Bonus Problem [10 Points]: Consider a link with transmission rate R and one-way propagation delay d is used to transmit data packet of size L bits. Both the header of data packet and the acknowledgement packet are of negligible size. Consider a go-back-N protocol with k_1 bits of sequence number and a selective repeat protocol with k_2 bits of sequence number. Under what conditions the selective repeat protocol can have higher maximum link utilization ratio than the go-back-N protocol?

$$\text{Prop delay} = d \quad \text{Pck size} = L$$

$$\text{Trans rate} = R, \quad T_{frame} = L/R$$

$$a = T_{prop} - T_{frame}, \quad \text{utilization} = \frac{W}{1+2a}$$

$$GBN: w = 2^{k_1} - 1, \quad SR: w = 2^{k_2 - 1}$$

$$2^{k_2 - 1} > 2^{k_1} - 1 \Longrightarrow 2^{k_2} > 4^{k_1} - 2 \Longrightarrow$$

$$\Longrightarrow \boxed{k_2 > \log(4^{k_1} - 2)}$$