[1]Ref: Data and Computer Communications by William Stallings

Utilization in Error free sliding window control

In our discussion 'a' represents the ratio of propogation time to Transmission time. Let us normalize the transmission time to 1, then the propogation time becomes a. The throughput depends on both the window size and the value of a.
Station A begins to transmit the sequence of frames at time t=0.the leading edge of the first frame reaches Station B at time t=a. The first frame is entirely absorbed by time t=a+1. B immidiately sends back an acknowledgement which reaches Station A by time t= 2a+1. We have two consider two cases to evaluate the performance.

Case 1:

$$W >= 2a + 1.$$

The acknowledgement for frame 1 reaches A before A has exausted it's window. Thus a can transmit continuously with no pause and normalised throughput is 1.

Case 2:

$$W < 2a = 1.$$

A exausts its window at t=W and cannot send additional frames until t=2a+1. Thus normalized throughput is W time units out of a period of (2a+1) time units. Thus we have two equation for the Utilization.

$$U = 1 \qquad ifW >= 2a + 1$$

$$U = W/(2a + 1) \qquad ifW < 2a + 1$$

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ERROR CONTROL

Two types of errors are possible:
1) Lost Frame : A frame fails to arrive at the other side.
2) Damaged Frame : A recognizable frame does arrive but some of the bits are altered during transmission.
The most common techniques for error contrl are base on some or all of the ingredients:
Error Detection

Positive acknowledgement : The destination returns a positive acknowledgement to successfully recieved, error free frames.

Retransmission after timeout: The source retransmits a frame that has not been acknowledged after a predefined amount of time.

Negative acknowledgement and retransmission: The destination returns a negative acknowledgement to frames in which an error was detected.

These are called automatic repeat request. Three versions of ARQ has been standardized:

Stop and wait ARQ

Go-back-N ARQ

Selective reject ARQ

STOP AND WAIT ARQ

It's based on stop and wait flow control protocol. The source station transmits a frame and the it must await an acknowledgement from the destination. No other data can be sent until the estination's reply arrives at the source station.
Two types of errors are possible. First, the frame that arrives at the destination could be damaged. The reciever detects this using the error-detection technique and simply discards the frame. To account for this possibility, the source station is equiped with a timer. After a frame is transmitted, the source station waits for an acknowledgement. If no acknowledgement is recieved by the time that the timer expires, then the same packet is sent again.
The other type of error is a damaged acknowledgement. The destination sends a acknowledgement(ACK) for a packet to source. The ACK is damaged in transit and is not recogizable by A, which will therefore time out and resend the same frame.
For an example of the use of stop and wait ARQ, Assume the transmission of a sequence of frames from source A to destination B. Two types of errors can occur. The some frame say the third frame transmitted by A is lost or damaged and therefore no ACK is returned by B. A times out and retransmits the frame. Later, A transmits a frame labeled 1 but the ACK0 for the last frame is lost. A times out and retransmits the same frame. When B receives two frames in a row with the same label, it discards the second frame but sends back an ACK0 to each.

The Utilization for stop and wait ARQ

For stop and wait ARQ. With no errors, the maximum utilization is 1/(1+2a). The utilization can be defined as

$$U = T_f/T_i$$

where T$_f = timefortransmittertoemitasingleframe.$

$$T_i = totaltimethatthelineisengagedinthetransmissionofasingleframe.$$

For error-free operation using stop and wait ARQ.

$$U = T_f/(T_f + 2T_p)$$

Where T$_p ispropagationtime.DividingbyT_f andrememberingthata = T_p/T_f,$

$$weagainhaveU = 1/(1 + 2a).$$

If errors occur, we must modify the equation to U = T$_f/N_r.T_t$

Where N$_r istheexpectednumberoftransmissionofaframe.ThusforstopandwaitARQ, wehaveto$ U = 1 / N$_r(1 + 2a)$
A simple expression for N$_r canbederivedbyconsideringtheprobabilityPthatasingleframeisinerror.IfweassumethatACKsandN$
$(1{-}P).Thatiswehave(k{-}1)unsuccesfulattemptsfollowedbyonesuccessfulattempt; theprobabilityofthisoccuringisjusttheprod$

Nr = E [transmission] = sigma i=1 to infinity (i X Pr [i transmissions]) = sigma i=1 to infinity (i P$^(i{-}1){*}(1{-}P)) = 1/(1 - P)Sowehave : U = (1 - P)/(1 + 2a)$

Go back- N ARQ

In this method a station may send a series of frames sequentially numbered modulo some maximum value. The number of unacknowledged frames outstanding is determined by window size , using the sliding window flow technique. While no errors occur, the destination will acknowledge incoming frames as usual. If the destination station detects an error in a frame it may send a negative acknowledgement for that frame. The destination station will discard that frame and all other future frames untill the frame in error is correctly recieved. Thus, the source station when it recieves a REJ, must retransmit the frame plus all the succeding frames that were transmitted in the interim.

1.**Damaged Frame:** If the recieved frame is invalid, B discards the frame and takes no further action as the result of that frame. There are two subcases:

a. Within a resonable time period, A susequently sands frame. B recieves frame (i+1) out of order and sends REJ i . A must retransmit i and all subsequent frames.

b. A does not soon send additional frames. B recieves nothing and returns neither an RR nor a REJ.A's timer expires, it transmits an RR frame that includes a bit known as P bit, which is set to 1. B interprets the RR frame with a P bit of 1 as a command that must be acknowledged by sending an RR indicating the next frame that it expects, which is frame i. When A recieves the RR, it retransmits frame i.

2.**Damaged RR:** Two sucases: **a.** B recieves frame i and sends RR (i+1), which suffers an error i transit. Because acknowledgement are cumulative, it may be that A will recieve a subsequent RR to a susequent frame and that it will arrive before the timer associated with the frame expires.

b. If A's timer expires, it transmits an RR command as in Case 1b. It sets another timer, called the P-bit timer. If B fails to respond to the RR command, or if it's response suffers an error in transit, then A's P-bit timer will expire. At this point , A will try again by issuing a new RR command and restarting the P-bit timer. This procedure is tried for a number of iterations. If A fasils to obtain an acknowledgement after some maximum number of attempts, it initiates a reset procedure.

3. **Damaged REJ:** If REJ is lost it's equivalent to 1b.

Utilization in Go back- N protocol

For the expected number of frames to be transmitted we have the equation:

$$N_r = E[number of transmitted frames to successfully transmit one frame]$$

$$N_r = sigma for i = 1 to infinity(f(i) * P^[(i - 1 * (1 - P)$$

where f(i) is the total number of frames transmitted if the original frame must be transmitted i times. This can be expressed as:

$$f(i) = 1 + (i - 1)K$$

$$= (1 - K) + Ki$$

Substituting gives us

$$N_r = (1 - K)(sigma for i = 1 to infinity)[P^{i-1}(1 - P)] + K(sigma for i = 1 to infinity)[iP^{i-1}(1 - P)$$

$$= 1 - K + K/(1 - P)$$

$$= (1 - P + KP)/(1 - P)$$

Thus for the Utilization U we get

$$U = (1 - P)/(1 + 2aP) \qquad if \;\; W >= 2a + 1$$

$$U = W(1 - P)/(2a + 1)(1 - P + WP) \qquad if \;\; W < 2a + 1$$