EEENGM4221:
Broadband Wireless Communications

Lecture 9: Incremental Redundancy and Chase Combining

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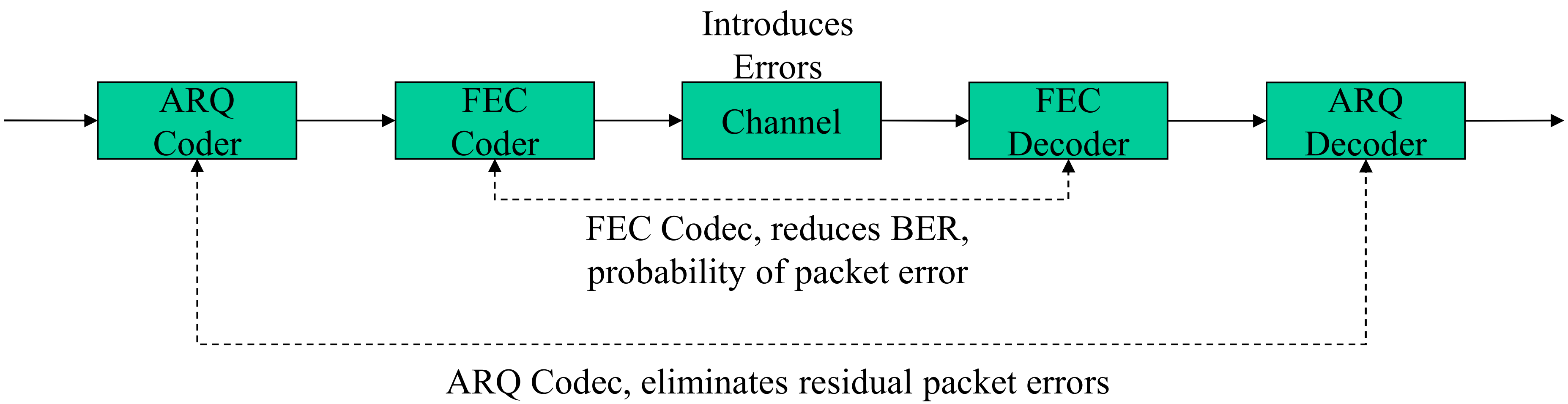
Reminder: HARQ



Ref: Lin & Costello

Incremental Redundancy (1)

- Incremental Redundancy aims to transmit the minimal redundancy required to correct errors
- Consider a conventional FEC approach
- A binary word of k data bits is encoded to a binary word of n coded bits by adding n-k parity bits. (assume k=8 and that the k data bits appear as the first k bits of the coded word [the code is systematic]
- For a lower ratio of k/n:
  - the rate of the code will be lower
  - the spectral efficiency will be less
  - The Error correcting capability of the code will be higher

Ref: Lin & Costello

Incremental Redundancy (2)

- So for example:

Original data word:

d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8

Coded word for n=k=8, r=1 no error correction capability:

d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8

Coded word for n=12, r=2/3 some error correction possible

d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	p_1	p_2	p_3	p_4

Coded word for n=16, r=1/2, increased error correction possible

d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8

Incremental Redundancy (3)

- But which code rate should be used?
- Errors are Random. It is unknown how many errors will occur
- Ideally the highest possible rate would be used but since this cannot be determined, an alternative approach is needed
- The principle of Incremental Redundancy is to first transmit a packet with a high rate code and then gradually lower the rate until error free communication of the packet is achieved

Incremental Redundancy (4)

- So the highest rate is transmitted first:

First Transmission	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8

- If this data is not error free, redundancy is added by transmitting parity bits:

Second Transmission	p_1	p_2	p_3	p_4

- The receiver now has access to:

Data Available at Receiver	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	p_1	p_2	p_3	p_4

- It may be possible to determine the correct data from this

Ref: Lin & Costello

Incremental Redundancy (5)

- If not, more redundancy may be added

Third Transmission

p_5	p_6	p_7	p_8

- The receiver now has access to:

Data Available at Receiver

d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8

- It is more likely to be possible to determine the correct data from this
- If not, further redundancy may be added and so on…
- Ultimately, this will be limited by the range of code rates implemented but the principle remains the same

Ref: Lin & Costello

HARQ - ‘Icebreaker’ Question

- Consider a ‘simple’ HARQ scheme (BPSK, AWGN)

An example packet of data could be:	0	1	1	0	1	0	0	1
This could be BPSK modulated to:	-1	1	1	-1	1	-1	-1	1
An example noise vector (real for simplicity) could be:	0.1	-0.2	-1.2	-0.3	0.7	0.2	-0.3	0.2

- What errors would occur?

HARQ - ‘Icebreaker’ Answer

- Consider a ‘simple’ HARQ scheme (BPSK, AWGN)

Data:	0	1	1	0	1	0	0	1
BPSK modulated to:	-1	1	1	-1	1	-1	-1	1
Noise vector:	0.1	-0.2	-1.2	-0.3	0.7	0.2	-0.3	0.2
Received symbols:	-0.9	0.8	-0.2	-1.3	1.7	-0.8	-1.3	1.2
Hard Limiting would result in output data:	0	1	0	0	1	0	0	1

- If the effects of FEC are neglected, a retransmission would be requested
- In the more realistic case of FEC, more errors might be required before a retransmission would be required

Ref: Lin & Costello

HARQ - A Harder Question

- Consider BPSK, AWGN and neglect FEC again…

Data:	0	1	1	0	1	0	0	1
BPSK modulated:	-1	1	1	-1	1	-1	-1	1
First Noise Vector:	0.1	-0.2	-1.2	-0.3	0.7	0.2	-0.3	0.2
Second Noise Vector:	0.2	0.1	-1.3	-0.3	1.0	-0.2	-0.4	0.3
Third Noise Vector:	1.1	0.2	-0.2	-0.3	-0.3	-0.4	-0.2	0.3
Fourth Noise Vector:	0.1	-0.2	-0.3	1.1	0.7	0.2	-0.3	0.2
Fifth Noise Vector:	0.2	0.1	1.0	-0.3	-0.3	1.2	-0.4	0.3
Sixth Noise Vector:	0.1	-1.2	-0.4	-0.3	-0.3	-0.4	-0.2	0.3

How many times must we transmit the packet to be able to receive it error free?

A. 1
B. 2
C. 3
D. 4
E. 5
F. More than 6

Review of Lecture 9

- We introduced the concept of Incremental Redundancy as an enhancement of ‘simple’ HARQ from lecture 8
- We set up a question. This didn’t tell us anything about Chase Combining. But the answers will!