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RESEARCH

SPIS: Signal Processing for Integrated Sensing Technologies Using 6G Networks with Machine Learning Algorithms

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Abstract

The proliferation of integrated sensing techniques in Sixth Generation (6G) networks is an increasingly significant aspect in facilitating efficient end-to-end communication for all users. The suggested methodology employs a digital signal processed with terahertz bandwidth to assess the impact of 6G networks. The primary focus lies in the design of 6G networks, emphasizing key parameters such interference, loss, signal strength, signal-to-noise ratio, and dual band channels. The aforementioned factors are combined with two machine learning algorithms in order to determine the extent of spectrum sharing among all available resources. Thus suggested approach for detecting signals in the terahertz communication spectrum is evaluated using 10 devices across four situations, which involve interference, signal loss, strength, and time margins for integrated sensing. Also the assumptions are based on signal processing devices operating within millimeter waves ranging from 5 to 10 terahertz. Interference and losses in the specified spectrum are seen to be less than 1%, but the time margin for integrated sensing with 99% maximized signal intensity remains at 85%.

Keywords 6G networks · Integrated sensing · Terahertz communication · Digital signals

1 Introduction

The allocation of a certain range of radio frequencies for use by several generations of networks is crucial for facilitating point-to-point communication between network nodes. In the context of millimeter wave operations, the available bandwidth options typically span from 30 to 300 GHz [1]. However, the advent of Sixth Generation (6G) networks necessitates a greater allocation of radio resources, which entails a shift towards utilizing terahertz frequency ranges [2]. One of the salient attributes of millimeter wave technology is its ability to support high data rates for 6G networks, even at low frequencies [3]. Therefore, considerable importance is placed on the integration of sensing capabilities, allowing 6G networks to acquire knowledge and respond to dynamic environmental conditions. The propagation characteristics of millimeter waves are advantageous for implementing network layer functions, as they allow for significant

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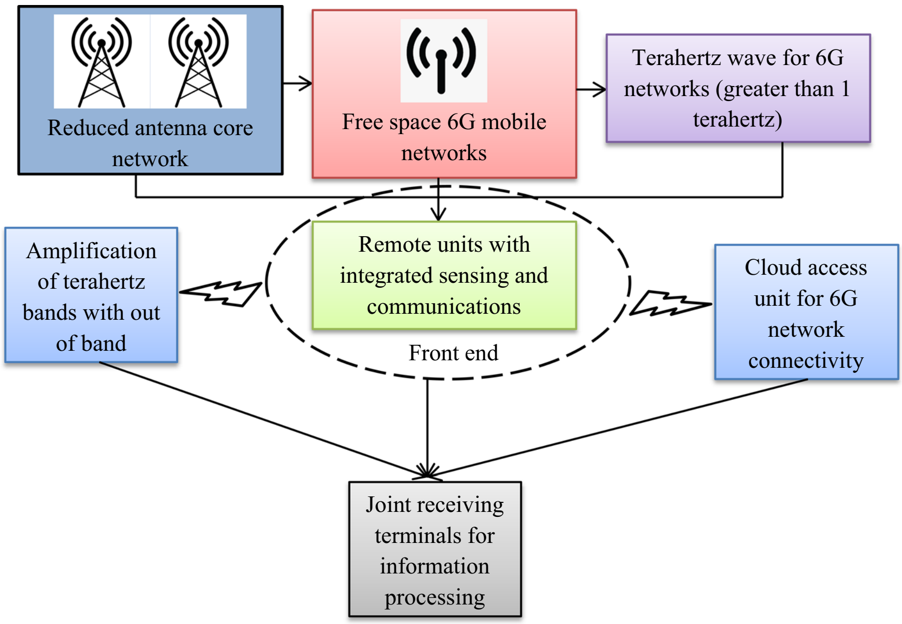

Fig. 1 Terahertz 6G networks for integrated sensing and communications

reduction in path loss inside free space [4]. Furthermore, the utilization of Digital Signal Processing (DSP) enables the integration of many antenna elements in millimeter wave systems, resulting in enhanced gain and improved link performance [5].

On the other hand, the use of Fifth Generation (5G) networks now entails running at significantly elevated frequencies. As a result, the deployment of 6G networks within the required spectrum bands presents a significantly greater level of difficulty. Hence, it is crucial to optimize the learning capabilities of 6G networks to enable efficient allocation of radio resources. The efficient communication for integrated sensing activities is made possible through the utilization of millimeter wave technology, which is distinguished by its wide bandwidth and compact antenna size. This enables the requisite signal to efficiently flow over established Line-of-Sight (LOS) channels. Furthermore, it is imperative to improve the penetration capabilities inside the terahertz frequency range by the augmentation of wave propagation across many channels and spectrum ranges. Figure 1 depicts the block diagram of the proposed 6G networks, which employ terahertz resource allocation. The current arrangement results in a notable reduction in the size of the antenna processing equipment, hence facilitating uninterrupted connectivity for networks operating in open space. After establishing communication with the network infrastructure, the allocation of terahertz frequency ranges can be determined by considering certain wavelength ranges. After the allocation of terahertz operating ranges, the remote units will be interconnected in the front end, facilitating access to cloud networks through suitable amplification within the spectrum ranges. During the last stage, the integration of sensing and communication is implemented across all terminals in order to facilitate information processing, hence enabling the development of a dependable connection.

1.1 Major Contributions

When cross-module sharing, communications, and other issues are required for integrated sensing, the best option is to eliminate all interference and losses in the transmitted signal. Even with well-developed 6G networks, cross-network sharing is problematic because of weak signal strength, which causes different transmission time margins in the channels under consideration. Therefore, by combining machine learning algorithms, the suggested method analyses a number of cross transmission approach factors in the presence of millimetre wave and terahertz communication ranges. Additionally, when suitable resources are assigned to two channels, the outage probability which is represented by a resource consignment that divides random inputs into different probability classes is shown. The signal-to-noise ratio in the integrated sensing process is lowered as a result of proper resource assignment, keeping the receiving systems at the proper boundary points. In order to address the noted deficiencies in the current methodology, the suggested approach introduces a novel system model that incorporates machine learning methods. This integration enables the system to perform integrated operations of sensing and communications, with the following parametric objectives.

- To design a low cost network that operates at minimized interference values in considered spectrum ranges.
- To minimize the signal noise levels by identifying complete characteristics at free space using millimeter waves.
- To maximize the signal strength by operating the 6G networks using dual bands (terahertz communication ranges).

2 Background and Related Works

This section conducts an analysis of the existing literature pertaining to the distinctive features of 6G networks, with the aim of offering a comprehensive understanding of integrated sensing technologies. Numerous academics have proposed diverse methodologies to characterize the impact of preceding generation networks through the optimization of various resource allocations. The introduction of 6G represents an advancement over previous generation networks, characterized by the implementation of distinct wave operating principles and expanded bandwidth ranges. The signal processing strategy employed in 6G networks involves the utilization of terahertz boundary values, as opposed to the conventional approach of defining fixed ranges for operation [1]. In the context of terahertz allocation, a significant proportion of signals are transported across various frequency ranges, resulting in the integrated communication process operating in a state of reduced complexity. In order to build terahertz communication, it is important to mitigate a greater number of undesirable signals from 6G networks, hence posing a significant challenge to current generation networks. Furthermore, the integration of terahertz communication systems with millimeter waves can be achieved, wherein the processing of each state is effectively managed through the utilization of machine learning algorithms [2]. The utilization of machine learning techniques enables the comprehensive observation of entire information pertaining to all states through the usual variation process. In order to achieve compatibility within specified frequency ranges, it is necessary to employ a specific signal processing technique when utilizing millimeter waves in conjunction with machine learning algorithms. In addition, a radio frequency band is introduced as the final component of the communication spectrum, specifically designed for sensing applications. This band operates throughout the 0.1–10 terahertz bandwidth, effectively encompassing the whole spectrum required for processing routine operations [3]. The establishment of a standard operating point for 6G networks can be facilitated through the allocation of bandwidth ranges. However, if these ranges are set, the ability to engage in dynamic operation is hindered, resulting in a decrease in operational efficiency.

In order to effectively handle dynamic activities, a comprehensive analysis is conducted to assess the associated problems, requirements, and potential future prospects. Subsequently, a data processing system incorporating signaling techniques is implemented in conjunction with 6G networks [4]. A comprehensive examination of integrated sensing technologies is conducted in response to the various changes occurring in society. It is found that a top-down strategy can be employed in this analysis. One significant limitation of the top-down strategy in 6G networks is the underutilization of assigned resources at lower levels, resulting in unoccupied spectrum during various time intervals. In order to mitigate the issue of excessive spectrum consumption, researchers have identified the occurrence of blockage in 6G networks resulting from varied access [5].

To address this, they have proposed the introduction of a micro mobility optimal service that covers the entire area. The implementation of micro mobility operations leads to a reduction in the number of antenna elements, while maintaining the network's performance at the same level. However, the introduction of mobility in any network operation might have an impact on signals corresponding to different ranges. Even with routing given for these signals, accommodating them within the required spectrum ranges becomes very challenging. When considering routing, it is necessary to take into account various limits within the spectrum. This includes the identification of distinct materials through the use of joint localization principles [6]. The use of a localization procedure enables the utilization of local spectrums to mitigate reflection loss in both indoor and outdoor settings, facilitating uninterrupted radio access without encountering scattering issues. In order to effectively implement 6G networks under the aforementioned conditions, it is imperative to identify integrated techniques for sensing and communication in a seamless manner. This will afterwards enable the provision of all functionalities inside wireless settings. The utilization of localization principles varies from supporting contexts due to the absence of discernible scattering signals.

One of the recent advancements in terahertz communication networks involves the identification of a two-dimensional material with photonic structures. This material enables the extension of support to 6G networks through the utilization of the magnetization principle [7]. The approaches utilizing photonic structures have limitations in providing only low-dimensional values. In cases where high-dimensional requirements arise, these methods are unable to adapt to changing environmental conditions. The advancement of terahertz modulations has enabled the provision of comprehensive flexibility to networks that remain in an idle state, without the need for integrated sensing capabilities. However, the expansive nature of the network enables the provision of a substantial level of dimensionality, as 6G operations are constructed using non-destructive modes. The transition from 5 to 6G networks enables the interconnection of various technologies, facilitating the selection of frequency ranges without encountering any interference [8]. By selecting frequency ranges that correspond to changing wavelengths, it is feasible to maximize the spectrum and enable the utilization of integrated radar and communication procedures utilizing predetermined radio frequency chains. One significant limitation of combined operations is the potential for irreparable damage and significant distortion if the links are severed. In order to mitigate signal distortion

Table 1 Existing vs Proposed

References	Methods/algorithms	Objectives			
		A	B	C	D
[10]	Reconfigurable Intelligent Surface (RIS) based optimization	✓	✓		
[11]	Multiple Input Multiple Output (MIMO) with terahertz operating ranges		✓	✓	
[12]	Intelligent interference with DSP	✓			✓
[13]	Terahertz communication for material identification			✓	✓
[14]	Millimeter wave pulse detection method		✓		
[15]	Discontinuous reception for power quality monitoring	✓			✓
[16]	Artificial intelligence based wireless network operations	✓	✓		✓
Proposed	Integrated sensing and communication with millimeter wave at terahertz communication range using machine learning	✓	✓	✓	✓

A: Minimization of interference and propagation in 6G networks; B: Varying noise levels; C: Analysis of signal strength; D: Dual band spectrum

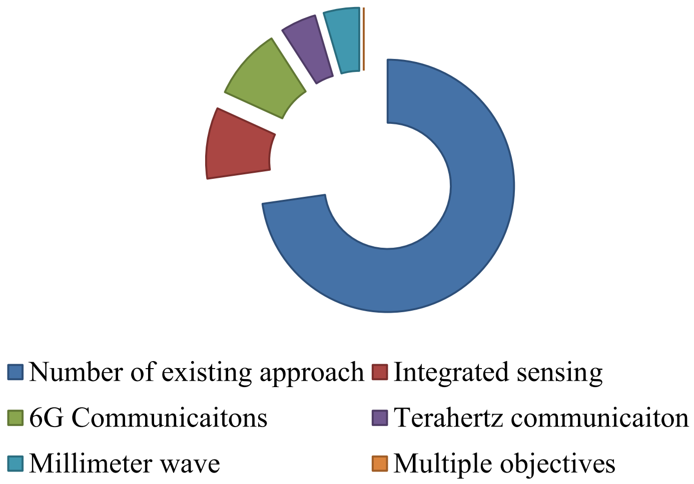

Fig. 2 Objective recognitions for existing approaches

and ensure optimal signal performance, the utilization of millimeter waves has been implemented, particularly in response to temporal variations [9]. This approach facilitates the creation of partly disrupted models within the designated spectrum ranges. When partial distributed models are available, the resulting noise figure will exhibit a significant increase, hence enabling the 6G network to carry out both linear and non-linear operations. In addition to the aforementioned concepts and approaches, Table 1 and Fig. 2 presents a comparison of the most pertinent operations in 6G networks. All of the current methods listed in Table 1 take into account 6G communication as a component of optimization techniques. According to [10], all sensing operations for numerous channels are processed using reconfigurable intelligence surfaces, but in this case of detections, interference cannot be equalized under any circumstances. Similar to this, [11] uses several users to perform a beamforming method for functioning in terahertz frequencies, increasing the overall signal intensity. Nevertheless, this kind of system's /time margins expand at different operating ranges, thus a strong signal will persist and go underutilized. As a result, using millimetre waves, an intelligent sensing technique with DSP units is implemented [12], improving the way the results are observed. Even so, DSP approaches can improve an integrated system, therefore allowing for the coexistence of various signals with distinct route utilizations is crucial. Similar to this, in today's networks, material identifications are handled via terahertz communications [13]. If multiple materials are present and have different impacts, a combined sensing procedure is required in these situations when maintenance issues are more noticeable. Furthermore, every pulse is identified using the 6G communication spectrum across many bands [14] by improving signal precision; nonetheless, the likelihood of detection is constrained when dealing with clusters. On the other hand, boundary restrictions exist in [15] because the majority of sensing procedures in 5G networks are performed with low outage probability, allowing users to witness discontinuous receptions in terms of power spectrum.

The utilization of cross transmission techniques is crucial to mitigate packet congestion in present and future networks, as a greater number of users will fill the available spectrum. Furthermore, the use of 6G networks in integrated sensing opens the door to several three-dimensional applications linked to modernization, navigation, and position identification. Therefore, the suggested approach lays out a clear course for finding new uses for millimetre wave and terahertz communication with 6G networks.

2.1 Research Gap and Motivation

The communication signal performance in earlier generation networks (3G/4G) was constrained by a number of factors, including the fact that all signals were transmitted at the same frequency ranges on the allotted channels, making it very challenging to maintain low interference levels for transmitted packets. Furthermore, there is a greater likelihood of outages, which prompts the receiver to respond outside of predetermined parameters and leaves the majority of signals unused. Therefore, reduced free space losses are taken into consideration when carrying out integrated sensing procedures in order to surpass the present baseline ratio. The analysis of Table 1 reveals that a significant number of advanced technologies have been established for the purpose of evaluating the performance of 6G networks. However, the majority of algorithms are unable to effectively adapt to changes in the environmental spectrum due to the fact that given resources do not conform to specific constraints.

Furthermore, it should be noted that none of the methods mentioned are aligned with the fundamental principles of millimeter wavelengths. Consequently, the implementation of terahertz communication for extended wireless support is not adequately established. In order to ensure optimal functionality, the 6G network necessitates localization within a specific range, even when employing millimeter waves. This localization is necessary to mitigate the interference caused by noise signals, hence enabling the network to operate effectively within dual spectrum ranges. Hence, the discovered deficiency in the current methodology must address the following inquiries.

RG1: Whether the 6G networks can provide integrated sensing and communication with low interference and propagations?

RG2: Can the network operations be extended with low noise spectrum with the presence of millimeter waves?

RG3: Is it possible to maximize the signal strength during communication mode with automated learning process?

RG4: Will the dual band spectrum support the 6G networks at terahertz bandwidth operations?

3 Proposed System Model

The incorporation of integrated sensing technologies in the construction of 6G networks assumes a significant role in facilitating DSP functionalities. Therefore, it is of great significance to develop 6G networks that are designed considering signal wave circumstances. In the proposed model, millimeter wave representations are incorporated. The development of sensing and communication technology heavily relies on high data rate signals, leading to the exploration of terahertz ranges in analytical representations. Since a significant portion of communication technology design relies on mathematical models, the proposed method takes into account the computational techniques that are represented as follows and the flow representations for parametric detections is provided in Fig. 3.

3.1 6G Wave Propagation

In the majority of software-defined architectures, it is feasible to arrange the system states such that each wave can be propagated using a micro channel model, hence optimizing the utilization of the full spectrum. Therefore, the Line of Sight (LOS) sites are designated for the purpose of determining the propagation constants, as denoted in Eq. (1).

$$PL_i = min \sum_{i=1}^{n} (C_{p1} + .. + C_{pi}) d_i + 20 \log_{10} f_c \tag{1}$$

where $C_{p1} + .. + C_{pi}$ denotes propagation constants. d_i represents total propagation distance. f_c indicates carrier frequency.

Equation (1) establishes that the propagation of millimeter waves over long distances is contingent upon minimizing line-of-sight (LOS) obstacles. Therefore, the carrier frequency is modified utilizing a micro channel model in the absence of any obstructions in the channel representations.

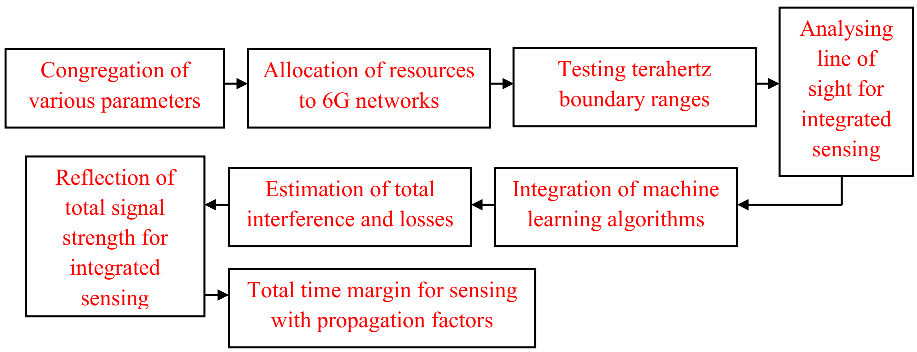

Fig. 3 Flow diagram of parametric detections in proposed method for integrated sensing

3.2 Level of Interference

In the context of next-generation networks, it is observed that the implementation of millimeter wave operations can result in a significant increase in interference levels. Consequently, there exists a potential for the presence of external noise figures within the channel. Therefore, it is imperative to minimize the level of interference by employing Eq. (2) in the following manner.

$$I_i = min \sum_{i=1}^{n} \frac{power_i \times G_i}{N_t BW_i + int_{in}} \tag{2}$$

where $power_i$, G_i represents input power and gain. N_t denotes thermal noise. BW_i, int_{in} indicates bandwidth and interference margins.

According to Eq. (2), minimizing the input power results in a reduction of thermal noise within the system, thereby leading to a decrease in total interference within the channel. The act of minimizing enables the generation of a signal capable of achieving terahertz communication range.

3.3 Free Space Loss

In the context of 6G communication, it is important to consider the potential impact of environmental factors on signal loss when millimeter waves are transmitted across free space. Hence, the quantification of signal loss is conducted at both the transmitting and receiving ends, wherein the measurement accounts for both the reflected and incident angles, as indicated by Eq. (3).

$$SL_i = min \sum_{i=1}^{n} Tr_p - Rr_p \tag{3}$$

where Tr_p, Rr_p denotes transmission and reception power of 6G signals.

Equation (3) offers a means of quantifying the assessment of transmitter and receiver signal properties, taking into account the presence of active signals. When encountering reflected waves, the overall signal along the path is regarded as free space loss, which should be minimized due to the potential for the reflected millimeter wave signal to traverse multiple mediums.

3.4 6G Signal Strength

In order to ensure uninterrupted network connectivity, it is important to conduct an analysis of the signal strength percentages in the presence of varying intensities, taking into account the dynamic nature of the surrounding settings. Therefore, the magnitude of signal strength is assessed in relation to both the on and off states. If the percentage of on signals is greater, the maximum level of signal intensity can be employed, which is determined by Eq. (4) as stated below.

$$strength_i = max \sum_{i=1}^{n} \frac{O_c - O_i}{O_i} \times 100 \tag{4}$$

where O_c, O_i denotes signal concentration in both off and on conditions.

According to Eq. (4), when there is a significant disparity between the off and on states, the signal strength can be optimized despite the presence of intensities. Consequently, by employing terahertz modulation, it becomes feasible to transmit signals over extended distances.

3.5 Narrowband 6G Communications

In the context of communication spectrums, it is imperative to acknowledge the presence of two signals that propagate under millimeter wave conditions. Consequently, it becomes essential to incorporate narrowband waves into the analysis of radio resources, which are characterized by the transmission of multipath signals. Hence Eq. (5) is derived to model the transmission of information across multipath channels to many destinations.

$$Dual_i = max \sum_{i=1}^{n} \sqrt{\frac{\rho_t + \rho_r}{\rho_m}} l_g \tag{5}$$

where ρ_t, ρ_r denotes number of transmitters and receivers. ρ_m indicates number of multipath. l_g represents gain of two paths.

Equation (5) elucidates the imperative of optimizing the gain of sent and received signals inside multipath channels, hence necessitating the utilization of narrow band modulation techniques employing terahertz waves in the context of 6G networks.

3.6 Signal to Noise Ratio

In the context of 6G networks, it is anticipated that a higher number of signals will experience interference within the same spectrum. This interference is mostly attributed to the presence of several forms of noise. It is imperative to take into account additional sources of noise that alter the properties of the signal, as stated in Eq. (6), notwithstanding the presence of thermal noise during system evaluations.

$$SNR_i = min \sum_{i=1}^{n} \frac{transmit_p}{DC_i} - O_n(i) \tag{6}$$

where DC_i denotes interference cancellation. $transmit_p$ indicates total transmit power. O_n describes the presence of other noise.

Equation (6) establishes that by cancelling interference in the transmitted signal power, it is possible to diminish the presence of undesirable signals. If other noise signals are effectively mitigated, it is possible to achieve total reduction in signal-to-noise ratio without any further adverse impacts in the context of 6G networks.

3.7 Time Margin

The majority of channels within 6G networks are managed by the utilization of time margins, whereby each signal is partitioned into many clusters. Hence, when clusters are present, it is imperative to observe the channel response as denoted by Eq. (7).

$$\tau_i = max \sum_{i=1}^{n} cluster_i \theta_d \theta_a \tag{7}$$

where $cluster_i$ denotes multiple paths for 6G signals. θ_d, θ_a represents angle of departure and arrivals respectively.

3.8 Objective Functions

The objective functions in 6G networks are formulated by taking into account all the parametric circumstances. The min–max constraints are assessed through the use of Eqs. (8) and (9). The objective functions that have been formulated are a case study focused on enhancing the efficiency of 6G networks by considering the use of millimeter waves and terahertz connectivity.

$$obj_1 = min \sum_{i=1}^{n} PL_i, I_i, SL_i, SNR_i \tag{8}$$

$$obj_2 = max \sum_{i=1}^{n} strength_i, dual_i, \tau_i \tag{9}$$

Equations (8) and (9) indicates the multi-objective functions with min–max criteria that functions with respect to considered parameters. Hence for the minimization case the propagation constant where wave propagation is measured must be minimized in 6G communication networks which is indicated as PL_i. Similarly the other reduction factors denote interference, losses and signal to noise ratio. Conversely for maximization in the process of integrated sensing 6G signal strength, dual band communication and time margin that includes multiple path for detection in considered signals must be increased for all millimetre waves where integrated sensing of digital signals are processed. The integration of goal functions with machine learning algorithms is essential in assuring the effective operation of 6G networks. Therefore, the process of integration is delineated through a series of algorithmic phases in Sect. 3.

4 Machine Learning for 6G

In order to meet the connectivity requirements of forthcoming wireless networks, an improved network connectivity is needed. This enhanced connectivity is achieved through the utilization of machine learning techniques, which facilitate the system's ability to accommodate extensive resource access. In contrast to conventional radio networks, 6G networks provide the capability to effectively train each channel within the available spectrum through the utilization of machine learning algorithms. This approach enables the optimization of network performance to its maximum potential. All data transmitted throughout the network will undergo analysis and testing to ensure that the signal is processed without any interference from the initial stage [17–19]. One of the primary justifications for prioritizing machine learning is the potential to optimize a greater number of large-scale performances in 6G networks, hence establishing improved overall performance. The resolution of security issues in 6G networks can be achieved by the use of a clustering approach, wherein each desired signal is divided into multiple clusters, facilitated by large-scale computations. Additionally, it is feasible to enhance the operational efficiency of the network by employing machine learning methods for distributed performance in 6G networks. The selection of machine learning algorithms is influenced by many limitations present in conventional algorithms that aim to enhance the functionality of 6G wireless networks. Many standard algorithms face challenges in terms of computing difficulties and robustness when applied to 6G network operations. Moreover, machine learning algorithms has the capability to adjust and acclimatize to dynamic surroundings, as they undergo training and evaluation processes that are tailored to outdoor situations. Moreover, the incorporation of sensing capabilities enables the 6G networks to acquire knowledge, optimize performance, make decisions, and take actions based on machine learning principles. The proposed methodology involves the selection of two optimal algorithms in the field of supervised learning for the purpose of conducting parametric evaluations and comparisons. These algorithms encompass nearest neighbor classifiers and support vector machines.

4.1 Support Vector Machine

In the context of 6G networks, it is necessary to establish a clear demarcation between communication lines and spectrums in order to facilitate the provision of integrated sensing capabilities across certain frequency ranges. Therefore, the suggested method incorporates a support vector machine that utilizes maximum and minimum margin settings. This allows for the definition of 6G ranges without the need for any loss medium. The 6G networks undergo training using labeled data resources, which enables the generation of predictions at the output for certain target functions. In the context of support vector machines, each dataset is partitioned into several classes of separable data, allowing for the allocation of supplementary resources to address any potential interference from signals. Moreover, the support vector machine is capable of effectively handling high-dimensional data in the context of future advancements in 6G networks. The inclusion of high and low data sets inside 6G networks offers significant functional benefits across the whole radio spectrum. This enables the flexibility to modify signal spectrum and channel utilization based on individual requirements. One notable benefit of employing support vector machine in 6G networks is the ability to make prompt decisions on spectrum utilization. This is achieved by categorizing the spectrum into primary and secondary bands based on comprehensive evaluation of cognitive attributes. Support Vector Machines (SVMs) accurately classify the dataset based on the available spectrum, allowing for efficient millimeter wave communication at each decision boundary. Moreover, the regularization capabilities inherent in support vector machines offer a flexible approach to include terahertz communication into any dimensional space. The mathematical formulation of the support vector machine model in 6G networks, using well-defined boundaries, can be expressed as follows.

4.1.1 6G Band Separation

An essential resource for the development of 6G networks involves the allocation of a distinct set of channels, wherein each input point is effectively isolated through the utilization of input functions. Therefore, Eq. (10) defines two distinct categories of bands that are designated for the purpose of integrated sensing and communication functions.

$$band_i = \sum_{i=1}^{n} f_o + \left(f_i z_i\right) \tag{10}$$

where f_o,f_i denotes first and last band of frequencies. z_i represents input functions.

Equation (10) describes that band of frequencies are added and for every input set the classification process is carried out as separation process.

4.1.2 Point of 6G Networks

Support Vector Machines (SVMs) utilize high-dimensional space, where linear parameters are employed to represent the vectors in this space. Consequently, SVMs offer an alternative approach to DSP, allowing for the representation of signals in curved shapes instead of straight lines.

$$dim_i = \sum_{i=1}^{n} \left(z_1 + .. + z_i\right)^{\aleph} \tag{11}$$

where $\aleph$ indicates the dimensionality (number of users).

Equation (11) describes that if more number of users is present in the defined spectrum then based on dimensions the spectrum shape can be defined for integrated operations. Boundaries must be restricted for all 6G networks that use terahertz communication features for integrated sensing, as a cooperative mechanism is used in these situations. Because users are always restricted to specific boundary ranges when utilizing cooperative techniques, curved representations rather than straight lines can be created using SVM, allowing for the consideration and feeling of all available regions.

4.1.3 Radial 6G Networks

Given that signals are processed using digital methods, it becomes feasible to construct a localized integrated operation for communication. This enables the utilization of alternate operations that dictate the radial functionalities of a 6G network. Therefore, the radial 6G network may be mathematically described by utilizing the exponential function in the following manner.

$$rad_i = \sum_{i=1}^{n} e^{-\left(z_1 + .. + z_i\right)^2} \tag{12}$$

Algorithm 1 Support vector machine

Begin PROCEDURE SVM
Given
$z_1 + .. + z_i$: Input data functions
f_o: Band of frequencies
for i=1:n **do**
1. $band_i$ for dividing entire spectrum based on wavelength
2. dim_i for changing the spectrum shape according to dimensions
end
else
for all i=1:n **do**
3. rad_i for exponential functions to achieve local solutions
end
end PROCEDURE

To attain locally optimal solutions, radial 6G networks are examined, wherein the dimensions specified in Eq. (11) need to be expanded to accommodate a growing user base. Consequently, Eq. (12) employs a different communication selection mechanism to enable integrated sensing features, thereby maintaining access to all independent channels in terahertz communication without any white space.

The algorithmic flow for support vector machine for 6G networks is provided and the block representation are deliberated in Figs. 4 and 5.

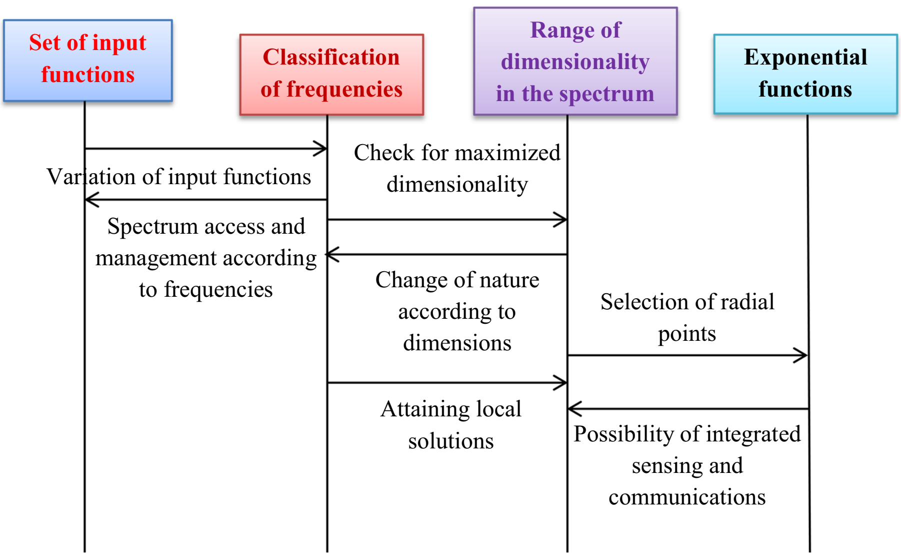

Fig. 4 Support vector machine for 6G integrated sensing and communications

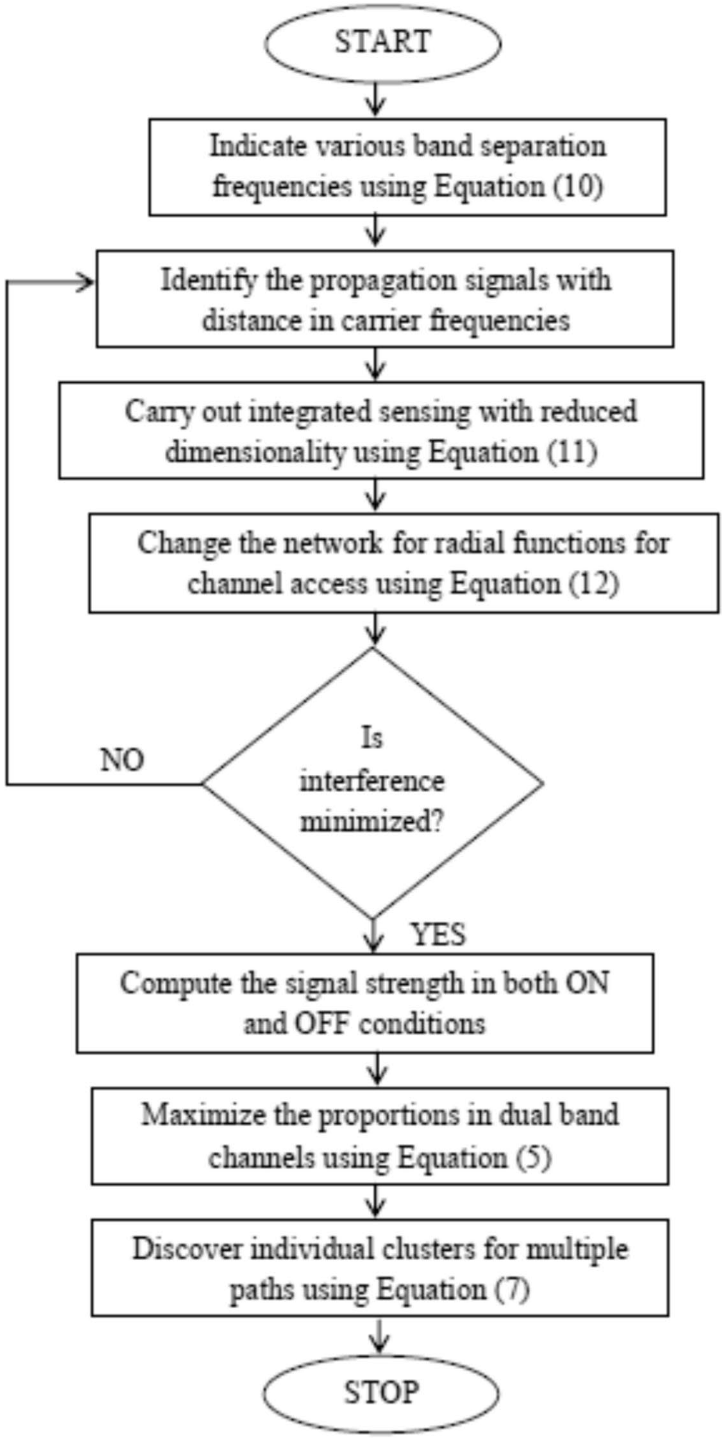

Fig. 5 Flow chart of SVM for integrated sensing

4.2 K-nearest Neighbor

In the context of 6G, the integration of sensing and communication processing systems involves identifying several points of resemblance, which facilitate the combination of underutilized spectrum ranges. Once the various ranges of the spectrum are merged, it is generally considered that any remaining places not belonging to these ranges are vacant or unoccupied. Hence, the K-Nearest Neighbors (KNN) algorithm can be incorporated into the goal functions in order to select the nearest neighbors that yield the most optimal classification improvements. This allows for the selection of modulation channels that exhibit the highest classification changes. Moreover, it is conceivable that all 6G networks have the capacity to retain vast amounts of data. Consequently, 6G gadgets possess the capability to adapt and acquire knowledge from dynamic surroundings, as well as perceive and utilize the existing dataset to anticipate forthcoming alterations. Furthermore, the utilization of K-nearest neighbors (KNN) in the context of 6G networks enables the operation of neighboring devices at distinct frequency ranges. This characteristic is widely seen as a key benefit, as it allows for the efficient sharing of frequency ranges among multiple users. Moreover, the K-nearest neighbors (KNN) algorithm makes decisions for each resource inside the 6G spectrum ranges, so transforming the execution of various operational stages into separate different phases. In the initial state, two distinct locations are selected and connected by a straight line. This connected form allows for the execution of integrated operations that are suitable for the given surroundings. Although the K-Nearest Neighbors (KNN) algorithm lacks the ability to adapt to dynamic situations, it can nevertheless operate effectively by leveraging a combined approach that involves sharing resources with its closest neighbor. By utilizing the aforementioned correlation, it becomes feasible to construct a novel collection of data points, hence facilitating the removal of resilient noise from 6G networks. One additional benefit of KNN is its ability to achieve high precision in integrated sensing and communication through the use of millimeter waves, without requiring any prior training. The mathematical formulation of the K-Nearest Neighbors (KNN) algorithm in the context of 6G networks can be expressed as follows.

4.2.1 Integrated Sensing Distance

In order to enhance the effectiveness of integrated sensing and communication ranges, it is necessary to conduct distance measurements of each neighboring unit for the purpose of suitable resource allocations. In the context of 6G networks, a significant proportion of signals are designed to function at their maximum range. This enables the potential for long-distance communication by employing distance representations, as outlined in Eq. (13).

$$KNN_{dist} = \sum_{i=1}^{n} \left(PO_1 - PO_i\right) + PO_n \tag{13}$$

where PO_1, PO_i and PO_n represents neighboring point distance.

Equation (13) indicates that the difference between neighboring points must be minimized therefore an average distance measurement can be processed at all considered points where resources are shared at average distance values.

4.2.2 Resource Allocation with KNN

The allocation of resources for all defined 6G networks is contingent upon the distance measurements. In the suggested technique for efficient sensing and communication utilizing millimeter waves, resources are shared with the nearest neighbors, as denoted in Eq. (14).

$$KNN_{RA} = \sum_{i=1}^{n} NE_i \rightarrow NE_1 \tag{14}$$

where NE_i, NE_1 indicates neighboring resources that is shared with first user in network.

Algorithm 2 K-Nearest Neighbor

```
Begin PROCEDURE KNN
    Given
     PO_i, PO_n: Number of neighboring points
     NE_i, NE_n: Number of neighboring resources
    for i=1:n do
        1. KNN_dist for calculating the distance between available neighboring points
        2. KNN_RA for sharing the resources with neighboring units
    end
    else
    for all i=1:n do
        3. RC_i for performing resource consignment with available neighbors
    end
end PROCEDURE
```

4.2.3 Resource Consignment

In order to ensure the proper allocation and distribution of resources, it is imperative to employ input variables for verification. Consequently, it becomes necessary to assign some inputs to a probability class, enabling the invocation of neighboring entities throughout the sensing process. Hence Eq. (15) is derived to establish a comprehensive framework for defining a set of resource consignment in the following manner.

$$RC_i = \sum_{i=1}^{n} \frac{NE_i \rightarrow NE_i}{sen_i} \tag{15}$$

where sen_i indicates number of integrated sensing process.

Equation (15) denotes that all consignments are processed with large network sharing therefore there is an increase in number of sensing units. The algorithmic flow for KNN in 6G networks is provided as follows and the block representation are deliberated in Figs. 6 and 7.

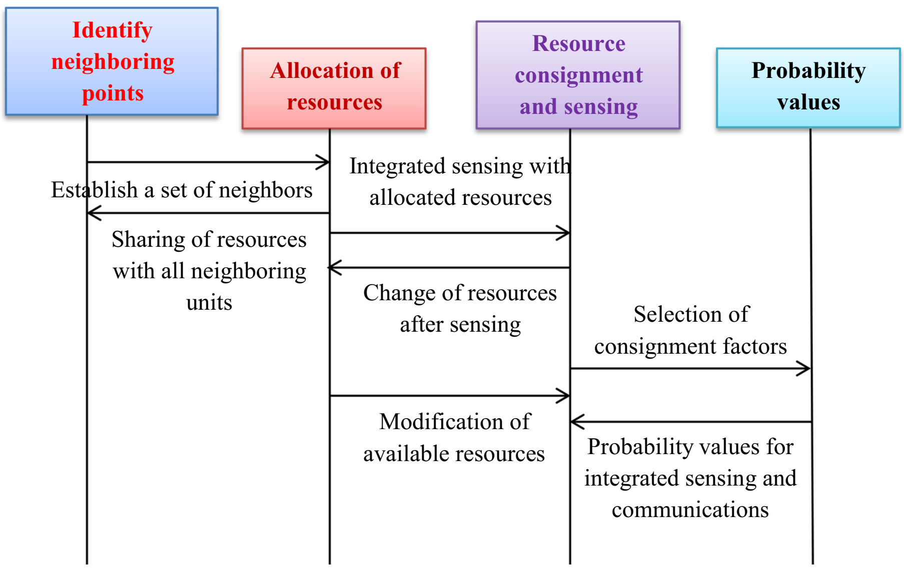

Fig. 6 KNN for 6G integrated sensing and communications

5 Results

This section presents an examination of real-time analysis for the suggested method, utilizing both support vector machine and K-nearest neighbors algorithms. The aim is to evaluate the potential of 6G networks in facilitating integrated sensing and communication through the application of DSP techniques. In order to conduct real-time experimentation, a total of ten devices have been equipped with specifications capable of supporting 6G technology. These devices have the capability to effectively span millimeter wavelengths. In the case of all ten 6G networks, the assigned frequency ranges are established within the 5 to 10 terahertz region, ensuring the transmission of signals at high data speeds inside the system. In the early phase, there may be discrepancies in some frequencies within the millimeter wavelength range. Consequently, a learning technique is employed to facilitate signal sharing, while ensuring that environmental parameters remain unaffected. On the other hand, signals that fall outside the designated spectrum ranges are deliberately avoided, resulting in line-of-sight (LOS) being established solely for a restricted set of signals that are present inside the spectrum. In the context of 6G networks, the utilization of high frequency spectrum ranges necessitates the evaluation of interference levels during preliminary stages prior to transmission. It has been observed that the designated signals experience minimal interference when provided with adequate power. In order to get real-time outcomes, a dual communication network is devised, wherein one pathway is designated for transmission purposes, while the other is allotted for the reception of diverse signals. To mitigate the risk of failure in digital signal transmissions, it is imperative for networks to maintain a continuous "on" state during the entire duration. During this active state, the majority of signals establish high-dimensional and radial points without any kind of sharing. In the final stages, the low-dimensional signal exhibits a comprehensive spectrum, enabling any user to access all resources using integrated sensing technologies. During the aforementioned sharing procedure, coverage regions are partitioned into clusters based on

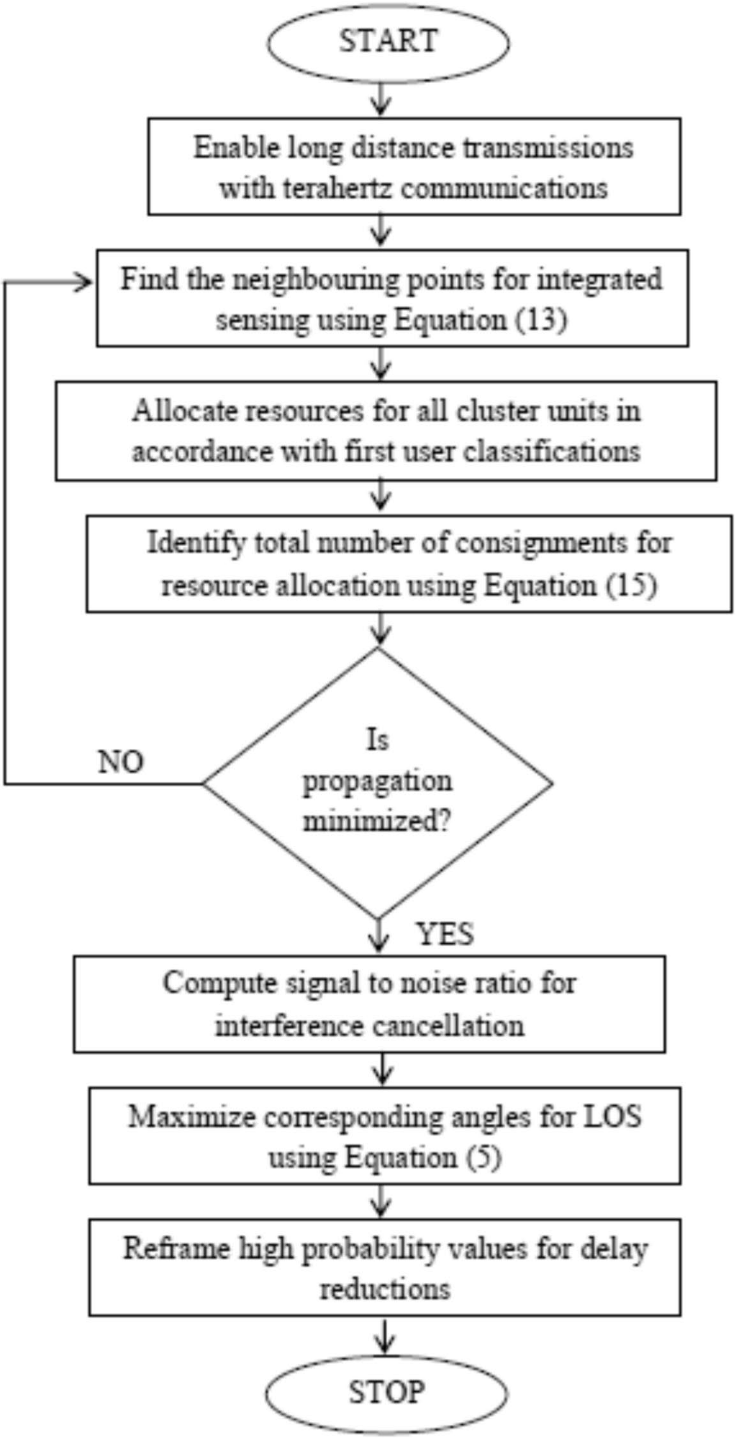

Fig. 7 Flow chart of KNN for integrated sensing

Table 2 Significance of parametric scenarios

Scenarios	Importance
Level of propagation and interference	To reduce the interfering signals at low propagation values
Amount of losses with noise ratio	To ensure low loss values and noise spectrums for desired signals
Maximization of signal strength	To increase the amount of strength for integrated sensing to all desired signals
Convention dual bands and time margins	To integrate two band process according to varying time periods

Table 3 Simulation parameters

Bounds	Requirement
Operating systems	Windows 8 and above
Platform	MATLAB communication toolbox
Version (MATLAB)	2018 and above
Version (Communication toolbox)	1.6
Applications	6G network design and sensing with communication
Data sets	Number of desired signals with device communications

varied distance points, and consignments are allocated accordingly. In order to assess the results, a series of parametric scenarios have been devised and their importance has been documented in Table 2.

Scenario 1: Level of propagation and interference.

Scenario 2: Amount of losses with noise ratio.

Scenario 3: Maximization of signal strength.

Scenario 4: Convention dual bands and time margins.

All of the aforementioned situations were evaluated using a carefully prepared experimental setup. The resulting outcomes were then compared and analyzed in order to facilitate further investigations. Decisions were reached by comparing MATLAB graphs that were simulated using the communication toolbox. The primary rationale for conducting plot and three-dimensional analyses lies in the inherent limitations of altering device setup to examine variations under specific conditions. Consequently, all modifications are implemented within the specification tool box, while comprehensive details regarding simulation platforms can be found in Table 3.

The communication toolbox can also be used in the design stage thereby a suitable path can be established in the network in order to perform device-to-device communications with changing radio spectrum. The detailed description of all parametric scenarios is as follows.

6 Scenario 1: Level of propagation and interference

The propagation and interference of signals in 6G networks may result in the potential loss of the entire transmission under some circumstances. Therefore, in order to mitigate such circumstances, the propagation waves are examined by taking into account the factors of distance and carrier frequencies. The logarithmic value of the distance separation between examination points offers a method for determining the optimal line-of-sight (LOS) for all communications, hence enhancing the propagation characteristics of terahertz waves during transmission and reception. The extent of interference in the systems is further examined in relation to the input power provided, with significantly greater variances detected when the gain is maximized. In the aforementioned scenario, it is possible to decrease the input power level as a means of addressing limitations related to bandwidth and interference. In contrast, the integration of sensing processes involves a distinct separation of power and gain values, resulting in a reduction in interference margins.

Figure 8 and Table 4 illustrates the comparison outcomes for propagation and interference where both the considered parametric values are reduced in projected model as compared to existing approach. To verify the considered scenario total propagation distance is set at 4.16,4.82,5.45,6.23 and 6.91 with input power values as 5,7,10,13 and 15 respectively. In the above mentioned values as maximum distance measurements are provided for signal propagation it is highly possible to reduce the amount of interference in the system. Moreover with increasing gain, the input margin increases in a direct proportional amount thus the system adapts to current environmental conditions.Please confirm the section headings are correctly identified.correct

As self-adaptation procedure is provided in the learning phase of machine learning algorithms the integrated sensing process can be carried out at low interference values. With the considered distance the interference for proposed system remains at 10,7,3,2 and 1 percent whereas in existing approach percentage of interference is 14,11,9,6 and 4 respectively.

7 Scenario 2: Amount of Losses with Noise Ratio

It is imperative to ensure that only the intended signal is present in each spectrum region. The presence of any undesirable signals can lead to failure mode in integrated sensing. In order to mitigate instances of failure, an analysis is conducted on the extent of free space loss in the suggested strategy. The quantification of free space loss can be achieved by evaluating the transmission and reception power of signals, with the discrepancy between the sent and received power serving as an indicator of the overall signal loss in the designated spatial segments. In addition to the representation of noise, it is possible that additional external sources of noise may also be accounted for. The separation between transmit power and interference cancellation contributes to the determination of the overall signal-to-noise ratio in the context of 6G networks. Moreover, in the event that there is a requirement to mitigate additional noise, the system can be designed to incorporate direct reduction scenarios. However, if interference is not effectively cancelled, the 6G networks may have a higher level of loss than initially anticipated. The simulation outcome of loss measurements is presented in Fig. 9.

From Fig. 9 and Table 5 it is obvious that total amount of loss in signals are reduced in proposed method as compared to existing approach. To verify this scenario in real time the transmitted power is considered with same values in scenario 1 and the interference cancellation percentage with output values from previous scenario is considered to be 43,47,54,59 and 65 respectively. For the above mentioned interference cancellations and power values the percentage of loss is much higher for existing method thereby the amount of desired signals in 6G is reduced. Whereas in proposed method the loss values

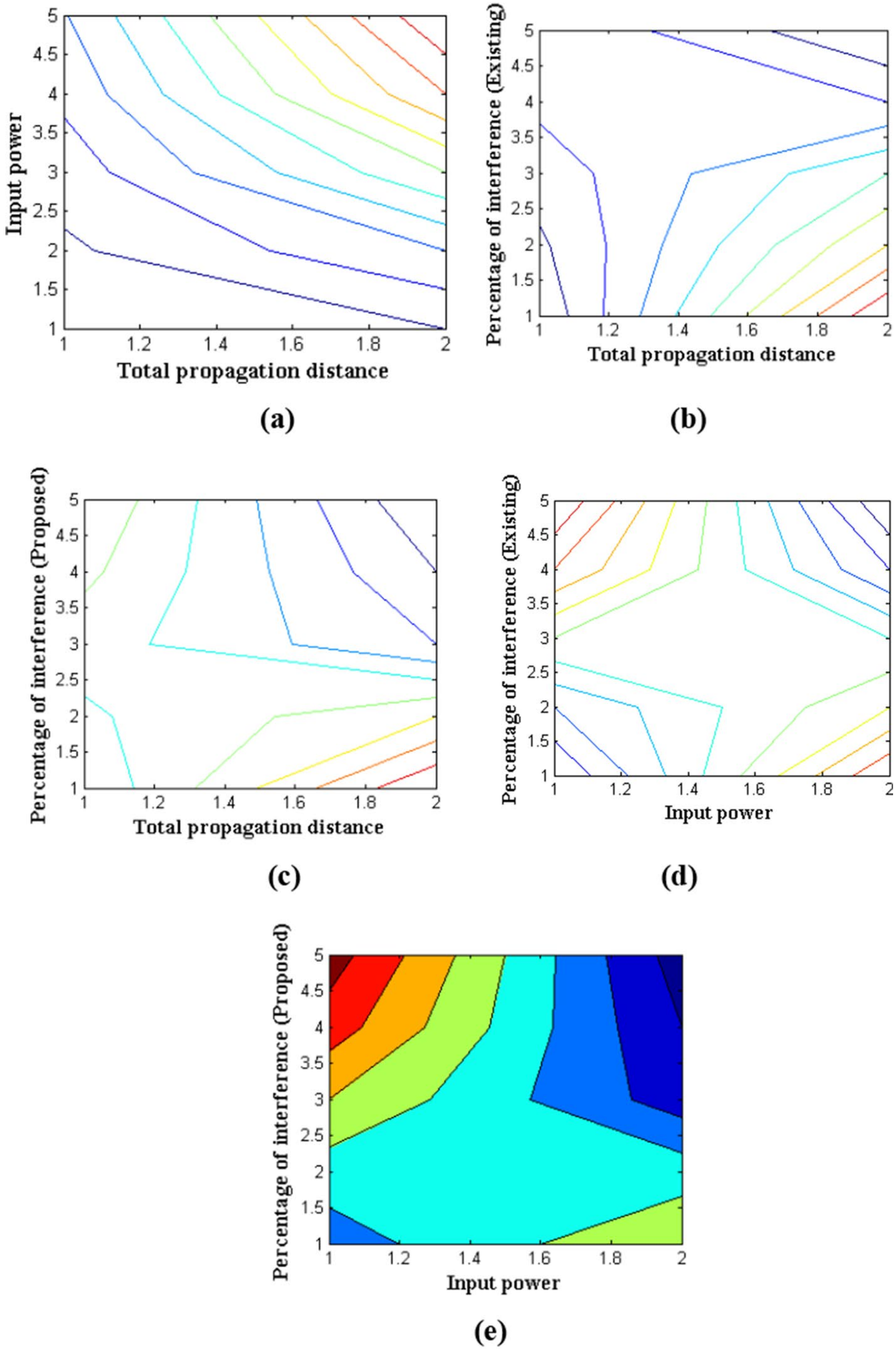

Fig. 8 Total interference and propagation measurements (a) Input power (b) Interference (Existing) (c) Interference (Proposed) (d) Input power vs Interference (Existing) (e) Input power vs Interference (Proposed)

Table 4 Interference analysis for varying propagation distance

Total propagation distance	Input power	Percentage of interference (Existing)	Percentage of interference (Proposed)
4.16	5	14	10
4.82	7	11	7
5.45	10	9	3
6.23	13	6	2
6.91	15	4	1

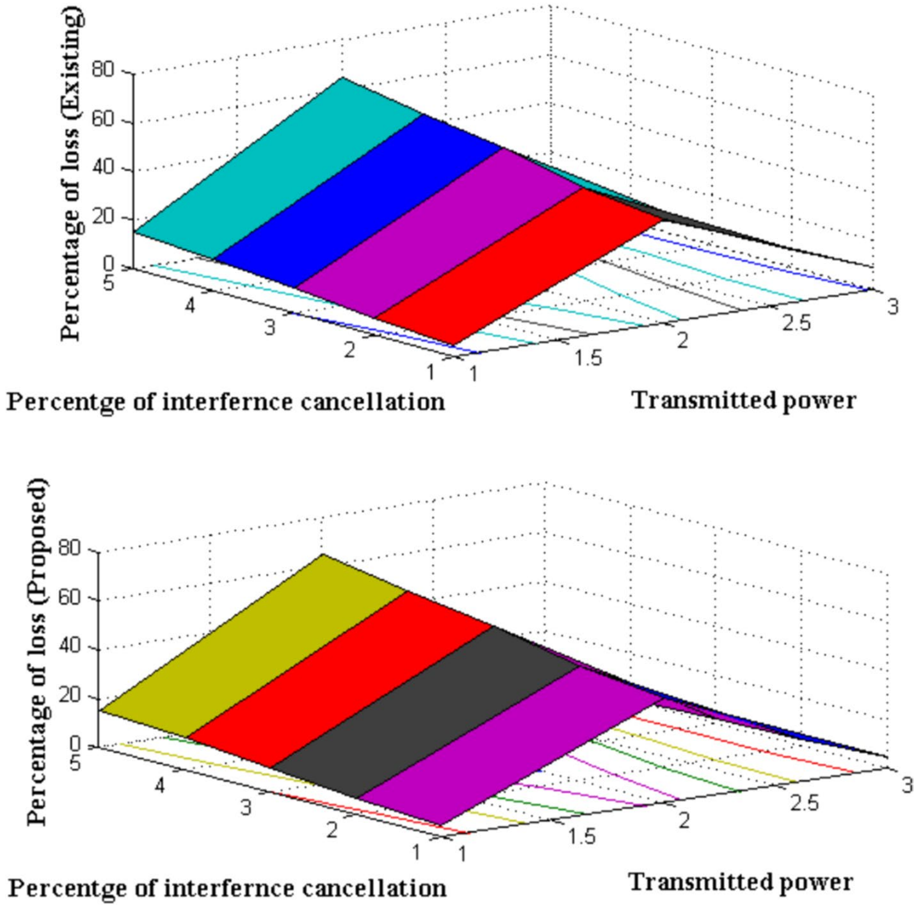

Fig. 9 Percentage of loss after interference cancellation

in desired signals are reduced to 1% therefore integrated sensing with DSP waves can be processed. Even at low interference cancellation that remains at 43% the loss values for existing and projected model remains at 9% and 5%. Conversely for increasing values it is possible to reduce the loss to further extent with considered transmission power.

Table 5 Loss representations for transmitted power

Transmitted power	Percentage of interference cancellation	Percentage of loss (Existing)	Percentage of loss [4]
5	43	9	5
7	47	7	3
10	54	6	2
13	59	4	1
15	65	3	1

8 Scenario 3: Maximization of Signal Strength

If the output values are minimized in both of the aforementioned circumstances, it is feasible to maximize the signal strength without imposing any additional limits. However, in practical scenarios, it is quite challenging for 6G networks, which rely on extensive processing resources, to attain such capabilities. Hence, in this particular scenario, the optimization of signal strength is achieved by taking into account two distinct circumstances that are associated with the presence or absence of signal. The majority of 6G networks that engage in integrated sensing operations are often deployed on conditional spectrum, wherein designated resources within the spectrum are utilized. Therefore, the distinction in values between the on and off conditions is determined through intensity factors, allowing for modifications to be implemented or the sharing process to be finished, even if the 6G networks stay in the off condition. Furthermore, by including the fusion of support vector machine and K-nearest neighbors algorithms, it becomes feasible to enable 6G networks to acquire knowledge from past data and subsequently modify signal strength prior to signal processing.

Figure 10 and Table 6 provides the comparison outcomes in terms of signal strength for proposed and existing approach where it is possible to achieve maximum signal strength with proposed approach as compared to existing system. To prove the representation of signal strength total on and off periods are considered where most of the time periods the 6G networks remains at on state. The total off periods remains at 20,16,12,7 and 5 with remaining time periods are present under on conditions. With high active time period the percentage of signal strength is maximized to 99% in case of proposed method as compared to existing approach. The comparison can be made with low on periods that is considered to be 80 and during this case percentage of signal strength for existing and proposed method remains at 74% and 89% respectively. Furthermore if signal strength is increased then 6G network resources remains at half utilized state as unnecessary on time periods are neglected.

9 Scenario 4: Convention Dual Bands and Time Margins

In order to optimize performance in signal processing systems, it is recommended to utilize a dual band approach together with appropriate time margins. Therefore, the suggested solution utilizes a standard dual band system that is divided into distinct frequency ranges of 100 GHz and 1 terahertz. Dual band operation can be achieved by partitioning the networks into clusters, which allows for the monitoring of both the departure and arrival rates of signals. The enhancement of network compatibility has

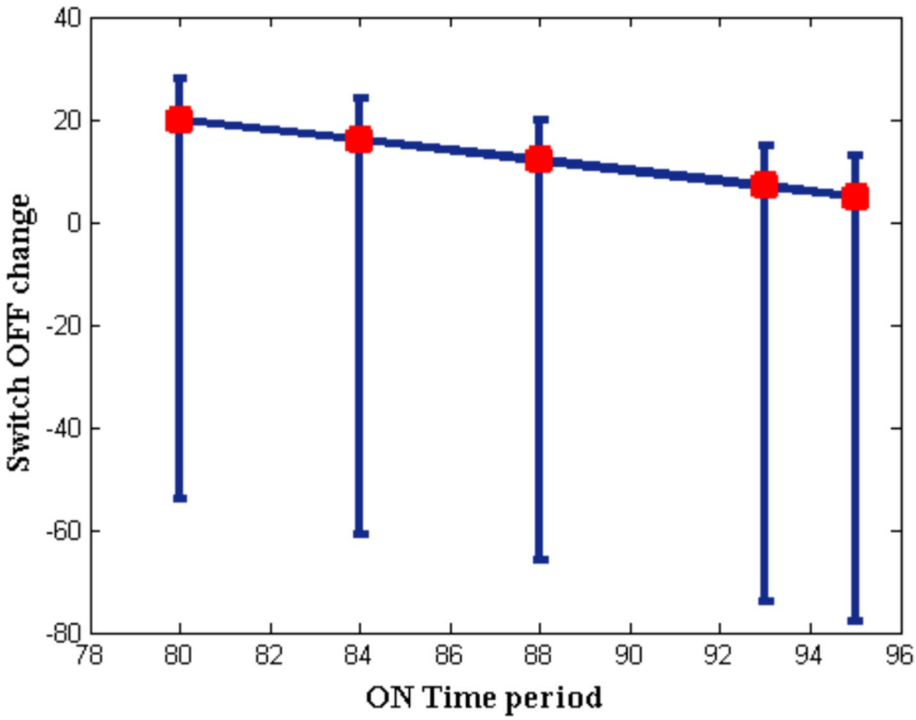

Fig. 10 Signal strength variations in on and off time periods

Table 6 Total signal strength for ON and OFF conditions

On time period	Off time period	Percentage of signal strength (Existing)	Percentage of signal strength (Proposed)
80	20	74	89
84	16	77	94
88	12	78	97
93	7	81	99
95	5	83	99

enabled the establishment of various signal pathways through the utilization of routing procedures that prioritize the selection of the shortest distance. If the departure time period is significantly greater, the operation of dual band networks will not be able to support 6G networks. This is because the allocation of clusters and resources is based on the predetermined band ranges. Alternatively, dual band operations can be achieved by considering the first and last bands of frequencies as input functions. The simulation outcome for dual operating situations is illustrated in Fig. 11.

From Fig. 11 and Table 7 it is realistic that time margins for dual band operation is maximized for proposed method as compared to existing approach [4]. The major reason for such maximization is that number of clusters is much higher therefore the departure time period of signals is reduced. To prove the real time outcomes with simulation study only two bands of frequencies are considered and the signals that are transmitted with

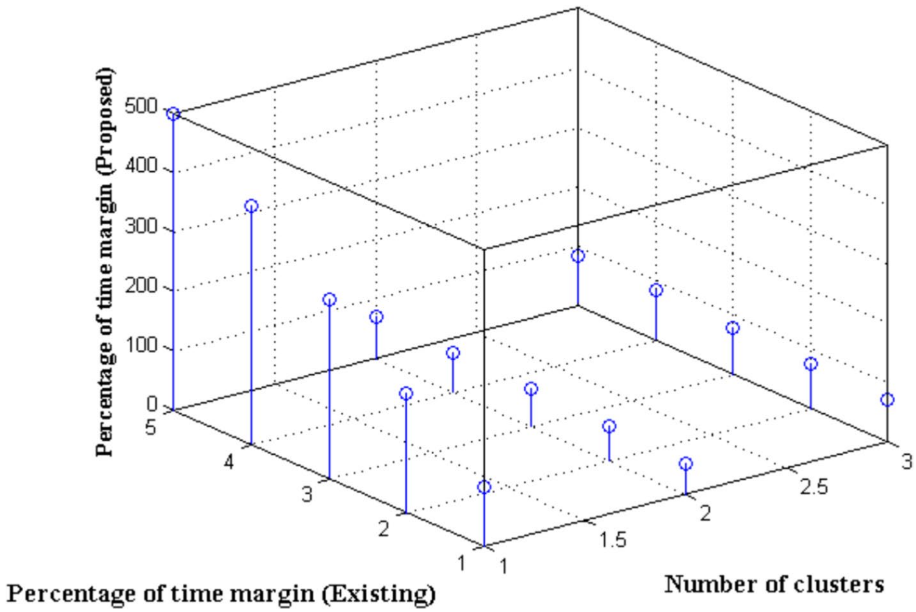

Fig. 11 Time margins with division of cluster regions

Table 7 Maximized time margins for clusters in integrated sensing

Number of clusters	Percentage of time margin (Existing)	Percentage of time margin (Proposed)
100	52	71
200	58	75
300	63	79
400	66	83
500	69	85

desired ranges are chosen. The number of clusters is carried from 100 to 500 in step variations where percentage of time margins in both proposed and existing approach is maximized to certain extent. In outcome simulation the percentage of time margin is observed to be 52,58,63,66 and 69 in case of existing approach whereas in proposed method the time margins are maximized to 71,75,79,83 and 85 percentages respectively.

9.1 Time Complexity

Since there are two channels in this instance and a shorter sensing time is required, a comparative experimental analysis of temporal complexities is conducted. Time complexity describes how possible remote sensing units connected to cloud computing units must jointly receive correct information, decreasing the complexities at receiver, in addition to indicating reductions in time periods with respect to programming requirements. In contrast, SVM and KNN are designed with discrete dimensions and communication units in situations where low-complexity integrated sensing of DSP signals is required. Furthermore, time complexity dictates that each cluster must respond quickly because two channels will sense and report to the cloud computing units at the same time. One channel will have significant complexity that cannot be decreased in any way for a subsequent sensing procedure if it communicates the felt outcomes beyond defined limits. Figure 12 shows the results of the time complexities for the suggested and current methods.

From Fig. 12 it is much clear that complexities with respect to time periods are reduced for proposed method as compared to existing approach. Since the complexities are reduced both allocated channels can function appropriately in multiple paths across various clusters thereby achieving proper time margins with proper response. To verify the simulation outcome the iterations are grouped in to five different sets which is termed as best epoch and it varies from 20,40,60,80 and 100. For the aforementioned best epoch time complexities are reduced to 5.1,4.2,3.6,3.3 and 2.4 s whereas in existing approach time complexity is reduced only within limited range of 13.6,13.1,12.7,12.2 and 11.5 s respectively. Therefore with reductions in time complexities the interference and losses can also be controlled if machine learning algorithm is combined with parameters that are defined for integrated sensing in 6G networks.

10 Conclusions

DSP systems are of utmost importance in the context of 6G networks, since they are responsible for executing data operations at high speeds by utilizing binary representation, where the combination of 1 s and 0 s is used to convey information. In the context of 6G networks, a significant portion of users tend to remain in an out-of-band state,

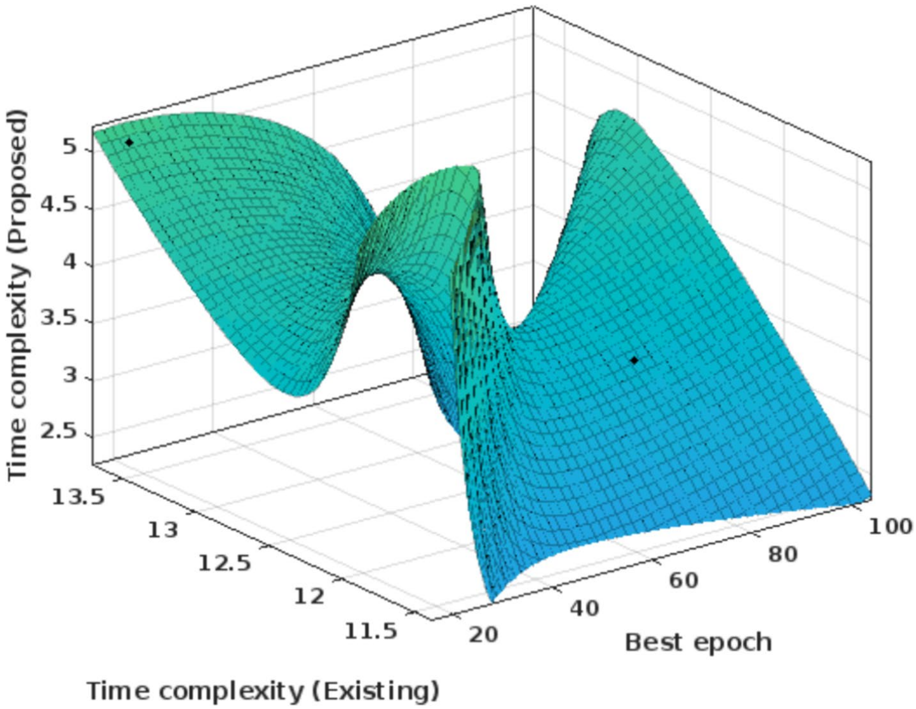

Fig. 12 Comparison of time complexities with variations in best epoch

wherein the radio spectrum remains unutilized. In the aforementioned scenario, the utilization and distribution of radio spectrum are rendered infeasible, thereby impeding the integrated functioning of sensing and communication systems. Therefore, the suggested technique involves the formulation of an analytical model for 6G networks, which encompasses all operations pertaining to the efficient communication process that may be disseminated to all users. Machine learning algorithms play a significant role in facilitating the pooling of network resources and mitigating free space loss inside this particular analytical model. The suggested method allows for accurate observation of LOS sites, enabling the establishment of low path propagation and identification of interfering signals. Given the capability of 6G networks to acquire knowledge regarding the dynamic radio spectrum, it becomes feasible to incorporate many adaptive characteristics that facilitate environmental assistance. Furthermore, apart from minimizing loss, it is feasible to employ a dual band channel that operates through alternating on and off intervals, hence enhancing the signal intensity for sensing activities. Furthermore, the use of the terahertz band is of significant relevance as it allows for the division of each unit into several clusters, resulting in the development of a reduced signal to noise ratio.

Four scenarios are used to do a real-time examination of the combined model's effects, and a comparison with the corresponding existing approach is also carried out. The current technique only restricts interference to 4%, but in scenario 1, where interference is found during sensing in 6G communications, a lowered ratio is observed for less than 1% in the predicted model. The losses seen in the following scenario are likewise minimized to 1% for the suggested method due to decreased interferences, whereas the existing methodology exhibits large losses with 3% after sensing. Since 6G networks are being used for integrated sensing, it is necessary to boost the signal intensity in both channels in order to improve throughput. Using the suggested method, 99% of the signal strength is attained, compared to 83% in the old way. The temporal margin for integrated sensing can be improved in all clusters due to higher signal intensity, resulting in 85% margins as opposed to 69% in the case of the current technique. In future, it is anticipated that 6G networks would be capable of efficiently allocating high resources, hence mitigating potential failures in the presence of artificial intelligence algorithms.

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Declarations

Competing interests The authors declare no competing interests.

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