# HaulPass Fiber
# QOS and Flow Control
# White Paper

VUBIQ NETWORKS

*Making Millimeter Wave Ubiquitous*

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# Foreword

As data networks continue to evolve, the physical interconnections between networking devices now include cable, fiber and wireless. Bandwidth requirements, in terms of data quantity, data speed, and number of users, fuel the well-known exponential growth curves. And more recently, add the important parameter of minimizing delay or network latency that results in even more stringent performance requirements for the global internet. Voice, video, web queries, and generic data transfers are the driving applications that produce the worldwide zettabyte-level traffic.

In the environment of high-bandwidth networks, the first choice for physical interconnection, whether inside the data center or between continents, is optical fiber. Fiber optic technology has the bandwidth necessary to support growth, and if feasible to deploy, provides a good return on investment. However, as network density increases, along with rising costs of planning, zoning and installation of fiber cable, the global communications industry is seeking viable alternatives.

One effective alternative is wireless connectivity, especially the new generation microwave and millimeter wave technologies that can support gigabit data rates (microwave) and 10+ gigabit rates (millimeter wave). Planning and installation of a wireless point-to-point link is significantly less expensive and much less time consuming than fiber deployment.

This white paper examines quality of service (QOS) considerations in the context of the Vubiq Networks HaulPass Fiber product, which operates in the E-Band millimeter wave radio spectrum (70-80 GHz). The HaulPass Fiber, as its name indicates, is a wireless link that can extend and augment existing fiber optic networks without the cost of fiber installation and without the delays incurred due to typical planning and zoning requirements.

Many microwave and millimeter wave radio link products in the market today incorporate internal Ethernet switches, which require configuration for both operation within the radio, as well as configuration for interfacing with customer networks. As such, these switch-oriented radios necessarily require complex network management support that adds to the total operating cost. In addition, internal Ethernet high-speed switch technology increases product size/footprint, requires higher power, increases system latency, and drives up equipment cost.

For all the above reasons, with an eye towards decreasing cost and simplifying integration into existing networks, the HaulPass Fiber by design has no Ethernet switch. The 10 gigabit data port connects directly through to the radio modem, significantly reducing latency and power consumption. The result is a smaller footprint, cooler running, faster and lower cost product. We at Vubiq Networks consider this improved and simpler design to be superior in performance, while simultaneously reducing the total operating cost for network managers.

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# 1 Introduction

### 1.1.1 Purpose

The purpose of this document is to aid users of the HaulPass Fiber millimeter wave RF radio link in configuring the connected switch, router or switch/router in order to optimize the network quality of service (QOS) for traffic traversing the Link.

The HaulPass Fiber radio link acts as a low-latency Ethernet Layer 2 forwarding engine that is agnostic to the Ethernet data that it sends across its RF Link and by design performs no switching or routing functions.

The vast majority of existing microwave and millimeter wave link products in today's market have an integral Ethernet switch/router. HaulPass Fiber intentionally does not have an internal Ethernet switch/router by design. This approach relieves many issues and performance parameters that impact existing radio products that have complex internal Ethernet switching functions such as:

- Adds additional data processing and store and forward latency
- Incurs additional complexity and corresponding management
- Provides much less plug and play convenience during installation
- Forces the network to always use its internal switching and routing functionality by a switch/router chipset chosen by the radio provider rather than the user
- Requires more power to support the additional switch/router hardware
- Results in a more expensive radio

Given the above technical parameters, Vubiq Networks intentionally designed the HaulPass Fiber radio hardware and software to be much simpler to use, resulting in lower latency, lower power, and importantly, be completely agnostic with respect to network data processing.

For the best use of the HaulPass Fiber radio link, it is important to properly configure any external switch, router, or switch/router equipment connected to it. The correct QOS configuration on external equipment is needed so it performs well in combination with the user's LAN/WAN networking needs.

## 1.2 Acronyms and Abbreviations

The table below gives a list of abbreviations and acronyms used in this document.

| Acronym or Abbreviation | Description |
|---|---|
| 10G | 10 Gigabits per second Ethernet |
| 802.1P | IEEE Networking standard that supports priority handling of Ethernet MAC frames using a priority field in the MAC frame and now incorporated into IEEE 802.1Q |
| 802.1Q | IEEE Networking standard that supports virtual local area networking (VLANs) on an IEEE 802.3 Ethernet network. NOTE: The header for 802.1Q also contains handling optional "priority" handling of MAC frames as previously defined in IEEE 802.1P |
| 802.3 | IEEE 802.3 is a working group and a collection of standards defining the physical layer and data link layer's media access control (MAC) of wired Ethernet. |
| 802.3x | IEEE 802.3x is the original Ethernet full-duplex standard that among other things, defined Ethernet flow control PAUSE frame format and processing. |
| COS (or CoS) | Class of Service |
| CRC | Cyclic Redundancy Check |
| DRR | Deficit Round Robin |
| DSCP | DiffServ Control Point |
| E-band | Range of radio frequencies from 60 GHz to 90 GHz in the electromagnetic spectrum |
| ECN | Explicit Congestion Notification |

| Acronym or Abbreviation | Description |
|---|---|
| FCS | Frame Check Sequence |
| FEC | Forward Error Correction |
| FIFO | First-In, First-Out Queue |
| FQ | Fair Queuing |
| G | Giga (1 billion) |
| GFP | Generic Framing Procedure |
| GHz | 1 billion hertz (cycles per second) |
| Hz | hertz (cycles per second) |
| IEEE | Institute of Electrical and Electronics Engineers |
| IETF | Internet Engineering Task Force |
| IP | Internet Protocol |
| IPv4 | Internet Protocol (IP) version 4 |
| IPv6 | Internet Protocol (IP) version 6 |
| LAN | Local Area Network |
| LSP | Label Switch Path (MPLS connection) |
| MAC | Media Access Control |
| MPLS | Multi-Protocol Label Switching |
| MPLS-TE | Multiprotocol Label Switching (MPLS) Traffic Engineering |
| PHY | Physical Protocol chipset or Physical Layer |
| PQ | Priority Queuing |
| PTP | Precision Time Protocol |
| QOS (or QoS) | Quality of Service |
| RED | Random Early Discard |
| RF | Radio Frequency |
| RR | Round Robin |
| RSVP | Resource Reservation Protocol |
| RSVP-TE | Resource Reservation Protocol (RSVP) Traffic Engineering |
| RTP | Real-Time Protocol |
| RX (or Rx) | Receive |
| SFP | Small Form factor Pluggable transceiver module |
| TCP | Transmission Control Protocol |
| TCP | Transmission Control Protocol |
| TCP/IP | Transmission Control Protocol over Internet Protocol |
| TE | Traffic Engineering |
| TOS | Type of Service |
| TX (or Tx) | Transmit |
| VoIP | Voice over Internet Protocol |
| WAN | Wide Area Network |
| WRED | Weighted Random Early Discard |
| WRR | Weighted Round Robin |
| XAUI | 10 Gigabit (X for ten) Ethernet Attachment Unit chipset to chipset Interface bus |

## 1.3 Links and References

| | |
|---|---|
| Cisco Article on Traffic Shaping vs Rate Limiting | https://www.cisco.com/c/en/us/support/docs/quality-of-service-qos/qos-policing/19645-policevsshape.html |
| MaxLinear BCM85110 SoC modem information | https://www.maxlinear.com/product/infrastructure/wireless-networking/microwave-and-millimeter-wave-modems/millimeterwave/mxl85110 |
| Queuing Discipline (FIFOs vs Fair Queuing) | https://book.systemsapproach.org/congestion/queuing.html |
| Wikipedia: Bandwidth Management in Priority Queues | https://en.wikipedia.org/wiki/Priority_queue#Bandwidth_management |
| Wikipedia: Ethernet Flow Control | https://en.wikipedia.org/wiki/Ethernet_flow_control |
| Wikipedia: Explicit Congestion Notification (ECN) with IP and TCP | https://en.wikipedia.org/wiki/Explicit_Congestion_Notification#Operation_of_ECN_with_IP |
| Wikipedia: FIFO | https://en.wikipedia.org/wiki/FIFO_(computing_and_electronics) |
| Wikipedia: IPv4/IPv6 Type Of Service (TOS) | https://en.wikipedia.org/wiki/Type_of_service |
| Wikipedia: Network Scheduler | https://en.wikipedia.org/wiki/Network_scheduler |
| Wikipedia: Network Traffic Classification | https://en.wikipedia.org/wiki/Traffic_classification |
| Wikipedia: Quality of Service (QOS) | https://en.wikipedia.org/wiki/Quality_of_service |
| Wikipedia: Queue (as an abstract data type) | https://en.wikipedia.org/wiki/Queue_(abstract_data_type) |

# 2 HaulPass Fiber Queuing, Discard and Flow Control

## 2.1 PAUSE Flow Control Overview

### 2.1.1 What PAUSE-based Flow Control is

The PAUSE flow control mechanism allows an Ethernet device to send PAUSE request frames to the Ethernet device or devices that are sending it data to request the sending device(s) to temporarily stop sending data to the device that is causing a congested state to occur.

In an uncongested state of the device's hardware line queue (64 kilobyte FIFO queue in the case of HaulPass Fiber) PAUSE flow control frames are not sent. However, if and when the hardware line queue processing the ingress data goes above a certain threshold ("Almost Full" threshold in the BCM85110), then a PAUSE frame is transmitted to the egress queue of the same Ethernet interface.

The PAUSE frame contains the time requested for the Ethernet device that receives it to temporarily stop sending traffic. The time requested is called the "quanta" and is expressed as a 16-bit value in 512 bit times. A PAUSE frame can also be sent with a quanta of zero to then cancel that timer and allow the sending Ethernet device to resume sending. If the time expressed by the quanta expires, then the sending device can resume sending frames.

### 2.1.2 What PAUSE-based Flow Control is Not

Ethernet PAUSE flow control is:

- Not intended to solve the problem of steady-state overloaded networks or links.
- Not intended to address lack of network capacity.
  - Properly used, flow control can be a useful tool to address short and long term overloads on a single link.
- Not intended to provide end-to-end flow control.

End-to-end mechanisms, typically at the Transport Layer are intended to address such issues. A common example is TCP Windows, which provides end-to-end flow control between source and destination for individual L3/L4 flows using sequence numbers to detect dropped packets and then adjust the window smaller if necessary to decrease that given TCP flow's rate.

## 2.2 HaulPass Fiber QOS and Flow Control Needs in Switch/Router Networks

The main reason why flow control and QOS are needed with the HaulPass Fiber is due to the fact that there may be a throughput mismatch between the maximum capacity/bandwidth of its 10 Gigabit Ethernet interface versus a potential lower capacity on the RF Link interface. This in its very nature will act in a network as possible network congestion in the direction of data from the external switch/router to the RF Link.

In addition to possible lower capacity, when there are disturbances to the RF link such as rain fade, temporary obstructions, etc., this will cause the bandwidth to be reduced until the disturbance has passed and normal link operation resumes.

The high-level diagram below at Figure 1 shows how two HaulPass Fiber radios running as a link process frames across a link.

 

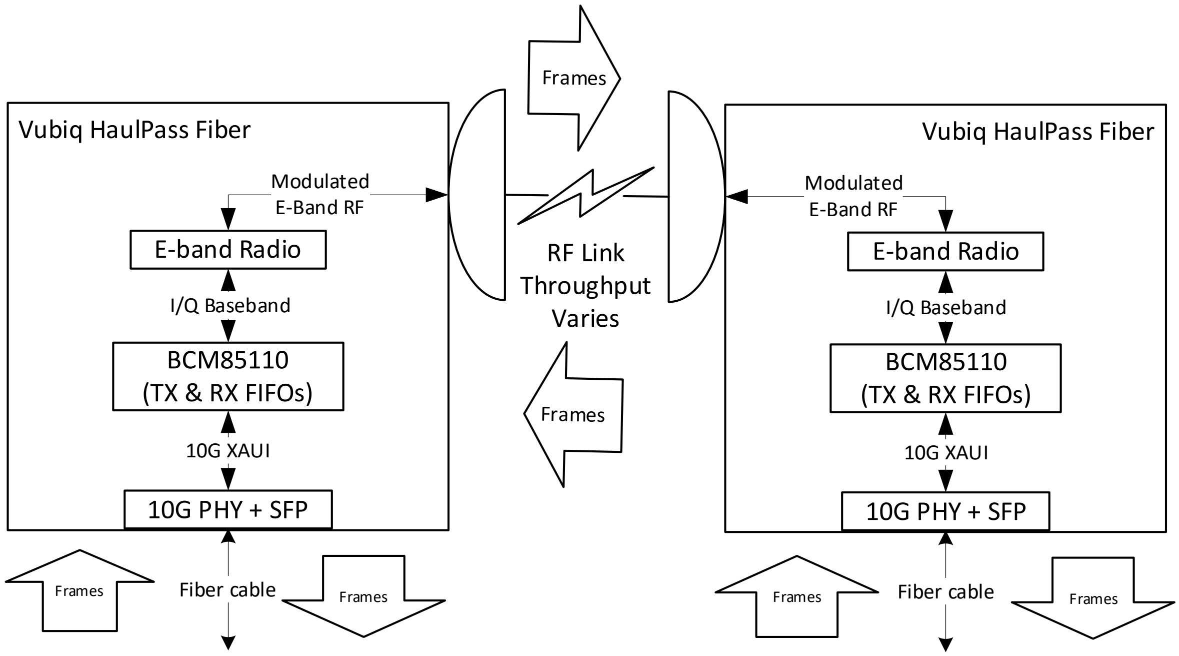


**Figure 1. HaulPass Fiber Link High-level Diagram**

In the above diagram, the normal traffic flow clockwise from left to right would be processed as follows:

1. Ethernet frames will be received up to the maximum capacity of 10 Gigabit Ethernet into the Small Form Factor Pluggable (SFP) transceiver.
2. The SFP does optical-to-electrical conversion and sends any valid data one byte at a time to the 10G PHY chipset.
3. The 10G PHY chipset will then send that data (again a byte at a time) to the BCM85110 modem's MAC function.
4. The MAC function will then process the Ethernet MAC frame and while doing so, at the end of the MAC frame, will process the four-byte Frame Check Sequence (FCS) Cyclic Redundancy Check (CRC) field against the CRC calculated from the actual received data.
   - If there is a mismatch between the two, that frame is then discarded and counted in the MAC's FCS error statistic.
   - If there is a match, the processing continues.
5. While the FCS check is being processed, byte data from the frame is sent to the input of the TX FIFO (NOTE: In the BCM85110, TX is defined as going to the RF link and RX is defined as coming from the RF link).
6. During insertion of data into the TX FIFO, if the threshold for "Almost Full" is detected, then if enabled (default), the TX MAC will signal the RX MAC to send a PAUSE flow control frame to the 10G interface (more details in subsequent sections).
7. During insertion of data into the TX FIFO, if the FIFO becomes full (congestion case), then that MAC frame will be discarded to allow the current FIFO data to be used by the next frame.
8. If the TX FIFO is not full or approaching full, then the output of the FIFO is emptied one byte at a time, where the Ethernet frame at the head of the FIFO is encapsulated and sent as a Generic Framing Procedure (GFP) frame into the radio modulator. As part of the process, Forward Error Correction (FEC) data is also calculated and combined with the associated GFP frame before being mapped into the modulation airframe as payload data.
9. The GFP frame then traverses the Modulated RF Link and is received by the peer HaulPass Fiber unit.
10. After demodulation at the peer unit, the GFP frame and associated FEC data are processed. If the processing of the data indicates an error, then the internal logic will attempt to correct the error.

 

- If the data has no error, or if there is an error and the FEC logic is able to correct it, then RX processing continues.
- If there is an uncorrectable error, then the GFP frame and the associated encapsulated Ethernet frame is discarded.

11. The RX GFP logic then calculates what the GFP CRC should be.
    - It there is a match, then RX processing continues.
    - If there is a mismatch, then the GFP frame and its associated Ethernet frames is discarded and the RX GFP CRC error metric is incremented.
12. The Ethernet frame is then extracted from the GFP frame and stored into the RX FIFO one byte at a time.
    - NOTE: For the RX FIFO, like the TX FIFO, there is also a check for “Almost Full” and “Full” with a similar GFP flow control mechanism. However, this is intentionally not further described in this document due to the fact that this flow control should be avoided. To avoid this aspect of the RX flow control, a recommendation is given below.
13. At the output of the RX FIFO, the RX MAC takes data one byte at a time to build a frame, calculating the FCS and then sending the frame and the FCS one byte at a time to the 10G PHY.
14. The frame is sent to the SFP and subsequently to the 10G fiber cable from the SFP. A more detailed diagram of the logic inside the BCM85110 between the XAUI interface to/from the modem modulation logic is shown below at Figure 2. NOTE: The TX parser, RX Parser and TX correction blocks are not described above as these logic blocks are only involved when the frame is detected to be a Precision Time Protocol (PTP) frame or packet. For all other frames/packets, these blocks are effectively a pass-through.

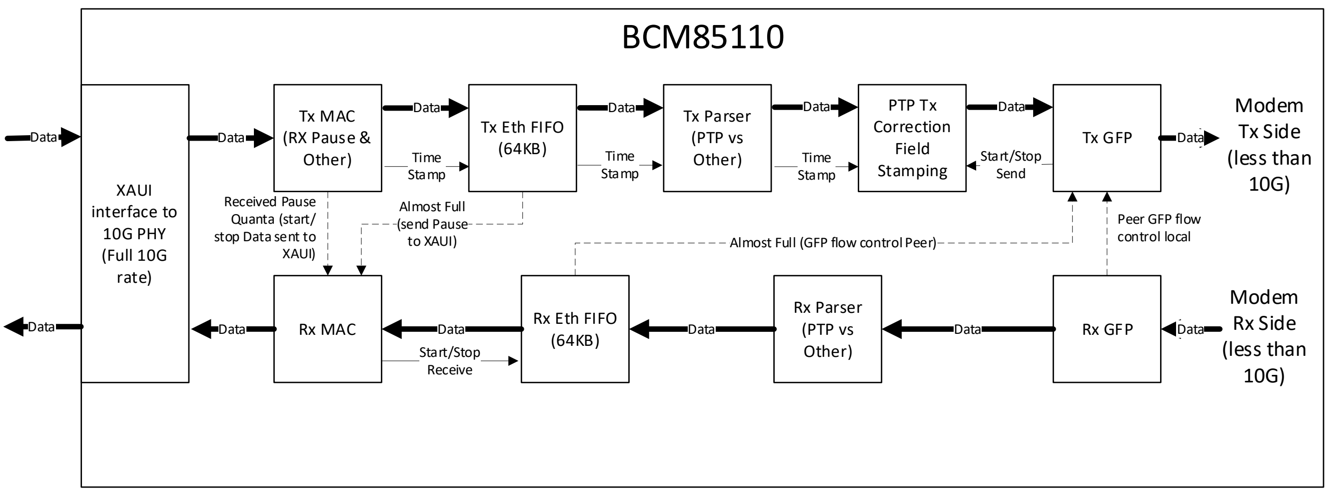


**Figure 2. BCM85110 XAUI-to-Modem Logic Diagram**

Congestion can occur when more ingress data is coming into the 10G Ethernet port than what can be queued for egress data sent over the RF link.

The HaulPass Fiber has two FIFO queues, one for queuing Ethernet frame data from 10G Ethernet to the RF link (called the TX FIFO) and another one for queuing Ethernet frames from the RF link to the 10G Ethernet interface (called the RX FIFO).

These FIFOs are contained in the BCM85110 Modem.

## 2.3 HaulPass Fiber FIFO Queue Behavior

Each 64 KB FIFO has an ingress function (data in) and an egress function (data out), and is used to temporarily hold the data during the time that it is being received from the interface (from the 10G interface for TX FIFO, and from the RF link for RX FIFO).

The maximum emptying rate for each FIFO will be regulated by the current egress link rate. The egress data sent to 10G SFP interface is fixed at 10G Ethernet rate. However, for egress data being sent to the RF Link, the RF Link rate will be less than full 10G Ethernet rate. The HaulPass Fiber has two modulation modes, High Throughput (HT) and Low Error (LE). The maximum rate for the HT mode is 9.987 Gbps and the maximum rate for the LE mode is 9.276 Gbps. In addition, the rate on the RF Link can also vary through the use of the ACMB (Automatic Code, Modulation Baud) feature that can change the throughput rate based on distance (i.e., for longer distance links, the maximum rate will shift to a lower throughput) and environmental conditions (things like rain, temporary full or partial beam blocking, etc. will cause the RF link to vary in speed).

While the FIFOs are being processed, they constantly monitor the level (amount of data contained) in the FIFO and monitor for the following conditions:

- FIFO empty
- FIFO almost empty
- FIFO almost full
- FIFO full

For those thresholds:

- If the FIFO almost full threshold is reached, that will then cause the MAC to transmit a PAUSE frame requesting the external Ethernet device to stop sending frames to the HaulPass Fiber.
- If the FIFO full threshold is reached, then all frames will be discarded until there is yet again enough room for frames to be queued.
- If a pause frame was sent out and the FIFO then goes to an almost empty state, the modem will send out a PAUSE frame with a quanta of zero to allow up to full transmission rate from the external Ethernet device.

## 2.4 HaulPass Fiber Frame Discard Behavior

Frame discard in the modem is simple in nature in that when and if more data comes into the FIFO than can be handled versus the amount going out such that that data exceeds the 64 kilobyte storage/queuing capacity of that FIFO, then those Ethernet frames will be dropped. Frames will then continue to be dropped until the point that the FIFO can again contain enough free space to store and queue new Ethernet frames.

This is true of both the TX FIFO that handles ingress data from the 10G interface encapsulated into an egress GFP frame transmitted to the RF Link, and received ingress GFP frames from which Ethernet frames are de-encapsulated and put into the RX FIFO, which then transmits egress Ethernet frames to the 10G Interface. If a frame cannot fit due to a space constraint in the associated FIFO, the frame is dropped.

For the RX FIFO regarding frame discard, it typically should not ever fill as the RF link ingress rate will always be lower than what can be sent egress on the 10G Ethernet link.

However, for the TX FIFO regarding frame discard, frame discarding will occur if the 10G ingress data is not properly flow controlled.

## 2.5 HaulPass 10G Ethernet Side 802.3x PAUSE Flow Control

As mentioned in section 2.3 above, the BCM85110 modem TX FIFO will use flow control by sending 802.3x PAUSE flow control Ethernet frames. A flow control frame is sent to request devices on the 10G link to stop sending data anytime that the TX FIFO goes above the “Almost Full Threshold”. Then as the TX FIFO empties and gets below the “Almost Empty” level, another 802.3X Flow control frame is sent to allow data flow to resume.

When sent, the frame uses the reserved 802.1D multicast address of 01-80-C2-00-00-01. This address ensures that any switch, router or switch/router that receives it will process it locally and not forward that frame to other devices in the network. This also means that to have flow control work, the switch, router or switch/router must be configured to support ingress processing of receive PAUSE flow control frames and to properly stop and restart traffic flow to the HaulPass Fiber’s 10G interface accordingly. Otherwise, in congested situations (large amounts of data, bursts, etc.) without Flow Control being honored and the TX FIFO overflows, then traffic will be discarded.

## 2.6 HaulPass Radio/GFP Flow Control

For the RX FIFO in the BCM85110 modem, it also supports flow control by using a proprietary GFP frame-based mechanism to inform the other side of the RF Link that it should slow down traffic.

However, this mechanism would only be useful for a case where a switch, router or switch/router connected to the HaulPass Fiber unit on the 10G interface itself were to enable/use flow control to request the HaulPass Fiber unit to request it to stop sending data.

This setup of a switch, router or switch/router is not recommended and should be avoided at all costs. Any switch, router or switch/router connected to a HaulPass Fiber unit should be able to handle wire rate traffic so that flow control in this direction is not used.

Although the GFP flow control mechanism is supported by the BCM85110 modem, is not further discussed in this document.

# 3 External Switch/Router QOS Recommendations

## 3.1 Typical Switch/Router QOS Overview

It is important to understand that QoS is not just a single tool or feature. Instead, it is a framework that accomplishes a quality of service objective using multiple tools as shown in figure 3 below:

- Classification and marking
- Policing and dropping associated with policing
- Scheduling and dropping associated with scheduling.
- Congestion management (e.g., PAUSE and Priority-based flow control)
- Other platform/interface specific tools

A high-level diagram of typical mechanisms/functions used in switches, routers and switch/routers is shown below at Figure 3.

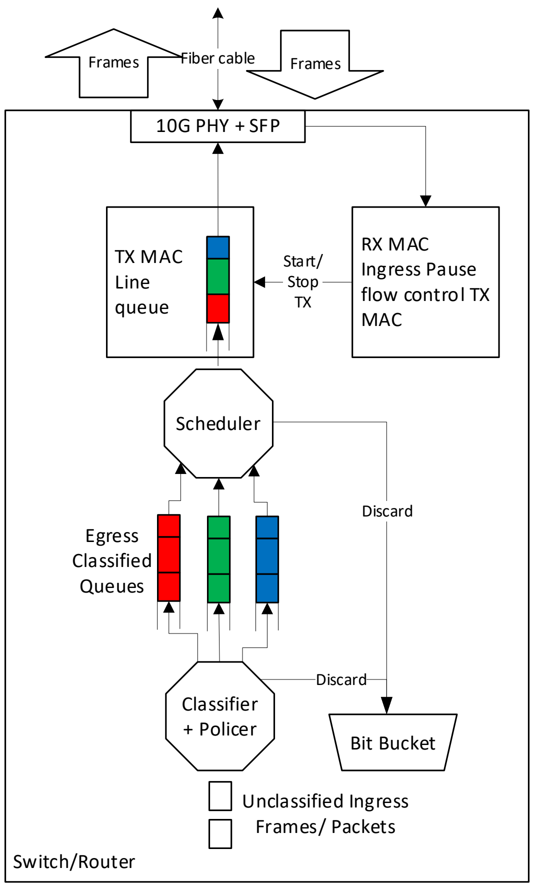


**Figure 3. Typical Switch/Router TX Processing Diagram**

## 3.2 When Switch/Router QOS May Not Be Needed

When it comes to the need for having QOS setup on the switches, routers or switch/routers connected to the HaulPass Fiber, QOS configuration may not be needed in the case where the actual traffic to go over a HaulPass Fiber never exceeds the minimum capacity of the RF link itself. So, for example, if networking devices/equipment on both sides of the link have less total bandwidth needs than the RF link can provide, then QOS is not strictly necessary.

 

Another case is where the networking protocols and usage of the network are less sensitive to frame/packet loss. An example of this could be a simple network already running mostly web and TCP-based traffic. In those cases, it might be OK to not set up QOS, as TCP and other web protocols can behave acceptably in that TCP connections will detect packet loss and reduce the traffic flow automatically.

With the above cases, it is still recommended that the switches, routers or switch/routers connected to a HaulPass Fiber link enable ingress RX PAUSE frame detection and handling and disable egress TX PAUSE frame to the HaulPass Fiber 10 Gigabit Ethernet interface.

## 3.3 When Switch/Router QOS Will Be Needed

Besides basic/simple networking cases as listed3.2 above, in most cases some kind of QOS will be needed in order to properly classify various traffic types. For these cases, it will be necessary to determine which traffic types need priority and/or minimum latency, how/when various traffic types are sent as appropriate, and what traffic to discard so that other more important traffic makes it properly across the HaulPass Fiber unit's RF link.

## 3.4 End-to-End Environment and Architecture using HaulPass Fiber with Switch/Routers

The diagram below at Figure 4 shows the overall environment of two HaulPass Fiber units running in a link each attached to a switch, router, or combined switch/router at each end in relation to data forwarding and QoS elements.

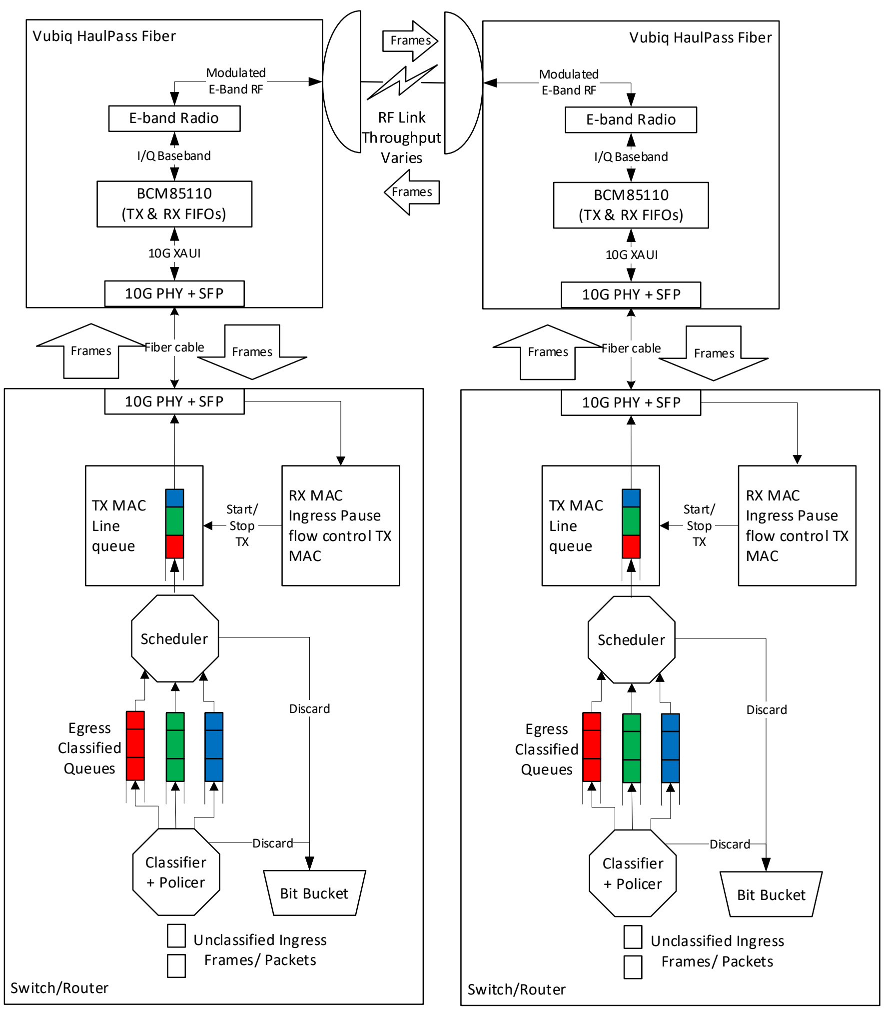


**Figure 4. HaulPass Fiber link with Switch/Routers Functional Diagram**

 

For the above diagram, as the HaulPass Fiber queuing, PAUSE flow control and tail drop discarding is fairly simple, most of the needs to get QOS working when using a HaulPass Fiber will reside in the configuration and setup of QOS in the switch, router or switch/router attached to the Haul Pass Fiber.

Also, when it comes to QOS, there is usually no need to do anything for traffic from the HaulPass Fiber unit to the router as QOS is used to avoid frame/packet loss by avoiding congestion in the BCM85110 modem.

## 3.5 Switch/Router Flow QOS Recommendations

### 3.5.1 MAC-level Recommendations

#### 3.5.1.1 RX 802.3x PAUSE Frame Flow Control

For QOS and HaulPass Fiber, the most important aspect of configuration in the switch, router or switch/router is to make sure support for reception of RX Ethernet PAUSE frames is enabled. Frames will then be recognized and processed in order to flow control the TX Ethernet frames sent from the switch/router to the HaulPass Fiber 10 Gigabit interface. This will have the impact of preventing packet loss due to possible congestion of the TX FIFO inside the BCM85110 modem.

Therefore:

- The switch/router must be configured to receive and process incoming Ethernet PAUSE frames. Network traffic will then pause and resume on that interface accordingly.
- The HaulPass Fiber must be configured to transmit outgoing Ethernet pause frames to prevent TX FIFO full and associated frame discarding (this is the default setting).

#### 3.5.1.2 TX 802.3x PAUSE Frame Flow Control

To avoid packet loss in most use cases of the HaulPass Fiber, the switch/router TX PAUSE frame setting must be disabled in order to prevent Ethernet PAUSE frames to be transmitted to the 10G interface of the HaulPass Fiber unit. If the switch/router were to enable egress PAUSE frames to the HaulPass Fiber unit, this could cause the RX FIFO to fill to the point that it discards frames before they can get to the switch/router.

Therefore:

- The switch/router must not be configured to transmit Ethernet PAUSE frames.
- The HaulPass Fiber unit must be configured to ignore incoming Ethernet PAUSE frames (this is the default setting).

#### 3.5.1.3 TX MAC Line Queue Shaping or Rate Limiting

Some switch/routers at the MAC/line level can support transmit rate limiting (average rate going out of the line interface in a start/stop fashion as needed) or transmit rate shaping (where packets are metered out at a “smooth” rate with controlled gaps between frames). For those switch/routers that support this feature, this is a good way to avoid congestion such that if configured/used properly, it is possible to avoid TX FIFO congestion.

If the switch/router supports rate limiting and/or rate shaping:

- Rate limiting and rate shaping will usually be the better method to use to avoid congestion.
- For the actual rate configured, the value of the rate on the switch router should be equal to or less than the maximum observed rate of the HaulPass Fiber Link running on an unobstructed link.

 

### 3.5.2 TX Scheduler Recommendations

This section describes possible scheduling options in the switch/router that may aid in reducing the chance of TX FIFO congestion in the HaulPass Fiber. Please note that these capabilities, methods, etc. can vary from one switch/router to another.

#### 3.5.2.1 Fixed Priority Queuing/Dequeuing

Most switch/routers will have some level of priority queuing. This is often called “Class of Service” (COS) type queues. Priority queuing allows for frames of one type to be sent in preference of another when sending frames/packets to the switch/router’s egress line/interface queue/FIFO. In many cases, this can be an important configuration, and must be set correctly in the switch/router for traffic destined for the HaulPass Fiber unit.

Therefore:

- Traffic classes must be selected and prioritized in the configuration of the switch/router to first classify that traffic (using the classification methods that the switch/router supports), and then once classified, assign that classified traffic into one or more priority queues.
- For priority queues on sending, it is not necessary to also tag the traffic using 802.1P priority, as the HaulPass Fiber does not differentiate between priorities since it will ignore and transparently pass on the priority field in the 802.1P/802.1Q header of the MAC frame.

#### 3.5.2.2 Scheduled Queuing/Dequeuing

Scheduled queuing/dequeuing (as opposed to priority queuing) in a switch/router is where pre-classified traffic is placed into a given queue such that that egress traffic out of that queue is scheduled in a more complex manner, and usually has some associated set of tradeoffs in relation to other scheduled queues in the system. The subsections below provide some suggested methods and options that may be useful in configuring QOS for use with the HaulPass Fiber.

NOTE: This section usually applies more to the routing functionality of a router or switch/router. Most Layer 2 only switches do not have this functionality and instead have some kind of Class of Service (COS) queuing/scheduling based on either strict priority or strict priority in combination with basic shaping capabilities.

##### 3.5.2.2.1 Scheduling Options

Depending on the capabilities of the switch/router or router, various scheduling methods may be used to best handle the given classified traffic from multiple queues to be sent to the single egress line/interface queue. Some examples of these methods include Round Robin (RR), Weighted Round Robin (WRR), Deficit Round Robin (DRR), Deficit Weighted Round Robin (DWRR), Fair Queuing (FQ) and others.

This document offers no specific recommendation for scheduling options. However, when configuring your switch/router, it is important to choose for each queue or set of queues appropriate scheduling methods/algorithms. In this way, a balance is established in the configuration so that various classified traffic/protocols/flow can share the egress 10G interface to the HaulPass fiber such that all desired traffic types can be transported across the shared RF Link.

##### 3.5.2.2.2 Queue Shaping and/or Rate Limiting

In some switch/routers and routers that have the ability to do Shaping and/or Rate Limiting at the line level, they may also have the ability to support queues above the line queue and also be configured to either shape or rate limit the traffic going through these queues.

If this feature is available in the switch/router, then it is recommended to use it for traffic flows/types that want to reserve a given maximum amount of traffic expressed as a bit per second rate. When used, normally it is a good idea to have the shaped/limited traffic not exceed the capability of the RF link and also still allow for some leftover amount for Best Effort (BE) traffic to go across the RF link as well.

#### 3.5.2.2.3 Discarding in the Queues

Another important function of scheduled queues in a switch/router is when a given queue becomes full based on the depth/storage capacity of the queue and/or availability of frame/packet buffers, is to understand the mechanism used to discard data in the queue. The method chosen can affect QOS in regard to when frame/packets are discarded, why they are discarded, and then how they are discarded.

On the subject of "how" frames are discarded in a queue, the typical options are:

- Tail drop
  - Drop any packets trying to enter the queue when queue is full and/or no buffer space is available.
- Discard all
  - Drop all packets in the queue, not just ones entering it.
- Random Early Discard (RED)
  - Packets in the queue are chosen randomly as to which packets are discarded to allow room for additional packets to enter the queue.
- Weighted Random Early Discard (WRED)
  - Packets are again randomly dropped, with the addition of "weighing" multiple queues and frames/packets in them and then discard the less important frames/packets first.

With the above methods, tail drop is usually the default discard behavior for handling data in a given queue that is full. However, if a given queue is handling protocols such as TCP, then using RED or WRED is usually a better methodology as TCP flows will react better in reducing the flow rate as compared to Tail Drop or Discard all mechanisms.

In general, when configuring QOS on a switch/router and using TCP flows, there will be better overall performance when using RED or WRED. With better overall performance, this will also reduce occurrences of congestion in the HaulPass Fiber unit's TX FIFO (by making data flow into it more consistent).

#### 3.5.2.2.4 Queue Depths and Buffering

For a given shaped queue, a switch/router may have the capability to configure the depth of the queue (in packets and/or bytes) and possibly the maximum number of buffers to store the packets for a given queue.

For queue depths and buffering, Vubiq Networks has no specific recommendations, but setting depths and buffers allowed for various queues may be helpful in balancing out traffic between traffic types to get the desired egress output flow of packets to the HaulPass Fiber. For cases when buffer limits are reached and/or queue depth is exceeded, these events can be used to trigger a discard policy for the queue. Some examples for discard methodologies would be Random Early Discard (RED) or Weighted Random Early Discard (WRED) on packet flows that run TCP flows. This will allow TCP flows to perform better than Tail Drop with respect to how the TCP flows react and either slow down or speed up to avoid packet loss situations.

## 3.5.3 TX Classification and Policing Recommendations

### 3.5.3.1 Classification Options

This section describes how packets are classified relative to various egress queues in a switch/router and classification methods used.

#### 3.5.3.1.1 LAN Port, VLAN and IP Subnetwork Mapping

One of the key functions of a switch/router that is related to "classification" is the handling of data from various LAN ports, collections of ports and data from ports into virtual LANs, and then subsequently mapping of LAN ports and Virtual LANs into IPv4 and IPv6 subnets.

The key consideration here when using HaulPass Fiber is to properly configure your switch/router such that any traffic not intended to be transported across the RF link is not sent to the 10G port connected to the HaulPass Fiber unit.

 

With respect to QOS for the HaulPass Fiber, a recommendation is to configure what traffic gets routed to the link by a unique subnet such that normal handling of LAN ports and virtual LANs will only send data to the HaulPass Fiber when it is appropriate for data to cross that subnet and not for other traffic that is not needed/wanted to be sent through the RF link.

#### 3.5.3.1.2 802.1p Priority

Another option for classification of frames at Layer 2 is for the switch/router to parse and use 802.1p priority fields contained in 802.1D VLAN headers in the Ethernet ingress frames received by the router. These fields can then be used by the switch/router to enqueue egress queues such that the most important data to be sent to the HaulPass Fiber link is prioritized over the less important data.

NOTE: The HaulPass Fiber is agnostic to 802.1p priority frames coming into a switch/router, and can have their 802.1D/802.1p header data removed by the switch/router prior to sending to the HaulPass Fiber 10G link. This will save 4 bytes per frame as far as bandwidth used on the RF link as well.

#### 3.5.3.1.3 IPv4 Type of Service (TOS) and IPv6 Traffic Class

Another method of classification supported by most switch/routers is IPv4 using the Type of Service (TOS) field and IPv6 Traffic Class field. These fields in IP packets can be used in a QOS context where the switch/router can parse the field and determine which egress queue to select to get appropriate egress scheduling and apply any specific discard policy in order to help choose which packets to send in preference to others to the egress line queue connected to the HaulPass Fiber 10 Gigabit port.

#### 3.5.3.1.4 Port IDs

In IP packets there is a field called the Port ID. Port IDs are divided into two main categories:

- Well known/assigned Port IDs
- Dynamically assigned Port IDs

In general, use of Port IDs can provide a simple and fast lookup method to classify an IP packet as a given protocol.

Both User Datagram Protocol (UDP) and Transmission Control Protocol (TCP) have Port IDs from which a switch/router can then use that Port ID based classification to choose how to filter or forward the data, and also which egress scheduling queue is chosen to handle it.

In the case of HaulPass Fiber links, the router can be configured first whether given Port IDs are forwarded to it or filtered (disallowed and/or discarded) and if OK to forward, enqueue into an appropriate egress queue. Then once in the egress queue, schedule it to the HaulPass Fiber or in the case of congestion, apply the discard policy of the queue.

#### 3.5.3.1.5 Layer 4 (Transport) through Layer 7 (Application) Data Classification

Besides methods such as those used at MAC Layer 2 (802.1P), IP Layer 3 (TOS, Port ID), some switch/routers can have additional classification methods at layers above that by parsing the data field itself of IP packets to determine higher level protocols and/or application of the traffic. This methodology is sometimes called "Deep Packet Inspection."

What those methods are is beyond the scope of this document. However, these methods if available in the switch/router, as similar to other classification methods, can be first used to forward or filter packets and then once classified, if packet is to be forwarded, enqueue those packets into appropriate egress queues for subsequent transmitting or discarding in congested conditions.

#### 3.5.3.1.6 Other

Lastly, in regard to classification, a given switch/router may have other proprietary and/or unique methods for implementing packet classification.

With respect to HaulPass Fiber, any and all methods that can be supported by a given switch/router should be investigated to see if they could be useful to forward or filter packets. Once classified, if packets are to be forwarded, then enqueue those packets into appropriate egress queues for subsequent transmitting or discarding in congested conditions.

#### 3.5.3.2 Discarding, Filtering and Firewalling Prior to Queuing

When practical, discard any traffic not intended/desired to go across the RF link. Any methods available to avoid sending unnecessary traffic across the RF link should be used. This can help in reducing the traffic across the RF Link to allow needed traffic to use and share the bandwidth.

### 3.5.4 Other QOS and Frame Processing Options

#### 3.5.4.1 Frame Size and Fragmentation

Some switch/routers offer the ability on ingress ports to process large IP packets (which may be contained in Ethernet “Jumbo” frames) such that when they are received, the router can break up the large IP packets into smaller packets before enqueueing them on egress ports be sent to a HaulPass Fiber 10G Ethernet port.

If this feature is available on a switch/router for the cases that the RF link has to carry multiple protocols and data flows, it is preferable to avoid sending large sized IP packets and/or jumbo frames to the HaulPass Fiber. Using fragmentation can reduce the overall average sizes sent to the HaulPass Fiber resulting in better utilization of the RF Link, for both fair sharing fairness and reduction of the number of jumbo frames (especially in burst) that might fill the FIFO to quickly and cause congestion.

### 3.5.5 Multi-Protocol Label Switching (MPLS)

When feasible, MPLS offers a useful alternative to classic Ethernet Bridging/Switching and IPv4/IPv6 routing. MPLS can be used to create various tunnels through the network that then can have the traffic queued and regulated. Many other point-to-point radios that have built in switch/router chipsets use this as a primary networking method.

HaulPass Fiber can be used as a point-to-point connection for external routers running MPLS at 10G wire rate.

One very useful feature/function of MPLS is called MPLS Traffic Engineering (MPLS-TE). MPLS-TE can be used to define how traffic flows through an MPLS core network. By properly configuring and using MPLS-TE, traffic can be steered across appropriate MPLS links along with control of how much data flows across those links. MPLS-TE attempts to prevent network congestion and balance network traffic. Preventing Network Congestion is the most important feature of MPLS-TE with respect to using MPLS running over HaulPass Fiber links.

MPLS-TE accomplishes this by creating Label Switched Paths (LSPs) that form unidirectional tunnels to carry traffic. These tunnels can then be configured with parameters such as bandwidth and priority.

For bandwidth control on an MPLS TE link, categories of bandwidth can be setup such as:

- Maximum link bandwidth
  - Sets the total useable maximum bandwidth of the MPLS link.
  - This can be set up with respect to a HaulPass Fiber link to be at or below the maximum observed bandwidth reported from the RF Link metrics.
- Maximum reservable bandwidth
  - For a given MPLS-TE link, sets the maximum amount of bandwidth to be used for “reserved” traffic.
  - Reserved traffic is used for important traffic with high priority and/or low latency requirements. It can also be used for reserved traffic using Resource Reservation Protocol (RSVP) for MPLS TE (RSVP-TE).
  - For use with a HaulPass Fiber RF link, typically the Maximum Reservable Bandwidth should be at or below the minimum observed bandwidth reported by the HaulPass Fiber from the RF link metrics. This will ensure that high priority and/or reserved traffic will be given priority over other best effort traffic if and when the TX FIFO in the HaulPass Fiber unit becomes congested.

 

### 3.5.6 Voice and Video Traffic using RTP Compression

Real Time Protocol (RTP) is a protocol that runs over Internet Protocol (IP) that is intended for high-priority and low-latency traffic. Specifically, RTP is an often-used protocol for carrying voice (as in Voice over IP or VoIP), or video streams.

One key feature in RTP that is sometimes missed is that RTP supports a feature called RTP header compression. Once an RTP connection/session is established for a Real Time data flow (such as VoIP), RTP header compression allows packets in a given RTP connection to use smaller headers. This feature, when enabled, can significantly reduce the bandwidth needs for real time traffic streams.

When using RTP protocols such as VoIP over HaulPass Fiber links, it is recommended to enable RTP header compression in the end stations and/or the switch/routers in order to reduce the bandwidth used on the RF link and help avoid congestion of the HaulPass Fiber unit's TX FIFO queue.

Making Millimeter Wave Ubiquitous

Vubiq Networks, Inc.
9231 Irvine Blvd, Irvine, CA 92618 USA
www.vubiqnetworks.com

 