LDPC codes for Enhanced Reliability in 5g NR networks

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Department Research Day
Inspiring Minds, Advancing Frontiers

[Insert team members names: Dwarakanath Reddy,Hemanth Kumar,Siva Charan

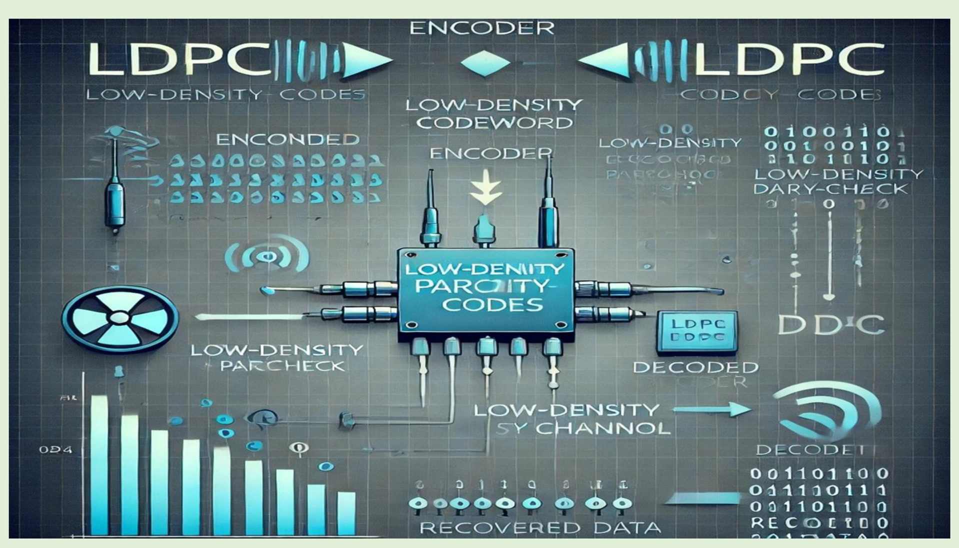
Supervisor : << DR.AMBAR BAJPAI >>

Abstract

When sending data over a noisy channel, errors can happen, like **when a 0 is received as a 1 because of noise**. To fix this, extra bits (redundancy) can be added to the original data, which helps detect and correct errors during transmission.

The simplest way to add redundancy is by repeating each bit multiple times, but this method is not efficient. In 1948, Shannon introduced a concept called "channel capacity," which defines the maximum data rate that can be sent over a noisy channel without errors. Over time, better error-correcting codes were developed, like turbo codes used in 3G and 4G networks.

LDPC codes, introduced by Robert Gallager**,** are an improved type of error-correcting code that adds extra bits in a smart way. They use a special type of matrix called a "**sparse matrix**," with mostly zeros and a few ones, to efficiently detect and fix errors. LDPC codes are highly effective and can come close to achieving the maximum data rate (Shannon's limit) for reliable communication, making them suitable for fast data transmission in modern communication systems like 5G.



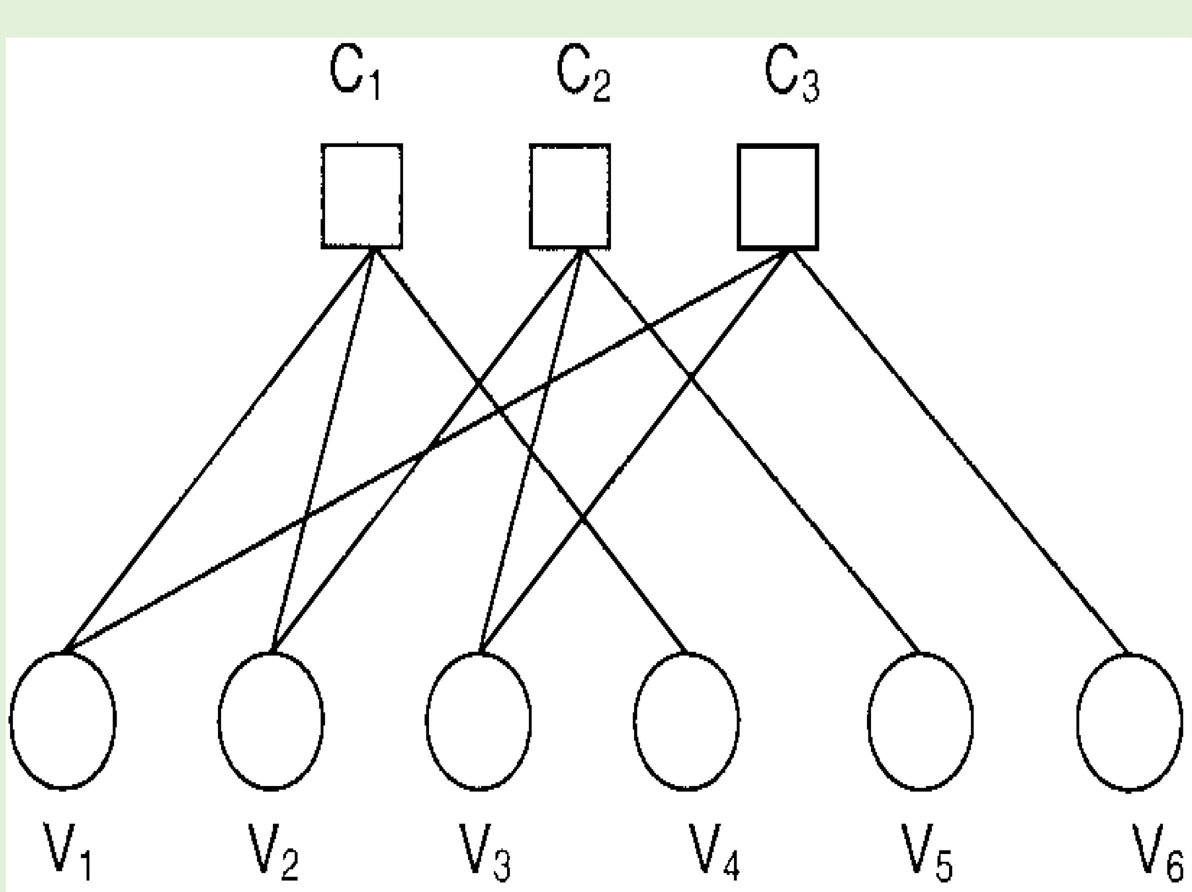
Background

Low-Density Parity-Check (LDPC) Codes

LDPC codes are error-correcting codes used in 5G communication to ensure reliable data transmission over noisy channels. Introduced by **Robert Gallager** in the 1960s, they are popular due to their efficient error correction with low complexity.

LDPC uses a sparse matrix for encoding, meaning most elements are 0s. This matrix multiplies an input data vector to create a codeword containing the original data and extra parity bits for error detection and correction.

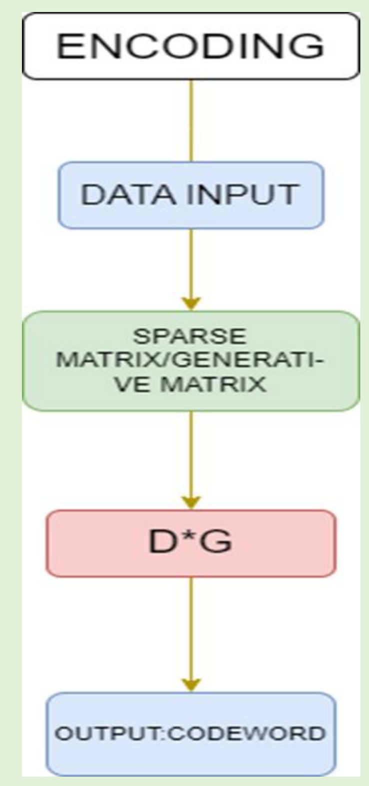
Decoding is done using the **Message Passing Algorithm** (or **Belief Propagation**) on a **Tanner graph**, where nodes represent codeword bits, and edges show relationships. The algorithm iteratively updates bit estimates to detect and fix errors.



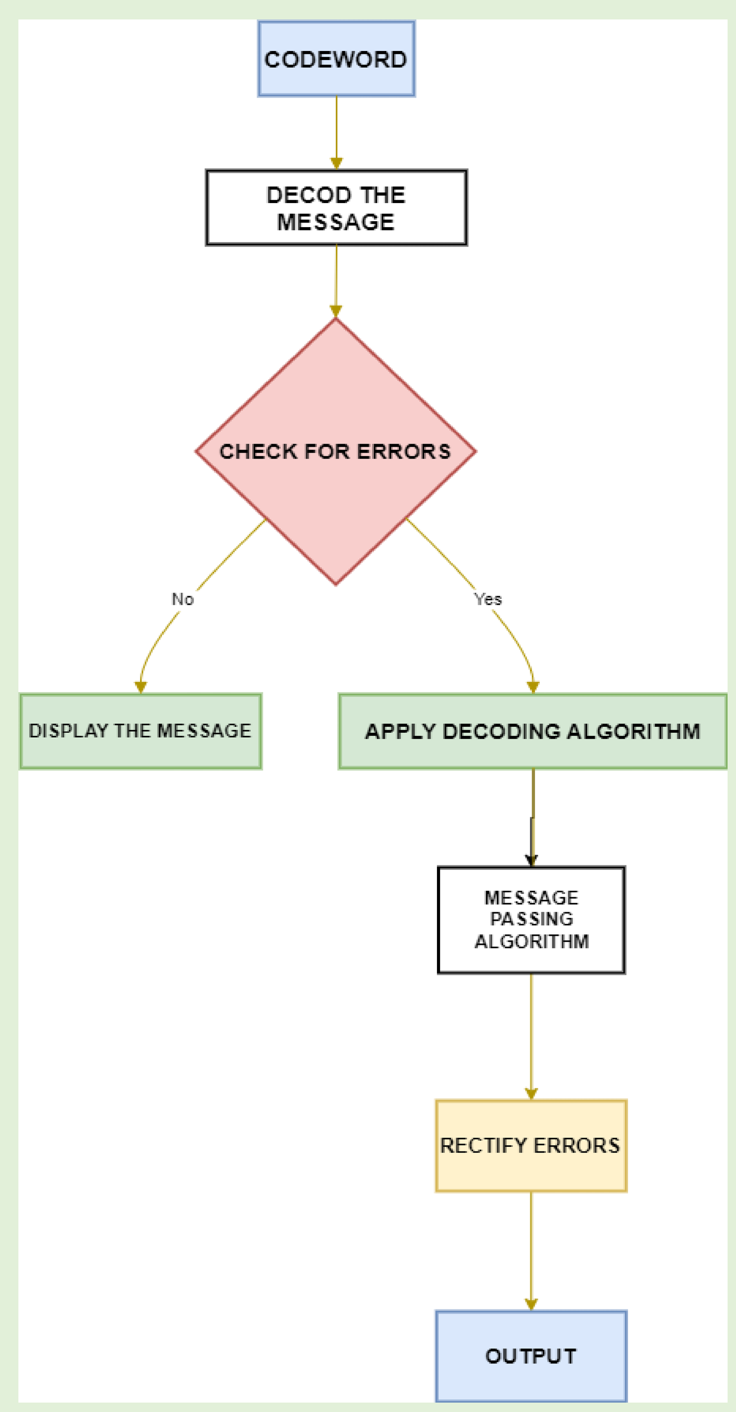
Methods

The project will involve the following methods:

Encoding



Decoding



Expected Outcome

Correct Message Recovery: Through the application of LDPC encoding and message passing decoding algorithms, the project aims to accurately recover the original transmitted message, even in the presence of noise.

Sample outputs:

```
>> GEN
Generated Generator Matrix G:
     1     0     0     1     0     1
     0     1     0     1     1     0
     0     0     1     0     1     1
>
```

```
>> LDEN1
Encoded data (codeword):
   1   0   1   0   1   0   1   1   1
```

Conclusion

LDPC (Low-Density Parity-Check) codes are a key component in enhancing the reliability and efficiency of 5G communication systems. They offer superior error correction capabilities, which are crucial for maintaining data integrity in high-speed networks. LDPC codes help achieve lower latency and higher throughput, essential for supporting advanced 5G applications like IoT, autonomous vehicles, and ultra-reliable low-latency communication. By optimizing these codes, we can ensure robust and efficient data transmission, making them an integral part of the future wireless communication.

Future Perspectives

As We have completed the encoding and decoding steps, the next phase involves testing the LDPC codes in **different noisy communication channels** to evaluate how well they can correct errors. This includes measuring performance under various noise conditions. Additionally, **We will check the speed and efficiency of the decoding process** to determine if it meets the requirements for real-time 5G applications. These tests will help provide a better understanding of how well the LDPC codes perform in different situations.

Impact on Society

LDPC codes make 5G networks more reliable and faster by reducing transmission errors. This leads to better internet speeds for users, improved connectivity in remote areas, and energy-efficient devices with longer battery life. It supports the development of new technologies like smart cities and autonomous vehicles. Overall, LDPC codes enhance communication and bring innovations that improve daily life.