Problem 1

$$\frac{P_r}{P_t} = K\left(\frac{d_0}{d}\right)^{\gamma}$$

$$\frac{0.175\ mW}{0.95\ mW} = 1 \times \left(\frac{1}{d}\right)^{0.38} \Rightarrow \boxed{d \simeq 85.78\ m}$$

Problem 2

A) Since the nodes are using the CSMA access protocol, they can decide to transmit only after they sense the medium and detect that it is free. In our scenario :

- A will detect the medium as busy because it can sense G's transmissions.
- B and E will detect the medium to be free because they are outside G's coverage, and because CTS/RTS is not used.

Therefore, only B and E can decide to transmit; and hence, the possible communication pairs are:

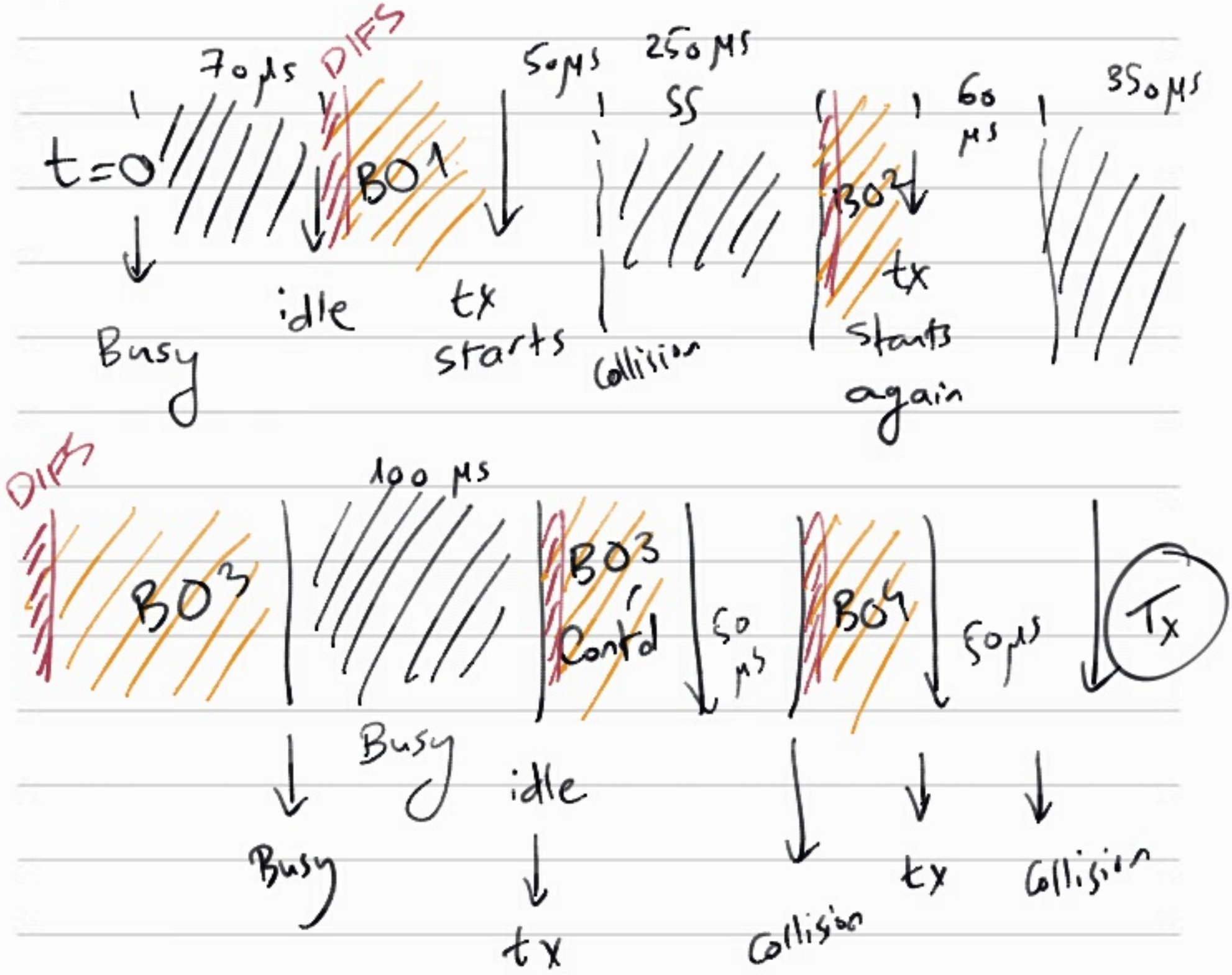
- $B \longrightarrow A$
- $B \longrightarrow E$
- $E \longrightarrow B$

Where $E \longrightarrow A$, $E \longrightarrow G$ and $B \longrightarrow G$ are not included because in these cases the receiver nodes are outside the transmitters' covera

Out of the above, the pairs where B transmits (i.e. $B \longrightarrow A$ and $B \longrightarrow E$) may experience collisions with the $G \longrightarrow A$ pair because A is within B's coverage, and hence, it might receive B's transmissions simultaneously while receiving G's transmissions.

B) In this case, only G can decide to transmit The only possible communication pair is $\boxed{G \longrightarrow A}$, which can collide with the transmissions of the pair $B \longrightarrow E$, by similar reasoning as above.

Problem 3



By refering to the timeline above (which is NOT properly scaled), total time to finish tx is:

$70\,\mu s + DIFS + BO1 + 50\,\mu s + 250\,\mu s + DIFS + BO2 + 60\,\mu s + 350\,\mu s + 2\,DIFS + BO3 + 100\,\mu s + 50\,\mu s + DIFS + BO4 + 50\,\mu s$

$+$ Successful transmission time

$$= 980\,\mu s + \text{total BO time} + 5\,DIFS + t_{Tx}$$

Where BO denotes a backoff duration. In order to find the BO durations, we should consider the following:

- During the 1st transmission attempt, $CW = CW_{min} = 32$.
- The CW value then increases exponentially at each retransmission attempt up to a maximum value of $CW_{max} = 1024$.
- The actual BO duration can then be computed as $\frac{3}{4} CW \times$ slot duration

∴ BO1 = 3/4 x 32 x 20μs = 480 μs (x2)
BO2 = 3/4 x 64 x 20μs = 960 μs (x2)
BO3 = 3/4 x 128 x 20μs = 1920 μ (x2)
BO4 = 3/4 x 256 x 20 μs = 3840 μs

Total BO time = 7.2 ms

The last successful transmission consists of a DIFS + BO + RTS/CTS/data/ACK sequence for each frame, with a SIFS duration separating the control and data frames.

Data frame time = Frame Size / bit rate

$= 2660 \times 8 / 24 \times 10^6 = 886.67\ \mu s$

$$\#\ \text{of frames} = \frac{\text{file size}}{\text{data bits per frame}} \rightarrow \begin{cases} \text{frame bits} \\ - \text{header bits} \end{cases}$$

$$= \frac{100 \times 1024}{(2660 - 100)} = 40$$

$\Rightarrow$ 40 frames needed.

We know that the RTS, CTS, and ACK frame sizes are 20, 14, and 14 bytes respectively

therefore, $t_{RTS} = \frac{20 \times 8}{24 \times 10^6} = 6.67\ \mu s$

$$t_{CTS} = t_{ACK} = \frac{14 \times 8}{24 \times 10^6} = 4.67\ \mu s$$

Therefore, the total time needed for the successful transmission is :

$$40 \times \Big(DIFS + \frac{3}{4} CW_{min} \times slot\ duration + t_{RTS} + SIFS + t_{CTS} + SIFS + t_{data} + SIFS + t_{ACK} \Big)$$

$$\{ - \tfrac{3}{4} CW_{min} \times 20\mu s + \tfrac{3}{4} \times 512 \times 20\mu s$$

→ BO of 1st frame is different that that of the remaining 39.

$$= 40 \times (50 + 480 + 6.67 + 10 + 4.67 + 10 + 886.67 + 10 + 4.67)\ \mu s + \tfrac{3}{4} \times 20 (512 - 32)$$

$$= 65.7072\ ms$$

Finally, we get the total time from t=0 to the end of the successful transmission :

$$98\mu s + 7.2\ ms + \underbrace{5\ DIFS}_{(50\mu s)} + 65.7072 ms$$

$$= \boxed{74.1372\ ms}$$

Problem 4

G hears the CTS and reads a duration value of 2.35 ms. Therefore, G will not attempt to transmit during the following 2.35ms.

(after DIFS)

After waiting for 2.35 ms, G initiates the backoff procedure. Since B has finished sending the frame to A, and no other transmissions occur, then no collisions will occur and only 1 backoff is needed with duration $= \frac{3}{4} \times 32 \times 20\,\mu s$

$= 480\,\mu s$

Finally, an RTS/CTS sequence is needed which requires $t_{RTS} + SIFS + t_{CTS} + SIFS$

∴ G waits for: 2.35 ms + 50μs + 480μs
+ 80μs + 10μs + 80μs + 10μs

$= 3.06$ ms

before it can start transmission.