1. ARQ-->

ARQ (Automatic Repeat reQuest) is an error control mechanism used in communication systems, including 5G, to ensure reliable data transmission. It involves the sender retransmitting data packets that are not correctly received by the receiver. In 5G, ARQ is part of the data link layer protocols to maintain data integrity and reliability over the air interface.

How ARQ Works in 5G

1. Packet Transmission:
   The sender (UE or gNodeB) transmits data packets to the receiver.

2. Error Detection:
   The receiver checks each packet for errors using error detection codes (e.g., CRC).

3. Acknowledgment:
   If a packet is received correctly, the receiver sends an ACK to the sender.
   If a packet is received with errors, the receiver sends a NACK to the sender.

4. Retransmission:
   Upon receiving a NACK, or if an ACK is not received within a specified time, the sender retransmits the erroneous packet.

Advantages of ARQ in 5G

1. Reliability: Ensures that data is correctly received, enhancing the reliability of the communication link.

2. Efficiency: Selective Repeat ARQ and HARQ mechanisms optimize bandwidth usage by minimizing unnecessary retransmissions.

3. Scalability: Can be adapted to various types of traffic and quality of service (QoS) requirements, making it suitable for the diverse applications supported by 5G.

2. HARQ->

Hybrid Automatic Repeat reQuest (HARQ) is a sophisticated error control mechanism used in 5G networks to ensure reliable data transmission and improve spectral efficiency. HARQ combines traditional ARQ error correction with Forward Error Correction (FEC), allowing for more efficient handling of errors and reducing the need for retransmissions.

Key Components of HARQ in 5G

1. Forward Error Correction (FEC):

Description: FEC adds redundant bits to the data packet before transmission, enabling the receiver to detect and correct certain errors without needing a retransmission.

2. ARQ Mechanism:

Description: ARQ requests retransmission of packets that are received with errors. HARQ enhances ARQ by incorporating FEC to reduce the number of retransmissions needed.

3. Soft Combining:

Description: The receiver combines information from multiple transmissions (original and retransmissions) to improve the

likelihood of correct decoding.

HARQ Process in 5G

1. Initial Transmission:
   The transmitter (UE or gNodeB) encodes the data packet using FEC and sends it to the receiver.

2. Error Detection:
   The receiver checks the received packet using error detection codes (e.g., CRC). If no errors are detected, an ACK (Acknowledgement) is sent back to the transmitter.
   If errors are detected, a NACK (Negative Acknowledgement) is sent, indicating the need for retransmission.

3. Soft Combining and Retransmission:
   Upon receiving a NACK, the transmitter either retransmits the entire packet (Chase Combining) or sends additional parity bits (Incremental Redundancy).
   The receiver combines the new transmission with previously received data (soft combining) to improve the chances of correct decoding.

4. Repeated Process:
   This process is repeated until the packet is correctly received and an ACK is sent, or a maximum number of retransmissions is reached.

HARQ Configuration in 5G

1. Number of HARQ Processes: Multiple HARQ processes can

operate simultaneously to increase throughput and efficiency. Each process is identified by a unique HARQ process ID.

2. Timing: HARQ retransmissions are carefully timed to ensure minimal delay while maximizing the chances of successful decoding.

3. HARQ Feedback: HARQ feedback (ACK/NACK) is transmitted in uplink control channels, such as Physical Uplink Control Channel (PUCCH) or Physical Uplink Shared Channel (PUSCH).

Advantages of HARQ in 5G

1. Improved Reliability: HARQ significantly reduces the error rate, ensuring more reliable data transmission.

2. Enhanced Spectral Efficiency: By reducing the number of retransmissions needed through effective error correction, HARQ improves overall spectral efficiency.

3. Lower Latency: Soft combining and efficient retransmission strategies help to minimize latency compared to traditional ARQ.

4. Scalability: HARQ can adapt to various channel conditions and service requirements, making it suitable for diverse 5G applications, from eMBB (enhanced Mobile Broadband) to URLLC (Ultra-Reliable Low-Latency Communications).