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Future Robust Networks: Current Scenario and Beyond for 6G

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ABSTRACT

With the progress of smart technology and diversified application of existing networks, the future might not manage the rapid growth of traffic demand, i.e., 6G. Therefore, future robust networks (FRNs) are investigated to get enough bandwidth and solve problems to achieve strong communication and self-configuration. Because the global positioning system (GPS) nodes have severe shortcomings, node localization is not appropriate for the self-configuring FRNs. A node localization mechanism scanning technology for calculating the distance between nodes, and multi-alteration scanning, and spatial triangulation techniques for calculating the distance between nodes are discussed in this article. In addition, the appearance of index modulation (IM) is an advanced modulation of the model. The subcarrier-index modulation (SIM) of different scenarios uses index mapping techniques for FRNs and beyond. We formulate locating positioning in wireless sensor networks (WSNs) through distance estimation techniques. The general model of SIM, along with its mechanism implementation, is also introduced. By improving the spectral efficiency, the comparison average bit error probability enhances the signal quality and frequency selectivity through the exhaustive search-based optimal detector at receiver for FRNs. Then, we study the potential applications of SIM in various scenarios such as downlink multi-user network and physical layer security.

KEYWORDS: FRNs; index carrier; self-configuration; smart array; WSN; 6G

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1. Introduction

According to the Cisco report, the total number of Internet Protocol (IP)-connected devices by 2022 would be three times that of the global population [1]. Mobile user flows have risen by 71% of total IP traffic, and average mobile link speeds will reach three times as high by 2021 [2]. Though, in 2030 and beyond, modern user specifications, modern applications, and strong network trends may lead to more challenging network engineering problems [3], which require the adoption of new communication modes in downlink multi-user network (MU-N) and physical layer security (PHY-S) [4]. By 2030, the Internet of Everything (IoE) will connect 50 billion devices around the world, which means that there will be an increased density of connections per square kilometer [5]. In the future, communication takes into account the high transmission loss of high frequency, especially the millimeter Wave ($mm - Wave$). Future robust network (FRN) such as 6G communication is more important because it can provide massive bandwidth. On the other side, the current networks such as 5G have main drawbacks, including limited coverage and difficulty penetrating through infrastructures.

Recent advanced technology has led to a massive revolution in distant communication in many fields, including electronic healthcare, industry (HCI), popular connections in the intelligent environment, industrial 4.0 and large-scale robotics, and large-scale unmanned migration of different dimensions. To effectively use different Wireless Sensor Networks (WSNs) for effective data exchange at a wide range, various WSN technologies have to be involved [6]. The demand for quick exchanging of multimedia-rich data and voice calls of top quality is the main driving force for this ongoing journey. With the development of new demanding applications and the multiplication of the user base, there are more urgent needs for novel technologies to improve data transmission rates and reduce latency, as shown in Figure 1 [7]. The first standard of the fifth generation, released in June 2018 and launched from South Korea in early April 2019, is called 5G New Radio (NR). At present, some assumptions for the 6G communication network have been studied. Since the launch of 5G in 2019, it was stated that it would reach the performance limits within ten years. Consequently, 6G will need to further increase the personal and downlink data rates at 100 and 50 times, respectively [8]. Thus, we scrutinize the gap between the initial ambition and the increasingly mature 5G network that stimulated the need for 6G.

Artificial intelligence (AI) is essential in 6G wireless networks due to its great ability for modeling systems that cannot be expressed by mathematical equations, and it is expected that AI tools will replace heuristics. At the same time, AI will realize real-time data analysis and an automatic no-touch system. The objectives of the research are to study the IM-based developing scenario such as index-based modulation (IM) [9], the spatial scattering modulation [10] that transfers additional information bits in the abundant scattering environment by manipulating the reconfigurable scatters, and utilize the variation of the received signal characteristics [11]. On the other hand, reconfigurable smart surface/wall/reflector array/area array/surface array is an intelligent device, which deliberately controls the propagation environment to improve signal quality at the receiver (Rx). [12, 13]. Firstly, we are producing a so-called site recognition problem, that is, how to get the site information of unspecified nodes. The most commonly used location (localization) system is the Global Positioning System (GPS). However, these nodes are usually large, making it challenging for node localization to be suitable for these self-configuring networks. So, in this paper, the node localization mechanism is applied to wireless sensor networks. Secondly,

Figure 1. FRNs from 5G to 6G.

subcarrier IM (SIM) is a frequency domain IM family implemented on sub-carriers with orthogonal frequency division multiplexing (OFDM). In recent years, OFDM has been regarded as the standardization of uplink and downlink waveform of 6G-FRNs and has triggered a SIM new wave of development. Compared with OFDM technology, SIM has a higher SE or EE and lower Power Ratio Peak to Average (PAPR) and lower media resource occupancy rate. The existence of the empty carrier likewise contributes to the strategy of PAPR decrease technology.

Nevertheless, much of the latest SIM research studies focus on the performance-enhanced SIM scenario, while the application of SIM still needs further investigation. In this paper, a SIM mode to tackle this problem is proposed. Index modulation (IM) emerges as an innovation modulation perception as well. The general model of SIM and its concrete implementation are introduced. Then, the potential applications of SIM in various situations, including downlink multi-user (MU) communication (MU-C) and physical layer (PHY) for security (PHY-S), are mentioned. Secondly, the challenges and possible future directions of SIM research are discussed. The 5G target service and its supporting technology and implementation technologies of the 6G communication network are also described. Finally, in the context of the increasingly stringent performance requirements of FRNs, the 6G network control is studied.

The remaining sections of this article are divided as follows: the location positioning sensors networks for FRNs are discussed in Section 2. Section 3 presents the future direction of SIM and key challenges associated with it, and section 4 shows the main findings and the conclusion.

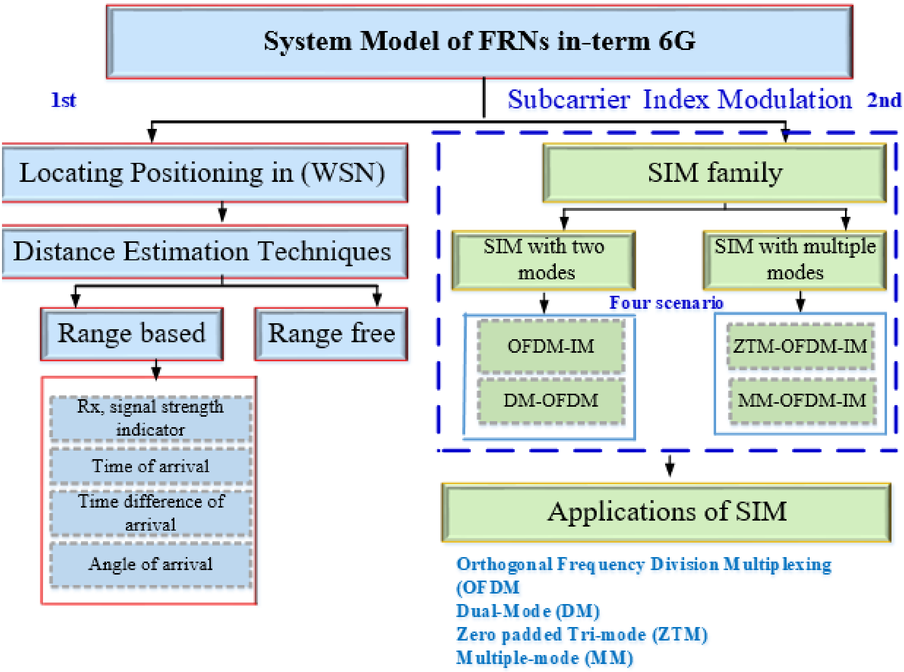


Figure 2. Flow chart of proposed work mechanism about FRNs for 6G and beyond.

2. The Proposed Model of FRNs for 6G

We represent in this portion the proposed model of the localization positioning of sensors mechanism for calculating the distance between nodes, multi-alteration scanning technique, and spatial triangulation technique. The proposed scheme is constructed based on the SIM of the different scenarios using index mapping techniques of FRNs and beyond. Figure 2 describes the overall work mechanism of FRNs for 6G and beyond.

2.1 Locating Positioning of Sensors Network

The accuracy of the current locating positioning of sensors has reached 0.5 meters and has wide-ranging application prospects. Localization, one of the vital elements of the network, is defined as a combination of different location information such as distance estimation, location estimation, and mapping [13]. As shown in Figure 3, most of the network positioning technologies in the network have three main steps: distance estimation stage, which includes a technique for estimating the relative distance between nodes; position calculation stage that consists of a relative estimation of node position; and positioning technology stage through which the information of location and distance are collected to minimize errors and accurately map node locations [14]. Distance estimation techniques are divided into two classifications: distance-based technique and distance-free technique. In the former category, the received signal power is calculated based on Equation 1.

$$P_r = c\frac{p_{tx}}{d^a} \leftrightarrow d = \sqrt[a]{c\frac{p_{tx}}{p_r}} \tag{1}$$

Where P_r is the signal's received power, C is the light's speed, p_{tx} is the transmitted signal's power, d is the path's length, and a is the path loss coefficient. The arrival time is the distance between nodes. It is estimated based on the time of signal propagation. The distance between the two nodes is proportional to the time needed to transmit the signal from the 1st node to the 2nd node, according to Equation 2.

$$d = v\_s * t \tag{2}$$

The time difference of arrival is computed based on Equation 3.

$$d = v\_sound * (t\_sound - t\_radio\ ) = v\_sound * \Delta t \tag{3}$$

Where v_sound is the propagation of sound speed in the vacuum, t_sound is the time of sound signal propagation, t_radio is the time of radio signal propagation, and Δt is the time difference between the two signals. The arrival's angle is given in Equation 4.

$$\Delta t = \frac{\delta}{(v + cos\ \theta)} \tag{4}$$

Where Δt is the arrival's angle, δ is the coefficient of antenna separation, θ is the difference between the times of wave arrival to each antenna, and v is the propagation's velocity. Location computation methods depend on lateral scanning technology. The position of the node at the network and the distance are calculated according to the precise measurement of three adjacent central nodes. When using the technology in three-dimensional space, four central nodes are needed, and when using three central nodes, this technology is called three side measurements, as shown in Figure 2. When using more than three central nodes, this technology is called multidirectional positioning. The node is intersected by three circles of three adjacent central nodes, and the radius is the distance from the primary node to the desired node [15]. Triangulation is a standard technique of calculating the location of a node. Figure 2 shows how the distance between nodes is calculated.

Pattern matching positioning, also known as map-based technology, includes two stages. The first stage (offline) involves recording the signal's parameters from the node

Table 1. Parameters for SIM framework.

Parameters	**Description**
m	Number of modes
$\lfloor . \rfloor$	Floor function
K	Number of subcarriers modulated by non-null
n	Cardinality subcarriers, number of modes
(:)	Binomial coefficient
Euler's number	e = 2.7183....

in a wireless map database. The second stage (online) occurs when the sensor is in working condition and calculates the route.

2.2 Subcarrier-index Modulation for FRNs

Subcarrier-index modulation (SIM) results include downlink (MU-C) and physical layer security (PHY-S) [19]. Different SIM scenarios include dual-mode (DM), which is different from the technique of activation of sub-carriers and signal constellations. All scenarios regard the idle state of the sub-carrier as an empty mode containing only the sign "0".

In that context, SIM depends on the index of sub-carrier mode pattern (SMPs) to embed additional data. The sent bits are divided into index bits (Ib) and constellation bits. In Table 1, parameters are shown, which are used in the model of SIM results for FRNs. Index bit helps define which SMPs are chosen and map the constellation bit to the constellation sign based on the chosen SMPS.

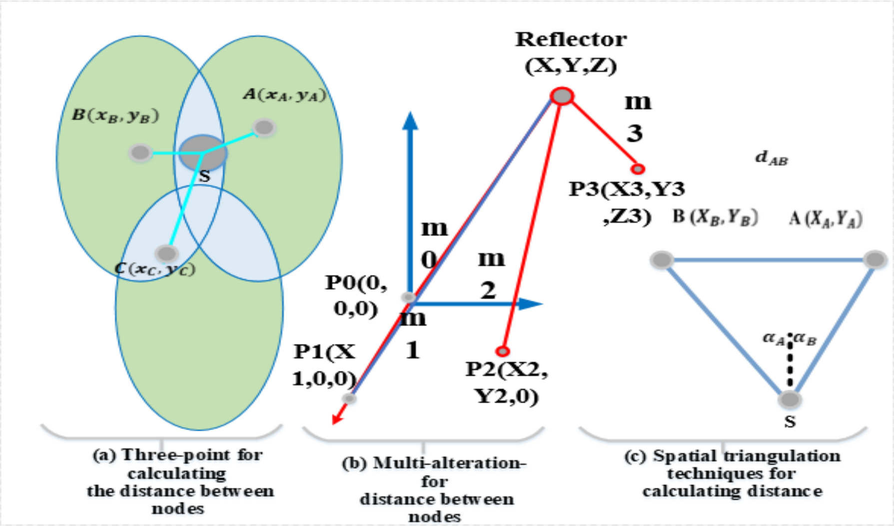
For the sub-blocks of (n), the numbers of SIM may be any integer (2 to n), the i mode is ki than "$m \in \{2, \dots, n\}, i = 1, \dots, m, k_1 + \cdots + k_m = n$", a total of SMPs is possible, so the system SE with $\left(\frac{\text{bps}}{\text{Hz}}\right)$ is represented as follows in Equation 5.

$$\eta = \frac{1}{n}\left[log_2\left(\left(\begin{smallmatrix} n \\ \cdot k_1 \end{smallmatrix}\right)\left(\begin{smallmatrix} n-k_1 \\ \cdot k_2 \end{smallmatrix}\right)\left(\begin{smallmatrix} n-k_1-\cdots-k_m-1 \\ \cdot k_m \end{smallmatrix}\right)\right)\right] + \frac{k}{n}log_2(M) \quad (5)$$

Index and constellation bits respectively correspond to the first and second items on the right. Adjustment of m, k, and k_i values, $\mathrm{i} = 1; \dots, \mathrm{m}$. Any m signal constellation intersection can be selected as m, in theory. However, m is usually obtained through the separation of the PSK, QAM constellation, as defined, to ease symbol Mod/Dem, and provide a good BER efficiency.

2.2.1 Dual-Mode SIM

In OFDM-IM, each sub-carrier is modulated in a conventional manner *M-array* constellation or empty mode, which reduces 1 to $\eta = \left[log_2\left(\begin{smallmatrix} n \\ k_1 \end{smallmatrix}\right)\right] + klog_2(M)/n$, as$m = 2, k_1 = n - k,$ and $k_2 = k$. As described in Figure 3, part of some sub-carriers in OFDM-



(a) Three-point for calculating the distance between nodes

(b) Multi-alteration-for distance between nodes

(c) Spatial triangulation techniques for calculating distance

Figure 3. (a) Three-point scanning technology for calculating the distance between nodes; **(b)** multi-alteration scanning technique for calculating the distance between nodes; and **(c)** Spatial triangulation technique for calculating a distance between nodes.

IM are inactive. The index of sub-carrier activation mode sends additional information bits through IM to enhance OFDM [12].

2.2.2 DM-OFDM

The same IM definition as OFDM-IM is monitored in DM-OFDM, excluding that both modes in DM-OFDM are non-zero, for $\mathrm{M} = 2$, the two non-zero modes are expressed as: $\{-1, +1\}$and $\{-\mathrm{j}, +\mathrm{j}\}$ such that *j* is the imaginary unit as shown in the DM-OFDM section of Figure 3. DM-OFDM's spectral energy is given by $= \left[log_2\left(n!_{k_1}^{n}\right)\right]/n + klog_2(M)$. Therefore, in the same modes, DM-OFDM has a higher SE than OFDM and OFDM-IM. Therefore, DM-OFDM has a higher SE in the same modes [11].

2.2.3 Multi-mode SIM

2.2.3.1 ZTM-OFDM-IM

The integration of OFDM-IM and DM-OFDM is studied within ZTM-OFDM-IM. It has two non-empty modes and a null mode. It attempts to improve the efficiency of

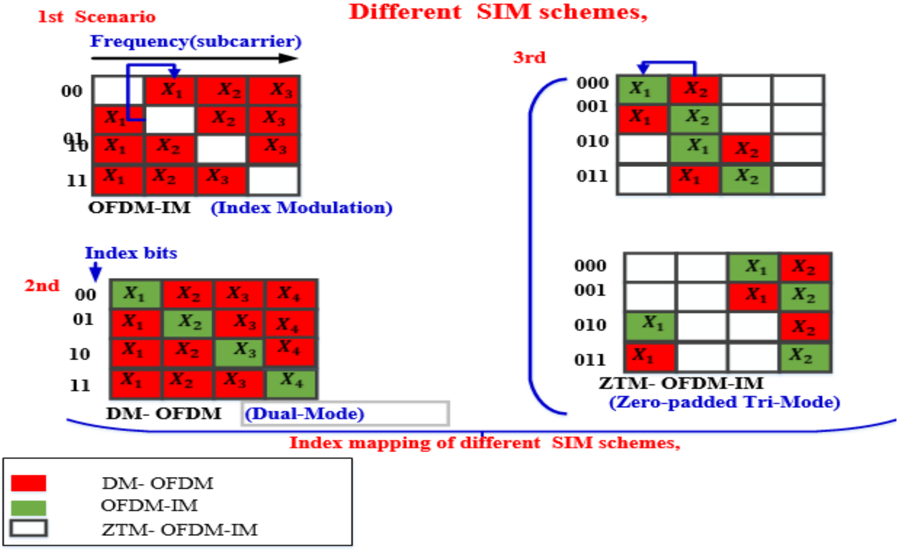


Figure 4. Index mapping for OFDM-IM, DM-OFDM, ZTM-OFDM-IM.

energy and OFDM-IM of DM-OFDM by utilizing multiple modes of DM-OFDM with high spectrum utilization and OFDM-IM with high energy utilization, as explored in Figure 4 part ZTM-OFDM-IM. Figure 4 features OFDM-IM (m = 2; k1 = 1; k2 = k = 3), DM-OFDM (m = 2; k1 = 1; k2 = 3; k =4), and ZTM-OFDM-IM (m = 3; k1 = 2; k2 = k3 = 1; k = 2) index mappings.

2.2.3.2 MM-OFDM-IM

Activated subcarriers transmit smart reflect M-array symbols from various signal constellations. In particular, it is possible to simplify it to:

$$\eta = [log_2(n!)]/n + klog_2(M) \tag{6}$$

Since m = n and $k_1 = \cdots = k_m = 1$. The number of modes is n and the complete replacement of these different patterns is used for IM purposes so that the factorial multiplication of all possible patterns increases MM-OFDM-IM has amplified the sign constellation by n = e times compared to the OFDM (SE). Just in Figure 5 (a), examples of index mapping are shown for MM-OFDM-IM m = 4; k1 = k2 = k3 = k4 = 1; k = 4 where n = 4 modulates the blank elements in null mode and modulates the different colored elements in various non-null modes to bear constellation sign $x1$.

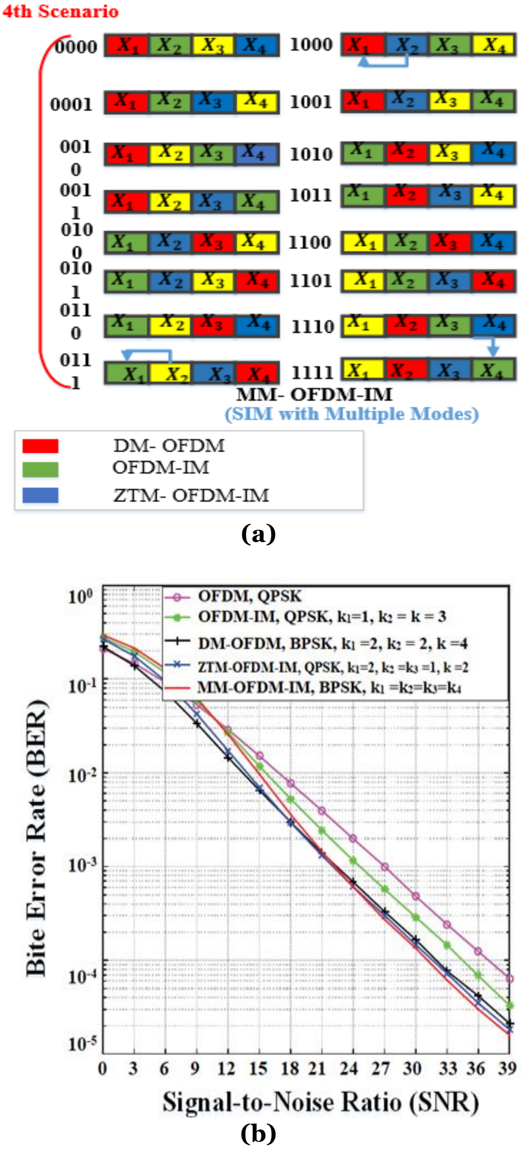


Figure 5. (a) Index mapping for MM-OFDM-IM; and **(b)** OFDM, OFDM-IM, DM-OFDM, ZTM-OFDM-IM, and MM-OFDM-OM efficiency comparison BER with n = 4, great CSI at the receiver, and frequency selectivity ML detector.

2.3 Average BER Probability of SIM Inclusion and Exclusion Criteria

In the middle to high SNR, at 2 bps/Hz SE, the OFDM gains about 3 dB, and SNR gain over the OFDM (WDM). DM and ZTM are even better than the traditional binary PSK (BPSK) OFDM, as shown in Figure 5. Aiming at the BER performance of SIM scenario, of DM, IM, ZTM-OFDM-IM AND MM-OFDM-IM ($n = 4$) and the receiver's perfect channel state results, various detectors are developed, including the optimal ML, log-likelihood ratio, and sequence detector [16]. It is assumed that the ML detector is in the frequency-selective Rayleigh fading channel. The parameters of all schemes are carefully chosen to approximate SEs as closely as possible. MM-OFDM-IM has the best performance in all schemes, although its SE value is higher than that of BPSK, DM-OFDM, and ZTM-OFDM-IM. In particular, under the 2 bps/Hz SE, the SNR gain of up to 6 dB can be achieved on OFDM through MM-OFDM-IM.

2.4 Applications of SIM

2.4.1 SIM in Downlink (MU-N)

Activating separate time slots (sub-carriers) is available in orthogonal time slots, which allows the use of the time slot for sending M sign to modulate partial information bits for each user. Conversely, in this way, when large numbers of users are required, their inter-user interference (IUI) is severe. By implementing OFDM access to SIM technology, we encourage the design of the broadcast system and include unicast and multicast services without causing user interruption [17].

Figure 6 indicates the base station and MM-OFDM-IM signal transfer to support t users at the same time as the unicast stream $b1 \ldots\ldots b_T$ and multicast stream b_0. In base stations, T unicast streams are dispatched and transmitted in different sub-blocks for the purpose of avoiding mutual interference. Notice that the sub-carrier allocation in the OFDM access system can be as adaptive as the sub-carrier allocation to meet various user needs. The multimode SIM generates each sub-block. That is, multicast flow describes SMP, and M-Meta sign is mopped unicast stream after the selected mode. The user-related SMP is first identified for the multicast stream transmitted on each user side; then, while assigning sub-carrier to users, the unicast stream is extracted. The point to be noted here is that additional spectrum/time resources are needed for OFDM transmission of multicast streams.

2.4.2 SIM in the PHY-S

PHY-S has become a popular and prevalent new security alternative that can complement password-based approaches. An OFDM-IM scenario based on PHY-S is being proposed to resolve this problem. The scenario is based on the mapping rules between the valid sender T_x and receiver R_x for index bits and CSI-based constellation bits [18]. Therefore in this regard, the sub-carrier selection is special freedom of degree of SIM. In OFDM, the selection of sub-carrier cannot often be performed technically.

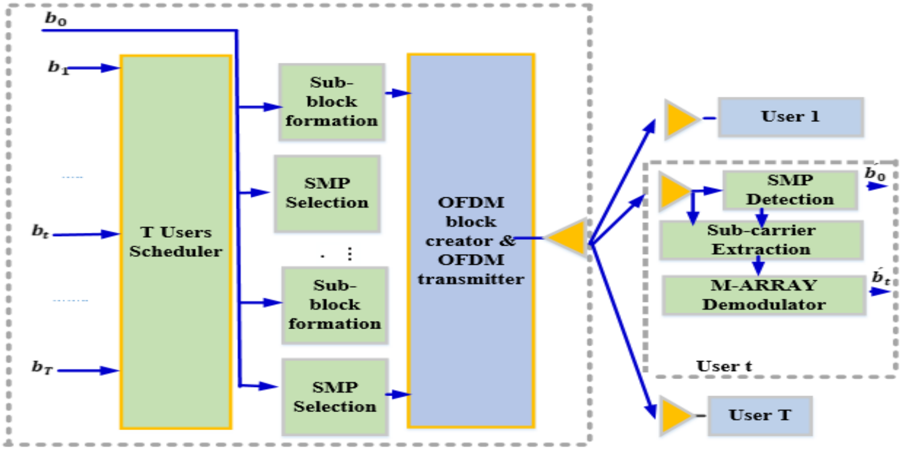


Figure 6. SIM-established downlink MU-C with unicast and multicast streams, where beta b_0 for all users is multicast traffic, and b_T beta for users t is a unicast stream.

In SIM, the array sign of M is restricted to the active sub-carriers. PHY-S in SIM is also distinct from PHY-S in OFDM. Next, we suggest a PHY-S technology based on the CSI OFDM-IM framework, which can simultaneously boost the system's protection and error performance. In Figure 7, the secure OFDM-IM describes (a) model and (b) security sub-block generation such that $\mathrm{n} = 4, \mathrm{k} = 2, \mathrm{M} = 2$, and adopts PSK signaling selection strategy and mode.

The legitimate T_x (Alice) requests to send secure messages via the OFDM-IM signal to the predetermined R_x (Bob) to prevent the due leakage through (Eve) information. So that they feel multiple channels of fading. Since Bob and Eve's R_x structure is identical to the current SIM system, we concentrate only on Alice's T_x structure and explain it in Figure 10. Let b_0 index bits and b_1 constellation bits first pass through the modulator of OFDM-IM, putting out sub-blocks of OFDM-IM. Bob's CSI feedback then processes each sub-block formed. Precisely, when the channel phase of the sub-carrier is greater than zero, then the sign is reversed on the sub-carrier by the actual and imaginary sign of components; in other cases, the sign remains consistent and unchanged. When the channel phases are circulated equally, then the threshold is set to zero. The sub-block is fed into the mode variation module after the reverse sign, which converts non-zero signs to those taken from various modes. Note that the channel phases of n sub-carriers also conduct this mode variation. In other cases, sub-carrier is used as a first mode with the first largest channel phase, then the second priority is given to the second largest mode, and in such a way, the list of priority goes on. Finally, in the resulting sub-block, the sign is re-organized where the non-zero sign can be transmitted over the sub-carriers of the highest channel amplitudes. In other

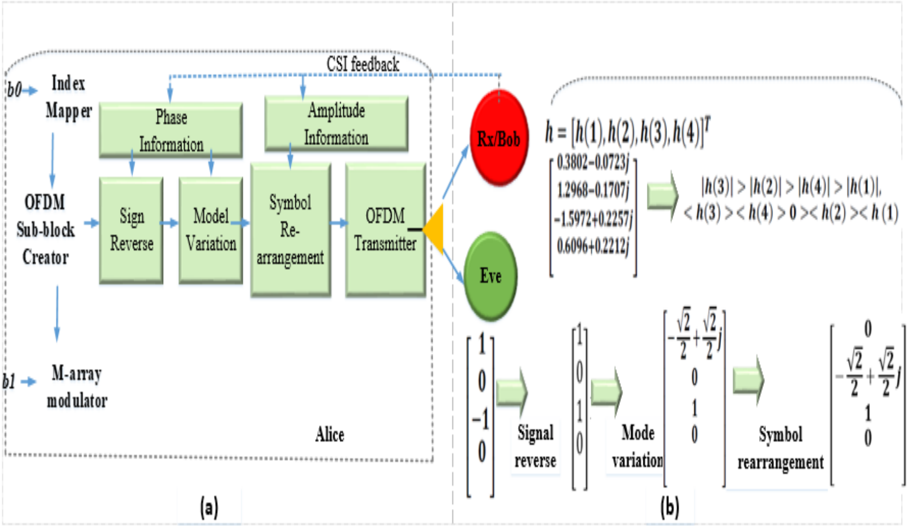


Figure 7. The secure OFDM-IM describes: **(a)** model; and **(b)** security sub-block generation, wheren = 4, k = 2, M = 2, and adopt PSK signaling selection strategy and mode.

words, Model 1 provides an example of a stable sub-block generation. Naturally, we have the active sub-carriers positions as Bob understands the CSI. Consequently, it is only needed for Bob to detect signals on the strongest k sub-carriers with their related modes. After that, the original active subcarrier indications and symbols can be built with the help of the channel's stage and amplitude information. However, Eve's situation is rather distinct. While the index and sign of the active sub-carrier under high SNR can be correctly interpreted by Eve, Due to the absence of CSI in the legal relation, it cannot enhance and sign the original index [19-21].

3. Key Challenges

In FRNs research, there are still many potential problems and challenges, especially in SIM technology. Besides, SIM itself is worthy of further study to promote SIM application and the future importance. Mapping/damping between the index bit and SMPs is a unique process in the SIM system. The low complexity mapping/damping approach is the secret to the SIM system's efficient implementation. Improving bit error performance, especially improving index bit performance, is also an essential guideline for study. The main challenges are listed in Figure 8.

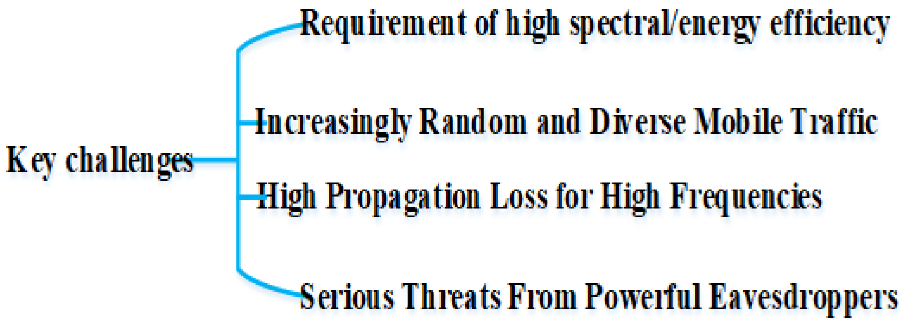


Figure 8. Key challenges of FRNs.

4. Conclusion and Future Work

This paper presents the general concept of IM-assisted SIM as a new paradigm beyond FRNs for the next generation potential 6G. Comprehensive derivation and computer simulation show that SIM in different scenarios can provide high spectral efficiency at very low SNR through an intelligent IM-assisted indexing mechanism. Using SIM-assisted communication scenarios effectively can potentially change the next-generation network, eliminating the need for complex networks. In contrast, future networks require components that are power-consuming and costly. The very low SNR region of operation can be considered a solution for the growing demand for advanced channel coding to obtain ultra-reliable results. From Section 1, the potential application of IM and other refined or generic scenarios, the design of low complexity models, the analysis of possible system defects, and more complex related models are considered an open research problem. Hopefully, our original findings contribute to providing future implementation and hardware damage-related obstacles in the sense of FRNs for 6G. The localization mechanism and its arrival angle in WSN are studied. The simulation results in the scenarios considered show that the accurate estimation of node locations does not require additional nodes when using GPS. By evaluating the efficiency of FRNs as 6G, optimizing the network technology, ensuring the development and management of the network sensor positioning mechanism, and testing the effectiveness of the angle of arrival, the SIM model has shown the promising potential of SIM, as MU-N and PHY-S. This paper revealed that SIM is considered an alternative solution to OFDM in the network model and has potential advantages in SE/BER compared to OFDM. Improving SE or EE, facilitating massive networking, and combining it with massive multi-input multi-output (MIMO) can be included in future SIM research trends.

Notations

Bold, lowercase, and capital letters represent column vectors and matrices, respectively. The real and imaginary parts of a complex variable X. P(.) denotes the event's probability. FX(x), represents the probability density function (PDF), cumulative distribution function (CDF), characteristic function (CF). Spectral/energy efficiency (SE/EE), hybrid automatic repeat request acknowledgment (HARQ-ACK), scheduling request (SR), orthogonal frequency division multiplexing (OFDM), peak-to-average power ratio (PAPR).

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Conflict of Interest Statement

The authors declare no conflict of interest.

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