EE5151: Communication Techniques

Oct. 2019 **Tutorial #5** KG / IITM

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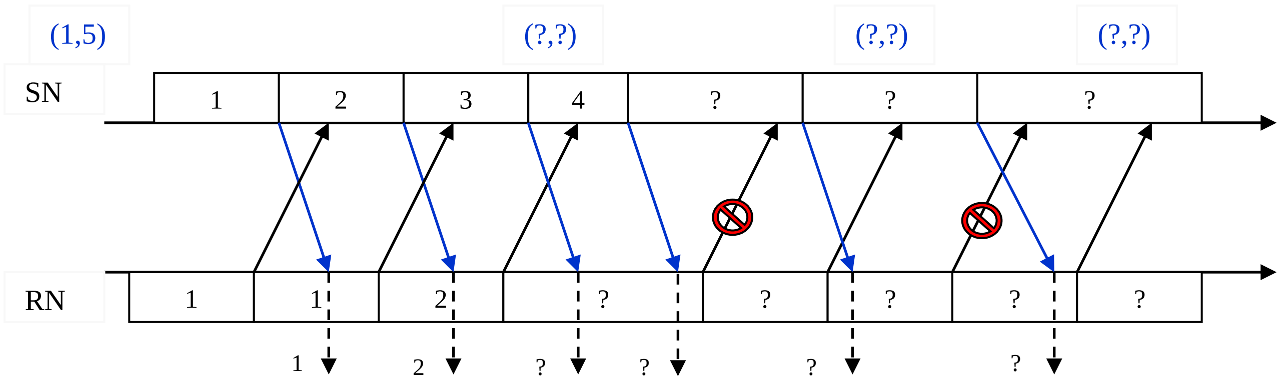
1. A go back 5 (n=5) ARQ protocol is evolving as given below. Fill in all the blank values marked with "?" including the buffer status at the transmitter (k, k+n-1) for k>0. Note that there are 2 uplink errors in this case.



2. A multi-bit framing system uses L=5 bit markers in each of the N=500 bit frames. The bit duration T=1μsec. Now, answer the following:

(a) What is the average frame acquisition time if sequential search is used?

(b) Instead, now we decide to use parallel search. What is the expression for the probability p_v that all the non-valid bit positions will produce a violation in n or less frames?

(c) Using the above expression, how much time should we wait if we need p_v to be at least 0.995?

3. For every K message bits, L bits of parity are calculated in a scheme which uses both row and column parity bits. The channel introduces error bursts of *maximum* duration P bits, and the *minimum* inter-burst time (in bit durations) is Q bits long. (Note that the inter-burst time is calculated between the first bit positions of two consecutive error bursts).

(a) For P = 15 and Q = 630, find K and L such that all error bursts can be detected in the most rate efficient manner using a rectangular matrix parity check code. Indicate the dimensions of this code and the code-rate.

(b) If for the same value of Q, the burst-length changes to P=50, re-calculate the dimensions of the most efficient rectangular code. What is the code-rate?

4. Consider a 20Mbps link between nodes A and B, where both nodes use bipolar signalling and equi-sized, 800-bit packets. These 800 bits includes a 16-bit CRC, RN, SN and other overheads, with the remaining bits making the payload. The round-trip time (including propagation, processing and buffering delays), is not more than 0.6msecs.

(a) Design an efficient go-back n ARQ scheme. How many bits are needed to specify RN & SN?

(b) If a selective repeat ARQ scheme with window size of 32 is instead used in the above link, how many bits Q should be appended to RN, (i.e., RN.$b_1b_2b_3\ldots b_Q$) to make this efficient in acknowledging "future packets to RN" received with or without error?

5. (*Hard Question*) Consider a "peculiar" multi-bit framing system where the odd-numbered frames are of length N/2 bits, while as, all the even numbered frames are N bits long. Both type of frames, however, use the same L-bit marker.

(a) Describe a sequential search procedure to find either frame boundary. (*Hint*: Use the fact that the L-bit marker has a definite periodicity.) What is the average frame acquisition time in bit duration, for this event?

(b) Now, to find the odd frame boundary, how much more symbol-durations (in addition to your answer in part (a)) will it take on the average?

6. Consider a 10 Mbps link with bipolar modulation between nodes A and B, where both nodes use 500 bit packets. The 500 bits includes a 16-bit CRC, RN, SN and other overheads, with the remaining bits making the payload. The round-trip time (including propagation, processing and buffering delays), is approximately 1.33 msecs.

(a) Design a selective repeat ARQ scheme where the window size is chosen such that the probability of reaching the window edge (before the first packet is acknowledged) is p^2, where p is the probability of packet being in error. Specify the size of RN and SN.

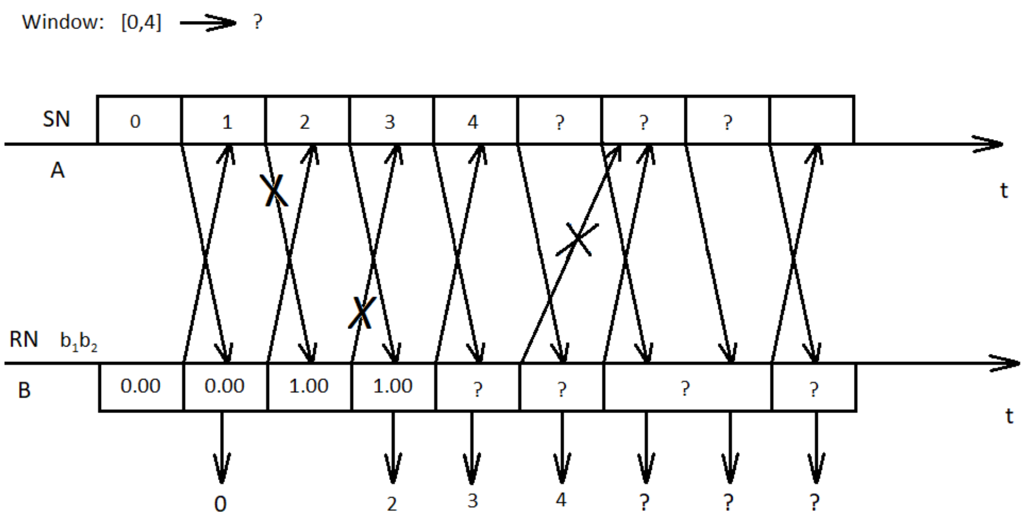
(b) For the same link, design an efficient ARPANET ARQ scheme, specifying the number of control bits that would be required (in the 500 bit packet).

7. There is a 4Mbps link between nodes A and B, where both the nodes continuously put out packets that are exactly 200 bits long. These 200bits include a 16-bit CRC, RN, and SN, and the remaining bits are the payload. The round-trip time, including the propagation, processing, and buffering delays is measured to be 3.0msecs.

(a) Design a go-back n ARQ scheme where the window is chosen so as to minimize the amount of overhead bits. Specify the choice of RN and SN.

(b) If p is the probability of a packet being in error, what is the (payload) throughput in Mbps for $p=10^{-3}$?

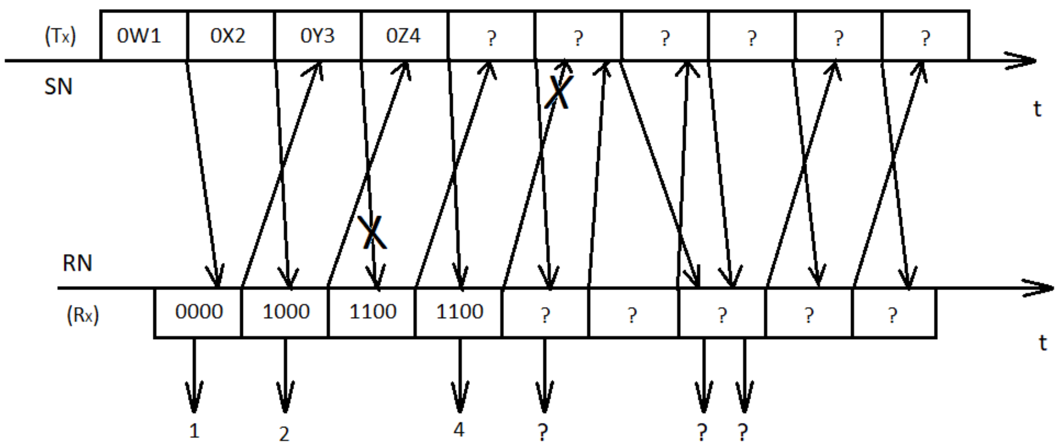
8. In a selective repeat ARQ scheme using a window of size n = 5 (and an appropriate value of modulus m), errors will occur in both uplink and downlink channels as shown below. Two bits (K = 2) are appended to the request number RN to specify "RN.b_1b_2" where b_i = 0 for NACK and b_i = 1 for ACK, for packets received future to RN. (The subscript "i" refers to the RN + i^{th} packet).



a) Complete the details marked with "?" in the above figure.

b) Specify the windowed packets (window limits) at every appropriate time index at the transmitter.

9. An ARPANET ARQ scheme uses 4 virtual channels (W, X, Y, Z) with independent stop and wait protocols, which are time multiplexed. The SNs are specified by (SN, VCID, PKT#) where VCID is the virtual channel ID (namely W, X, Y or Z) and PKT# is the packet numbers from the network layer. The RN is specified by 4 bits, which is self-evident in the figure below. Further assume that:
(i) The T_x will resend a lost packet in the first available opportunity.
(ii) In case that more than one VC is available, a new packet from the network layer will be assigned to the VCs in alphabetical order.



Complete the labels in the locations marked with "?" in the figure above, which is consistant with the given history and the above rules.

Additional Problems for Cellular TDMA and DS-CDMA (for tute #6)

10. Pseudo-Orthogonal DS-CDMA and Uplink Power Control: With an aim to be relatively insensitive to "time-of-flight" delays, we now consider pseudo-noise (PN) codes $\mathbf{c}_i$ on the uplink where the symbol duration is given by $T=NT_c$, with T_c being the chip duration and N being the spreading factor. Each chip is either +1 or -1, and let $\varepsilon_{i,j}=\mathbf{c}_i^T\mathbf{c}_j$.
(a) Prove that $E[\varepsilon_{i,j}^2] = N^2$ if i=j, and equals N if i≠j. State your assumptions clearly.
(b) For the first user, let $s_1(t)$ be the transmitted uplink signal over $kT \le t < (k+1)T$, corresponding to the DAC output for $I_1(kT)\,\mathbf{c}_1$, where data symbols I_1 are either +1 or -1. Given the measurement model $r(t) = \alpha_1 s_1(t) + n$, where n in AWGN with variance σ_n^2, find the expression for the Signal to Interference plus Noise ratio (SINR) after dispreading the signal appropriately.
(c) Now the second user is added on the uplink to give the new measurement model as below:
$r(t) = \alpha_1 s_1(t) + \alpha_2 s_2(t-\tau_2) + n$. The base-station now uses two de-correlators (de-spreading operations) in parallel, to detect the two streams. Find the SINR expressions involved in the recovery of both I_1 and I_2. Does τ_2 play any role in defining the de-correlation operation or in the SINR expression? Please explain clearly.
(d) Assume now that σ_n^2 is very small compared to the signal powers and that it can be neglected. If N=32 and $\alpha_1 = 10\,\alpha_2$, what will be the values of the two SINRs in part (c) above?
(e) Repeat (d) for N=256. Compare with (d) and comment.
(f) For N=256, what would be the SINRs if a third user is added to the uplink having $\alpha_3 = 4\alpha_2$?

11. TDMA MAC Channel: A cellular TDMA base-station is required to serve users who are up to 9km away on the uplink. The RF bandwidth used by this system is W=2MHz, and SRRC pulse shaping with excess bandwidth factor β=0.5 is used to produce the 8-PSK encoded waveforms. The frame duration is 6msec with 5 slots per frame of 1.2msec duration each.
(a) Find the symbol duration, and the number of symbols per slot.
(b) What is the number of guard symbols required on the uplink MAC channel to compensate for the worst-case time of flight difference?
(c) What is the effective (useful) bit-rate per user, if 10% of the slot duration is given for pilot symbols and other control overheads? What is the useful spectral efficiency in bits/sec/Hz ?
(d) Now, the RF bandwidth is increased to 20MHz and 50 slots are planned in every 6msec frame duration (with all other parameters as before). What is the new value of useful spectral efficiency?
(e) Recall also that the received power P_R in dBm at a distance d meters from the transmitter can be determined from the below formula in the log-scale:

$$P_R(d) = P_T - L - 10log_{10}(d^{\alpha})$$

where P_T is the transmit power in the dBm scale (note that 1mwatt = 0dBm), α is the path loss exponent, and L (in dB) accounts for all other fixed losses. Also recall that the receiver sensitivity or minimum detectable signal strength (MDS) required at the receiver is given by

$$MDS\ (dBm) = -174dBm + 10log_{10}(W) + NF(dB) + SNR(dB)$$

where NF is the receiver noise figure, and SNR is the signal to noise ratio required to achieve the target bit error rate for the given modulation.

(e1) Given P_T = 1watt, L=47dB, α=2, NF=6dB, and required SNR=8dB, find the link distance d for W=2MHz.
(e2) Repeat the above, but for W=20MHz.
(e3) If it is required to serve users up to 9km link distance on the uplink for W=20MHz, that should be the new P_T ? Compare with (e2) and comment.

12. Omni-antennas are used at the base-station in a FDMA based cellular system with frequency reuse-1/3 deployment. The side of each hexagonal cell is R=400 meters, and the path loss exponent, $\alpha = 3$. Consider the mobile user facing the worst-case downlink SINR, and take into account the set of only the first tier of interferers.
(a) What is the value in dB scale, of the ratio between the strongest interferer to the weakest interferer from this set?
(b) What is the worst-case SINR caused by this first-tier of interferers? (in dB scale) ?.
(c) Repeat (b) for (i) reuse 1/1, and (ii) reuse 1/7.

13. Consider a 1MHz wide, DS-CDMA system with spreading factor N=128. The uplink SINR required for any rate is 6dB, and the receiver noise variance is σ^2, and out-of-cell interference as well as voice-activity factor based "twiddle-factors" are neglected in the SINR expression. However, users are supported with 3 possible rates. In particular, if user(n) has rate R (and Rx power P), then user(n+1) has rate R/2 (and Rx power of P/2), and finally, user(n+2) has rate R/4 (and Rx power P/4). The users are added in the same "round-robin" order up to the acceptable noise rise. The lower rates are supported by repeating the same symbol either twice or four times, for R/2 and R/4, respectively.
(a) Find the pole capacity of M_P of the system. *Hint*: Assume that 3 can divide (M_P-1).
(b) If the noise-rise allowed is 6dB, how many users, M, can be supported by the system? Again, assume that 3 can divide (M-1).