Q1. User A's code 1 0 1 1 0 0

User B' code 1 1 0 0 0 0

a. user A → wants to send 0 and CDMA encodes 0 as -1, Hence A sends -1 1 -1 -1 1 1

User B → wants to send → Hence B sends

1 1 -1 -1 -1 -1

Receiver receives -1 1 -1 -1 1 1

1 1 -1 -1 -1 -1

---

0 2 -2 -2 0 0

When the receivers wants to receive user A's data - d_1^A (data of user A in timeslot 1)

$$d_1^A = \frac{\sum_{m=1}^{M} Z_{i,m} \cdot C_m^A}{M}$$

$$= \frac{0\ 2\ -2\ -2\ 0\ 0 \ * \ 1\ -1\ 1\ 1\ -1\ -1}{6}$$

$$= \frac{0+(-2)+(2)+(-2)+0+0}{6}$$

$$= \frac{-6}{6} = -1$$

Receiver succ. fully receives user A's code when it wants to receive user B's data.

$$d_1^B = \begin{array}{cccccc} 0 & 2 & -2 & -2 & 0 & 0 \\ 1 & 1 & -1 & 1 & -1 & -1 \end{array}$$

$$= \frac{6}{6}$$

$$= \frac{0+2+2+2+0+0}{6}$$

$$= 1$$

Succ. fully receiver user B's code

b. user A's code 101100, user B's code 001100

receiver receives =

$$\begin{array}{cccccc} -1 & 1 & -1 & -1 & 1 & 1 \\ -1 & -1 & 1 & 1 & -1 & -1 \\ \hline -2 & 0 & 0 & 0 & 0 & 0 \end{array}$$

When the receiver tries to receive user A's data

$$\frac{-2\ 0\ 0\ 0\quad 0\quad 0.}{1\ -1\ 1\ 1\ \ -1\ \ -1}$$

$$= \frac{-2+0+0+0+0+0}{6}$$

$$= -\frac{1}{3}$$

will not be able to detect.

Q2. MCS 6, 54Mbps, OFDM 64 Subcarriers, QAM 64, 3/4, SIFS = 10 μs, Slot time = 9 μs

a. Time to transmit 500B tcp payload

TCP adds 20B H, IP adds 20B, MAC adds 36B

Resultant data at link layer = 500 + 20 + 20 + 36

= 576B + 6bits for encoding

QAM 64 → 6 bits per symbol

48 data sub-carriers

1 OFDM symbol contain $48 \times 6 \times \frac{3}{4}$ bits

1 OFDM symbol takes 4 μs $= 216$ bits

# of OFDM symbols needed to send the frame

$$= \frac{576 * 8 + 6}{216} \simeq 22 \text{ symbols}$$

Time taken to transmit a line layer frame

= DIFS + Backoff + (Preamble + Data)

+ SIFS + (Preamble + ACK)

DIFS = SIFS + 2 * Slot time

= 10 + 2 * 9 = 28 μs

$$= 28 + \frac{15}{2} * 9 + (20 + 22 * 4) + 10 + (20 + 4)$$

Assuming preamble duration = 20 μs

802.11 ACK requires 1 OFDM symbol

= 237.5

b. Time spent in actually sending OFDM symbols = $22 \times 4 = 88$ μs

$$\text{Efficiency} = \frac{88}{237.5} = 0.37$$

c. We want an efficiency of 90%.

i.e) $$\frac{\text{Data transmission time}}{\text{Total time}} = 0.9$$

Suppose N number of frames to be aggregated
Hence we would send N 576 B frames together
Thus number of symbols needed for this

$$= \frac{(576) \times N \times 8}{216} = 22N$$

$$\frac{88N}{28 + \frac{15}{2} + 9 + 20 + 22N \times 4 + 10 + 20 + 4} = 0.9$$

$$\frac{88N}{88N + 149.5} = 0.9$$

$88N_1 = 70.2N_1 + 134.5$

$\Rightarrow 8.8N_1 = 134.5$

$N_1 = 15$

Q3. 4 nodes, Same sized frame, MCS 6 QAM64, 3/4

a. for each node time taken to transmit

is DIFS + Backoff + (Preamble + Data)

+ SIFS + (Preamble + Data)

$= 28 + \frac{15}{9} \times 9 + (20 + 2204) + 10$

$+ (20 + 4)$

$= 237.5$

$\text{efficiency} = \frac{(2204) \times 4}{(237.5) \times 4} = 0.37$

b. 802.11ax, OFDMA

262 Subcarriers, guard band = 0.8 μs

In case of OFDM 64 time samples

For OFDMA it is 262 time samples

On a 20MHz channel

20M time samples in 1sec

262 " " $\frac{262}{20M}$

$= 13.1\ \mu s$

When guard band of 0.8 µs added,

resultant OFDMA symbol duration

$= 13.1 + 0.8$

$= 13.9\ \mu s$

c. 52 tones are allocated to each user

500B TCP Payload at the Link layer

$= 576 * 8$ bits

1 OFDMA Symbol of RU 52 tone

Contains $= 52 \times 6 \times \frac{3}{4}$

$= 234$ bits

# of OFDMA Symbols $= \frac{576 * 8}{234}$

≈ 20 Symbols

d. Time required to transmit data from 4 users = T_{OFDMA}

$= DIFS + Backoff + Trigger + SIFS + Data + SIFS + Block\ ACK$

$= 28 + \frac{15}{2} + 9 + (20 + 2 * 13.9) + 10 + (20 + 20 * 13.9) + 10 + (20 + 4 * 13.9)$

$= 536.9$

$efficiency = \frac{Data}{T_{OFDMA}}$

$= \frac{(20 * 13.9)}{536.9}$

$= 0.52$

Q4. SampleYaRa same as SampleRate

except SampleYaRa samples at lowerrate only diff_time < threshold

at higherrate if diff_time > threshold

6, 9, 12, 18, 24, 36, 48, 54

1 – 18 lossless

24Mbps → 216

36Mbps → 252

48Mbps → 24

~~54~~ → 0

SampleRate would start at ~~54~~ → 4 Succ. failure

→ 48 → Samples 10th pkt at 36Mbps

↓ as lossless throughput of 36

24 is higher than the currentone

after sampling it observes that

Its throughput is higher than

the current one and

moves there.

48 → 36

at 36 it will keepSampling at 48 but not at 24

Sample Yaraa

54 → 48 → 36 since the diff-time < threshold
↓ ↓ 400 < 100
24 25.2 it will Sample at lowerrate
i.e, 36 using other principles
of Samplerate & will
move to 36 as well
Now, it will stay on 36 Mbps
and will not Sample at 48
as diff < threshold.

a channel becomes better 24 → 24
36 → 32.4
48 → 24
diff-time = 400

SampleRate was sending at 36, will Sample
at 48 as lossless throughput of 48 > curr-thpt of 36
But after Sampling realises that it does not
give better throughput. Hence Stays at 36 only
but keep Sampling at 48.

SampleTaRaa was sending at 36, it will not Sample at 48 as diff_time < threshold.

So, we can see SampleTaRaa took a better decision than SampleRate.

b. Channel becomes worse

24 → 36 → 48 diff_time = 1500us

↓ ↓ ↓

19.2 21.6 24

SampleRate was sending at 36 Mbps

& Sampling at 48 Mbps

now also it will sample at 48 will see

48 provides better thpt hence moves to 48

But will keep sampling at 36 as loss less thpt of 36 > Curr thpt of 48

SampleTaRaa was sending at 36 but was not sampling at 48 as diff was < threshold

Now, the diff time > threshold

1500 > 1000

& hence will sample at 48 & will move to 48. NOW, at 48 it won't sample at 36 as diff > threshold.

Hence, here as well we see sample & Rag took the right decision as the losses were mostly because of collision indicated by diff time.

Q5. b & c

Q6. TDMA → Synchronization available

FDMA → High B/W

CDMA → precise power control

CSMA/CA → Best effort.