TechLTEworld

LTE HARQ

Hybrid Automatic Repeat Request (HARQ) is a technique used in Long-Term Evolution (LTE) networks to improve the reliability and efficiency of data transmission. HARQ combines both error detection and correction techniques to ensure that data is accurately transmitted and received by the recipient.

In this article, we will discuss HARQ in detail, including how it works, its benefits, and its applications in LTE networks.

HARQ = ARQ + FEC

ARQ (Automatic Repeat Request)

ARQ (Automatic Repeat Request) is a transmission protocol used in communication systems, including LTE networks, to ensure the reliable delivery of data. It is a method for detecting and correcting errors that may occur during data transmission.

ARQ works by requiring the receiver to send an acknowledgment (ACK) message to the sender when it receives a data packet without errors. If the receiver detects errors in the data packet, it sends a negative acknowledgment (NACK) message to the sender, indicating that the packet needs to be retransmitted. The sender then resends the packet until the receiver sends an ACK message.

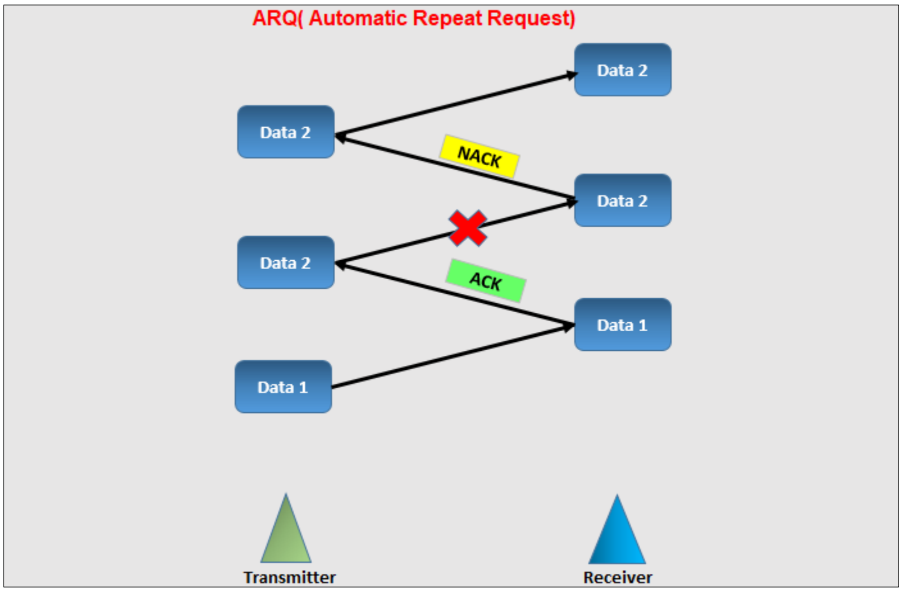
FEC = (Forward Error Correction)/Soft Combining.

Forward Error Correction (FEC) is a technique used in HARQ (Hybrid Automatic Repeat Request) in LTE networks to improve the reliability of data transmission. FEC is a process in which redundant data is added to the original data before transmission. The additional data allows the receiver to detect and correct errors without the need for retransmission.

In LTE, the FEC technique is implemented using a convolutional code, which is a type of error-correcting code. The convolutional code adds parity bits to the original data before transmission, which enables the receiver to detect and correct errors. The addition of the parity bits increases the size of the data transmitted, but it also improves the reliability of the data transmission.

The use of FEC in HARQ allows for more efficient and reliable data transmission, as it reduces the need for retransmission of data, which can result in increased latency and reduced throughput. In LTE networks, the combination of FEC and ARQ in the form of HARQ allows for efficient data transmission and error correction.

It is important to note that the use of FEC in HARQ is not a substitute for ARQ, but rather a complementary technique. ARQ is still necessary to correct errors that cannot be corrected by FEC, and to ensure reliable data transmission. The combination of FEC and ARQ in HARQ in LTE networks provides an efficient and reliable method for transmitting data with minimal delay.

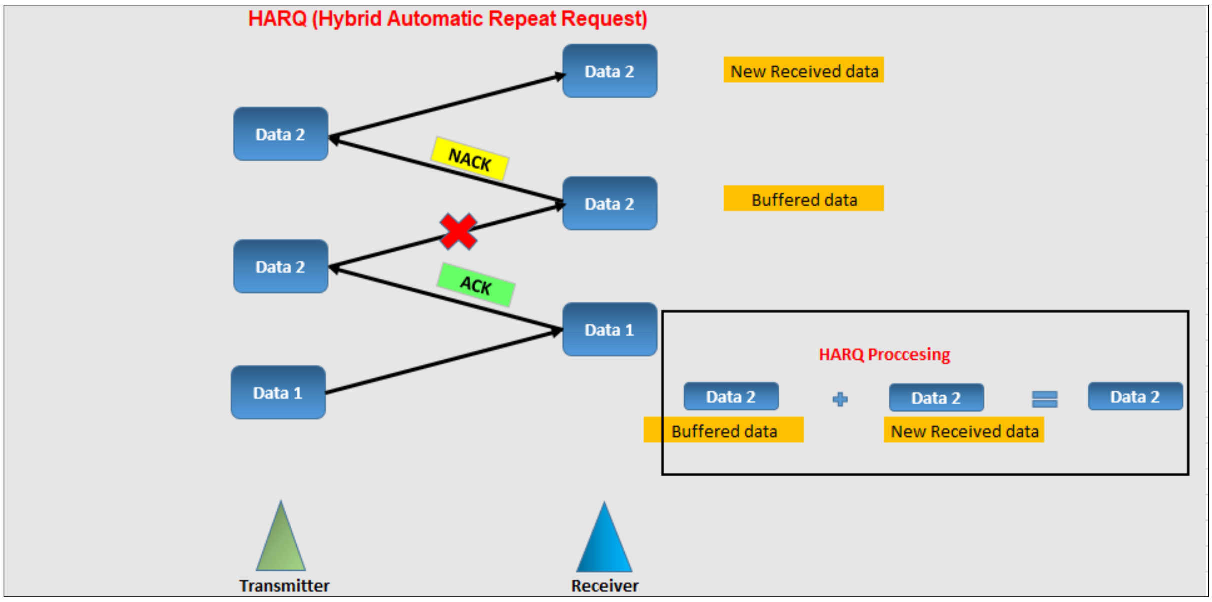


HARQ (Hybrid Automatic Repeat Request)

HARQ is a communication protocol that allows the sender to detect and correct errors in the transmitted data. It works by using a combination of retransmissions and error correction codes to ensure that the data is transmitted and received correctly.

When data is transmitted from the sender to the recipient, the recipient sends an acknowledgement (ACK) message to the sender indicating that the data has been received successfully. If the sender does not receive an ACK message within a certain period of time, it assumes that the data was not received correctly and sends the data again.

In the case of HARQ, the retransmission is not a complete retransmission of the original data but rather a retransmission of only the erroneous bits or packets. This means that only the parts of the data that were not received correctly are retransmitted, reducing the amount of data that needs to be transmitted and improving the efficiency of the communication.



Hybrid Automatic Repeat Request (HARQ) Types

- Chase Combining: Type #1 HARQ
- Incremental Redundancy: Type #2 or Type #3 HARQ

Chase Combining: Type #1 HARQ

Information = Data + Error Detection Bits (ED)+ Forward Error Correction bits (FEC).

Type 1 HARQ is also known as Chase Combining. In this process, the base station sends the same data to the UE (User Equipment) twice, with a short gap between the transmissions. The UE combines the original transmission with the retransmission if necessary, improving the signal quality and reducing the probability of decoding errors. If the UE still detects errors, it sends a NACK (not-acknowledgment) message to the base station, which then sends another retransmission of the data. Type 1 HARQ can support up to two retransmissions.

Incremental Redundancy: Type #2 or Type #3 HARQ

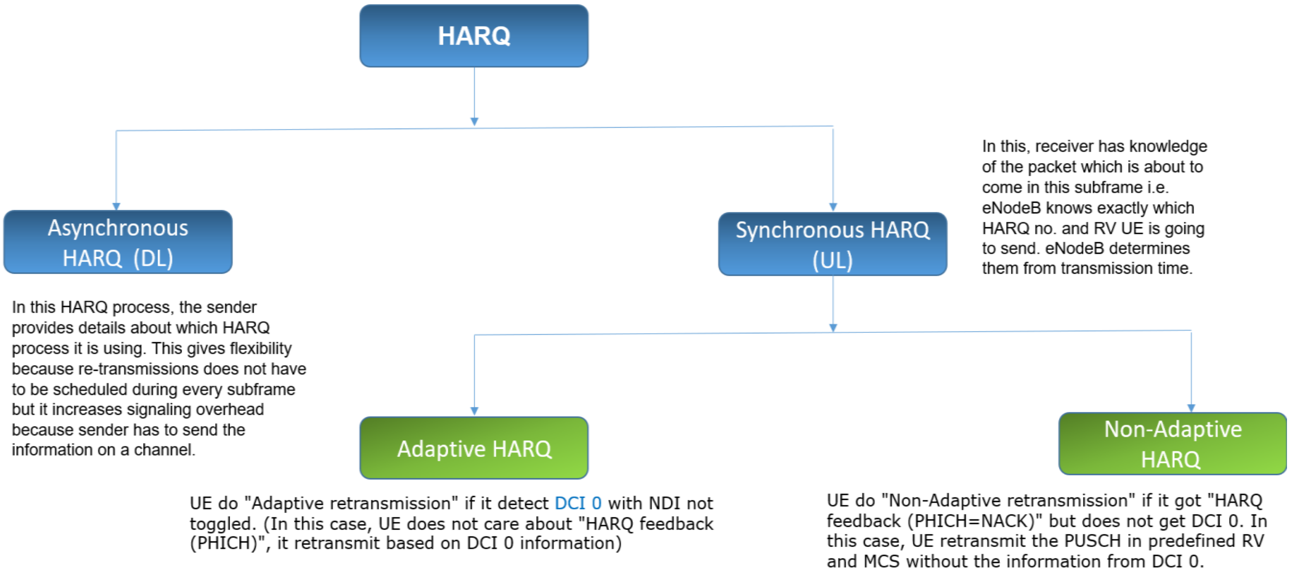
Information = Data + Error Detection Bits (ED)+ Forward Error Correction bits (FEC).

Type 2 HARQ is also known as Incremental Redundancy. In this process, the base station sends a portion of the original data to the UE, followed by additional redundant data in the retransmission. If the UE still detects errors, it sends a NACK message to the base station, which then sends another retransmission with additional redundant data. Type 2 HARQ can support up to four retransmissions.

Type 3 HARQ is used in the uplink direction, where the UE sends data to the base station. In this process, the UE sends the original data along with a parity check value (PCV). If the base station detects errors, it sends a NACK message to the UE, which then sends a retransmission with a new PCV. The base station can combine the original data with the retransmission to improve the signal quality. Type 3 HARQ can support up to two retransmissions.

HARQ for LTE Uplink and Downlink

- Synchronous HARQ – used in LTE Uplink transmission.
- Asynchronous HARQ – used in LTE Downlink transmission.



Asynchronous HARQ, on the other hand, is a technique in which the UE sends data to the base station, and the base station sends an ACK or NACK message to the UE in a later subframe. This type of HARQ is used in the downlink direction, where the base station sends data to the UE. The advantage of asynchronous HARQ is that it allows for greater flexibility in scheduling, as the base station can delay the feedback message to optimize the use of radio resources.

Synchronous HARQ is a technique in which the UE (User Equipment) sends data to the base station, and the base station sends an ACK (acknowledgment) or NACK (not-acknowledgment) message to the UE in the same subframe. This type of HARQ is used in the uplink direction, where the UE sends data to the base station. The advantage of synchronous HARQ is that it provides faster feedback to the UE, reducing the delay in retransmitting the data if errors are detected.

Adaptive HARQ is a technique that adjusts the modulation and coding scheme (MCS) used for the retransmission based on the channel conditions. If the channel conditions are good, the retransmission can use a higher MCS to improve throughput, while if the channel conditions are poor, the retransmission can use a lower MCS to improve reliability. This technique is used to optimize the use of radio resources while maintaining reliable transmission.

Non-Adaptive HARQ, on the other hand, uses a fixed MCS for retransmissions. This technique is useful when the channel conditions are relatively stable, as it can reduce the overhead associated with adjusting the MCS.

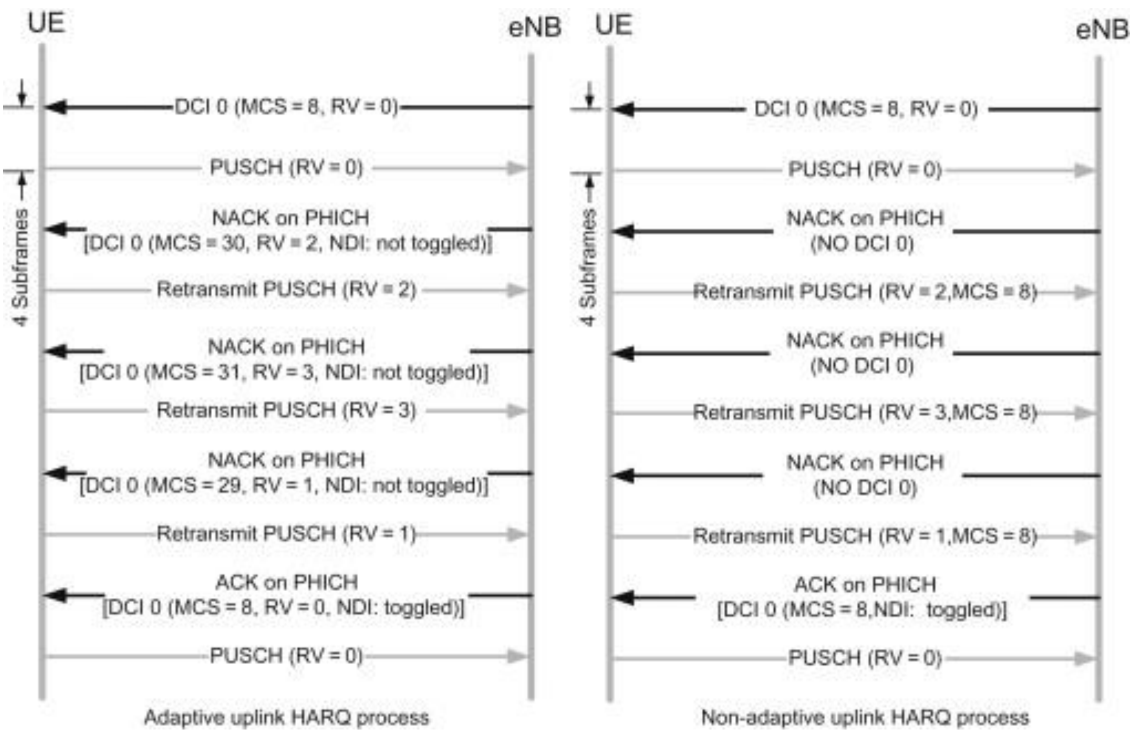


Fig Reference: www. https://www.sciencedirect.com/

Why there is 8 HARQ Process in FDD?

- Suppose UE receive the data at time “n”.
- It takes 3 ms of time to process the data from lower layer to upper layer (n+3 ms)
- So the ACK/NACK will be send in the next as n+4.
- If the HARQ response is NACK then again, the eNodeB will schedule the retransmission at n+4+4= n+8.
- As the data is transmitted back after 8 ms we are using 8 HARQ Process.

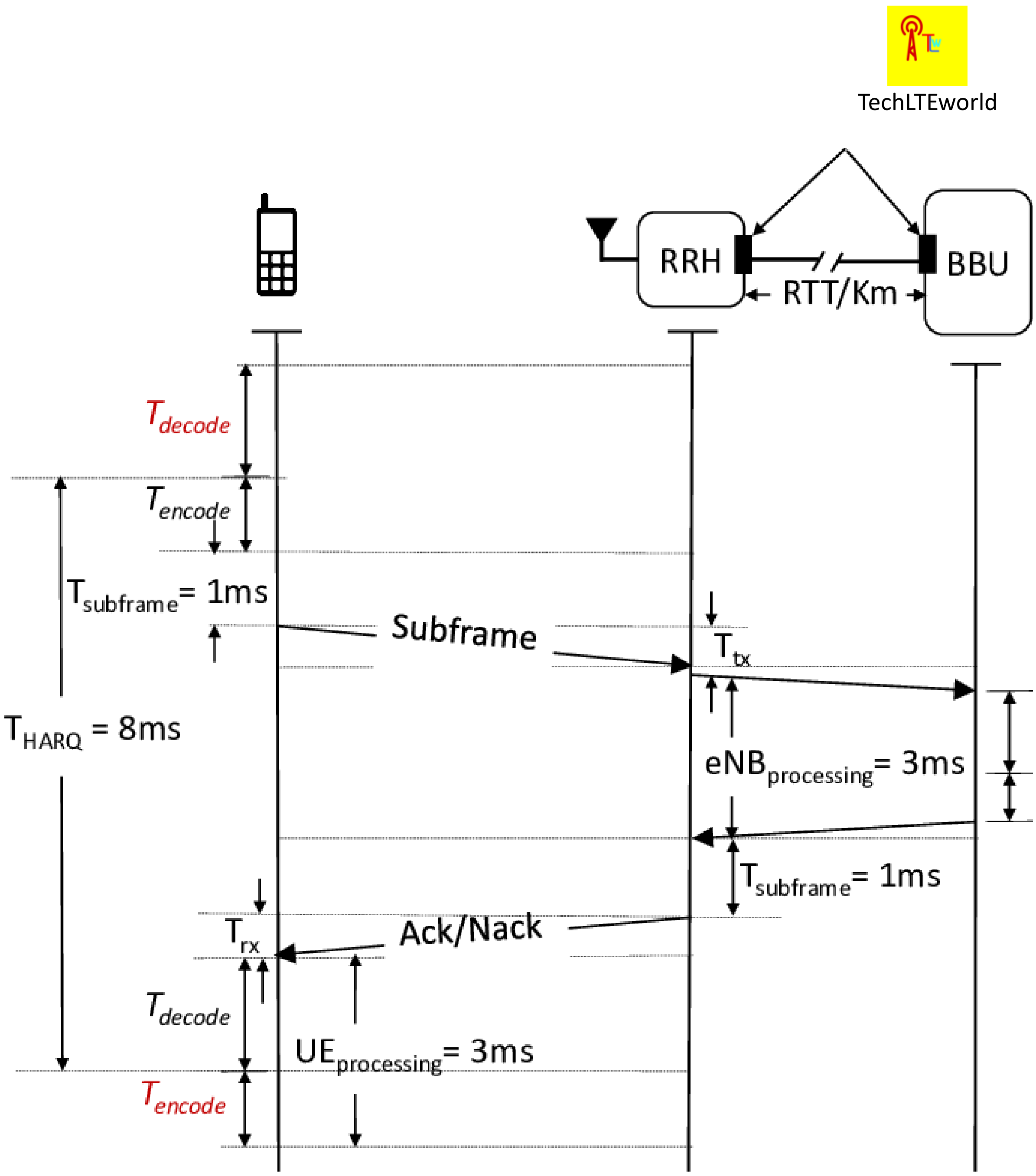
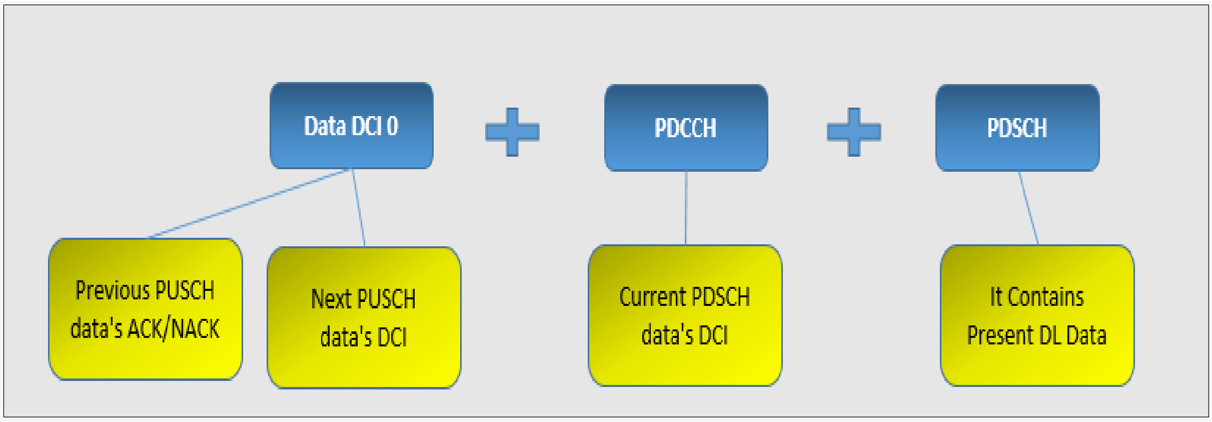


Fig : https://www.researchgate.net/

HARQ entity includes



DCI message includes the following information related to the HARQ process:

1. Transport block size: The DCI message includes information about the size of the data block that is being transmitted. This information is used by the receiver to determine how many subframes are required to transmit the data block.
2. Modulation and coding scheme (MCS): The DCI message specifies the modulation and coding scheme that is being used to transmit the data. This information is used by the receiver to decode the transmitted data and correct any errors.
3. Redundancy version (RV): The DCI message includes the redundancy version that is being used for the current HARQ transmission or retransmission. This information is used by the receiver to determine which version of the data is being transmitted and to decode the data correctly.
4. New data indicator (NDI): The DCI message includes a flag that indicates whether the current transmission or retransmission is carrying new data or a retransmission of previously transmitted data.
5. HARQ process identifier: The DCI message includes an identifier that indicates which HARQ process is being used for the current transmission or retransmission.
6. Resource allocation: The DCI message includes information about the allocation of radio resources, including the resource block (RB) allocation and the modulation and coding scheme (MCS) used for each RB. This information is used by the receiver to allocate resources for the HARQ transmission or retransmission.

Overall, the information contained in the DCI message is critical for the proper functioning of the HARQ process in LTE. By providing information about the data block size, modulation and coding scheme, redundancy version, NDI flag, HARQ process identifier, and resource allocation, the DCI message enables efficient and reliable transmission and retransmission of data over wireless networks.

NDI (New Data Indicator)

- ✓ NDI stands for New Data Indicator.
- ✓ It values may be 0,1.
- ✓ If NDI value is not changing then it is case of retransmission.
- ✓ If NDI bit is changing from 0->1 then it is new data transmission.

- ✓ The changing of NDI value from 0->1 ,1->0 is called NDI toggling.

  In LTE, NDI stands for "New Data Indicator." It is a flag that is included in the Downlink Control Information (DCI) message to indicate whether the transmission or retransmission is carrying new data or a retransmission of previously transmitted data.

  The NDI flag is used by the receiver to determine whether the received data is new or a retransmission of previously received data. If the NDI flag is set to 1, it indicates that the data being transmitted is new data that has not been previously received. If the NDI flag is set to 0, it indicates that the data being transmitted is a retransmission of previously received data.

  The NDI flag is an important parameter for the Hybrid Automatic Repeat Request (HARQ) protocol, which is used in LTE to ensure reliable transmission of data over wireless networks. When the receiver detects errors in the received data, it sends a Negative Acknowledgement (NACK) message to the transmitter, indicating that the data needs to be retransmitted. If the NDI flag is set to 1, it means that the retransmission is carrying new data, and the transmitter needs to use a new redundancy version (RV) to encode the data. On the other hand, if the NDI flag is set to 0, it means that the retransmission is carrying previously transmitted data, and the transmitter needs to use the same RV as before.

  Overall, the NDI flag plays a critical role in the reliable transmission of data over LTE networks by enabling efficient and effective use of the HARQ protocol.

RV (Redundancy Version)

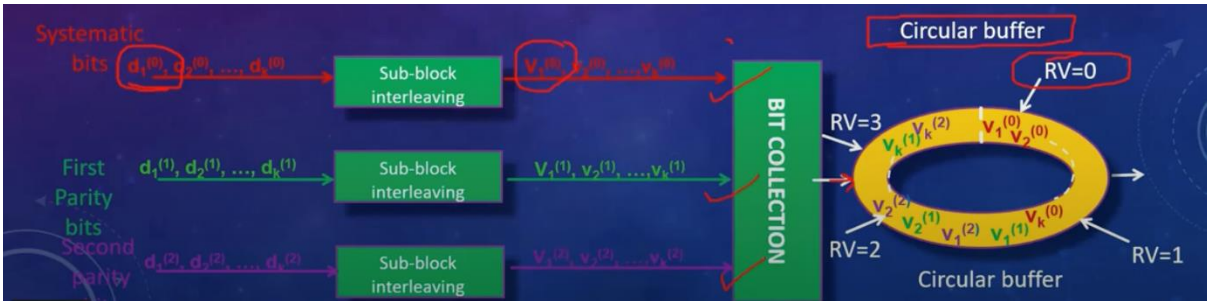
- ✓ RV stands for Redundancy Version.
- ✓ It values are 0,2,3,1
- ✓ Each value indicates some part of the data and are strongly coded.

0	New data
2	Retransmission
3	
1	

Why we have RV versions, how these RV versions created?

- As a part of PHY layer processing, TB (Transport block) first has to undergo CRC bits attachment process and followed by coding of the bits. Coding in LTE is done as Turbo coding and its coding rate is 1/3 which means on input of 1 bit the output will be 3 bits → The output of turbo coder is having 3 types of bits a) systematic bit b) First parity c) Second parity.

- The outputs of the turbo encoder (Systematic bits, first parity & second Parity bits) are first separately interleaved. The interleaved bits are then inserted into a circular buffer with systematic bits inserted first, followed by alternating insertion of the first and second parity bit. The bit selection then extracts consecutive bits from circular buffer to the extent that fits into the assigned resource, wrapping around the beginning of buffer if the end of buffer is reached.
- Redundancy Version: It defines the starting point in the circular buffer to start reading out bits. Different RVS are specified by defining different starting points to enable HARQ operation. Usually, RV=0 is selected for the initial transmission to send as many systematic bit as possible.



Regards

Techlteworld

http://youtube.com/@techLteworld

www.techlteworld.com

https://t.me/+Zv9SWJbksX3TRgLQ

https://www.linkedin.com/in/techlte-world-ba58071b7/

https://www.instagram.com/tlwlabs/