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Evaluation of Non-Orthogonal Techniques for Advance Wireless System

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Abstract**:** ***This article represents a comparative study of various types of multiple users' access schemes for cellular radio system. One of the promising technique for the significant bandwidth efficiency enhancement in future wireless cellular system compared to the conventional multiple access technologies, especially orthogonal multiple access is Non-Orthogonal multiple access(NOMA). NOMA have grater spectral efficiency and more massive connectivity over orthogonal in fading environment. Third generation partnership projects have recently been proposed NOMA for 4G (3GPP-LTE-A). It is a Novel technique focusing the solution for 5G, advanced multimedia applications and Internet of things in terms of supporting massive heterogeneous data traffic. This review paper primarily focus on diverse NOMA techniques and provides a detailed outline of the Cutting edge in NOMA basic principles, NOMA power domain and its other variants.***

Index Terms**:** ***coding, Interleaving, Scrambling, spreading.***

I. INTRODUCTION

From analogue 1st generation wireless phone system to recent Internet Protocol services including voice, message and data transmission, to meet the need of various requirements of the future generation of mobile communication different transmission & reception techniques have been initiated. The rapidly increasing demand for Mobile, Internet and the Internet of Things poses challenging demands for the future wireless radio communication such as higher efficiency of spectrum, more user equipment, large connectivity and higher data rate, reduced latency. The standardization of various generations of radio system for cellular communication are usually recognized by access techniques e.g. 1G technology - Frequency Multiple Access (FDMA) used in analogue system, 2G technology - Time Multiple Access (TDMA) of digital system, 3G technology - Code Multiple Access (CDMA) based on spread of spectrum for modulation, Space Division Multiple Access (SDMA), 4G is Orthogonal Multiple Access (OFDMA) based on CDMA concept to provide massive user connectivity [1][2][3]. Novel NOMA allows a BS to provide service to multiple subscribers using the similar resource block with different power coefficient allocated by various algorithms which are to be multiplexed using SC technique. NOMA guarantee not only that subscribers are served with weak channel conditions but also provide favorable channel conditions can simultaneously apply the similar bandwidth resources to the weak users. This result in NOMA System throughput can also be significantly greater than conventional orthogonal access if fairness of users' have been ensured. The idea behind this article is to provide basics of NOMA principles for transmission and reception in which SC precoding and SIC detection techniques were discussed. The rest of the paper provides the information about silent feature of NOMA, its classification and comparative overview of various NOMA schemes in terms of key characteristics.

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II. BASICS OF NOMA

NOMA's basic concept facilitates multiple users' connectivity in the domain of power. It utilizes a novel multiplexing within one of the resource block (time domain/frequency domain). Figure 1 illustrates the real world NOMA system concept for two users. It shows that the base station serves two users in any resource block with different power coefficient allocation depending on the signal strength of the user. As sown in figure 1 user 1 is with higher power coefficient and user 2 is with less power coefficient are allocated at the transmitter side. The receiver is utilizing the concept of SIC in which the user 2 signal is decoded first and then user 1 signal from the observation. The basic operation of NOMA relies on two key techniques which are SC of multiple users signal for transmitter and SIC for reception [15].

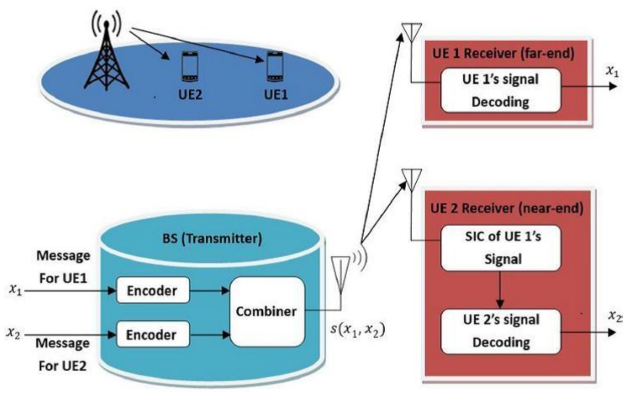

Fig. 1 Basic NOMA Concept [5]

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A. *Superposition Coding (SC)*

The capacity enhancement of a novel NOMA system is relying on superposition coding.

It allows to simultaneously transmitting multiple users information by a single resource block with different power levels. NOMA is utilizing the multiplexing concept in power domain and superimposing the users signal. It allocates higher power coefficient to a signal having poor channel condition and lower power coefficient to another user in case of two user NOMA system and then superposed signal is transmitted. Following Figures of QPSK constellation shows the example of the superposition high power coefficient user 1 signal and low power coefficient user two signal. It is also useful in broadcasting and television system.

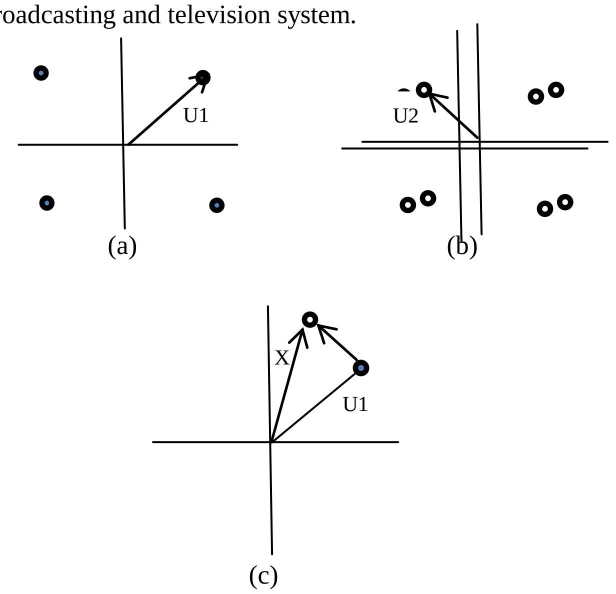
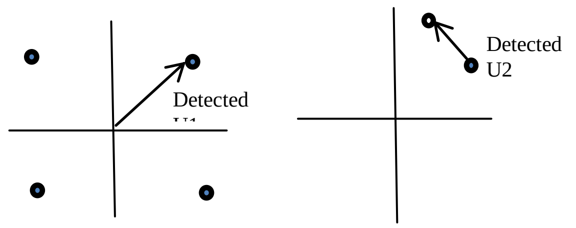


Fig 2: Signal constellation of UE1, UE2 and SC

B. *Successive Interference Cancellation*

In SIC various users' signals are extracted successively [16]. The extracted signal is eliminated from the received signal after detecting one user's signal before performing the next subscriber signal detection. In SIC receiving technique the other subscriber signal is considered to be an interferer and treated as a noise while detecting desired user signal and latter another user signal is decoded with the advantage of having already eliminated the previous signal. Before applying SIC, users are observed according to their strength, so that the stronger signal can be detected initially, and then it is subtracted from the superimposed signal, which segregate the weaker one from the rest. Following Figures of constellation shows the example of the detection of user1 and user 2 signals.



(a) (b)

Fig. 3: (a) Detected UE1 signal
(b) Detected UE2 signal

III. SILENT FEATURES OF NOMA

Improved Spectrum Efficiency

NOMA provides a greater spectrum utilization and improved capacity. This is often attributed that proposed scheme permits each RB to be exploited by number of customers .

Fairness

Significant highlight of NOMA is that it strengthens the weak users signal by allocating desired power coefficient. Due to this technique, NOMA is competent of ensuring an alluring trade-off between the fairness of different users in terms to achieve greater capacity. There are many advanced techniques of maintaining reasonable fairness.

Massive Connectivity

It is expected that the future wireless system will support the IoT's massive smart device connection. Existing NOMA offe rs a promising alternative design by using its Non-Orthogona l characteristics to solve this non-trivial task. Non Orthogonal allocation significantly increases users compare to OMA. It shows that numbers of users are not restricted by the RBs availability.

Compatibility

NOMA can be conjured as an "add-on" method for any OMA methods (CDMA/OFDMA) from a theoretical perspective. It introduces a new aspect, specially the domain of power. As per the develop state of SC for transmission and SIC for reception methods provided in previous literatures, NOMA can be integrated with the MA techniques provided in the old literatures.

Flexibility

NOMA scheme, such as MUSA, PDMA, and SCMA compare to other multiple access methods it is theoretically interesting and low-complexity scheme. Basically conventional access and proposed access are quite comparable, be dependent on number of users are using one resource.

Reduced Latency & Signaling Cost

OMA utilises the scheduling request for the uplink and downlink user's signal transmission which in turn increases the latency &cost of signalling which is not acceptable in massive connectivity system. In some NOMA scheme such dynamic scheduling is not used which in turn reduces the transmission latency as well as signalling overheads.

IV. NOMA SYSTEM MODEL

There are various NOMA solutions which are classified into various domains. NOMA is practically classified into single and multiple carriers NOMA. Single carrier NOMA scheme uses only one assigned resource for transmission, i.e. one carrier only. Multiple carriers NOMA utilize multiple resource blocks as a carrier. It may be observed as combinations of NOMA techniques (Hybrid), in which the subscribers of a system are arranged into different groups and each of group served by NOMA concept with the allocation of multiple resource blocks. The inspiration for considering Hybrid NOMA is an effective method for balanced trade-off between complexity and system performance [6]. Various examples of single and multiple carriers NOMA are mentioned below in the discussion of classification of NOMA.

Figure 4 shows the classification of NOMA techniques. NOMA techniques are classified into four major domains are Scrambling, Spreading (Non-LDS), Coding (LDS) and Interleaving.

A. *Scrambling Based NOMA*

This solution composed of resource Spread Multiple Access (RSMA) of Qualcomm, Low Code Rate and signature based Shared Access (LSSA)of ETRI and power-domain NOMA of NTT DoCoMo as shown in figure. This type of NOMA utilizes various scrambling signature pattern for every user, and uses coding (channel or repetition) for multiple users signal detection. It is performed after modulation in transmitter section. Elementary signal estimator (ESE) or Minimum mean square error (MMSE) with SIC techniques are used for the multi-user detection (MUD) [8].

RSMA makes use of PN long scrambling sequences however; it increases latency and decoding complexity. Hence to minimize complexity as well as latency short the length signature patterns are used in LSSA. RSMA can be single or multicarrier depending on type of application required and it utilizes low cross correlation property of signalling. In uplink Single RB RSMA is always used to minimize the effect of Peak Average Power Ratio (PAPR) and multiple RB RSMA is used for downlink NOMA Power domain is a novel scheme whose scrambling multiplication pattern are all ‘‘one’’. It allocates different power coefficient to different user which are having poor channel condition. It utilizes MMSE-SIC MUD technique for detection.

B. *Spreading Based NOMA*

This scheme utilizes low cross-correlation, non-sparse, non-orthogonal short PN spreading patterns. This solution composed of Multiuser Shared Access (MUSA) of ZTE, Non-Orthogonal Coded Access (NOCA) of Nokia, Non-Orthogonal Coded Multiple Access (NCMA) of LGE, Group Orthogonal Coded Access (GOCA) of Mediatek and Welch Bound spreading multiple access (WSMA) of Ericsson.

It uses different PN sequences for spreading and detecting algorithm for various receiving system. MUSA adopts complex-number spreading and code word level SIC decoding. NOCA uses low-correlation sequences in LTE based on cyclic shift of base sequence [26]and enhanced parallel interference cancellation (MMSE-PIC) method for detection with tolerable amount of error .NCMA generates spreading sequences by Grassmannian line packing problem and MMSE-PIC method for detection . The WSMA utilizes Welch bound spreading sequences and MMSE-SIC for detection of multiuser. The GOCA spreading sequences based on grouped orthogonal concept and MMSE-SIC for detection of multiuser.

C. *Coding Based NOMA*

Its unique feature is based on to prepare the codebook (sparse) with overlapped several domains (frequency, time, code, space) for multiple subscribers. This solution is consist of Pattern Division Multiple Access

(PDMA) from CATT, Sparse Code Multiple Access (SCMA) from Huawei and Low Density spreading Signature Vector Extension (LDS-SVE) from Fujitsu , LDS CDMA and LDS OFDM. It adopts the Message Passing Algorithm (MPA) for Multiple User Detection (MUD). Its complexity depends on codebook size. Further the complexity reduced with a Expectation Propagation Algorithm (EPA) approximately roughly similar to the performance of block error rate (BLER) [9].

PDMA is implemented in multiple domains and uses SIC Amenable multiple access (SAMA)[10]. It is designed to improve diversity and minimizing the interference between multiple users. It is used for uplink as well as downlink transmission.

LDS-SVE is the advanced version of LDS designed using larger signature vector. It can be used to exploit diversity of the channel. LDS CDMA is a novel technique of CDMA. LDS CDMA utilizes sparse spreading sequence rather than dense spreading sequence to minimize the interference [11].

LDS OFDM is a hybrid version of LDS CDMA and OFDM to improve spectral efficiency [12].

SCMA technique directly maps the coded multiple users data to the complex multidimensional code word according to the lookup table for different sparse codes in time, frequency domain. It improves performance, gain reasonably by using multidimensional constellation, LDS concept [13]. It is applicable in both uplink and downlink transmission.

D. *Interleaving Based NOMA*

In this technique multiple interleave channels are overlapped for different users data transmission and channel coding with low rate is used for detection. This solution composed of IDMA from Nokia, IGMA from Samsung, LCRS from Intel and RDMA from Mediatek with basic characteristics of IDMA [14].

IDMA is a first interleaving NOMA scheme, which makes use of random interleave patterns to distinguish different users. SC is used for data transmission and low-complexity ESE algorithm used for MUD and estimate log-likelihood ratio (LLR).

RDMA utilizes a repetition pattern with cyclic-shift to distinguish users’ signals and uses both frequency and time diversity. SIC technique is used for MUD whereas SC is used for data transmission.

LCRS adopts bit level interleaving, repetition, channel encoding and modulation for every user. MMSE-PIC is used for MUD. A Comparative table for key characteristics of various NOMA scheme is shown in table I.

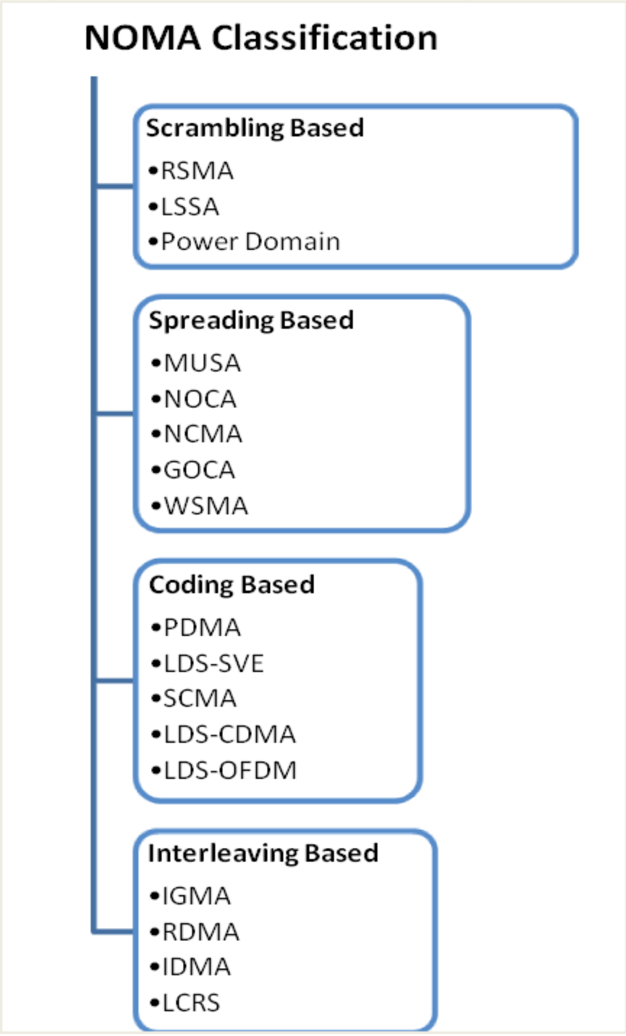


Fig 4: NOMA Classification

V. DESIGNING ASPECTS AT TRANSMITTER & RECEIVER

A. *Codebook or Spreading Sequence*

In LDS based NOMA scheme due to Non-Orthogonal allocation, interference created amongst the users. To realize the balance among receiver complexity & overloading factor an MPA technique is used for optimizing factor graph. MPA also achieve the marginal distribution due to the use of cycle free factor graph without negotiating spectral efficiency [6].

B. *Receiver Complexity*

For Massive Connectivity, MPA based receiver complexity is high which is overcome by advanced MPA techniques. MPA can also be used for detection and decoding which improves the detector performance. In SIC receiver error propagation degrades the performance which is improved by using nonlinear detection algorithm with more accurate detection capability [6].

VI. UPLINK AND DOWNLINK NOMA

In the uplink transmission process of NOMA , multiple subscriber transmit their own data to the base station using same RB and Base Station detects the data using SIC technique whereas in downlink NOMA , Base station generates SC signal from multiple subscriber information and then SIC technique is invoked by the users for interference minimization. The significant difference among downlink and uplink NOMA mentioned below.

A. *Transmission Power*

Compare to NOMA for downlink, the transmission power factor of the subscriber in NOMA for uplink are not modified. Transmission condition of every subscriber channel is responsible for this. So depending on subscriber's signaling conditions received SNR may be significantly vary at the BS, irrespective of their transmitted power level.

B. *Receiving Technique*

As shown in figure (a) in uplink transmission SIC receiver detects n stronger users and considering m other users are interferer then re-modulate the detected signal and remove the interference of other users for desired signal detection. From figure (b) of downlink transmission, the signal received from one group of users is separated from the interference due to by another group of user. This is accomplished by initially decoding the more powered signal of users, followed by re-modulating and removing it from the composite signal.

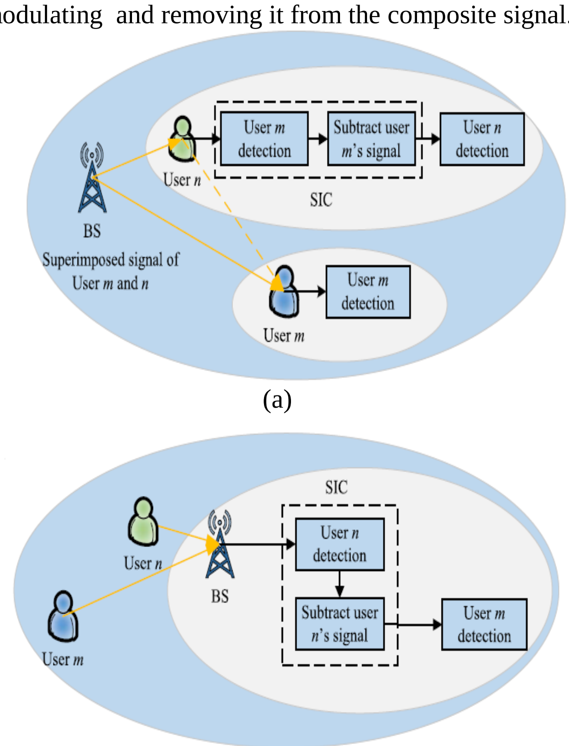


Fig. 5 (a) Downlink NOMA (b) Uplink NOMA [17]

I. Key characteristics comparison of various NOMA scheme

NOMA Techniques	Affiliation	Carrier	Decoding Algorithm	Complexity	Basic user Differentiation
RSMA	Qualcomm	SC/MC	ESE	Low	Low rate scrambling and channel codes are used.
LSSA	ETRA	SC	SIC	Low	Bit by bit or symbol by symbol level multiplexing with specific signature pattern.
Power Domain	NTT DOCOMO	SC	MMSE-SIC	Low	Multiple Subscribers signal with different power coefficient are transmitted
MUSA	ZTE	SC	MMSE-SIC	Medium	Use short length complex PN code for t transmission.
NOCA	Nokia	SC	MMSE-PIC	Medium	Use LTE low correlation sequence as a spreading code.
NCMA	LGE	SC	MMSE-PIC	Medium	Grassmannian line packing problem is used for spreading code.
GOCA	Mediatek	SC	MMSE-SIC	Medium	Group orthogonal sequences along with spreading symbols
WSMA	Ericsson	MC	MMSE-SIC	Medium	Welch Bound sequences are generated.
PDMA	CATT	MC	MPA	High	Each code with sparse mapping and particular diversity order is transmitted.
LDS-SVE	Fujitsu	SC	MPA	High	Extended signature vector
SCMA	Huawei	MC	MPA	High	Low Density data stream as per lookup table(codebook) is transmitted.
LDS-CDMA	-	SC	MPA	High	Novel type of CDMA uses low density signatures codes are used
LDS-OFDM	-	MC	MPA	High	LDS CDMA extension with orthogonal subcarrier mapping.
IGMA •	Samsung	SC	ESE	Low	Bit level interleaving and grid mapping pattern codes are used.
RDMA	Mediatek	SC	SIC	Low	Frequency and time diversity with cyclic shift repetition codes are used
IDMA	Nokia	SC	Complex ESE	Low	Bit level interleaving codes are used.
LCRS	Intel	SC	MMSE-PIC	Low	Use direct PN sequence spreading symbols.

VII. CONCLUSION

This paper surveyed the recent literatures of novel NOMA for future wireless radio system initially the basic NOMA concepts was discussed in which SC transmission and SIC reception techniques are studied. It highlights the NOMA silent features which give the information that how NOMA will be useful for future wireless system. The various NOMA techniques are classified into four domains: spreading, scrambling, coding and interleaving. The various NOMA techniques are compared with receiving algorithms, key characteristics and complexity. Depending upon the specific characteristics the NOMA schemes are useful for application specific environment but there is a scope of improvement in terms of complexity and latency which need to be explored. It is expected that the demand for the more connectivity and high spectrum efficiency NOMA will perform an interesting role in future wireless radio communication.

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