequency division multiplexing (OFDM). OFDM, when combined with a suitable cyclic prefix (CP), may counteract the delay spread of wireless channels using simple detection methods, making it a favoured solution for contemporary broadband transmission. Traditional OFDM, on the other hand, is incapable of meeting many of the increased demands imposed by 5G networks. In the mMTC scenario, for example, sensor nodes often broadcast different types of data asynchronously in narrow bands, but OFDM requires different users to be closely synchronised, or there will be significant interference across nearby sub bands. To address the additional issues in 5G networks, various methods of modulation, such as filtering, pulse shaping, and precoding, have been proposed to reduce out-of-band (OOB) leakage of OFDM signals. Filtering is the simplest way to limit OOB leakage, and with a well constructed filter, leakage above the stop-band can be considerably reduced. Pulse shaping is a sort of subcarrier-based filtering that eliminates overlaps between subcarriers even within the band of a single user; nevertheless, due to the Heisenberg-Gabor uncertainty principle, it typically has a lengthy tail in time domain. Using precoding to transfer data prior to OFDM modulation is another efficient way to prevent leakage. In addition to the previously described ways for reducing OFDM signal leakage, various new forms of modulations have been proposed expressly for 5G networks. To deal with significant Doppler spread in eV2X circumstances, for example, transmit data can be modified in the delay-Doppler domain. In 5G networks, the above modulations can be combined with orthogonal multiple access (OMA).

II. LITERATURES

Trung Kien Vu, et al. [1] “Joint Path Selection and Rate Allocation Framework for 5G Self-Backhauled mmWave Networks”, This paper will cover a wide range of subjects. This study analyses the challenge of path selection and rate allocation for multi-hop self-backhaul millimetre wave (mmWave) networks due to extreme path loss and unreliable transmission over long distances in higher frequency bands. Because enabling multi-hop mmWave transmissions increases the danger of increased delay, this research tries to answer the following critical questions: "how to identify the best multi-hop paths and how to distribute rates along these paths based on latency constraints?” In this context, a new system design is proposed that improves downlink telecommunications by utilising multiple antenna diversity, mmWave bandwidth, and traffic splitting algorithms. The problem is represented as a network utility maximisation problem with an upper latency bound, as well as network stability and dynamics. Using stochastic optimization, the problem is separated into two sub-problems: The use of reinforcement learning approaches is proposed for 1io path selection and 1iio rate allocation, as well as a framework for picking the optimal paths. The rate allocation problem is a nonconvex problem that is solved using the successive convex approximation method. It is critical to accurately assess the need for greater secrecy performance.

Jiteng Ma et.al. (2) “Recent Results on Proportional Fair Scheduling for mmWave-based Industrial Wireless Networks” In this research, an EPF scheduling technique is suggested to address the constraints of SPF scheduling in dynamic wireless channels. Extensive simulation results in ns-3 using the mmWave communication module show that the proposed EPF scheduler enhances the priority of UEs in NLOS positions over the SPF scheduler. For NLOS UEs, the EPF scheduler performs better in terms of throughput and fairness. As a result of the trade-off, the LOS UEs' performance suffers slightly. Beyond the 95th percentile latency decreases by 12.3 percent in a realistic random communication environment. Overall, the EPF scheduler is an appealing choice for industrial contexts with a lot of scatter.

Jiao Wang et.al. (3) “Interference coordination for millimeter wave communications in 5G networks for performance optimization” To meet future wireless network data rate demands, a dense deployment of base stations or access points is the most promising approach; yet, doing so may result in excessive intercell interference (ICI). To reduce ICI, numerous interference coordination (IC) techniques have been developed. Conducting 5G communication over millimetre wave (mmWave) bands is more complicated due to increased propagation losses and larger attenuation variance, all of which are affected by changes in the environment. Massive antenna arrays with beamforming techniques can be utilised to overcome high propagation loss, reduce interference, provide coordinated performance benefits without a high overhead, and provide high network capacity with multiplex transmitters. Coordination of users and beams for each transmitter within a big network is the key difficulty of a massive antenna array that uses beamforming techniques. To overcome this issue, we offer a unique two-level beamforming coordination method that divides a vast network into clusters. This approach maximises the utility function or minimises the signal-to-interference-plus-noise ratio (SINR) function within a cluster at the intracluster level, analogous to the user selection algorithms in a multiuser multiple input and multiple output (MU-MIMO). At the intercluster level, a dynamic time domain IC technique is used, collecting interference information for cluster-edge user equipment (UE) and dynamically assigning the UE among the clusters to decrease intercluster interference in a switched-beam system (SBS). According to simulation results, the suggested two-level IC technique achieves a greater edge user performance or cell capacity.

Dan Ye et.al. (4) "Dynamic Distributed Maximal Scheduling Algorithm for 5G Cellular Network" This chapter outlines the most recent technological options for 5 G communication. The primary contribution is the development of a full duplex cognitive radio for improving future 5 G spectrum use. Another notable accomplishment is the creation of a unique optimal scheduler for the maximum link capacity area. For a 5 G cellular network, a tuple-based dynamic distributed maximal scheduling technique is presented. It combines joint resource allocation with cross-layer control to optimise overall performance by adaptively adjusting backlog and queue length. Simulation results show that the proposed TDDMS outperforms others.

Marco Giordani et.al. (5) "An Efficient Uplink Multi-Connectivity Scheme for 5G mmWave Control Plane Applications" The significant susceptibility to the rapid channel dynamics that influence a mmWave environment is a challenge for the practicality of a 5G mmWave system. To deal with these channel differences, a periodic directional sweep should be undertaken to continuously monitor the transmission directions of each potential connection and to adapt the beam steering when a power signal drop is observed. In this paper, we present a measurement reporting system that enables a supervising centralised entity, such as a base station operating in the legacy band, to collect multiple reports on overall channel propagation conditions on a regular basis in order to make efficient scheduling and mobility management decisions. We contend that the suggested uplink multi-connectivity technique provides more quick, robust, high-performance, and energy-efficient network operations at the mobile terminal, particularly when dealing with extremely unstable channels and densely inhabited systems. Furthermore, we demonstrated that quick and fair initial user association, improved handover management, and reactive radio-link failure recovery are all possible.

Omid Semiari et.al. (6) "Context-Aware Scheduling of Joint Millimeter Wave and Microwave Resources for Dual-Mode Base Stations" A novel context-aware scheduling architecture for dual-mode tiny base stations operating in the mmW and W frequency bands was developed.

The proposed scheduler can guarantee delay for each user application. This context-aware scheduling problem has been described as a one-to-many matching game, which is then addressed using a distributed method. The proposed technique makes use of mmW band resources for opportunistic traffic offloads while ensuring the QoS of the UAs. We demonstrated that the suggested algorithm results in a two-sided stable scheduling scheme. The simulation results demonstrated the numerous benefits and performance benefits of context-aware scheduling for dual-mode networks.

Francesco Devoti et.al. (7) "Facing the Millimeter-Wave Cell Discovery Challenge in 5G Networks With Context-Awareness" The researchers thoroughly evaluated the diverse collection of network access difficulties faced by the use of mm-wave technology in future 5G networks. They advocate for new approaches to dealing with legacy network features in order to fully realise their enormous potential, with the cell discovery technique being one of the most crucial. We proposed novel cell discovery techniques that are strengthened by the context information provided by a separate C-/U-plane design. Because obstacles often reduce the effectiveness of directional finding algorithms, we studied the possibilities of a geo-located context database. The results suggest that it can significantly improve algorithm performance by lowering the impact of barriers. Furthermore, we explored the issue of numerous mmwave BSs that process each user access request collaboratively. We have demonstrated the importance of selecting the best group of BSs engaged in the finding. Furthermore, we have shown how poorly positioned users can significantly reduce discovery efficiency. To address this issue, we devised practical solutions that can successfully improve network behaviour. We believe that the trade-offs and problems discussed in this research, as well as the proposed solutions, can make a significant contribution to enabling mm-wave cell detection in 5G networks.

Yong Niu et.al. (8) "A Survey of Millimeter Wave (mmWave) Communications for 5G: Opportunities and Challenges" With the potential to provide orders of magnitude more capacity than present communication systems, mmWave communications have emerged as a promising choice for 5G mobile networks. We do a survey of mmWave communications for 5G in this article. The properties of mmWave communications encourage the redesign of architectures and protocols to solve difficulties such as integrated circuits and system design, interference control and spatial reuse, anti-blockage, and mobility dynamics. The existing solutions have been examined and evaluated in terms of efficacy, efficiency, and complexity. There is also discussion of the potential applications of mmWave communications in 5G. To encourage the development of mmWave communications in 5G, 14 open research challenges relating to new physical technology, software defined architecture, network status information measures, efficient control mechanisms, and heterogeneous networking have been presented.

III. METHOD

This study looked at beam sweeping and training for mm Wave ad hoc networks. A distributed technique is used in an interference-free environment to match users to access points for optimal beam training and beam width; an ideal beam width that balances throughput with training overhead has been proven to exist.

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The synchronisation of 60GHz WLAN is controlled and coordinated using low-frequency 2.4GHz wireless LAN (WLAN). Despite the fact that beam training does not employ the low-frequency band, the findings imply that handshakes between neighbours can improve by up to 58 percent. WLAN positioning techniques in the 5GHz band were used to aid the beam forming process for 60GHz WLANs; a similar out-of-band positioning technique is investigated, in which low-frequency information is used to obtain coarse alignment with the possibility of fine beam alignment using in-band measurements. The overhead of beam training was reduced as the number of users rose in multi-user systems with hybrid design. To be genuinely effective, the system model had to ignore interference, rely on a more complex hybrid architecture, and demand user variety. Channel variations create changes in angle-of-arrival (AoA) and angle-of-departure (AoD), creating a significant barrier to mm Wave communication in mobile environments. Beam tracking refers to the tracking of tiny motions on an individual OFDM symbol level. I'm concerned about the prospect of a failed beam (i.e. require a complete beam re-alignment). In this situation, beam tracking was studied.

A. Received Signal Model

The channel H, the precoding vectors f, the combining vectors w, each interfering symbol xi, and noise all have an effect on the received signal yo of the broadcast symbol xo at the targeted user pair. n.$y_0 = w^*{}_0 H_0 F_0 X_0 + \sum_{i \in \phi} w_i^* H_i f_i x_i + n$ 1

I'm going to suppose that xo and xi are N (0, Po), N (0, Pi), and n is N. (0, N m o). The subscript o denotes the signal of interest at the origin, whereas the subscript I denotes the interfering signal from user I. I use the single-path model to model the channel, as I did in previous work in mm Wave [9]. For an NLOS path, the path displays reflected surfaces in the physical world, such as buildings or automobiles. The effective channel H between a receiver and a transmitter communicating at a distance of r is a composite value calculated from large-scale path-loss (r), small-scale fading (h), antenna array response a() at the angle-of-arrival (AoA), and antenna response a() at the angle-of-departure (AoD).

$$H = \sqrt{l(r)}\, h a(\theta) a^*(\emptyset) \quad ....2$$

In the next paragraphs, I go over each term in detail. The optimal preceding and combining technique for a single path with minimal interference is beam creation towards the AoA and AoD. I'm assuming that the transmitter employs a preceding vector f to produce |a () f| 2 = Gtx (, and the receiver employs a combining vector w to produce |wa()| 2 = Grx (). (). A path's AoA or AOD, on the other hand, fluctuates as a result of network mobility. The beam shaping solution can only be used for a limited amount of time. As a result, it is critical to avoid overtraining in high-mobility conditions. I use the sectored antenna model to simplify the antenna response. The antenna gain in the sectored model is reduced to either a main lobe or a side lobe gain. The resultant gain of a N-antenna array at either the receiver or transmitter is

$$G^{\frac{tx}{rx}}(\theta, \emptyset) = \begin{cases} G_{ml}^{tx/rx} = \frac{2\pi}{\theta_{ant}} \frac{\gamma}{1+\gamma} \\ G_{sl}^{tx/rx} = \frac{2\pi}{2\pi - \theta_{ant}} \frac{1}{1+\gamma} \end{cases} \quad ....3$$

ant denotes the width of the main lobe beam, which is ant = 2 N. The main lobe/side lobe correction factor reflects the front-to-back ratio of the antenna array, which is the ratio of the maximum gain to the gain 180 degrees from the maximum. G tx/rx ml /Gtx/rx SL denotes the gain of the main and side lobes, respectively.

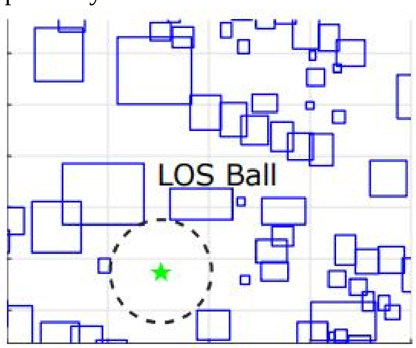

Figure 1: As an example, demonstrates a PPP network with construction obstacles.

For every constant C0 [2,] the correction factor is determined so that the array's total energy conveyed is always unity, G tx/rx ml ant 2 + G tx/rx sl 2ant 2 = 1. Array front-to-back ratios are usually on the order of the array size, e.g. N [83]. To simplify the calculations in our results, I utilise the equivalence of = N. At the same moment, they were both alone. The LOS ball model, which is a first-order approximation, takes into account the average LOS distance.

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The blockage probability function p is simplified as compared to other models, such as the exponential model [1,]. (r). Inside the ball, all users are considered LOS, but outside the ball, all users are considered NLOS. Using an impromptu mode of transmission. The interfering signals' resulting system gain Grx () Gtx () is treated as a discrete random variable.

$$k = \begin{cases} G_{ml}^{tx} G_{ml}^{rx} & w.p. \ \ p_{ml,ml} = p(G_{ml}^{tx})p(G_{ml}^{rx}) \\ G_{ml}^{tx} G_{sl}^{rx} & w.p \ \ p_{ml,sl} = p(G_{ml}^{tx})p(G_{sl}^{rx}) \\ G_{sl}^{tx} G_{ml}^{rx} & w.p \ p_{sl,ml} = p(G_{sl}^{tx})p(G_{ml}^{rx}) \\ G_{sl}^{tx} G_{sl}^{rx} & w.p \ p_{sl,sl} = p(G_{sl}^{tx})p(G_{sl}^{rx}) \end{cases} \quad ....4$$

(•) denotes the likelihood that the transmit or receive beam pattern will occur. For example, the probability of an interfering transmitter's side lobe being pointed at the receiver is (Gtx SL); similarly, the probability of an interfering transmitter's side lobe being pointed at the receiver is (Gtx SL) (Grx SL). G tx/rx sl = 1 G tx/rx ml = G tx/rx ml = G tx/rx ml = G tx/rx ml = G tx/rx ml = G tx/rx ml = G tx/rx ml = G tx/rx ml = G tx/rx ml = G The short-term effects are typical of effects that fade fast. I use a narrowband channel model with h as a random variable to get the fast fading channel coefficient. Using multicarrier techniques such as OFDM, wideband channels are converted to narrowband models. Long-term channel effects are caused by path-loss-affecting components such as building reflections or obstacles. I use the conventional unbounded path-loss model.

$$l(r) = \frac{A_m}{r^{\alpha_m}} ....5$$

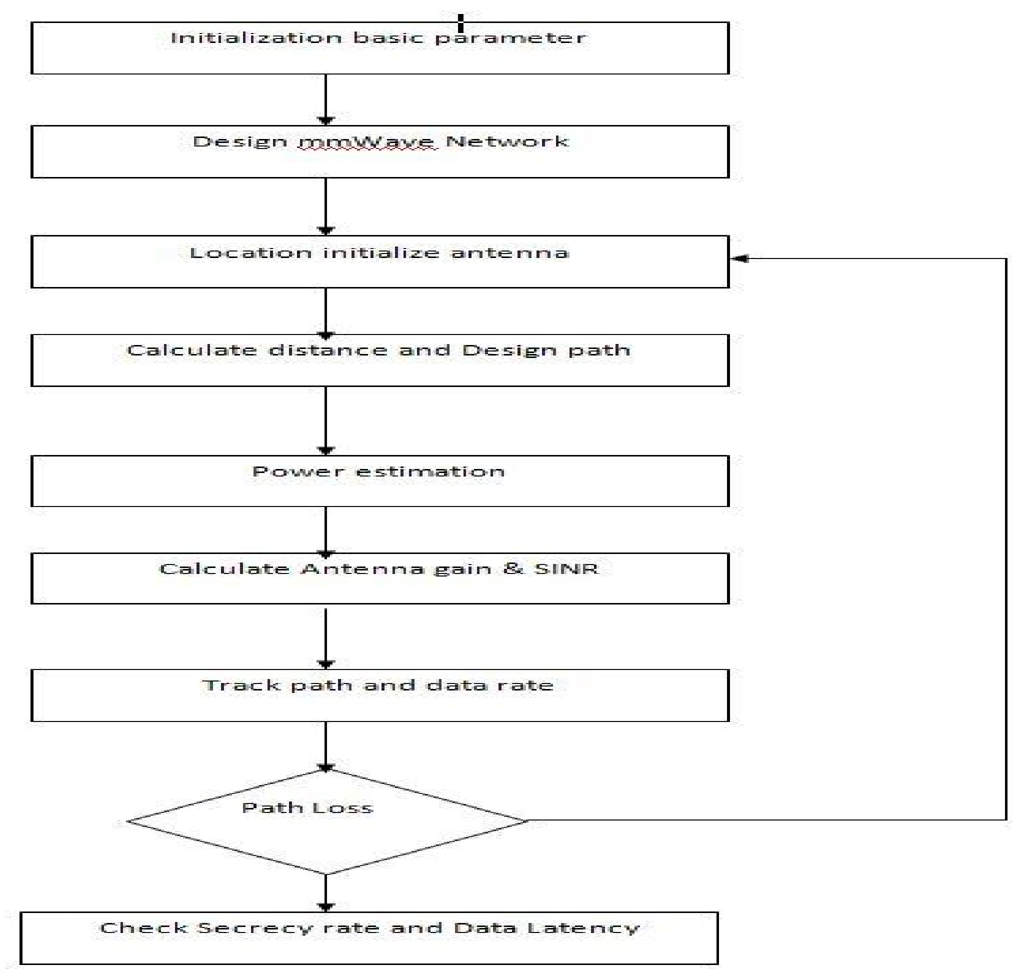

Figure 2: Working architecture flowchart

The detailed architecture of the entire suggested working is depicted in Figure 2. First, configure all of the core mmwave settings. Create a network and then connect the transmitter and receiver. After optimising the antenna, we establish its placement and path. Determine how much power they have and how well they communicate with one another, as well as their secrecy and latency rates.

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IV. RESULT

The data is analysed to demonstrate or comprehend the impact of mm wave channel characteristics and a big antenna array on the possible secrecy rate.

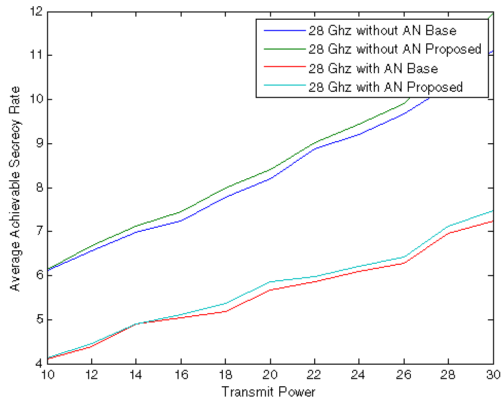

Figure The correlation between transmission power and achievable secrecy rate.

The influence of transmit power on the normal feasible mystery rate is depicted in Figure 3. We employ four distinct millimetre wave transporter frequencies, including one at 28 GHz. We can demonstrate that there are optimal transmit power values for increasing standard practical mystery rate for any of the commonly considered millimetre Wave frequencies.

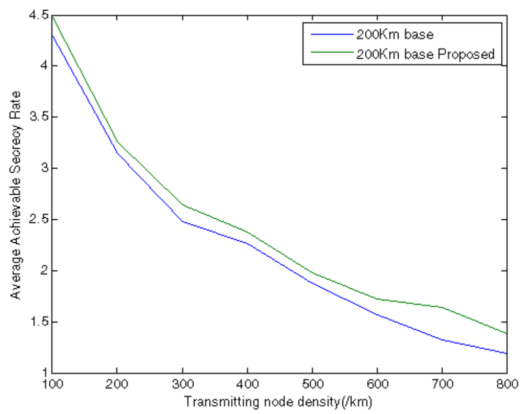

Figure 4 The implications of transmitting node density on average achievable secrecy at 60 GHz.

The influence of transmitting node density on the normal achievable mystery rate at 28GHz is depicted in Figure 4. The normal achievable mystery rate falls as the transmitting hub thickness increases. This is due to the fact that as transmitting hubs thicken, mm Wave impromptu systems become impedance constrained, and the blockage caused by other transmitting hubs has an effect on the presentation. More spies have been shown to have a negative impact on secrecy in large-scale millimeter Wave spontaneous occurrences.

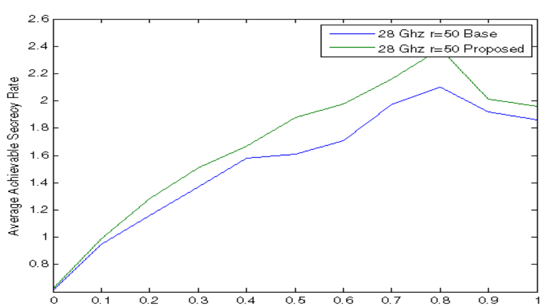

Figure 5 shows how the transmit power allocation factor affects the average achievable secrecy rate at 28 GHz: = 50/km2, e = 500/km2, and Pt = 30 dBm.

The impacts of the transmit power allocation factor on the normal reachable mystery rate are depicted in Figure 5. When the power designation between the data signal and AN is appropriately set, we discover that there is an ideal to improve the typical viable mystery rate. When the power designation between the data signal and AN is properly established, A can assist with upgrading mystery. The higher correspondence separation r disintegrates the odd execution once more. Furthermore, mystery transmission at 28 GHz surpasses mystery transmission at 38 GHz for a given r.

Figure 6 depicts the effect of transmit control on the usual feasible mystery with and without AN.

At 200 GHz, Figure 6 demonstrates the effect of transmit control with and without AN. When the transmitting hubs are thin (= 20/km2 in this image), the typical feasible mystery rate increases with the transmit control. In this case, using A with a power allotment factor of 0.85 will not improve secrecy.

V. CONCLUSIONS

This research suggests that mmwave be used to encrypt communication in an ahdoc network. This proposed concept contrasts noise-free versus noise-based systems. We design physical layers and manage communication architecture between various transmitters and receivers to maximize the rate of secrecy. The proposed strategy increases the rate of hiding.

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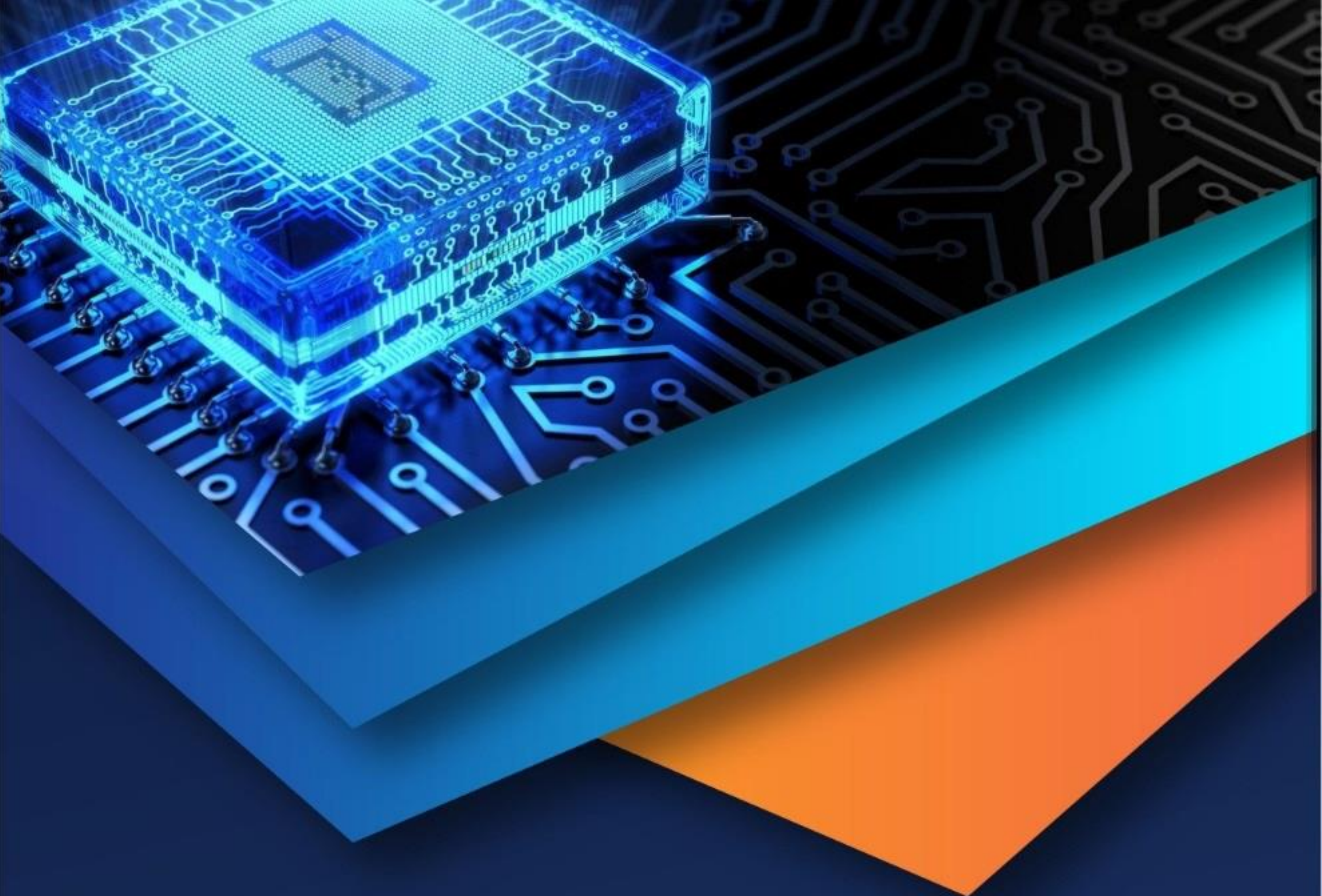

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