HARQ And 5G Numerology

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Simulation-Based Design of 5G Wireless Standards

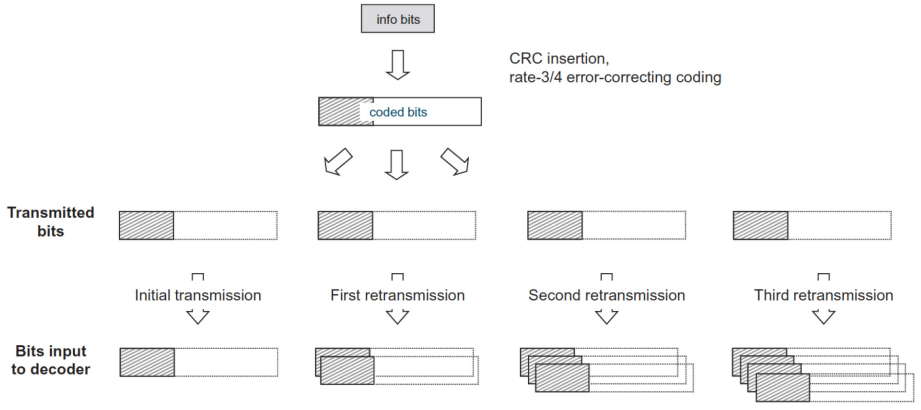
Agenda for today

- Finishing discussing HARQ
  - Reference – Chap6 of the 4G LTE/LTE-A book
- Will discussion 5G time/frequency frame structure
  - Section 7.1 to 7.4 of 5G NR book

Hybrid Automatic repeat request (HARQ) protocol

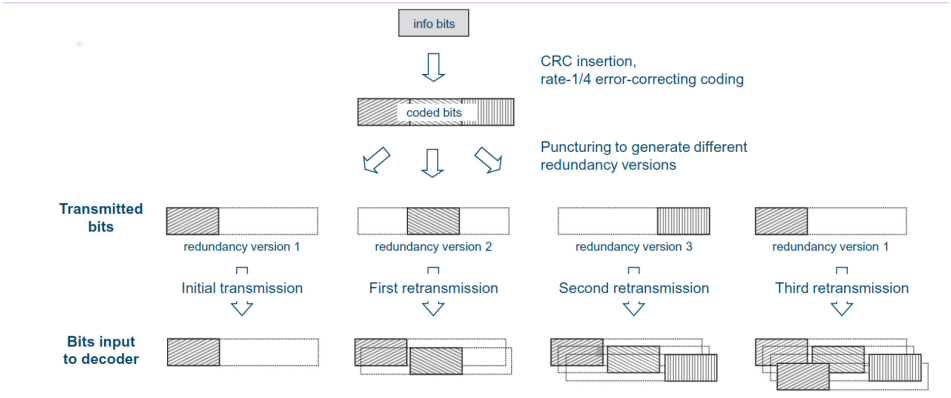
- 5G NR employs a combination of FEC and ARQ
  - Known as hybrid ARQ (ARQ)
- Erroneously received blocks are retained and receiver requests retransmissions of corrupted packets
- Two flavors of HARQ are used – Chase combining and Incremental redundancy

Hybrid ARQ – Chase combining



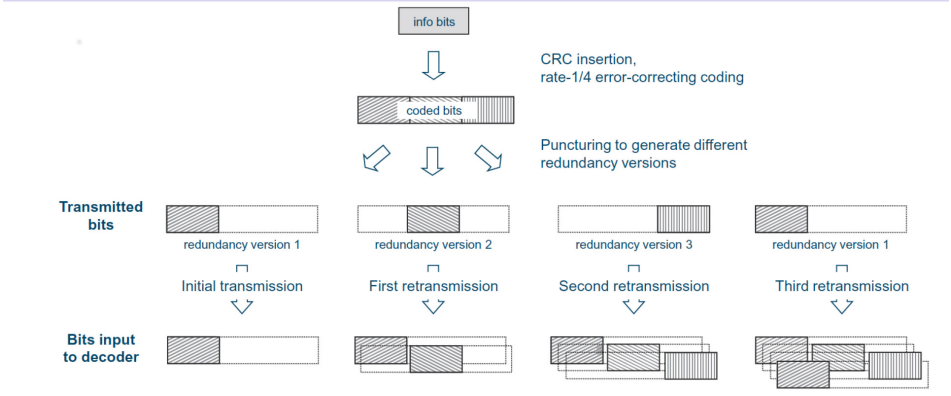
- Consider a code with rate 3/4
- Retransmissions consist of same set of coded bits as original transmission
- After each retransmission, the receiver combines each received channel bit with any previous transmissions of the same bit
- Combined signal is fed to the FEC decoder
- Effective code rate remain same

Hybrid ARQ – Incremental redundancy (IR) (1)



- Assume a basic rate-1/4 code. E.g., for 3 message bits, no. of o/p bits $= 12$
- For initial transmission, every third coded bit is only transmitted
  - Number of transmit bits $= 4 \Rightarrow$ Effective code rate $= 3/4$

Hybrid ARQ – Incremental redundancy (IR) (2)



- For 1st retransmission, 4 additional bits are transmitted, effective code rate $= 3/(4+4) = 3/8$
- For 2nd retransmission, 4 additional bits are transmitted, effective code rate $= 3/(4+4+4) = 1/4$
- For 3rd retransmission, 4 old bits are transmitted, effective code rate $= 3/(4+4+4) = 1/4$

Chase vs IR HARQ (1)

- Chase combining framework is easier to implement than IR but 5G NR provides a generic framework
- If all redundancy versions provide the same amount of information about the data packet
  - Order of the redundancy versions is not critical
- However, for some code structures, not all redundancy versions are of equal importance.
- E.g.,LDPC codes, where the systematic (message) bits are of higher importance than the parity bits
- Initial transmission should at least include all the systematic bits and some parity bits

Chase vs IR HARQ (2)

- In the retransmission(s), parity bits not in the initial transmission can be included
- If initial transmission was received with poor quality or not at all
  - A retransmission with only parity bits is not appropriate
  - As a retransmission of (some of) the systematic bits provides better performance
  - Better to use chase combining

5G NR numerology (1)

Subcarrier Spacing (kHz)	Useful Symbol Time, T_u (μs)	Cyclic Prefix, T_{CP} (μs)
15	66.7	4.7
30	33.3	2.3
60	16.7	1.2
120	8.33	0.59
240	4.17	0.29

- Scalable subcarrier spacing $= 2^{\mu} \cdot 15$ kHz
- Important aspect of OFDM is numerology design – subcarrier spacing and the cyclic prefix length
- For a certain fixed cyclic prefix length requirement in microseconds
  - relative overhead increases with larger subcarrier spacing
  - smaller cyclic prefix is preferable from overhead perspective

5G NR numerology (2)

Subcarrier Spacing (kHz)	Useful Symbol Time, T_u (μs)	Cyclic Prefix, T_{CP} (μs)
15	66.7	4.7
30	33.3	2.3
60	16.7	1.2
120	8.33	0.59
240	4.17	0.29

- A large subcarrier spacing is beneficial from phase noise
- Subcarrier spacing therefore needs to balance cyclic prefix overhead and phase noise requirements

Phase noise in OFDM