Performance analysis of NOMA using different coding techniques

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Abstract. To date, Non-Orthogonal Multiple Access (NOMA) is the best and most compatible technique to support for the incoming Fifth Generation (5G). However, the NOMA performance is affected by noise, interference and poor signal strength during transmission. Channel coding is required to correct transmission errors due to error propagation. Therefore, channel coding is an important technique that can detect and correct errors at the receiver side. This paper analyses the performance comparison of different channel coding schemes in order to suggest the optimum channel coding scheme for the 5G mobile communication system. The Bit Error Rate (BER) is being evaluated to assure that better performance can be achieved. The simulation was done using The Vienna 5G Link Level Simulator (LLS). The result of BER shows that LDPC perform better than Turbo and Convolutional which is 3.4x10⁻¹ for cell centred user and 4x10⁻² for cell-edge user.

1. Introduction
The present, multiple access schemes used in 4G communication systems is the Orthogonal Multiple access (OMA). Orthogonal Frequency Division Multiple Access (OFDMA) and Orthogonal Frequency Division Multiplexing (OFDM) are also part of the OMA technology. For the OFDMA system, the numerous narrowband subcarriers are the result of the division of the wideband signal, where every user is assigned to the orthogonal subcarrier disjointed by the frequency [1]. Later, a base station was able to communicate with each user on the subcarrier allied with the user [2]. In spite of the fact that 4G framework gives higher achievable information rate, the latency requirement of the Internet-of-Things (IoT) is still cannot be provisioned. The 4G Long Term Evolution (LTE) can only provide latency around 60 milliseconds using the OMA system [3]. Furthermore, the IoT devices would not just be remotely controlled and overseen by individuals, yet can also communicate with each other. In this way, some media applications of IoT needs very low transmission latency which is less than the human visual delay constraint of 10 milliseconds [4]. NOMA can offer the 2 milliseconds latency, which can meet the prerequisite of 5G system.

On the other hand, channel coding schemes such as Convolutional, Turbo, and Low Density Parity Check (LDPC) is important in order to provide better quality to support the new mobile services with improved features. Error correction coding is used to improve the error performance of the recovered
data at the receiving end. Thus, to achieve error free transmission that can support more users with better transmission quality, advanced channel coding schemes are required.

This paper focuses on the investigation of the BER performance using different channel coding schemes using the Multiple Input Multiple Output (MIMO) for the downlink transmission of NOMA. The aim of this study is to evaluate the performance of NOMA that is being applied with different coding techniques which are the Convolutional, Turbo and LDPC. To achieve this, Vienna 5G LLS is used as the simulation platform in order to validate the performance of the channel coded schemes.

2. Background

2.1. NOMA in MIMO
The NOMA 5G has been driven by the need to provide ubiquitous connectivity for applications such as automotive communications or vehicle to vehicle (V2V), machine to machine (M2M), remote control with haptic style feedback, huge video downloads, as well as the very low data rate applications like remote sensors and what is being termed the IoT.[5]. MIMO-NOMA can cater this because it can schedule more than 1 user for each subcarrier. The Power Domain NOMA (PD-NOMA) has been the primary focus because this technique utilizes superposition coding at the transmitter and Successive Interference Cancellation (SIC) at the receiver. The main advantage of PD-NOMA is that the performance of the system can be improved with SIC detection applied on the receiver side. SIC in the downlink transmission detects and decodes the information for all users efficiently. It can handle overloaded users of up to 200% and is less computational complex as compared to other methods [6].

2.2. System Performance
As the name infers, BER is characterized as the rate at which error happened in a transmission framework. This can be specifically deciphered into the quantity of errors that happened in a string of an expressed number of bits. When the medium between the transmitter and receiver is good and the transmit power at the BS is high, then the BER will be a little conceivably neglected and having no observable impact to the system.

2.3. Channel Coding Schemes
In this paper, the performance of the channel coding schemes of Convolutional, Turbo, and LDPC codes has been compared. For the Turbo and Convolutional codes, the rate matching procedure is identical to the standard. The interleaving is carried out directly on each of the three streams at the encoder output, for example, subblock-interleaving. After interleaving, the streams are passed to the circular buffer, where puncturing and/or repetition is performed in order to meet the output length, and consequently the target code rate. For the Turbo code, part of the systematic stream is skipped at the first transmission from the circular buffer.

As for the LDPC code, this study follows the 5G New Radio (NR) chain [7], in which the systematic codeword is passed to the circular buffer directly without interleaving. The codeword is then repeated in order to meet the target length. After the codeword rate is matched, it is then interleaved using a rectangular interleave. The interleaving pattern depends on the modulation order.

3. Methodology

3.1. Non Orthogonal Multiple Access
This simulation has configured one cell in the network using NOMA. In this cell, the Base Station (BS) splits the bandwidth equally between the two User Equipment’s (UE) that have good channel conditions (strong users). However, since the BS supports NOMA, it can superimpose those two strong UEs with the two other weak users.
Figure 1: User assignment for NOMA simulation [8]

Figure 1 shows the assignment of subcarrier for each user and each cell is allocated with 72 subcarriers. The cell supports two users only and therefore each one will get 36 subcarriers. There are two groups of two superimposed users (in the power-domain) and each group has one strong channel condition user than the other user. The strong channel condition users are represented by the corresponding Path Loss (PL) value of 80 and 90 dB and being configured to UE1 and UE2 respectively. Additionally, 110 and 115 dB PL indicate the weak channel condition users which are referred to UE3 and UE4. The results are obtained over the transmit power of the BSs. Table 1 summarizes the simulation parameters for this simulation. Time Selective Fading Channel Models which is Pedestrian A is selected for the analysis. The speed of the UE is set to 3 km/h for Pedestrian A [9] which is equivalent to 0.83 m/s.

| Parameter          | Value                                           |
|--------------------|-------------------------------------------------|
| Cells              | NOMA                                            |
| Number of users    | 4 (2 strong, 2 cell-edge)                      |
| Path-loss          | Strong: 80, 90 dB                               |
|                    | Cell-edge: 110, 115 dB                          |
| NOMA receiver      | ML                                              |
| NOMA power-ratio   | Fixed (second ratio)                            |
| Bandwidth          | 1.4 MHz (72 subcarriers)                        |
| Waveform/coding    | OFDM, LDPC, Convolutional, Turbo                |
| MIMO mode          | 2X2 CLSM                                        |
| Modulation/code rate| Adaptive (CQI based)                           |
| Feedback delay     | No delay (ideal)                                |
| Channel model      | Pedestrian A                                    |
3.2. Simulation Development

The simulation is conducted using The Vienna 5G LLS to analyse the performance of BER. The simulator supports the three coding schemes which are the Convolutional, Turbo and LDPC by using the power-domain NOMA that works by superimposing two users on the same resources in the power domain [11]. The gain provided by this scheme is maximized when the two imposed users have a large difference in their channel quality, for example a user with good channel conditions (cell centred UE) and a user with bad channel condition (cell edge UE). The superposition works by assigning the cell edge UE with most of the transmit power. Then, at the receiving side, SIC can be used to first detect the high-power user, subtract its signal from the total received signal, and then proceed to detect the low power user.

Alternatively, one can view the superimposed signal as just a normal signal with symbols being drawn from a super composite constellation. This allow the receiver to perform the detection using a Maximum Likelihood (ML) detector running on the composite constellation.

Furthermore, when it comes to producing result with NOMA, it is recommended to use the channel coding scheme as the sweeping parameter. The Convolutional and Turbo coding have been compared for the same decoder. The decoder is based on the Bahl-Cocke-Jelinek-Raviv (BCJR) algorithm [12], which is an efficient implementation of the bit-wise Maximum A-Posteriori (MAP) decoder. The supported algorithm is the sub-optimal ‘MAX-LogMAP’ which provides lower complexity. Furthermore, the LDPC decoder is based on layered Belief Propagation [13] or usually called Sum-Product algorithm. The layering is utilized through the Column Message Passing schedule [14]. The supported decoding algorithm is ‘PWL-Min-Sum’, where PWL stands for Piecewise Linear.

4. Result and Discussion

![Figure 2: BER performance using different coding techniques.](image-url)
Table 2: BER for Convolutional, LDPC and Turbo coding techniques.

| METHODS    | USERS          | Tx PowerBS | BER     |
|------------|----------------|------------|---------|
| LDPC       | U1  | Strong     |          | 1.1X10⁻¹ |
|            | U2  |            | -30dBm   | 3.5X10⁻¹ |
|            | U3  | Cell-edge  |          | 4.6X10⁻¹ |
|            | U4  |            |          | 4.9X10⁻¹ |
| Turbo      | U1  | Strong     |          | 1.5X10⁻¹ |
|            | U2  |            | -30dBm   | 3.9X10⁻¹ |
|            | U3  | Cell-edge  |          | 4.7X10⁻¹ |
|            | U4  |            |          | 4.9X10⁻¹ |
| Convolutional | U1 | Strong     |          | 1.8X10⁻¹ |
|            | U2  |            |          | 4.5X10⁻¹ |
|            | U3  | Cell-edge  |          | 4.9X10⁻¹ |
|            | U4  |            |          | 5X10⁻¹   |

The BER performance for different channel coding schemes is illustrated in Figure 2. We have fixed the negative value of the transmit power [8] to serve as the base line for comparison of the BER performance. The transmit power of -30 dBm is chosen to gauge the performance of the coding schemes which is the minimum value for the transmit power of a femtocell [15]. Femtocell is categorized as small cell and is the smallest with a range of around 10 m.

It is observed that at -30 dBm the value of the BER for UE1 using LDPC is 1.1x10⁻¹ while the BER for UE1 using Turbo and Convolutional codes are 1.5x10⁻¹ and 1.8x10⁻¹ respectively as tabulated in Table 2. It shows that LDPC outperformed the Turbo and Convolutional code by 3.4x10⁻¹ in terms of BER at -30 dBm of base station transmit power. UE1 performed much better than UE2 in terms of BER because UE1 has lower PL value than UE2. To investigate the cell-edge user performance, the result shows that UE3 using the LDPC scheme performs better than other UE that are using the Convolutional and Turbo codes.

From here, we can conclude that the LDPC code is the best coding channel to be applied in a small cell of NOMA, followed by Turbo code and Convolutional code. The implementation of small cells will be a crucial component of 5G networks, because of the ability to significantly increase network capacity, coverage, especially indoors and reduced the installation cost.

5. Conclusion

This paper has investigated the performance of different channel coding techniques in NOMA for the cell centred and cell edge users. The simulation results show that UE1 and UE2 have better values in terms of BER because of its good channel condition. UE3 and UE4 have higher BER values than UE1 and UE2 due to the high value of PL. Overall, the simulation result shows that LDPC code performs much better than Convolutional and Turbo codes. The resulting curve shows that NOMA allows the BS to support more users, and when combined with a sufficiently high transmit power, it offers higher
downlink spectral efficiency. For future recommendation, we will focus on mitigating the interference in multiuser multiple-input and multiple-output (MU-MIMO) NOMA using the DPC Broadcast channel.

6. References

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