Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**A Proposal for the Enhancement of the 802.16.1 MAC to Provide a per-Service Flow Reliable Connection Service**
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Re:	This document is a response to the following calls for contributions: Call for Contributions for Modifications of 802.16 MAC and 802.11a/HIPERLAN/2 PHY for the WirelessHUMAN™ Standard , 802.16.4-00/01. IEEE 802.16 Task Group 3 Call For Contributions: Proposed MAC Enhancements, Key Characteristics, and Evaluation Criteria: Session #11 , 802.16.4-00/25.
Abstract	This contribution proposes a per-Service Flow ARQ mechanism.
Purpose	For Consideration for inclusion in the proposed 802.16.3 and 802.16.4 MAC standards
Notice	
Release	
Patent Policy and Procedures	

A Proposal for the Enhancement of the 802.16.1 MAC to Provide a per-Service Flow Reliable Connection Service

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Introduction

Many business applications have been written which assume that the communications link they operate on is an inherently reliable LAN connection. A good example of such an application might utilize an older version of Novell Netware for same-segment communication. While the Transport Control Protocol (TCP) can provide reliable transport, this assumes that the application has been written to use TCP/IP, which is not the case for many legacy applications. The performance of TCP over wireless can also be improved with a properly designed link-layer ARQ. [1]

ARQ Algorithms

While there are several well-known ARQ algorithms, two are more commonly used; go-back-N and selective-repeat. Both of these algorithms require the sender to assign a monotonically increasing integer values to each transmitted packet. The difference lies in the method by which they handle lost packets. These methods are outlined below to assist in determining suitability.

The go-back-N algorithm receiver detects a loss when a packet arrives with a sequence number that is higher than expected. The receiver then sends a negative acknowledgement (NACK) to it peer to request a retransmission of the missing packet. The receiver then throws away any packets received whose sequence number is higher than that of the missing packet. The sending peer now begins retransmitting the missing packet and the following packets even tough they were received by the receiver.

The selective-repeat algorithm likewise notifies the peer of a lost packet by issuing a NACK. However, it buffers any other received packets with higher sequence numbers and sends out an ACK for each. The sending peer receives the NACK and retransmits the missing packet. Following this retransmission, the sending peer continues sending packets again. However, it begins where it left off prior to the retransmission. There is no retransmission of segments which were correctly received by the receiver peer prior to the lost packet.

The selective-repeat algorithm is clearly more efficient in its utilization of the link. However it requires that the receiving peer be able to buffer those packets with sequence numbers higher than that of the lost packet. If the receiving peer does not have the ability to buffer packets, the go-back-n algorithm must be used. Both of these algorithms will be available for use in this proposal.

Changes to Current Draft ARQ Header Fields

The current draft applies a 16-bit header to the beginning of each Data PDU. It includes a 4 bit retries value and a 12 bit sequence number. This proposal eliminates the retries value as it is not useful to send it across the link. It also combines the Fragmentation Sequence Number and ARQ sequence number into the Block Sequence Number (BSN). This removal of redundant functionality reduces the overhead experienced by smaller PDUs seen in IP networks and saves bandwidth.

Creating A Reliable Service

The creation of a reliable service begins with a Dynamic Service Addition or Change message with the inclusion of three parameters in the DSA or DSC; the ARQ Algorithm TLV, the Window Size TLV and the Retries Count TLV.

ARQ Algorithm Parameter

The ARQ Algorithm TLV indicates the ARQ protocol to be used.

The DSA/DSC-RSP message will contain:

1. An acknowledgement of this parameter, signified by the parameter s exclusion from an SFES (if one is included).
2. A different suggested value for the algorithm in the TLV parameter which is included in the SFES.
3. A negative acknowledgement signified by the presence of an unmodified copy of the TLV parameter in the SFES.

A peer may attempt to change the algorithm at any time using the DSC mechanism and this TLV parameter.

The DSA/DSC-REQ message includes the following QoS parameter.

Name	**Type (1 byte)**	**Length (1 byte)**	**Value (Variable Length)**
ARQ Algorithm	1	4	Unsigned 16-bit value 0 — selective-repeat - default 1 — go-back-n All other values are illegal, ignore TLV The peer sending this TLV parameter indicates its desire to use Service Flow ARQ by including this parameter. Service Flow ARQ is not used by default.

Window Size Parameter

The Window Size TLV indicates the maximum number of outstanding packets, which may be sent without receiving a NACK. Note that the receiving peer of the reliable packet stream is responsible for buffering higher sequence numbered acknowledged packets and thus has final say for the window size. The DSA/DSC-RSP message will contain:

1. An acknowledgement of this parameter, signified by the parameter s exclusion from an SFES (if one is included).
2. A different suggested value for the window size in the TLV parameter, which is included in the SFES.
3. A negative acknowledgement signified by the presence of an unmodified copy of the TLV parameter in the SFES.

Maximum Values for Window Size, where N is window size and

Go-back-n : (2**N) – 1

Selective-repeat: N < (Max Sequence # / 2)

A peer may attempt to change the window size at any time using the DSC mechanism and this TLV parameter.

The DSA/DSC-REQ message includes the following QoS parameter.

Name	**Type (1 byte)**	**Length (1 byte)**	**Value (Variable Length)**
Window Size	1	4	Unsigned 16-bit value Range: Depends on ARQ algorithm The peer sending this TLV parameter indicates its desire to use Service Flow ARQ by including this parameter. Service Flow ARQ is not used by default.

Retries Count Parameter

The Retries Count TLV indicates the maximum number of attempts that will be made to retransmit any packet. Note that the receiving peer of the reliable packet stream is responsible for buffering higher sequence numbered acknowledged packets and thus has final say for the window size. The DSA/DSC-RSP message will contain:

1. An acknowledgement of this parameter, signified by the parameter s exclusion from an SFES (if one is included).

2. A different suggested value for the Retries Count in the TLV parameter which is included in the SFES.
3. A negative acknowledgement signified by the presence of an unmodified copy of the TLV parameter in the SFES.

A peer may attempt to change the Retries Count at any time using the DSC mechanism and this TLV parameter.

The DSA/DSC-REQ message includes the following QoS parameter.

Name	**Type (1 byte)**	**Length (1 byte)**	**Value (Variable Length)**
Retries Count	1	4	Signed 16-bit value Range:1 — 15 Default: 4 0 or 15+ are invalid values, ignore TLV The peer sending this TLV parameter indicates its desire to use a Reliable Service by including this parameter. Service Flow ARQ is not used by default.

ARQ Timeout Parameter

The ARQ Timeout TLV indicates the maximum number of frame times that may elapse before the receiving ARQ peer should consider the retransmission retries to have expired. This value will depend upon many factors including the flow s priority and bandwidth as well as the number of active stations. Therefore, there is no default value.

The DSA/DSC-RSP message will contain:

1. An acknowledgement of this parameter, signified by the parameter s exclusion from an SFES (if one is included).
2. A different suggested value for the timeout in the TLV parameter which is included in the SFES.
3. A negative acknowledgement signified by the presence of an unmodified copy of the TLV parameter in the SFES.

A peer may attempt to change the timeout at any time using the DSC mechanism and this TLV parameter.

The DSA/DSC-REQ message includes the following QoS parameter.

Name	**Type (1 byte)**	**Length (1 byte)**	**Value (Variable Length)**
ARQ Timeout	1	4	Unsigned 16-bit value

			Range:1 — 64k Default: N/A 0 is an invalid value, ignore TLV The peer sending this TLV parameter indicates its desire to use a Reliable Service by including this parameter.

The ARQ Timeout Parameter is treated differently depending upon the ARQ algorithm chosen.

ARQ Timer Expiration – Selective-Repeat

If the timer expires, the receiving peer must reset the expected sequence number value to that of the next packet received. All buffered packets with higher sequence numbers contiguous to the expired packet's sequence number must be released and allowed to proceed through the network.

ARQ Timer Expiration – Go-Back-N

If the timer expires, the receiving peer must reset the expected sequence number value to that of the next packet received. All buffered packets with higher sequence numbers contiguous to the expired packet's sequence number must be deleted and not allowed to proceed through the network.

ARQ-ACK/NACK MAC Layer Message

Including the Window Size and Retries Count QoS Parameters with a DSA/DSC results in the creation of a reliable Service Flow. This message is used to acknowledge the latest received packet. The generic header carries the Connection ID, so that the sequence number that is to be acknowledged and Service Flow are carried in this message.

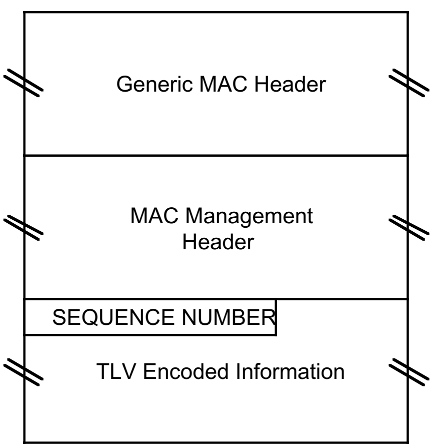

Figure 1 ARQ-ACK/NACK Message

The Sequence Number is formatted as follows:

Name	Type (1 byte)	Length (1 byte)	Value (Variable Length)
Sequence Number	TBD	4	Unsigned 16-bit value MSB:

ACK/NACK			ACK = 0 NACK = 1 All other bits in byte must be set to zero. LSB: Sequence Number Range: 0 — 255 Other values in any field are invalid

ARQ State Machines

The ARQ state machines for both ARQ algorithms are shown in figures 2- 5.

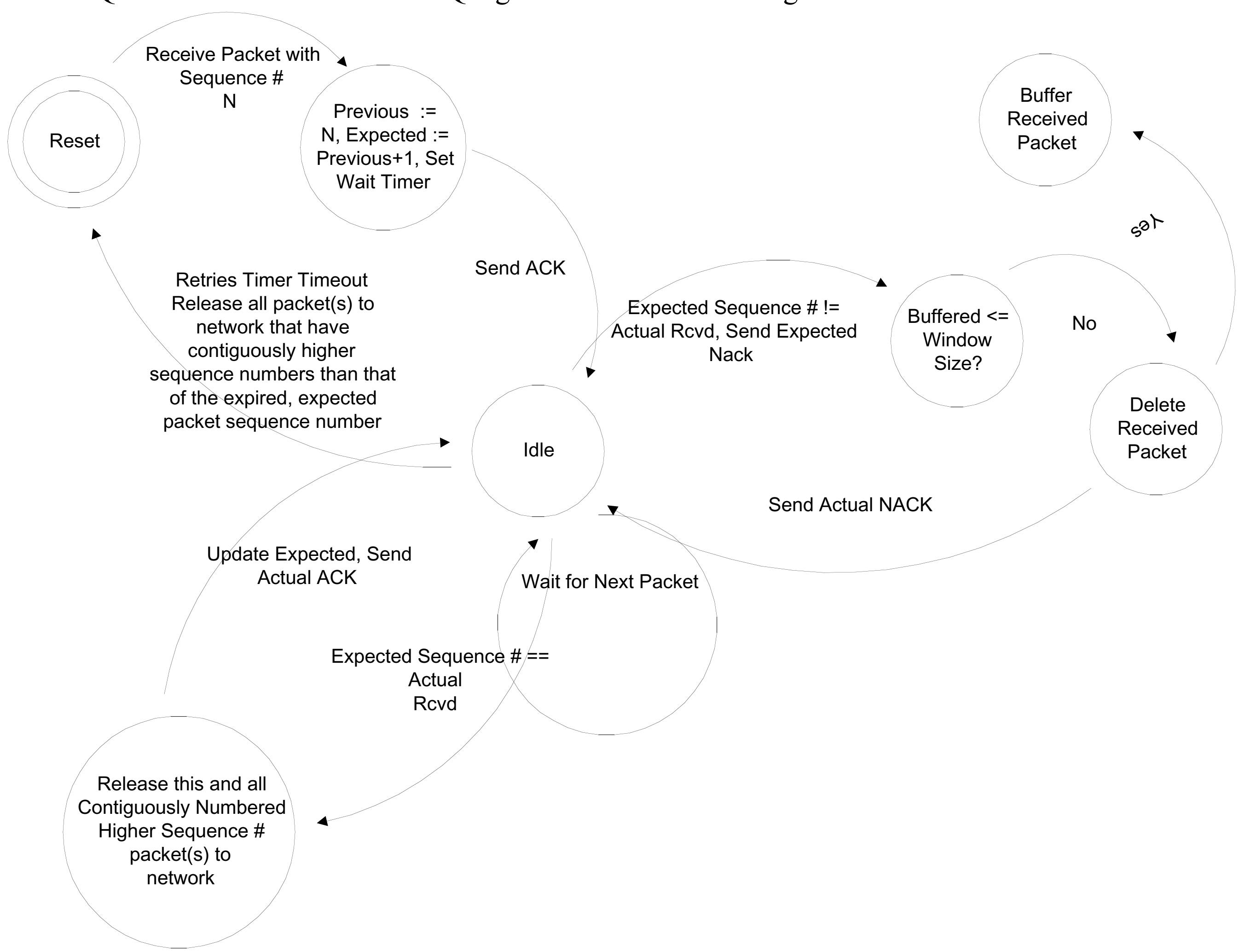

Figure 2 selective-repeat receive state machine

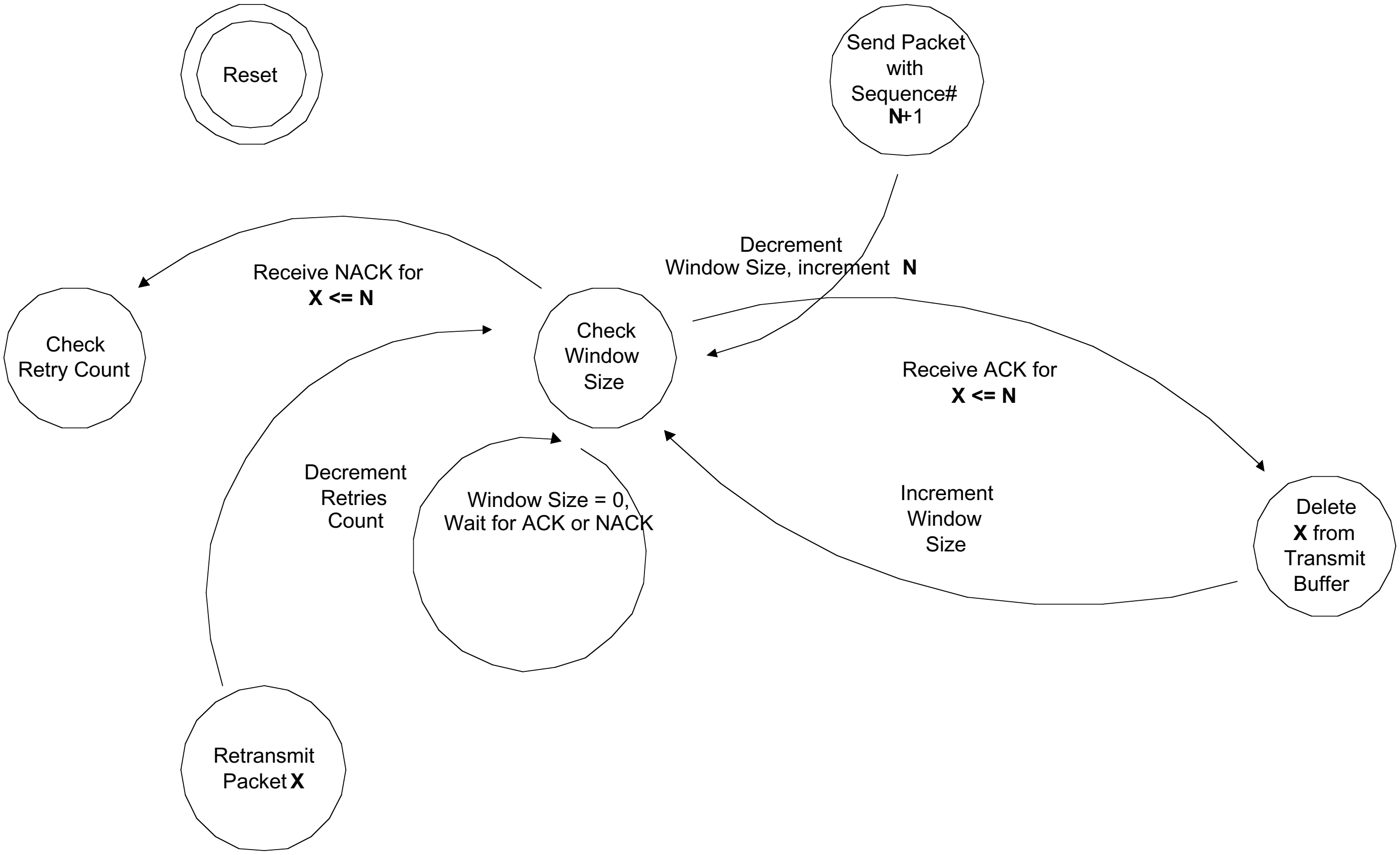

Figure 3 selective-repeat transmit state machine

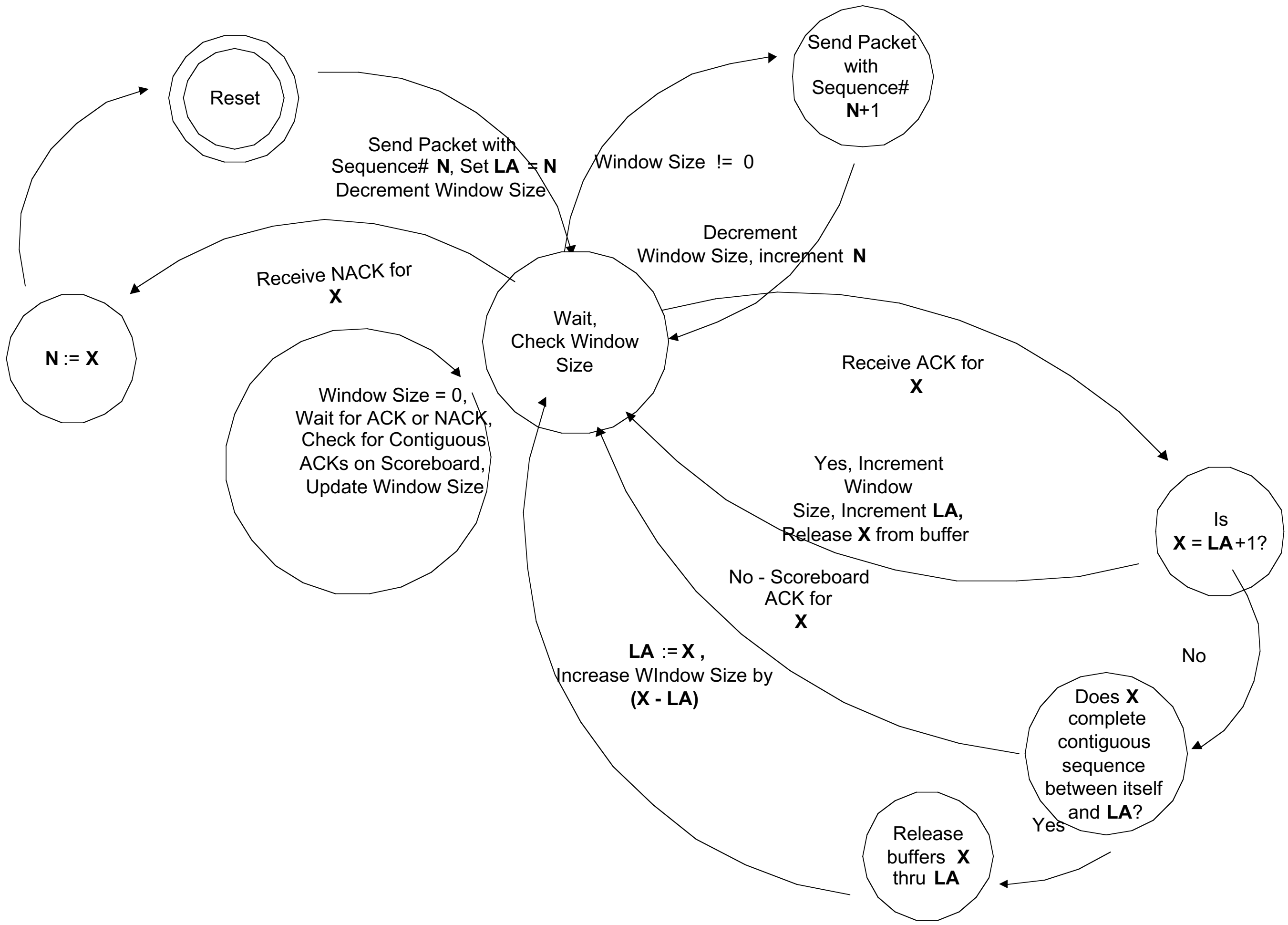

Figure 4 go-back-n transmit state machine

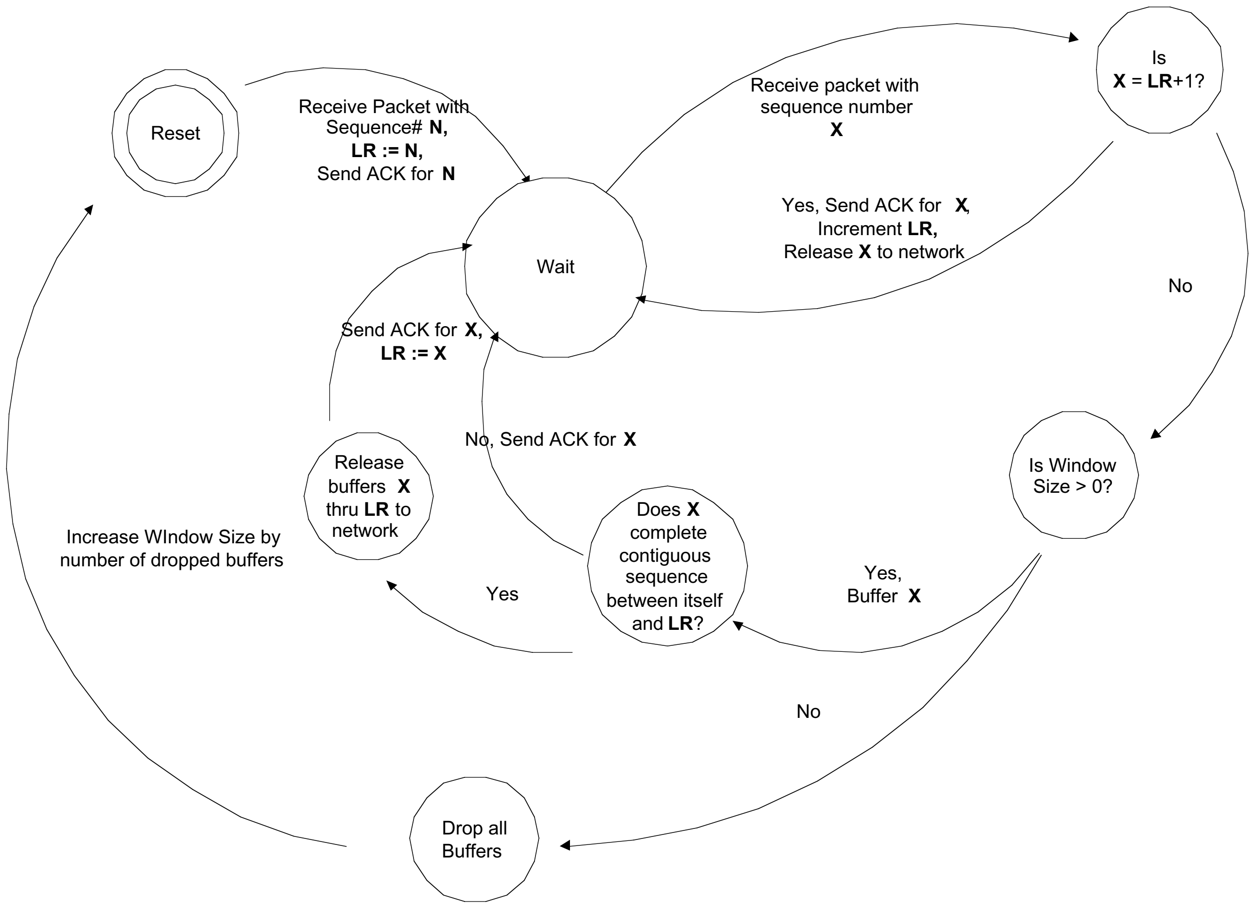

Figure 5 go-back-n receive state machine

References

1. *Improving TCP/IP Performance over Wireless Networks*, Balakrishnan, Seshan, Amir, and Katz, Computer Science Division, UC Berkeley, Proceedings of the 1st ACM International Conference on Mobile Computing and Networking (Mobicom) November, 1995.