The MIMO-OTFS Technique in the Next 6G Communications

Ali J. Ramadhan[1,2] and Ali Taei Zadeh[1]

[1]Department of Computer and IT Engineering, University of Qom, Qom, Iran
[2]Department of Computer Engineering, University of Alkafeel, Najaf, Iraq

*Corresponding Email : ali.j.r@alkafeel.edu.iq

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Abstract. *The orthogonal time-frequency space (OTFS) technique is a promising method of waveform modulation that encodes data in the delay-doppler (DD) domain. OTFS distinguishes itself from conventional multiplexing methods by employing two-dimensional modulation to alternate between the time-frequency (TF) domain and the delay-Doppler domain. This feature enables the management of Doppler shifts induced by high-speed objects, which is not possible with conventional modulation schemes such as orthogonal frequency division multiplexing (OFDM). The main objective of this work is to provide a concise and comprehensive introduction of this emerging subject, emphasizing its system concept. In addition, we analyze crucial elements of OTFS modulation, including techniques for data detection, channel estimation, MIMO, and multiuser systems.*

Keywords:

OTFS, 6G, MIMO, Superimposed Sequence Pilot, Delay-Doppler, High Mobility.

1. Basic and Background of MIMO Wireless Communication

MIMO-OTFS can enhance spectral efficiency even more, whereas OFDM provides simple implementation, robust resistance to multipath fading and narrowband interference, and exceptional spectral efficiency. Orthogonal Time Frequency Space (OTFS) modulation is a highly promising technique that guarantees dependable communication in dynamic scenarios involving frequent movement of individuals. Wireless communication has had significant advancements since the 1960s, with LTE emerging as a prominent method for next-generation wireless transmission systems. The LTE Advanced (LTE-A) framework utilizes Multiple-Input Multiple-Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) techniques to attain the highest possible data transmission rate. The rationale for incorporating MIMO technology in existing wireless frameworks is to enhance the performance of capacity-limited systems, improve quality and coverage, and leverage Long-Term Evaluation to increase the capacity, coverage range, and data transmission reliability of the wireless systems [1]. One of the prevalent wireless frameworks is Wireless Local Area Networks (WLANs) which interconnect laptops, Personal Digital Assistants (PDA), cell phones, and other handheld gadgets as shown in Fig. 1 [2].

LTE is a wireless and mobile communication technology that provides novel features and benefits in comparison to alternative technologies [3]. The primary objectives of this system are to enhance the rates of data transmission in both the downlink and uplink directions, provide a more adaptable data transfer capacity, improve spectral efficiency, and increase the number of clients that can be accommodated. The LTE/LTE-A technology is driving developments in communication in transit towards a 5G transmission scheme, as depicted in Figure 2.

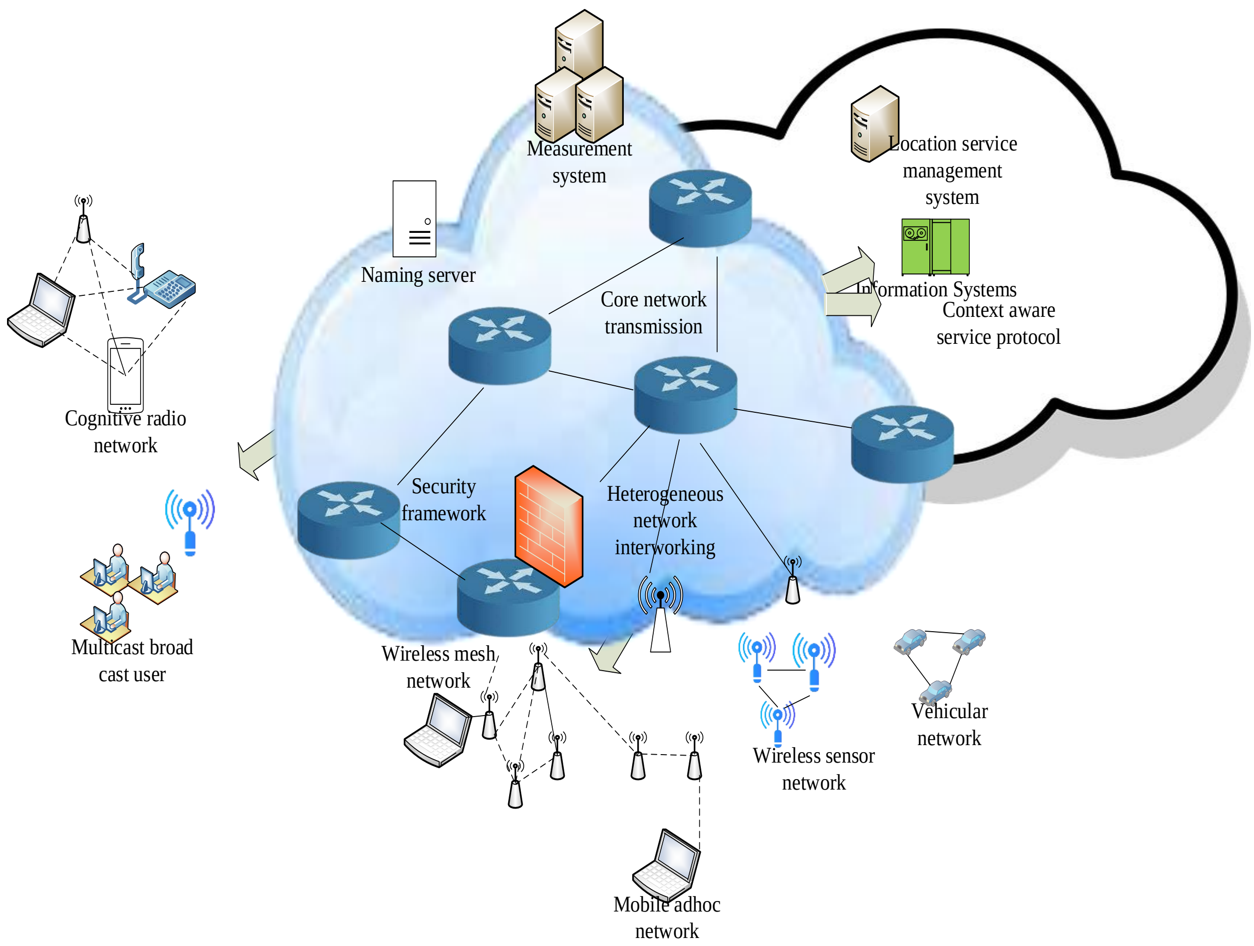

Fig. 1. Wireless communication [2].

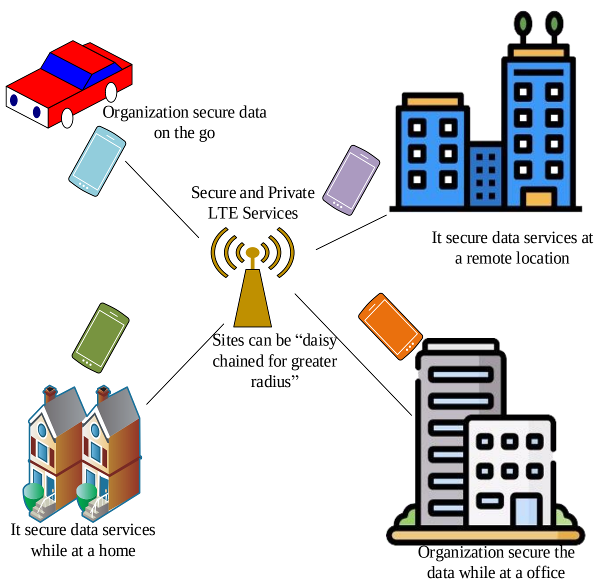

Fig. 2. Communication systems [2].

The LTE-A standards aim to enhance range efficiency and optimize spectrum utilization by minimizing the number of antennas employed in devices. The types of antennas commonly used in digital communication systems include Single Input Single Output (SISO), Single Input Multiple Output (SIMO), Multiple Input Single Output (MISO), and Multiple Input Multiple Output (MIMO). Multipath fading is a phenomenon that causes signal degradation, and it is advisable to use numerous antennas at both ends to improve signal quality assessments [4].

MIMO systems are conventional wireless communication systems that utilize single-user systems for downlink communication [5], as depicted in Figure 3.

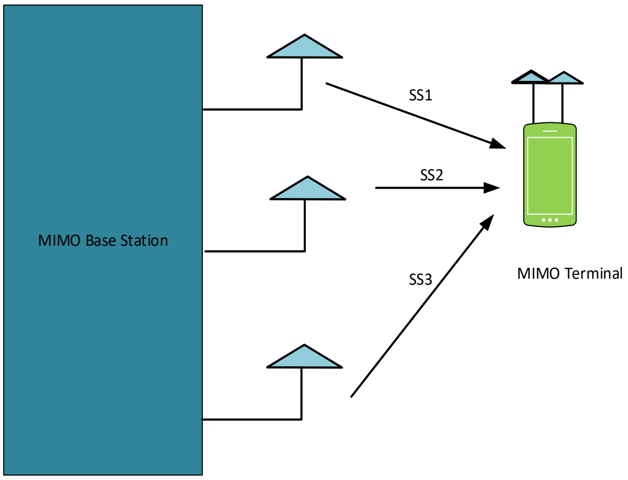

Fig. 3. Single-user MIMO system in downlink [2].

MIMO networks employ multiple antennas at both the transmitting and receiving ends of a data stream, thereby improving the reliability of transmission and minimizing interference. Nevertheless, it is necessary to strike a balance between diversity and multiplexing gain, since the highest multiplexing gain and maximum diversity cannot be employed concurrently. The IEEE 802.16 standard for broadband wireless access utilizes multiple antennas. The IEEE 802.16e version has the added advantage of Spatial Multiplexing (SM) for 2x2 downlink Multiple-Input Multiple-Output (MIMO) systems, resulting in a doubling of communication speed [6]. Multiuser MIMO systems, as depicted in Figure 4, can be set up in either co-located or distributed configurations. The purpose of the co-located arrangement is to increase coverage and minimize interruptions.

M-MIMO, short for Massive Multiple-Input Multiple-Output, is an essential technology for 5G and next mobile transmission schemes. It entails the use of a significant number of base station antennae and users. This study investigates the utilization of Single-user and MU Massive MIMO technologies in a downlink system with a single cell. The main focus is on evaluating the capacity of the total rate [7].

Wireless communication employs two different methods for duplexing: Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) [8], as illustrated in Figure 5.

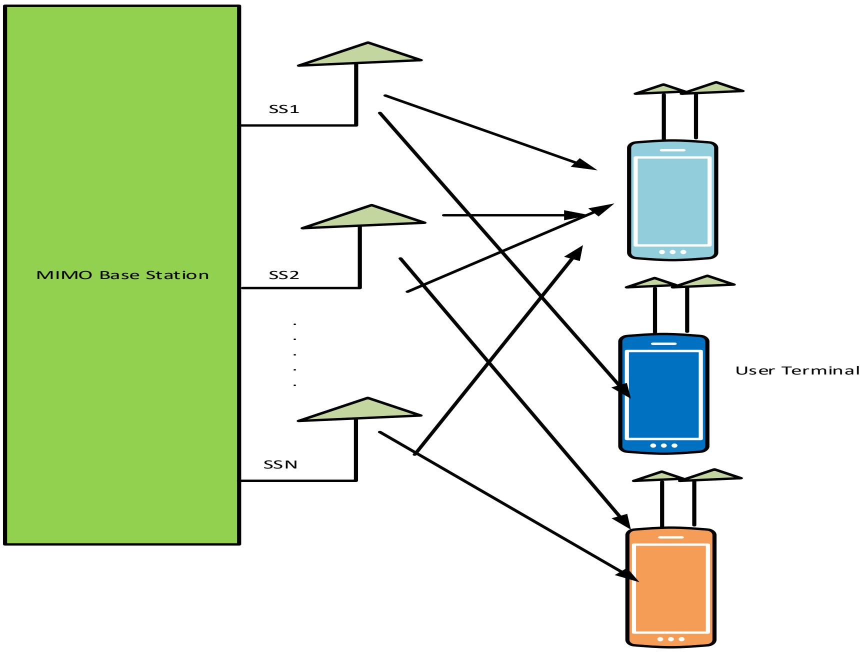

Fig. 4. Multi-user MIMO system for downlink [2].

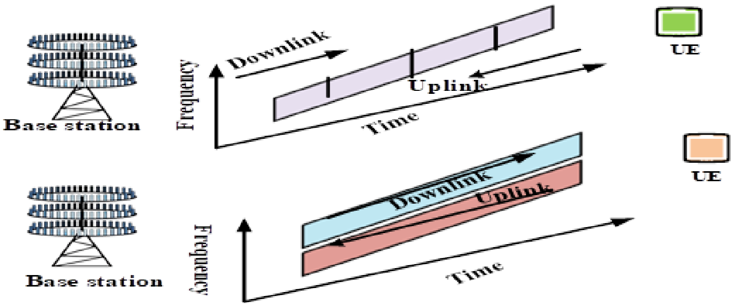

Fig. 5. Pilot and data transmission in TDD and FDD systems [2].

Time division duplexing (TDD) employs distinct time slots for transmission in both uplink (UL) and downlink (DL) scenarios, while frequency division duplexing (FDD) does not allow for channel reciprocity in transmission. In Massive Multiple-Input Multiple-Output (M-MIMO) systems, increasing the number of antennas can enhance the Degrees of Freedom (DoF) and decrease the required transmission power. This is achieved by having a larger number of antennas, which provides a greater number of samples for signal processing. M-MIMO provides several benefits, including straightforward precoding and detection, advantageous propagation and channel hardening, decrease of inter-user interference, increased total capacity, and precise beamforming [9].

In MU-MMIMO with TDD mode, the channel is assumed to be flat for the duration of the coherence interval, denoted as T, as depicted in Figure 6. During each coherence period, four steps are executed: training phase, channel estimation, transmission of downlink data, and uplink communication [10].

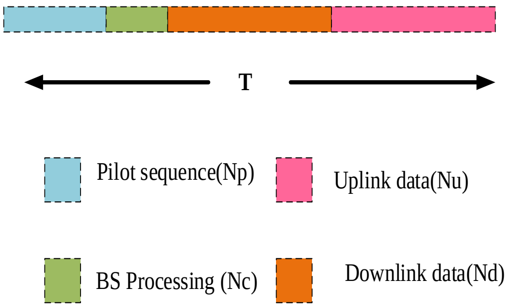

Fig. 6. TDD protocol [2].

Massive MIMO, employing a greater quantity of transmitter antennas, has the capability to facilitate bidirectional communication between the transmitter and receiver, offering exclusive connections and a substantial level of connectivity to cater to IoT devices. Figure 7 depicts the block diagram of a huge MIMO system, where M transmitting antennas are used to serve K users. Typically, the value of M is significantly larger than K [11].

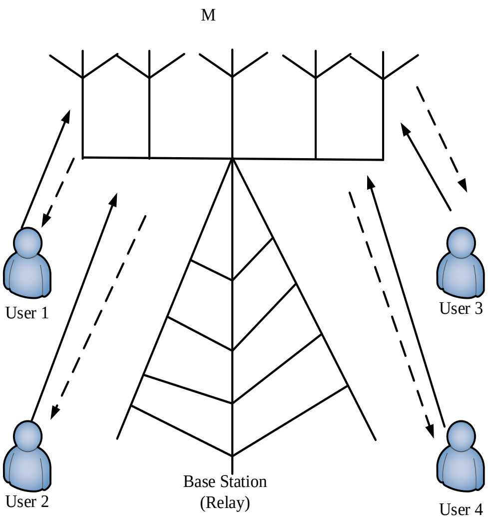

Fig. 7. Massive MIMO communication model [2].

Beamforming is a technique used to improve the transmission of signals from a base station to a radio by focusing the signal strength and coverage in specified directions. Figure 8 illustrates the beamforming method of communication using the antenna array of a 5G base station [12].

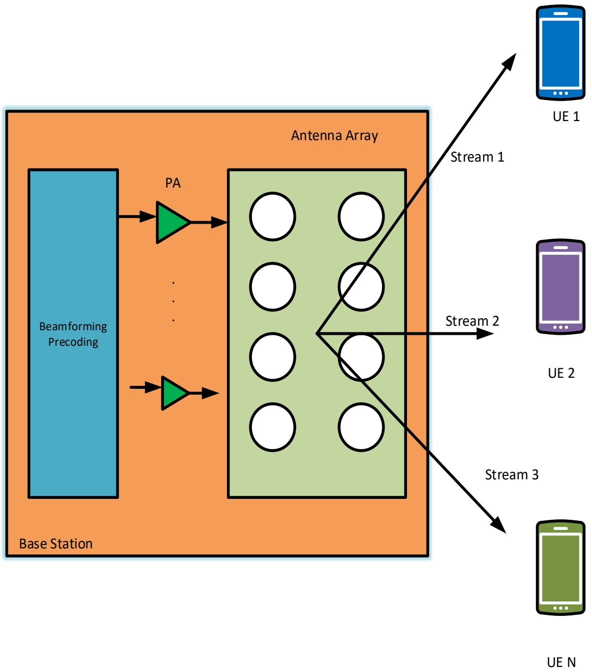

Fig. 8. Beam forming model of communication [2].

In a Time Division Duplex Mode Operation (TDD) huge MIMO system, the Channel State Information (CSI) is acquired through uplink training and by exploiting channel reciprocity. In the TDD M-MIMO structure depicted in Figure 9, the training sequence is transmitted in the uplink direction to prevent the excessive transmission of orthogonal pilot sequences in the downlink [13].

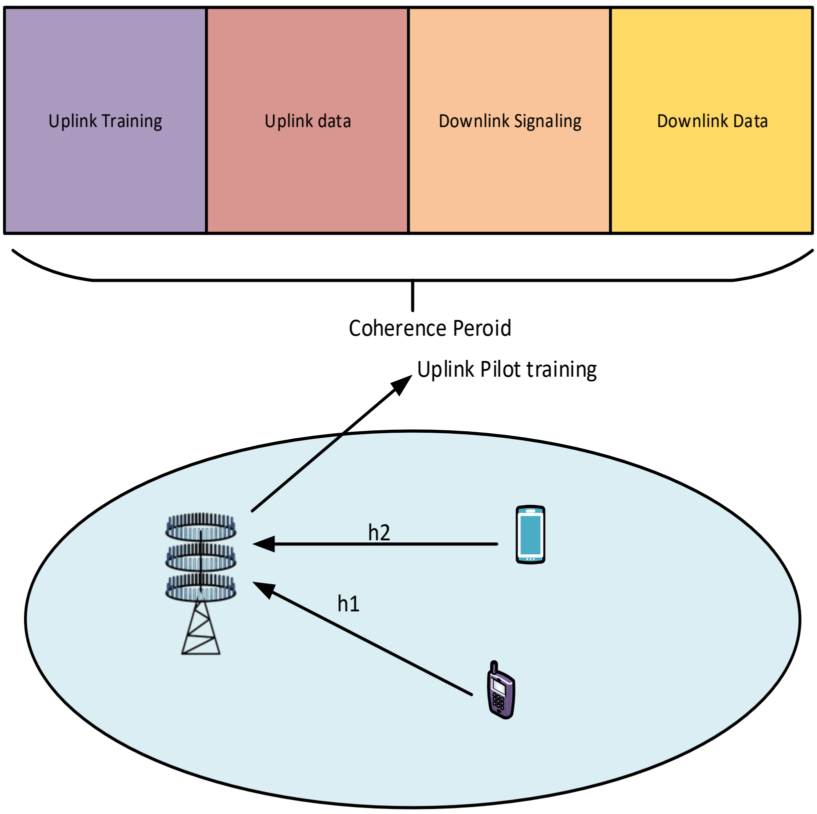

Fig. 9. TDD mode operation in channel estimation Process [2].

This technique enhances the efficiency of mobile systems by isolating unrelated noises and interference within a single cell. The CSI, or Channel State Information, is utilized for the purpose of data transmission and channel acquisition. The base station employs the reciprocity between channels and the pilot training in an uplink path to calculate the CSI. The presence of a large number of base station antennas can lead to improvements in spectral efficiency. However, it can also result in pilot contamination or pilot pollution. MIMO has various advantages, such as enhanced spatial diversity, increased array gain, and improved spatial multiplexing. Spatial Diversity Gain mitigates the effects of fading by generating many replicas of the signal, whereas Array Gain enhances signal robustness and fidelity by enhancing the array's resistance to noise. Spatial Multiplexing Gain enhances the data rate without requiring extra bandwidth or transmission power, while also reducing interference by increasing the distance between users [14].

2. Literature Survey

This section discusses Massive 6G MIMO – OTFS, Pilot Design-based Channel Estimation, Superimposed Pilot Design, and Channel Estimation and Data Detection, and finds the research gaps in relevant recently published papers.

The research [15] presents a new method called path division multiple access (PDMA) that utilizes orthogonal time frequency space (OTFS) for large-scale multiple-input multiple-output (MIMO) networks with high mobility in both the uplink (UL) and downlink (DL) directions. The authors introduce a novel approach called high mobility DL CE, which involves a new LCD that allows the Unit (UT) to demodulate each DD domain information signal independently. They also propose a method for estimating channels and a randomized pilot design-based CSI collection system for DL M-MIMO-OTFS in the presence of a fractional Doppler. The authors provide a pilot framework that is deterministic and an approach called tensor-based OMP for collecting downlink CSI.

The study [16] presents a discussion on low-complexity transmitter precoding for MU MIMO-OTFS. It introduces two approaches that aim to reduce computational complexity and minimize performance degradation in comparison to BD precoding. The paper suggests that these strategies provide encouraging answers for large MIMO networks.

The paper [17] introduces an OTFS modulation technique for large MIMO networks, including channel estimation to reduce intersymbol interference (ISI). The technique employs 3D inner product proportion reduction difference structured orthogonal matching pursuit (3D-IPRDSOMP) to combine characteristics of 3D structured sparse channels. The performance of the SM-OTFS model is evaluated and found to be superior to that of the STC-OTFS model in several MIMO scenarios. The low complexity detector for MIMO systems utilizes OTFS modulation and employs the MRC approach to linearly combine transmitted symbol vectors.

The article [18] examines different approaches to enhance channel estimation in high-mobility MIMO-OTFS setups. The main objective is to decrease the time it takes to process data and enhance the frameworks used for estimating communication channel properties. The paper presents DD alignment modulation (DDAM), a technique that eliminates the Doppler effect caused by multi-path signal mechanisms. This enables all multipath signal mechanisms to reach the receiver at the same time and in a way that enhances their constructive interference.

The research [19] introduces a preliminary design for channel evaluation (CE) in the MIMO-OTFS network using OTFS, a method that efficiently calculates the channel matrix including Doppler and fractional delay. Additionally, a new OTFS system called SIM-OTFS is proposed. The study also examines the efficacy of the SIM-OTFS design in high-mobility vehicle schemes within intelligent transportation networks. The authors also examine the incorporation of CE and device activity identification in grant-free RAS, utilizing LEO satellites to achieve substantial differential DD shifts.

The paper [20] introduces a time-division duplex technique that utilizes machine learning to enhance prediction accuracy in settings with both low and high mobility. The paper also introduces a pilot-based channel estimate approach in the MIMO-OFDM framework, which is determined in real-time by the estimation algorithm and the design of the pilot. Additionally, it explains a method for designing downlink pilots in OFDM systems by utilizing DL-based channel estimates, known as ChannelNet. A novel approach is given for DL, M-MIMO-OTFS, which involves a deterministic pilot design and a CSI collection mechanism based on the CE algorithm.

The article [21] examines the downlink of large MIMO systems in the absence of cells and introduces two pilot-based channel estimation (CE) methods: "EP-CHE" and "SP-CHE". The suggested methods for data identification and channel estimation are iterative and employ an overlaid pilot pattern to improve the efficiency of the spectrum. The UL NOMA strategy is suggested for tackling user connectivity concerns in huge MIMO-OTFS networks. The 2D-OTFS modulation technology outperforms conventional multicarrier modulation systems by offering low-complexity linear equalizers for a 2 × 2 MIMO output-to-feedback scheme.

The work [22] introduces a 2-timescale CE methodology that employs a dual-link pilot communication strategy and coordinate descent algorithm to estimate quasi-static BS-RIS channels. Additionally, a method utilizing passive beamforming and a low-complexity channel estimation technique is suggested.

The work [23] discusses the challenges of merging and estimating channels in wideband THz mMIMO systems employing uniform planar arrays. The system offers a way for mitigating beam squint using time-delay and minimal complexity, as well as an improved version of the orthogonal matching pursuit (OMP) technique for accurate channel estimation. The authors suggest a data-aided channel estimate method to enhance spectral efficiency in stacked pilot and data communication systems. In addition, they provide a deep learning-based method for estimating and tracking channels in vehicle millimeter-wave communications.

The paper [24] presents innovative and efficient channel estimation (CE) techniques for the double-intelligent reconfigurable surfaces (IRS)-assisted MIMO interaction framework. These techniques include anchor-assisted CE, multi-user massive multiple-input multiple-output millimeter wave systems, and time-division duplex techniques. In addition, they propose a time-division duplex technique using machine learning that leverages temporal channel correlation to obtain channel state information (CSI).

The work [25] presents a method for estimating the channel in beamspace using a technique called prior-aided Gaussian mixture LAMP (GM-LAMP). This method is specifically designed for mmWave large MIMO systems and also includes a strategy for multi-user uplink channel estimation. The researchers create a channel model that operates on two different frequency bands and a conditional generative adversarial network (cGAN) specifically designed for massive MIMO systems. This study investigates the issues of channel estimation (CE) in multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) systems. The research employs a hybrid intelligent reflecting surface (IRS) framework and utilizes algebraic techniques to address these challenges. The proposed methods exhibit superior performance in terms of precision, speed, and complexity compared to standard methods.

The research [26] introduces an uplink mMTC S-IoT system that utilizes SPs code domain non-orthogonal multiple access over a satellite-ground channel model, incorporating route loss and shadowed-Rician fading. The proposal suggests a balance between spectral efficiency (SE) and system performance by employing a MIMOOFDM-IM technique. This technique utilizes a superimposed pilot scheme to enhance SE while maintaining a low bit error rate (BER). The research also examines the generalized superimposed training (GST) approach for uplink cell-free mMIMO frameworks. It analyzes the spectral efficiency (SE) of a UL hardware-constrained "cell-free MIMO system with MRC receiver filters". The authors also examine the peak-to-average power ratio (PAPR) of the OTFS waveform by employing transmit frame topologies for channel estimation techniques.

The paper [27] introduces adaptive channel estimate algorithms for MU-MIMO systems utilizing the LMS and BLMS techniques. These systems are more computationally efficient and do not necessitate prior knowledge or analysis of the time-varying statistics of the MU-MIMO channel at both the initial and second order. The suggested architecture simplifies the design of the receiver and employs a unified approach and data-driven receiver architecture. This paper introduces a novel adaptive primary guard technique for transfer lines, based on PSI (Phase Shift Index), which guarantees robust protection in case of unreliable source networks. The IAP-SP approach guarantees accurate channel restoration while reducing computational expenses. The BR-MP-EM method updates communication for the integration of UAD and CE problems and employs EM techniques in the outer iterations. The work introduces USC modulation, which incorporates novel OTFS and OTSM algorithms for the purposes of channel estimation and detection. The article also explores the ideas of Superimposed Pilot Design, Pilot Design Channel Estimation, Massive MIMO-OTFS, and Channel Estimation and Data Detection.

Furthermore, Table 1 below covers the main research gaps in the recently published papers.

Table 1 Research Gaps of Existing Work [2].

Category	Methods	Research Gap
Massive MIMO – OTFS.	PDMA scheme [28],	• Interference Management.
	Delay Doppler [29].	• Robustness to Channel Variability.
Pilot Design Based Channel Estimation.	DRL [30],	• Computational Complexity.
	DL [31].	• Computational Resources.
Superimposed Pilot Design.	Message Passing Algorithm [32],	• Computational Complexity
	Gaussian Distribution [33].	• Robustness to Channel Variability.
Channel Estimation & Data Detection.	Expectation Maximization [34], Discrete Fourier Transform [35].	• Scalability. • Complexity.

3. MIMO, OTFS and 6G Techniques

OTFS modulation is a modulation technique that multiplexes information symbols in the DD domain, resulting in a stable and sparse channel. It outperforms OFDM in both coded and uncoded systems and is resistant to delay-Doppler shifts. OTFS also gains advantages from the combination of time-frequency diversity, which guarantees reliable communications over doubly dispersive transmissions. Nevertheless, it presents difficulties for the development of transceiver structures and algorithms, particularly when addressing fractional inter-doppler interference (IDI). The Interference-Delay Interval (IDI) is the main limiting factor for the accuracy of channel estimation in OTFS (Orthogonal Time Frequency Space) systems. To mitigate the widening of the channel induced by fractional Doppler, it is necessary to develop a practical method. The use of windowing in the time-frequency (TF) domain can enhance the efficiency of channel sparsity in the delay-domain (DD). However, the paper does not offer any specific method for constructing windows [36]. The modulation and demodulation of OTFS are shown in Fig. 10.

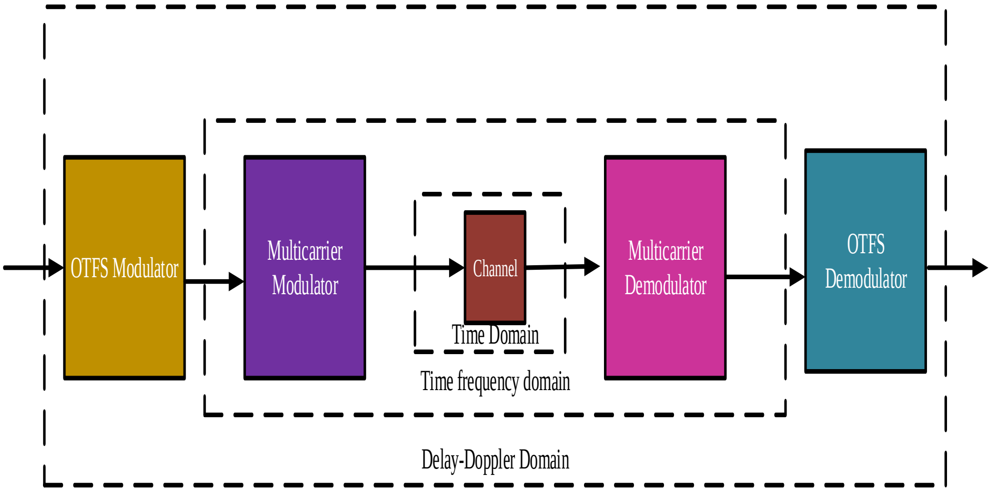

Fig. 10. Modulation and demodulation for OTFS [2].

OTFS modulation can be applied in various next-generation wireless networks, such as automotive networks, millimeter-wave communications, non-terrestrial networks, and underwater acoustic communications. The system provides enhanced traffic safety, collaborative control, and assistance for autonomous vehicles. Additionally, it offers robust defense against oscillator phase noise, rendering it well-suited for mmWave telecommunications. OTFS's Doppler resistance enhances its performance in transmitting data in the DD domain, rendering it well-suited for underwater acoustic channels. The device's low power consumption and simplicity make it an attractive compromise between complexity and performance [37].

6G is an emerging wireless technology that seeks to establish a widespread, intelligent, secure, adaptable, and reliable wireless system. The system will utilize satellite links to establish a ubiquitous wireless network. The key performance indicators (KPIs) for designing 6G include measuring the system's capacity, latency, management capabilities, intelligence and automation, and extending network coverage beyond the terrestrial domain [38]. It will need ground-breaking discoveries in every area of wireless communications to meet the KPIs listed in Table 2.

Table 2 Performance Indicator of 5G and 6G [2].

Key Performance Indicator (KPI)	5G	6G
1. **System Capacity**		
Highest Data Rate (Gbps)	20	1000
Knowledgeable Data Rate (Gbps)	0.1	1
High Spectral Efficiency (B/S/Hz)	30	60
Knowledgeable Spectral Efficiency (B/S/Hz)	0.3	3
Ideal Channel Bandwidth (Ghz)	1	100
Capability Of Area Traffic (Mbps/m2)	10	1000
Density Of Connections (Devices/Km2)	10^6	10^7
2. **Latency of the Network**		

Key Performance Indicator (KPI)	5G	6G
Total Lag (ms)	1	0.1
Latency Jitter (ms)	NA	10^{-3}
3. **System Administration**		
Energy Effectiveness (Tb/j)	NA	1
Dependability (PER)	10^{-5}	10^{-9}
Mobility (km/h)	500	1000

The Key Performance Indicators (KPIs) encompass metrics such as the highest possible channel bandwidth, the capacity to handle area traffic, the density of connections, the Packet Delivery Ratio (PDR), the data rate experienced by users, and the peak spectral effectiveness. The 6G plan may necessitate peak data rates of up to 1 Tb/s, representing a speed that is 100 times greater than that of 5G. In order to meet this requirement, it is necessary to investigate the potential bandwidths of the THz band [39].

Developing affordable and power-saving Nano-transceivers for THzCom applications is difficult because of the fluctuating absorption loss in the THz band over extended transmission lengths. To tackle this issue, researchers are currently exploring carrier-based modulation-based spectrum allocation methods for THzCom designs. These techniques utilize TW bandwidths to encode data into single-carrier waveforms and/or pulses, which are subsequently increased in frequency using a series of frequency multipliers to reach greater THz band frequencies. Nevertheless, the impact of IBI (power leakage) is a noteworthy constraint on performance, particularly when users need many sub-bands to fulfill their quality of service requirements. In order to achieve equitable distribution of data transmission rates among users in a multiuser THzCom system, one can employ spectrum allocation methods based on DAMC. In order to enhance the spectral efficiency (SE), it is necessary to explore novel approaches for distributing the spectrum across many bands. One approach is to divide the total bandwidth (TW) into sub-bands of varying sizes and utilize adaptive sub-band (ASB) methods. To optimize the use of the spectrum and promote operator adaptability while ensuring quality of service and priority, it is necessary to employ Enhanced Digital Signal Processing (DSS) [40].

In the future of 6G, efficient implementation of Dynamic Spectrum Sharing (DSS) relies heavily on spectrum control, as it directly affects both the communicated services and communication [41], these technologies are represented in Fig. 11.

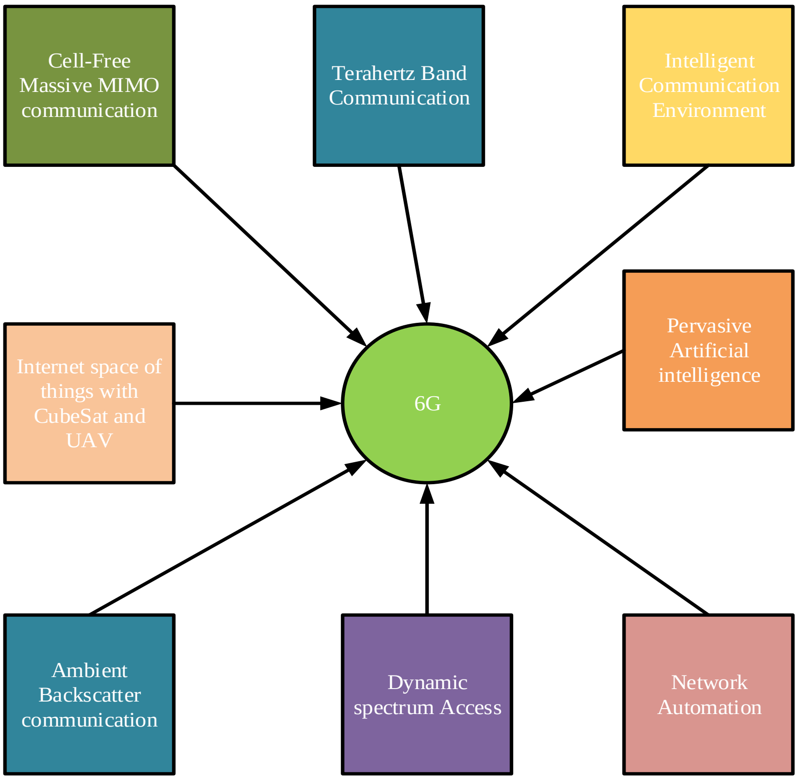

Fig. 11. 6G enabling technologies [2].

Blockchain provides a comprehensive solution for managing spectrum security by storing tamper-proof records of spectrum-sharing activities and transmitting the facts on the blockchain. The present DSS architectures consist of centralized and decentralized keys, as depicted in references [42], Figure 12, and Figure 13.

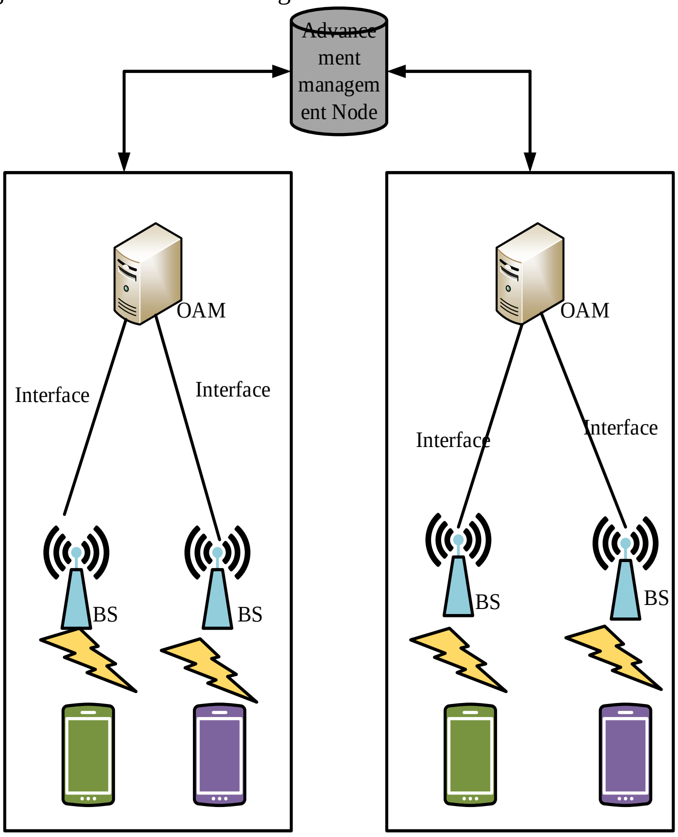

Fig. 12. Centralized DSS architecture [2].

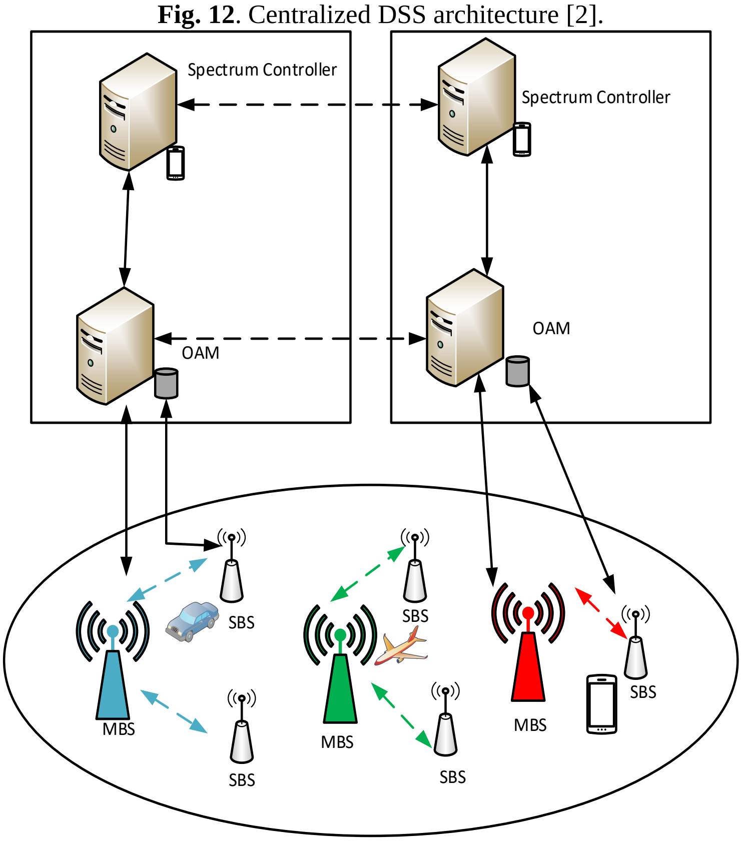

Fig. 13. Decentralized DSS architecture [2].

Centralized decision support system (DSS) architectures employ autonomous management nodes (AMNs) to minimize interference amongst operators and efficiently manage shared spectrum resources in a unified manner. AMNs are utilized in operator-level DSS designs to supervise the allocation and prediction of spectrum. Decentralized DSS designs employ spectrum controllers to establish communication and ascertain spectrum needs. Nevertheless, the implementation of this technology in real-world scenarios has been slow because to concerns around security, privacy, incentive structures, and quality of service guarantees. 6G spectrum management requires the implementation of advanced technologies such as blockchain and AI to ensure flexibility and efficiency [43].

The 6G goal is to surpass the capabilities of 5G by the year 2030, with a specific focus on four essential elements: intelligent connectivity, profound interactivity, holographic communication, and widespread connectivity. In order to accomplish these goals, 6G networks must fulfill specific requirements and face various challenges. These include achieving a peak rate of 10 Tb/s, ensuring dependable global connectivity, optimizing energy efficiency, maintaining constant connection, providing ubiquitous information, instilling confidence, integrating sensing, computation, interaction, and management, as well as overcoming non-technical obstacles such as industrial barriers, political issues, and consumer habits. Possible technologies encompass THz interactions, UV interactions, large-scale receivers, improved channel coding, and holographic radio. The research and development stage is now under progress, with certain fields relying on other fields [44].

Based on the aforementioned 6G vision and the current stage of growth and emerging trends in the associated tools, we anticipate that the fundamental methodological aspects of 6G will encompass the characteristics depicted in Figure 14.

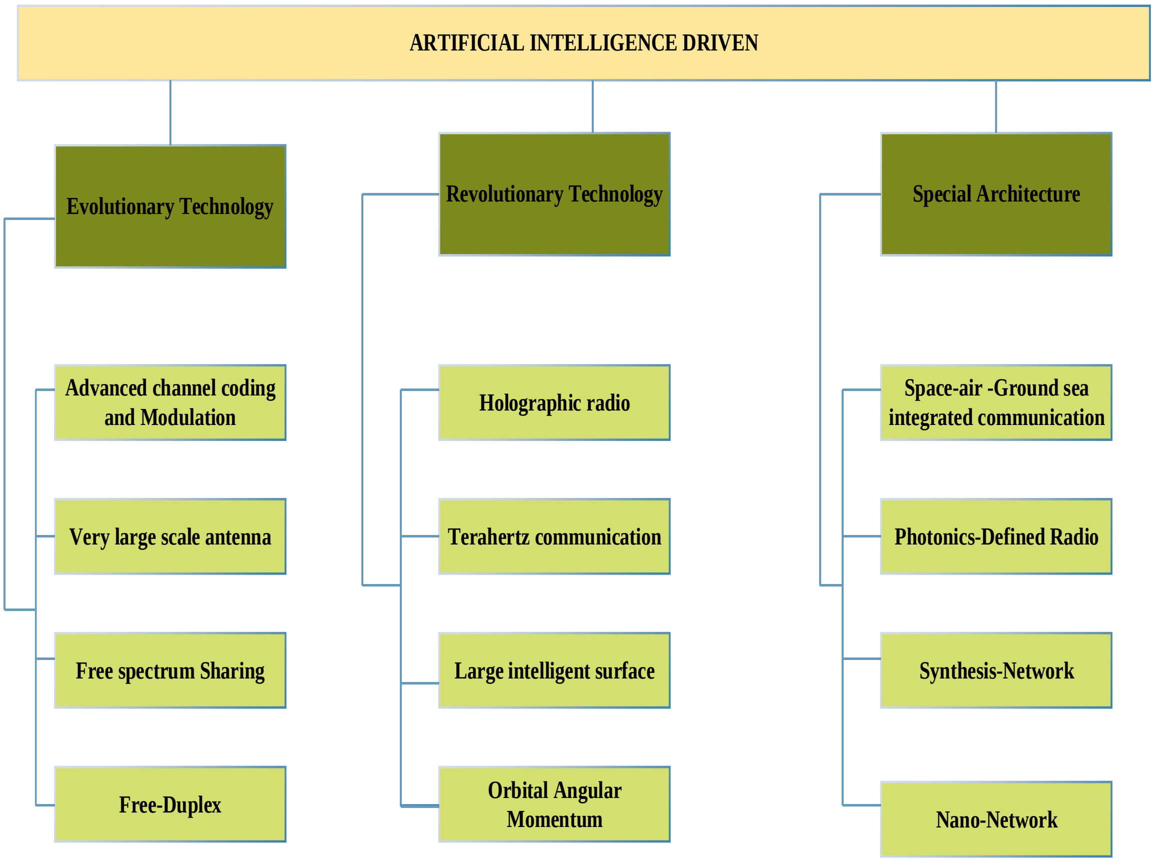

Fig. 14. Potential technologies of 6G [2].

This section examines innovative technology in wireless communication, specifically focusing on radio holography. The existing 5G system is encountering difficulties as a result of progress in the physical layer, necessitating the development of novel concepts and frameworks for 6G. Holographic radios utilize the recording of the electromagnetic field in space to produce ultra-high-density, pixelated spatial multiplexing, and generate holographic images. These radios have the capability to control electromagnetic radiation, enhance network bandwidth and spectrum efficiency, and accomplish the convergence of radio frequency (RF) settings, imaging, and wireless communication. Nevertheless, the handling of hologram radio data necessitates an AI framework that exhibits low latency, high dependability, and excellent scalability. The energy consumption, latency, and adaptability requirements of 6G necessitate a structured hybrid optoelectronic compute and signal processing system. The terahertz wavelength range, spanning from 0.1 to 10 THz, is anticipated to provide data speeds of up to Tbps, facilitating high throughput, minimal latency, and new request capabilities for 6G [45].

Terahertz bands provide benefits in wireless communication, such as the ability to handle networks with terabits per second (Tbps) speeds, wide bandwidths, and effective eradication of high temporal domain interference. Nevertheless, they also face obstacles such as significant signal loss, severe signal weakening, limited capacity to bend around obstacles, vulnerability to obstructions and shadows, reduced susceptibility to moisture and rainfall, and substantial swings in signal strength. The manufacturing of THz components is advancing, and an increase in output power is anticipated in the near future. The main research focuses for THz communications include propagation measurements, channel modeling, and the application of meta-materials and semiconductors. The advent of 6G is anticipated to improve service quality through technological advancements [46].

Terahertz (THZ) transmissions are typically accomplished by arranging the emitter in two ways: using either optics-based or electronics-based technologies. Photonics-based techniques provide a high modulation order and can be utilized for transmitting data at high rates. Nevertheless, transmission distances are frequently limited by the combination of significant propagation loss and low power. Electronics-based approaches are effective for wireless networks operating in the 100-150 GHz frequency band, with frequency multiplication being the prevailing way. Hybrid microwave photonics strategies can integrate many technologies to enhance overall performance. Collaboration between the International Telecommunication Union and the World Radio Council is necessary to foster global consensus on THz [47].

4. Proposed Methodology

As 6G wireless communication becomes more prevalent and high-speed connectivity is required in further instances of great mobility, channel estimation, and data detection concerns must be resolved. The currently available works address problems including high pilot overhead, inaccurate modeling, high receiver complexity, low spatial resolution, and low signal-to-noise ratio. To address these problems, we suggest a thorough strategy that uses a cutting-edge technique called Zeros added Superimposed Sequence Pilot to ensure reliable communication with low complexity equalization in MIMO-OTFS. This method includes sequentially delivering pilot signals, which minimizes pilot overhead while reducing spectrum efficiency and inter-user interference. It has better receiver equalization. For accurate data identification, the equalizer reduces inter-symbol interference, frequency domain effects, and Delay Doppler (DD) domain inter-user interference. The Dynamic Orthogonal Matching Pursuit (DOMP) method overcomes the limitations of the conventional OMP method and yields findings for channel estimates that are more precise. The suggested approach uses superimposed pilot signals to lessen user and symbol interference. It is possible to successfully reduce pilot overhead and limit interference by arranging the data, pilot, and guard symbols in the (DD) Domain.

We primarily focus on the estimation of channels as well as information detection in the present research using massive MIMO- OTFS modulation via 6G communication, in which the 6G communication provides global coverage for high mobility scenarios that leads to reliable communication. This research includes five consecutive phases which are listed as follows:

- Two-fold Preprocessing.
- Uplink and Downlink Parameter Extraction.
- Modulation and Demodulation.
- Data Detection & Recovery.
- Three-Stage Equalization.

The architecture of the proposed framework is given in Fig. 15.

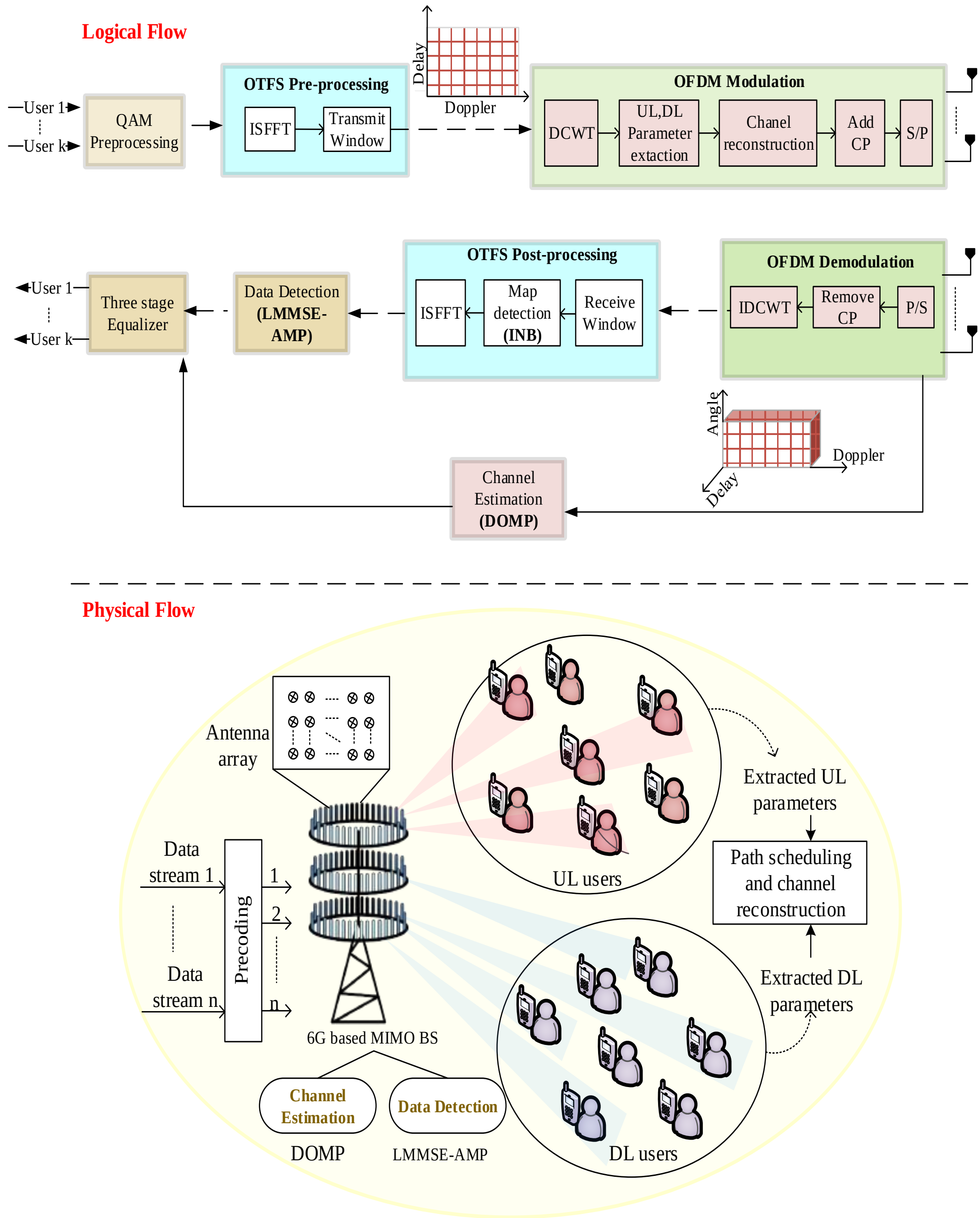

Fig. 15. The Architecture of the proposed framework.

In our next work, we will propose a novel approach for channel estimation and data detection in high-mobility scenarios using Massive MIMO-OTFS modulation in the context of 6G communication. We will discuss a comprehensive strategy to address existing challenges such as high pilot overhead, inaccurate modeling, and high receiver complexity. We will introduce a Zeros added Superimposed Sequence Pilot technique to minimize pilot overhead while improving spectral efficiency. The proposed method utilizes innovative preprocessing steps including noise suppression using the Entropy-Based Adaptive Filtering Algorithm, and superimposed pilot sequences to enhance data detection accuracy. Additionally, we will describe the architecture of the proposed framework and discusses phases such as Uplink and Downlink Parameter Extraction, Modulation and Demodulation, and MAP Detection. We will highlight the effectiveness of the proposed approach in achieving reliable communication with low complexity equalization in high-mobility scenarios, laying a foundation for advanced wireless communication systems like 6G.

5. Conclusions

This study presents a comprehensive description of the OTFS-MIMO-6G wireless communication method. MIMO and OTFS are state-of-the-art technologies designed for 6G networks, with the goal of delivering dependable and seamless connectivity for mobile networks. The article has concentrated on the aspirations, requirements, scenarios, important technologies, and system architectures related to 6G. The purpose of this study is to provide a thorough explanation of the OTFS-MIMO-6G technology to researchers in industry and academia, with the goal of encouraging further research in this area.

6. Future Works

Our upcoming projects will focus on ensuring dependable communication through channel estimation and data detection using OTFS-MIMO for 6G communications. We will prioritize low pilot overhead, complexity, and high spectrum efficiency. The primary goals include of enhancing signal quality by suppressing noise, retrieving uplink and downlink characteristics, suggesting the use of Dual-Tree Complex Wavelet Transform for high-mobility scenarios, and mitigating inter-symbol interference (ISI) caused by the channel. The key advancements of this approach encompass entropy-based adaptive filtering, the Dynamic Orthogonal Matching Pursuit algorithm, enhanced naive Bayes, a hybrid technique amalgamating approximate message passing and linear minimum mean square, and a three-stage equalizer utilizing Rock Hyraxes Swarm Optimization. The recommended work is assessed based on performance characteristics including Signal-to-Noise Ratio (SNR) versus Mean Squared Error (MSE), Detection Probability, Pilot Overhead versus Normalized Mean Squared Error (NMSE), User velocity versus NMSE, Bit Error Rate (BER) versus NMSE, Throughput versus number of users, SNR versus Throughput percentage, and Latency versus Number of Users.

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