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IoT APPLICATION PERFORMANCE OPTIMIZATION BY CONGESTION AVOIDANCE SCHEME

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Abstract

Communication via remote means has evolved significantly, now capable of supporting the essential control mechanisms of high-definition digital industrial processes. The Industrial IoT networking known as 5G NR, provides flexible control and sub-bandwidth transmission capabilities, particularly suitable for efficiently managing small data packets crucial for industrial automation. While the minimum process duration serves as a reliable metric for assessing robustness in modern wireless communication, its exploration within the framework of IoT technology remains limited. This paper explores IoT based industrial automation control through networking, employing a delay optimization strategy integrated with database channel control to avoid congestion in traffic. Leveraging the Grey Wolf Optimization (GWO) Algorithm method, this study proposes a reliable minimum cycle time evaluation for IoT network communication, addressing the associated challenges effectively.

Keywords: Grey Wolf Optimization Algorithm (GWO), Internet of Things (IoT), Wireless Sensor Network.

1. INTRODUCTION

In IoT based wireless communication key control in commercial structures applications establish requirements for the secure correspondence in terms of efficiency and quality, which vary depending on the user demand. For instance, the automation role in the generation of industrial production process terms in the sales for 1 to 10 milliseconds and consistency more than 99.9999% [1]. The user demand presented by the industrial plant based infrastructure are inherently extremely costly, requiring process times of less than 1ms and consistent nature of 99.9999999%. [2], [3].

5G New Radio (NR) is another physical layer (PHY) known as that is normalized in IoT services. 5G NR uses a flexible technique and packet structure to promote execution and enable unusual opening transmission for data packets [4]. As can be shown in [5, 6] the majority of current study on URLLC has concentrated on analyzing idleness and dependability via the air interface. For contemporary applications, the minimum cycle time (MCT) could be an important metric. The MCT gives the lower bound of the best achievable time for each wireless network [7]. Achieving appropriate MCT for the application with a predetermined amount of information delivered and a predetermined number of sensor nodes are the primary objective of wireless communication networks [8].

2. RELATED WORK

Two alternative channel architectures for IoT products and services is examined (3GPP TR 38.90 Delivery and the NYUSIM) [1] to show difficulty in choose constraints under framework and capability in 5G era. Data traffic and power usage advancement

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under green radio is for research activities and practical utilization for development of Wi-Fi architecture [2]. Non-Orthogonal Multiple Access (NOMA) focused for next stage

Technology innovation by incorporating additional productivity including energy-space and code-space with energy-space superposition coding (SC) [3].

Work on cutting edge innovation performed that permit green 5G application with energy reaping supports for Wi-Fi networks [4].

IoT advancements effects in terms of throughput, greenness, and reliability considered for utilization as key issues that incorporates the optimized model based on thoroughly radio asset distribution, and enhancement for IoTs [5].

Encouraging advantages are demonstrated in association with the techniques for assisting IoT to resolve challenges integrate 5G environments with Mobile-Edge Computing (MEC) [6]. A legitimate design presented for network based on IoT, for dealing with portability among unique section to networks, notwithstanding a joint energy and sub channel distribution [7].

A study giving an outline of the cutting edge NOMA exploration and developments projects for examination of challenges in regards to NOMA in IoT under 5G platform [8]. Pareto front multi-objective scheme suggested for accomplishing a steadiness among local area and data focus esteem using pre-select data center areas for the multi-objective model under optimal conditions for the high-quality cell community network divided between Software define network (SDN) and NFV [9].

A strength and range productive IoT network frameworks proposed where data transmission is imparted to the cell framework for data transmission and lower energy consumption for wireless data transmission [10].

The radio antenna developed for use in upcoming IoT services in the HFSS software for efficient design and a working range of 28 GHz [11]. Issues inspected for industry services in obtaining high transmission performance to help the industrial IoT (IIoT) [12].Modern organization necessities examined for a structure that utilized practicality in over 5G IoT services in the US, Europe and four chose nations to figure out the significance of separating prerequisites and approaches for modern organizations [13].

A vision for a Beyond 5G Wireless Isochronous Real Time (WIRT) frameworks introduced for modern control organizations, intended for supporting quick control applications. WIRT focuses on super remote connections with very low latencies and a wired network in dependability [14].

Table 1: Existing survey as comparative overview on different technologies involved in 5G.

MIMO	NOMA	5G IOT	5G ML	MEC	5G	References
Yes	-	-	-	-	-	[1]
Yes	-	-	-	-	-	[2]
-	Yes	-	-	Yes	-	[3]
-	Yes	-	-	-	-	[4]
-	-	-	-	-	Yes	[5]
-	-	-	-	-	Yes	[6]
Yes	-	-	-	-	-	[7]
Yes	Yes	Yes	-	-	-	[8]
-	-	-	Yes	-	Yes	[9]
-	-	-	-	-	Yes	[10]
-	Yes	-	-	-	-	[11]

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3. METHODOLOGY

5G based multiuser (MU) network utilize frequency & time domain features to user end through OFDMA.

3.1 OFDM Overview

High transmission rates and the ability to deal with many transmitter signals are provided by orthogonal frequency division multiplexing, or OFDM. Its unique quality is its ability to considerably reduce Inter Symbol Interference (ISI) in comparison to other multiplexing techniques. It is an effective wide band frequency division multiplexing (FDM) system that reduces disturbance across different frequencies to improve communication. This is the ideal scheme for Wireless transmission as it can assist with fulfilling the prerequisites of proficient utilization of frequency band and limit the transmission cost. OFDM handles multipath impact by changing sequential information utilizing Fast Fourier Transform (FFT) and Inverse FFT (IFFT).

3.2 Grey Wolf Optimization Algorithm

Due to simple implementations, straightforward ideas and low system information requirements the metaheuristic optimization algorithms are getting very popular in modern technology. Current optimization techniques can avoid local optima and are widely applied across all fields. There exist several methods that stem from several combinatorial optimization issues. A novel method called "Grey Wolf optimization" was released in 2016. The social behavior of grey wolves, which operate in a hierarchical leadership structure, serves as an inspiration for this hunting approach. The elite predators, grey wolves, often inhabit packs of five to fifteen animals. The strategy of hunting classified into four groups α, β, ∆, and Ω. α-wolves taken as leader of the group that has authority of making decision for hunting place, rest state. The α-wolves are dominant and instructing others for following them. They play a significant part in generating novel solutions. When it comes to helping α-wolves make decisions, β-wolves go above and beyond. When the alpha wolves die, they make a decision. They pay attention to the α-wolves' decisions and respond accordingly. We refer to the wolves as subordinate wolves. They are the property of scouts, elders, guardians, hunters, and sentinels. ∆-wolves oversee Ω-wolves and obey alphas and betas. Wolves have the lowest position and serve as scapegoats. They trail all other wolves in charge. They don't matter since they can prevent others from having internal issues.

Three types of hunting are distinguished in GWO: tracking, surrounding, and assaulting the target during the exploration and exploitation phase. Exploitation is the process of finding the best solution while surrounding and assaulting the prey, while tracking is the process of locating the best solution throughout a global search area.

3.3 Proposed Work

OFDM data in the time domain and subcarrier, known as a resource element (RE), in the frequency domain make up IoT services. OFDM, as a multi-transporter regulation method, has been broadly taken on by IoT correspondence frameworks, under LTE and Wi-Fi(R). It has several advantages, including efficient execution, less channel latency, and adjustable frequency space. Its disadvantages, such as the reductions in efficacy due to greater side-lobe frequency band curves and the strict synchronization requirements, are often overlooked. In this way, novel approaches are being explored for IoT data correspondence frameworks to overcome some of these constraints.

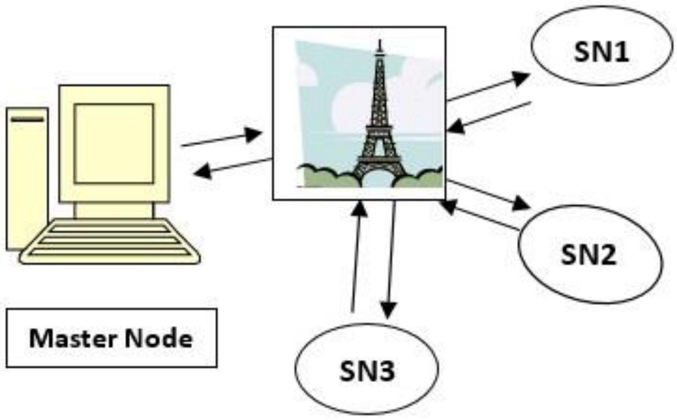

Fig 1: Industrial communication network based on IoT

A 20 MHz channel transfer speed LTE architecture, for example, uses 100 asset blocks, each with 12 subcarriers, at a 15 kHz individual subcarrier frequency. Ten percent of the dispensed range is used in this way, resulting in packet losses. Additionally, each OFDM data set's cyclic prefix of 144 or 160 samples results in an additional ~7% productivity loss, for a total loss of 17 percent in possible extraterrestrial proficiency.

With the now-established ITU requirements for IoT 5G NR architectures, applications need to be able to handle increased data rates, reduced dormancy, and more efficient range usage. This paper compares and contrasts OFDM inside a traditional system with the novel balancing process known as GWO based Multi-Carrier OFDM.

3.4 GWO-OFDM 5G NR Multi-Carrier Modulation

The basic reliable transmission capacity to convey a single bundle while varying the number of OFDM pictures in the time domain is determined by the GWO improvement problem. We employ MATLAB simulation to validate the packet error rate (PER) requirement as it is linked to the data transport speed, adjustability, and coding strategy. The mix of modulation order (M) and coding rate (C) varies at each site and for different boundaries and payloads, from high request to low, and the needed transmission bandwidth (Wt) is not fully established.

With FBMC (Filter Bank Multi-transporter) balances, GWO OFM 5G NR is seen as a speculative Filtered OFDM. Groups of subcarriers (sub-groups) are separated using GWO OFM 5G NR, whereas the whole band is separated in filtered OFDM and individual subcarriers are separated in FBMC.

When compared to FBMC, this subcarrier block allows one to reduce the channel length. Similarly, QAM may always be used with GWO OFDM IoT framework as it has the orthogonal symmetry (in comparison to FBMC) and is compatible with current MIMO schemes. There are sub-groups within the whole band of subcarriers (N). There is an appropriate amount of subcarriers in each sub band, and not every subgroup should be used for a particular transmission. Every sub band has a registered N-point IFFT with zeros embedded for the unallocated transports.

A channel of length L divides each sub band, and the responses from the various sub-groups are combined. The separation is completed in order to reduce the out-of-band transmission symbols. Although different channels might be used for each sub band, this approach uses a similar channel for every sub band. The IFFT yield per sub band is channeled using a Chebyshev window with determined side-curve decreasing.

The result is an FFT-based GWO crucial get handling for OFDM. For the FFT activity, the sub band separation extends the get time window to the subsequent force-of-two length. A subcarrier principal curve is compared to each other's recurrence esteem. Per-subcarrier leveling is frequently used to modify the combined effect of the channel and the sub band separation. Since no channel affects are presented, just the sub band channel is leveled in this model. In order to get the optimal SNR, noise is added to the received signals.

3.5 Minimum Bandwidth for Reliability Constraints

Reliability can be assessed by packet error rate (PER) performance. The PER is affected by many parameters, including signal-to-noise ratio (SNR) value, coding, modulation, payload length and the number of antennas. The SNR value is further affected by the transmitted power P_{TX}, path loss P_L, and transmission bandwidth for one packet Wt

$$SNR = \frac{P_{TX}.PL}{N_0.W_t} \qquad (2)$$

where N_0 = kB, where kB is the Boltzmann constant and is the temperature Assuming that all OFDMA slaves use the same numerology parameter and do not interfere with one another, interference is not taken into account. Among all of these variables, Wt determines the frequency and time domain resource grid shape and influences both latency and reliability performance. So, using the answer to the following optimization issue, we first find the minimal bandwidth needed to translate one packet into various amounts of OFDM symbols Nsymb and achieve a PER lower than 10^{-6}:

$$\min_{M,C} W_t$$

$$s.t. N_{symb}.RB.12 \geq \frac{L}{M.C} + N_{sc,DMRS}^{RB}.RB \quad (3a)$$

$$RB = g(W_t, \mu) \quad (3b)$$

$$PER(L, M, C, SNR, N_{RX}) < 10^{-6} \quad (3c)$$

Equation (3a) states that the RBs in a packet must be large enough to map the modulated data subcarriers and DMRS. This is calculated by multiplying the total number of OFDM symbols (Nsymb) by 12 RBs. The potential RBs given Wt and SCS that correspond to the chosen are shown in equation (3b) above. Wt causes a rise and decrease in the quantity of RBs. Equation (3c) indicates how the adjustment of M and C to meet the PER requirement will impact the value of Wt from Equations (3a) and (3b) (3c) [15 -20].

To achieve the PER requirement with high SNR or NRX at the receiver side, in particular, larger M and C can be used. Additionally, data bits are mapped to fewer data subcarriers that are distributed across fewer symbols and narrower channel bandwidth. On the other hand, lower M and C are required to achieve the same PER with low SNR and a single receiving antenna. This means that more data subcarriers must map to more OFDM symbols or a larger bandwidth. Table 2 for this article contains a list of all the symbols' definitions along with the simulation values that go with them.

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Table 2: Simulation Parameters for IoT under 5G framework in the Industrial Environments

L	Physical layer payload size (bit)	1 and 10 (bytes)
M	Modulation order	4,16,64,256
C	Coding rate	Refer [18]
µ	Numerology parameter	0,1,2 in FR1 and 2,3 in FR2
RB	Number of resource blocks	Refer to [17]
N_{symb}	Number of OFDM symbols in a packet	2,4,7 in DL,>=1 in UL
N_{RX}	Receiving antenna number	1 at FR1, 2 at FR2
PER	Packet error rate	$<10^{-6}$
T^{μ}_{Symp}	OFDM symbol duration including CP(µs)	71.35, 35.68, 17.84, 8.92 for µ=0.3
P_{rx}	Transmission Power	20dBm
PL	Path Loss	90,115dB at FR1, 94dB at FR2

4. RESULTS

The GWO optimization issue determines the minimum reliable bandwidth to transmit a single packet while the number of OFDM symbols in the time domain changes. Since the PER is dependent on the packet bandwidth, modulation, and coding method, we utilize MATLAB simulations to verify the PER requirement as stated in equation (3c). At each site, we change the combination of M and C from high order to low for varying optimization parameters and payload. Equations (3a) and (3b) (3c) may be used to get the corresponding required Wt. If the parameters selected fulfill (3c), a simulation is performed to determine the minimum reliable bandwidth needed to send a single packet; if not, M and C should be combined in a lower order and the procedure repeated. To attain low PER, several packets are produced for each parameter specified. The tapped delay line model and the clustered delay line (CDL) model from the IoT under 5G standard [20] are selected, respectively, to describe omnidirectional transmission with angular spreads. We selected a transmission power level of 20 dBm in accordance with the IoT framework.

Since there is no industrial channel measurement data for the 5G NR frequency ranges under IoT applications, the path loss and delay spread values are determined based on the results at 2.25 and 5.4 GHz [21]. A medium-sized facility with a maximum link distance of 35 m, the steam generation plant is characterized by considerable multipath fading. The device serving as a BS is positioned above the other devices in relation to the ground. The steam generation plant's maximum path loss and delay spread are 90 dB and 55 ns, respectively.

The industrial site usually comprises of a vehicle assembly plant with assembly work cells, stacked storage facilities, and machining areas connected by a maximum connection distance that has been set. The characteristics of the CDL channel are established based on the results of the channel measurement [22]. The arrival and departure have an angular dispersion of 41 and 80 degrees, respectively, in azimuth. The simulation does not employ beamforming. Beamforming can be utilized to obtain the appropriate SNR for industrial sites with longer communication ranges and larger route losses. Each location's Doppler shift is set to a value calculated at a speed of 2.5 m/s.

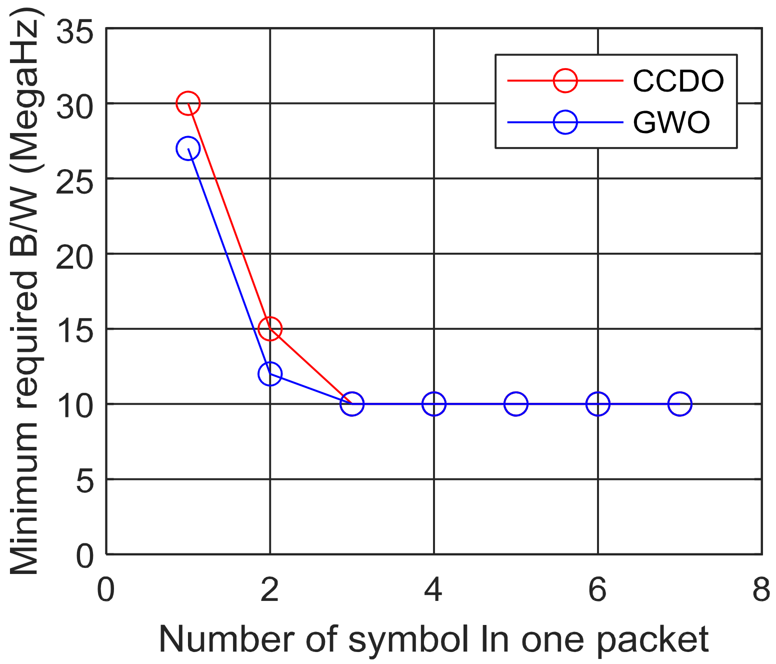

Fig 2a: The minimum needed bandwidth for packet transmission, Wt, may be found by calculating equation (4.2) for PER< 10^{-6} based on the number of OFDM symbols in a single packet. Ten and one hundred bytes are the PHY payload sizes. The parameters of numerology at (a) μ = 0–10 are applied.

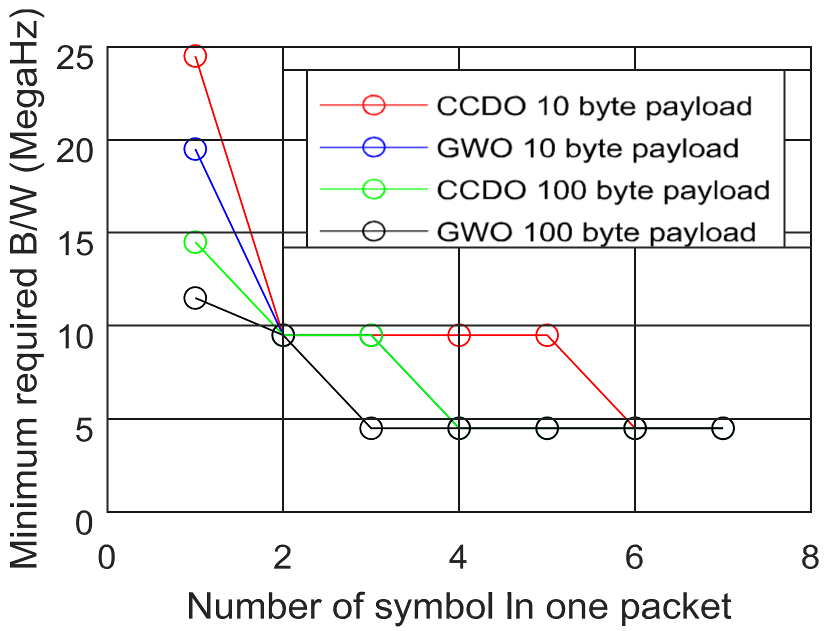

Fig 2b: The minimum needed bandwidth for packet transmission, Wt, may be found by calculating equation (3) for PER< 10^{-6} based on the number of OFDM symbols in a single packet. Ten and one hundred bytes are the PHY payload sizes. We employ the numerology parameters when μ = 2, 3.

The minimum Wt required to achieve a PER of 10^{-6} at a certain location is shown in Figs. (2a) and (2b) (b). In the AA plant, the payload is modulated using M = 2 (QPSK) and C = 349/1024 to satisfy the dependability requirement. M = 4 (16QAM) and C = 658/1024 in the steam generating plant provide the required dependability performance. According to (2a), the minimum needed Wt for each decreases with Nsymb and increases with L. The lower bound of the minimum required Wt, which is equal to 5 MHz for values of = 0 and 1, and equal to 10 MHz for values of = 2, is determined by finding the least BWP for each value.

When fixing Nsymb μ, the minimum required Wt grows in tandem with the SCS. As a result of lower values of M and C being needed to compensate for increased path loss and achieve the same PER performance, equation (2a) yields a larger minimum necessary weight in Fig. (2b) than in Fig. (2a). with a 100-byte payload size, no Wt value in Fig. 2b can satisfy the PER requirement for Nsymb 2 with = 1 and Nsymb 4 with = 2. The smallest BWPs correspond to a substantial number of RB with a 10-byte or 100-byte payload size and varying Nsymb; this value can satisfy criteria eq (3a) to (3c).

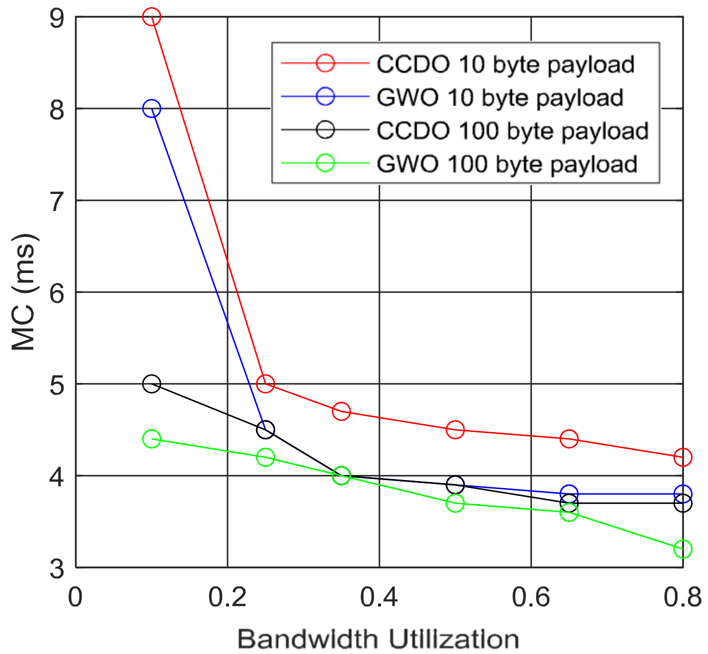

Figure 3: Minimum packet transmission time with respect to bandwidth utilization

In the figure 3 the results are shown in between the Minimum packet transmission (MC)) in msecs in the y-axis and the bandwidth utilization along the x-axis. It is performed at different values of payload at 1 byte and 10 byte for comparing the transmission under CCDO and proposed GWO approach. It has been found that the minimum packet transmission time for the proposed GWO based optimization scheme is giving lower MC values as compared to CCDO.As the bandwidth utilization is increasing the MC is decreasing for all the cases.

In the figure 4 the results are shown in between the Minimum packet transmission time (MC) in msecs in the y-axis and the number of OFDM signals in a data packet along the x-axis. It is performed at different types of modulation schemes at BPSK QPSK and 8PSKat the payload of 1 byte for comparing the transmission under CCDO and proposed GWO approach. It has been found that the minimum packet transmission time for the proposed GWO based optimization scheme is giving lower MC values as compared to CCDO for all the modulation schemes.

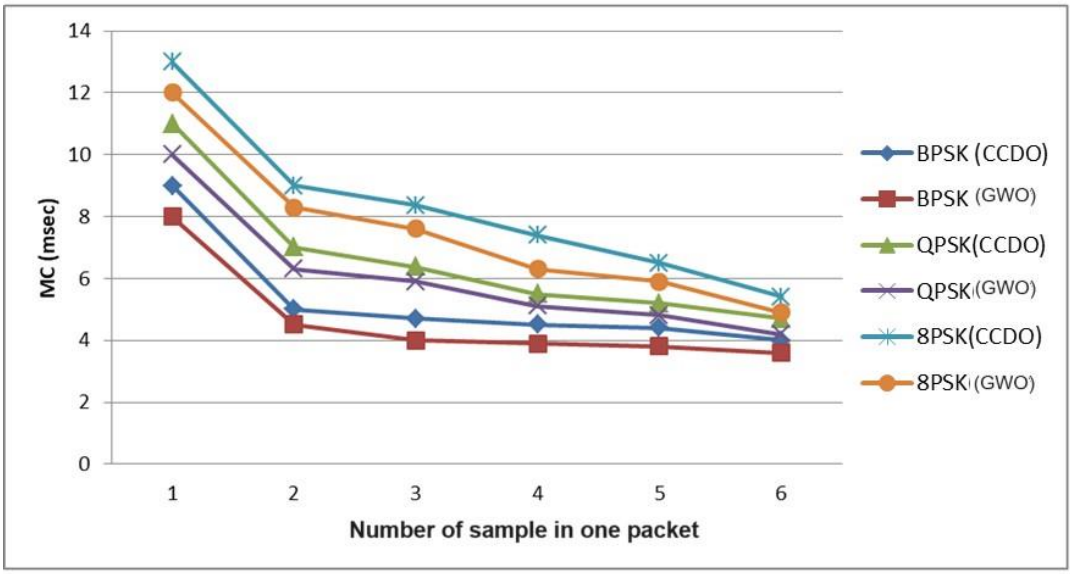

Figure 4: Minimum packet transmission time with respect to signal in a packet for 1 Byte payload

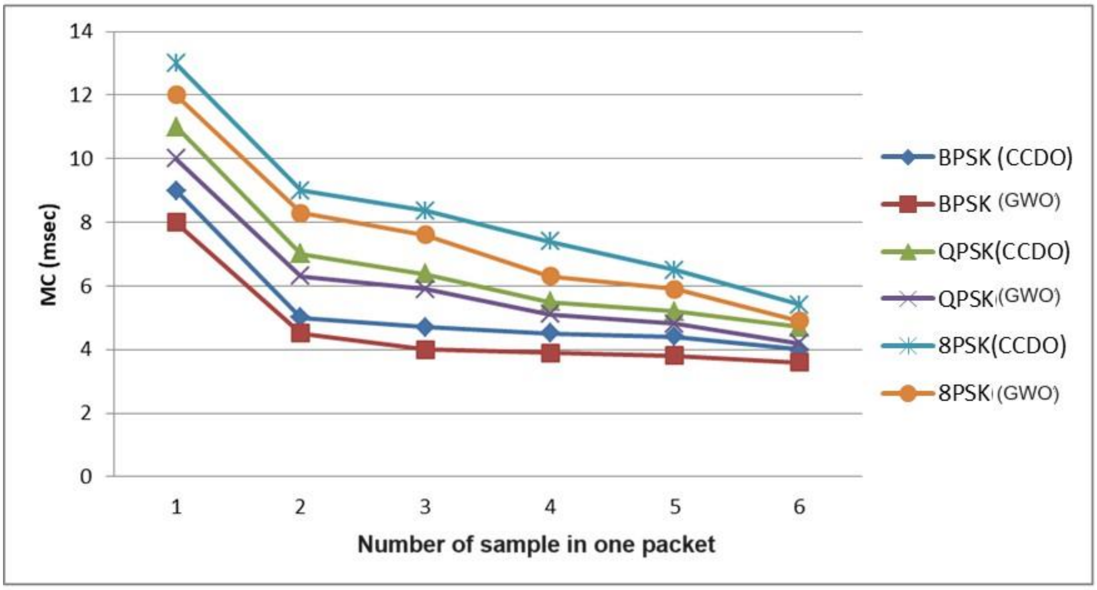

Figure 5: Minimum packet transmission time with respect to signal in a packet for 10 Byte payload

In the figure 5 the results are shown in between the Minimum packet transmission time (MC) in msecs in the y-axis and the number of OFDM signals in a data packet along the x-axis. It is performed at different types of modulation schemes at BPSK QPSK and 8PSK at the payload of 10 byte for comparing the transmission under CCDO and proposed GWO approach. It has been found that the minimum packet transmission time for the proposed GWO based optimization scheme is giving lower MC values as compared to CCDO for all the modulation schemes.

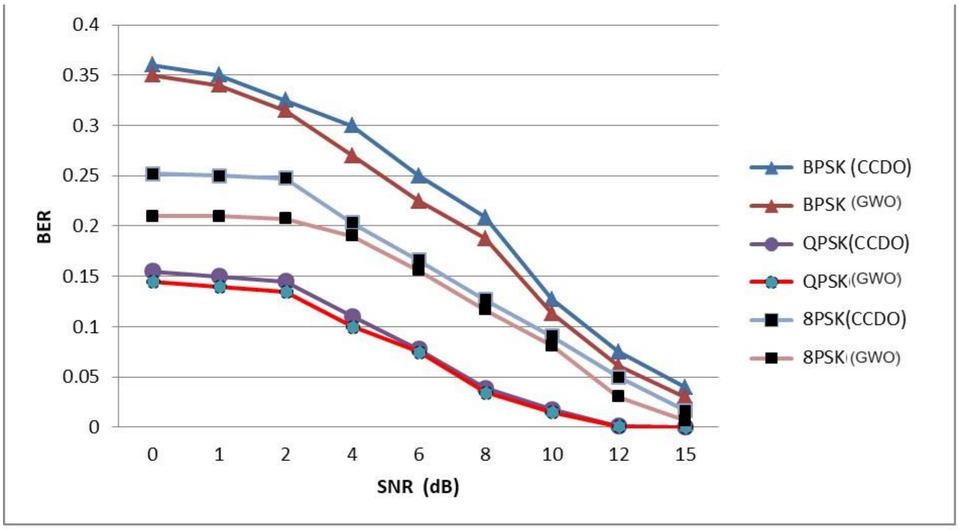

Figure 6: Bit Error with respect SNR in dB

Figure 6 displays the results between the SNR (dB) for data packet transmission along the x-axis and the Bit Error Rate (BER) on the y-axis. To compare the transmission under CCDO with the suggested GWO technique, it is done at various modulation schemes at BPSK, QPSK, and 8PSK. It has been discovered that, for all modulation schemes, the BER for the suggested GWO-based optimization approach is providing lower MC values than CCDO. In every situation, the BER decreases as the SNR rises.

5. CONCLUSION

Industrial scenarios that demand high dependability and prompt answers are supported by IoT 5G URLLC to assess the trustworthy MCT of the IoT 5G version 15's MCT, it was proposed to create an optimization problem with a reliability constraint that considers industrial channel characterization. For the sake of this study, we'll suppose that every packet that the master sends to every slave is included in a single packet. More research is required to determine whether scheduling several aggregated packets and broadcasting in the OFDMA mode would improve performance in a real-world application with a large number of slave nodes. Furthermore, it is anticipated that in a TSN framework, wireless technologies will coexist with conventional wired technologies. Investigating how IoT will fit into the architecture and evaluating end-to-end performance on mixed transmission networks are exciting. It's crucial to consider how IoT and other industrial wireless technologies handle anti-jamming and PHY security.

The basic characteristics of an OFDMA modulation scheme based on GWO at the broadcast and receive ends of a communication system are demonstrated by the example. It is crucial to look at different numbers for the side-lobe attenuation, FFT length, subcarriers per sub band, number of sub-bands, and SNR system characteristics.

GWO-based OFDM in 5G is believed to be superior to OFDM due to its increased spectrum efficiency. This strategy is promising for short bursts because sub band allocation has the advantage of reducing the size of the FFT and the guards between sub-bands. When compared to other optimization, which has a noticeably longer FFT length, the latter characteristic is also attractive. The result shows that IoT framework can achieve few milliseconds for control mechanism for different representative

Industrial locations. The suggested way under this method may be employed in the future to various non cellular wireless technologies that are now in trial mode in terms of cycle periods. A checking table may be included in the future to record different channel properties, such as path loss and signal angle, along with the related minimum required bandwidth, modulation, and coding. A network management entity may be established to preserve this table and compute the scheduling and transmission parameters using hybrid optimization techniques, therefore offering a dependable MCT. The modern optimization techniques has drawbacks of large complexity and large convergence time but they have better accuracy. It has been found that by combining two different weak optimization techniques a strong and better optimum solution may be found. In future we may focus on such topologies in optimization process to make the process simpler, fast but highly accurate.

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