| | |
|---|---|
| Project | **IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>** |
| Title | **Increasing Link Robustness in TG3 Systems** |
| Date Submitted | **2001-01-17** |
| Source(s) | Subir Varma<br>Aperto Networks<br>1637 South Main Street<br>Milpitas, CA 95035<br>Voice: (408) 719 9977<br>Fax : (408) 719 9970<br>mailto:svarma@apertonet.com |
| Re: | IEEE 802.16.1/D1-2000, December 2000 |
| Abstract | TG3 Systems operate in a more hostile environment as compared to systems operating in the higher frequency bands. In this contribution we suggest several techniques that can be used to increase the link robustness of TG3 systems |
| Purpose | |
| Notice |  |
| Release |  |

| | |
|---|---|
| Patent Policy and Procedures | The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures (Version 1.0) <http://ieee802.org/16/ipr/patents/policy.html>, including the statement ‘‘IEEE standards may include the known use of patent(s), including patent applications, if there is technical justification in the opinion of the standards-developing comittee and provided the IEEE receives assurance from the patent holder that it will license applicants under reasonable terms and conditions for the purpose of implementing the standard.”<br><br>Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto: r.b.marks@ieee.org> as early as possible, in written or electronic form, of an patents (granted or under application) that may cover technology that is under consideration by or has been approved by IEEE 802.16. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>. |

# Increasing Link Robustness in TG3 Systems

**Subir Varma**

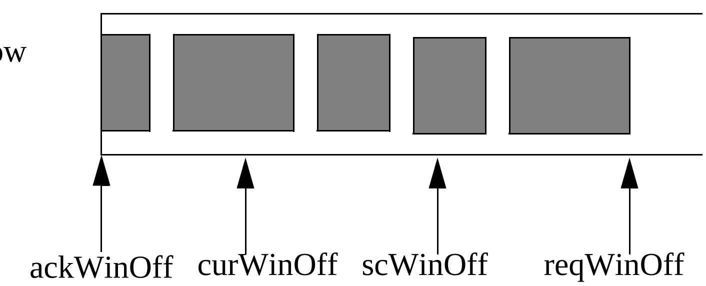
*Aperto Networks*

## 1.0 Introduction

Wireless systems operating in the Sub 10 band are subject to a wider variety of link impairments as compared to the higher frequency bands. Link impairments lead to bit errors and lost packets, which have a very detrimental effect on the performance of data traffic, especially that carried by the TCP protocol. In this contribution, we propose techniques that can be used to increase the robustness of the link:

## 2.0 ARQ

Contents of a flow
Transmit Buffer




reqWinOff - ackWinOff = Current Byte Backlog in Transmit Buffer
curWinOff - ackWinOff = Bytes transmitted but not yet ACKed
reqWinOff - curWinOff = Bytes received for transmission, but not yet transmitted
reqWinOff - scWinOff = Bytes received for transmission, but not yet scheduled
scWinOff - curWinOff = Bytes scheduled for transmission but not yet transmitted

**FIGURE 1. Counters Maintained at the Transmitter on a per flow basis**

Objectives of the ARQ protocol:

- It should be possible to support different levels of ARQ on a per flow basis, for example:

1. No ARQ for voice traffic
2. Limited ARQ for TCP traffic - limited number of re-transmissions, such that the number of re-transmissions can be changed.

- The ARQ protocol should not un-necessarily constrain the peak BW for the flow (by limiting the number of MPDUs per frame, for example).

- The ARQ protocol should avoid the use of timers to control re-transmissions.
- The ARQ protocol should enable the link layer parameters and/or size of the MPDU to change between re-transmissions.
- The ARQ protocol should be robust and recover from various error events, such as loss of ACK packets etc.
- The ARQ protocol should be simple to implement, and should be able to scale up to hundreds of connections per point to multipoint link
- Since upstream BW is at premium, the ARQ protocol should not consume an excessive amount of upstream BW for ACK slots.

## 2.1 Downstream ARQ Protocol

- The BS maintains the reqWinOff, scWinOff, curWinOff and the ackWinOff counters for each flow, at the transmitting end. The reqWinOff counter is incremented when a new CS-PDU arrives, the scWinOff counter is incremented when bytes from the transmit buffer are scheduled, the curWinOff counter is incremented when the bytes actually get transmitted and the ackWinOff counter is incremented when an ACK is received from the receiver. When an CS-PDUs gets scheduled for transmission, the BS creates the MPDU and inserts the curWinOff field into the MPDU header.
- The SS maintains an ackWinOff counter, on a per flow basis. The value of this counter is set to the sequence number of the next byte that the SS expects to receive. If a MPDU is received correctly, then this counter is incremented by the number of bytes contained in the MPDU. If the MPDU is lost or received in error, then the counter is not incremented.
- As long as there are bytes in the flow transmit queue that have not been acked, the BS schedules a special ACK packet in the upstream (on a per flow basis). The SS returns the ackWinOff value in the ACK packet. The SS also indicates in the ACK packet whether the last MPDU in the downstream frame was received correctly or in error.
- If an MPDU is lost, then the SS drops all subsequent MPDUs on that flow, until it receives the one with the expected sequence number. When the BS receives a NACK, it re-transmits all the bytes in the queue with sequence numbers of ackWinOff and greater.
- If one or more MPDUs are not able to get across after N re-transmissions, then the BS drops the first CS-PDU in its transmit queue. It then continues by sending the next HL-PDU, with the same Sequence Number (curWinOff) as the on that the SS is expecting. When the SS starts receiving a new CS-PDU, it drops the incomplete CS-PDUs that it was trying to re-assemble.

## 2.2 Upstream ARQ Protocol

The upstream ARQ protocol that is described in this section has the desirable property that all re-transmissions are controlled directly by the BS. This facilitates the operation of the

ARQ protocol, since the BS can allocate upstream BW for re-transmissions, without having to be prompted to do so by the SS.

- The BS updates its own copy of the reqWinOff field by examining the MAC header of REQ and data packets coming from the SSs. It gives upstream data slot allocations in the MAP packet, and updates the scWinOff counter with every grant allocation, by the number of bytes in the payload portion of the grant.
- On receiving an allocation, the SS creates and transmits the MPDUs, and increments its own copy of the curWinOff counter by the number of bytes in the transmission payload. On receiving an CS-PDU, it increments its copy of the reqWinOff counter by the size of the HL_PDU. It puts the curWinOff and reqWinOff counters in the appropriate fields in the MPDU header.
- If an MPDU is lost, then the BS detects this and sends a NACK back to the SS. It also allocates BW for re-transmission of the lost MPDUs. When the SS receives a NACK, it rolls back its curWinOff counter and sets it equal to the ackWinOff counter value received from the BS, and re-transmits the data.
- If an MPDU is not able to get across after N re-transmissions, then the BS sets the flush flag in the ACK. When the SS gets the flush, it drops the CS-PDU at the head of its transmit queue. If there are additional packets in the transmit queue, then it requests BW for them by using the REQ slots.

## 2.3 Comparisons with Other ARQ Schemes

The scheme described in the previous section is a variation of the Go-Back-N ARQ protocol. There exists an alternative ARQ scheme called Selective-Repeat (SR), in which the receiver buffers up out of order packets and explicitly informs the transmitter of the set of packets that were dropped. The transmitter then selectively re-transmits only those packets that were dropped. Some of the issues related to the implementation of the SR protocol in a point-to-multipoint network include:

- The SR receiver is more complex to implement, and requires a larger amount of buffering. In point-to-point links the number of connections is limited, however a link in a point-to-multipoint network supports hundreds of simultaneous connections, thus making the increased complexity more of an issue.
- In a point-to-multipoint network implementation of GBN, the receiver uses cumulative ACKs. These are able to ack several packets while using a single sequence number. This helps in minimizing the amount of ACK packet traffic in the upstream, which is crucial especially in the presence of hundreds of simultaneous connections. The SR protocol on the other hand requires that the receiver return information about the state of each and every packet that was received. The size of the ACK packet can be reduced by using a bitmap rather than a sequence number, but this restricts the number of packets that can be ack'd using a single ACK packet and thus the flexibility and scaleability of the system.
- The difference in performance between the GBN and SR protocols is a function of N, which is the number of packets that the transmitter is able to transmit, before it gets an

ACK for the first transmitted packet. For smaller values of N, the performance of GBN approaches that of SR. In the proposed scheme, ACKs are sent in the upstream portion of the frame for packets transmitted in the downstream portion, which means that N will be of the order of a few packets at most.

- In wireless networks with fading, usually packets are not lost according to an iid process, but losses occur in clusters. Under these conditions, it has been shown that the performance of GBN is close to that of SR, since a single NACK leads to the re-transmission of several lost packets [3].
- It is possible to implement partial SR functionality, while maintaining the protocol formats used for GBN, in the following way: The receiver buffers out of order packets, and sends a NACK for the first lost packet. The transmitter does not re-transmit all packets after the lost packet (as in regular GBN), but only the one that was explicitly requested by the CPE. This scheme will work well as long as the number of lost packets per frame (and per connection) does not exceed one or two. This scheme is used by the TCP protocol to receover from lost packets.

The proposed scheme does re-transmissions on a per-MPDU basis, rather than on a per CS-PDU basis. If re-transmissions are done on a per CS-PDU basis, then it can lead to significant problems for the case of moderate to high bit error rates and large CS-PDU sizes. In such cases, almost every CS-PDU will have errors in it, and unless re-transmissions are done at finer level of granularity, such as at the MPDU level, the system may not be able to recover from errors by using re-transmissions.

# 3.0 Link Layer Parameter Control

The wireless link is subject to greater number of impairments, as compared to wired transmission media. One of the objectives of the MAC and PHY layers is to protect the applications running in the higher layers from these problems. The link layer ARQ scheme described in the previous section offers a first level protection against errors, but does not work very well under extreme conditions. In such situations, the system should have the ability to appropriately change other parameters, at the MAC, PHY or Radio layers, in order to increase the robustness of the transmissions. Among the various parameters that can be varied, the TG1 specification incorporates the ability to control two, namely the modulation and the FEC. However, in general the protocol should have the flexibility to be able to control more than these parameters. An example of a parameter that can be controlled in a more dynamic manner is Transmit Power level. Others include various diversity related parameters such an polarization, antennae etc.

We propose that the MAP packet incorporate a separate field in each IE, upstream and downstream, that describes the set of parameters that are applicable for that burst. This field can be parsed by both the transmitter as well as the receiver, and can be used to appropriately set the link parameters, on a burst by burst basis. The presence of this field will enable the link control algorithms in the BS to react very quickly to changing link conditions, and vary link parameters without the need to exchange messages in advance of doing so.

## REFERENCES

1. V. Yanover, S. Varma and H. Ye, ‘‘Using the TG1 MAC for TG3 Purposes,” *Contribution Number 802.16.3p-00/56*, November 2000.
2. ‘‘Draft Standard for Air Interface for Fixed Broadband Wireless Access Systems”, *Document Number IEEE 802.16.1/D1-2000*, December 2000.
3. M. Zorzi and R.R. Rao, ‘‘ARQ error control for fading mobile radio channels,” *MILCOM’95*, San Diego, 1995.