

## ARQ and Flow Control

*Automatic Repeat reQuest (ARQ) is a technique to ensure reliable delivery of data by retransmitting frames that are received with errors or not at all. Flow control is the term for various techniques to stop or slow down transmissions to match the rate at which a receiver can accept data.*

*After this chapter you should be able to: explain how ACK frames ensure error-free transmissions; select an appropriate type of ARQ (from stop-and-wait, go-back-N and selective repeat) based on channel error rate and delay; and select appropriate flow-control method(s) to avoid over-flows.*

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### Retransmission Protocols

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Many frame-oriented data communication protocols require that the receiver acknowledge correct reception of each frame to ensure that no data is lost.

When a message is received without errors the receiver sends an “ACK” (acknowledgment) packet back to the sender to confirm correct reception.

A transmitter using ARQ sets a timer when a frame is transmitted. If the timer “goes off” (expires) before the receiver receives the corresponding ACK frame it knows the frame (or the ACK) was not correctly received and retransmits the frame. This technique is called ARQ (for Automatic Repeat reQuest) because the receiver does not have to ask for the frame to be retransmitted.

There are various types of ARQ. The version just described is called **Stop and Wait ARQ**. The transmitter waits after sending each frame until it receives the ACK or the timer expires. This is the simplest type of ARQ since the transmitter only has to store one frame in case a retransmission is required. However, it is inefficient if there is a long delay between transmitter and receiver.

**Exercise 1:** Assuming the one-way propagation delay,  $T$ , is much longer than the frame transmission time, what is the minimum delay between transmitted frames if no ACKs are lost? Geostationary satellites are located about 36,000 km above the equator. What is the minimum value of  $T$ ? If a frame contains a maximum of 1500 bytes, what is maximum data rate for such a link if it uses stop-and-wait ARQ?

Efficiency can be improved by allowing the transmitter to send more than one frame without waiting for each one to be acknowledged. The transmitter adds a serial number (or a count of the total packets or bytes transmitted thus far) to each frame. The serial number or byte count for the most recently received packet is sent back with each ACK. This

version of ARQ is more complex since the transmitter must store all un-acknowledged frames. This increases memory requirements at the transmitter.

There are also two ways that retransmissions can be handled:

The first, **Go Back N ARQ**, requires the transmitter to retransmit all frames starting with the first un-acknowledged one (the one whose timer expired).

The second, **Selective Repeat ARQ**, allows the receiver to acknowledge individual frames (or ranges of byte counts) received. This is more efficient because the transmitter only has to retransmit the lost frames. However, it makes the implementation more complex because the transmitter must store all un-acknowledged frames in case they are not ACK'ed and the receiver must store all frames after a missing frame so that a complete and correctly-ordered sequence of packets can be output.

**Exercise 2:** Create a table summarizing the three different types of ARQ. Include: throughput, transmitter memory, receiver memory and relative complexity.

**Exercise 3:** Assume a transmitter transmits 1000 data packets per second and has to retransmit an average of 5 packets when using go-back-N ARQ and only one packet using Selective-Repeat ARQ. If 10% of the data frames are lost, what is the throughput using go-back-N ARQ? Using Selective ARQ? Ignore delays and other overhead.

In many protocols ACKs can be appended as “piggyback” information on data frames being sent in the reverse direction. This reduces the overhead of sending ACKs.

Some protocols allow the use of a negative acknowledgment (NACK) that allows a receiver to ask for a retransmission if it knows that a frame was lost (e.g. a packet is received out of order). This can be faster than having the transmitter wait for a timeout.

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## Flow Control

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If the data sink cannot accept data as quickly as it is being received, it is possible for the received data to overflow the “buffer” memory available in a receiver.

When this is a possibility, communication systems often implement “flow control.” For example, a modem can often receive data from a computer faster than it can be transmitted over the channel. The modem can use a “clear-to-send” handshaking output to tell the computer when it is able to accept data. This is often called “hardware” flow control.

To avoid the need for a dedicated flow-control handshaking signal the modem can send special characters to the computer to tell it when to stop and start sending data. This is called “software” flow control. The XON (start sending, also control-Q) and XOFF (stop sending, also control-S) ASCII control characters are often used for this. However, this means that these characters cannot be used as data making it more difficult to sent binary data.

Another flow control method is to use ARQ with a limited “window” size ( $N$ ). The receiver can delay sending ACKs for received frames until there is room to store additional frames.

**Exercise 4:** Which of the above flow control methods can be used on unidirectional data links? Which are limited to frame-oriented protocols?