# Header Compression
## Capacity Calculations for Wireless Networks


## Abstract

Deployment of wireless transport in a data-centric world calls for a fresh network planning approach, requiring a balance between optimization of user quality-of-experience, and reducing total cost of ownership. As broadband services become mobile, there is an emerging need for reliable, predictable high-capacity delivery at any location. This paper reviews different capacity forecasting and contention ratio models, and discusses the importance of data compression in wireless point-to-point links.


## Capacity: Much More than Higher Modulation Rates

Traditionally, in wireless networks, the capacity discussions were closely associated with modulation and symbol rate. Today, the introduction of all-IP mobile networks has encouraged the adoption of a multi-leveled approach to improve the spectrum utilization of wireless backhaul infrastructure:

### Spectral Efficiency

Spectral efficiency refers to the bit rate of a wireless connection for a specified bandwidth. The following techniques can be used to improve spectral efficiency:

- Modulation. Generally speaking, the higher the better, offset by the increased vulnerability to noise interference.
- Compression. Layer 2-4 header compression and payload compression: improves spectral efficiency by reducing the traffic load.
- Scripts. Use of script 6A (instead of 5B) when applicable can improve spectral efficiency by 5%.

### Radio Links

The efficiency of each radio link in the backhaul network can be optimized with intelligent planning, with attention to the following details:

- Latency. Reduced latency allows for use of longer radio chains, and improves utilization capacity (subject to limitations inherent in the TCP window).
- System gain. System gain refers to the actual spectral efficiency measured at a distance. Planners need to ensure that the high-modulation signal is strong enough to realize link capacity and availability goals.
- Power adaptive ACM (Adaptive Coding and Modulation). The ability to optimize transmit power on the fly at any modulation rate.

### Wireless Network

When adopting a network-wide approach to backhaul infrastructure, the following optimization tools are at the planner's disposal:

- QoS mechanisms. Mechanisms such as WRED can improve utilization of an adaptive link, and are critical in implementation of tiered class-of-service models.
- Resiliency. Using Adaptive Bandwidth Recovery (ABR)[1] techniques, operators can meet legacy service availability goals, while using available capacity for broadband traffic - without risking voice services or network synchronization.
- Asymmetrical links. Broadband access service is asymmetrical by nature. Deployment scenarios can be adjusted to exploit this traffic behavior, increasing overall capacity while reducing cost and power consumption.[2]

Given the above multi-leveled framework, it is clear that the best approach would involve an optimal mix of all methods relevant to the backhaul network and the applications supported.

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[1] See Ceragon's Tech Brief, *Doubling Wireless Ring Capacity: Protected ABR*

[2] See Ceragon's Tech Brief, *Broadband Backhaul: Asymmetric Wireless Transmission*

## Contention Ratios in Network Traffic Modeling

Since the dawn of the telecom service industry, system architects have used contention ratios to determine the level of investment in backhauling infrastructure needed to provide all required services. For example, the contention ratio used for PSTN services was 1:8, whereas the contention ratio for broadband access is factored more aggressively, ranging from 1:20 to 1:50. Operators adjust these contention ratios periodically in order to reach quality of experience and revenue targets, while keeping an eye on expenses. It is important to note that worst-case scenario contention ratios, used primarily in defense and public safety networks, are rarely used in the telecom industry. Instead, operators design and implement their networks using more profitable, average-case scenarios.

The remainder of this technical brief focuses on increasing system capacity with the aid of advanced header-compression techniques.

## Choosing a Network Traffic Model

The main concern when designing a network to leverage the benefits of an innovative new technology, is to select a reasonable base scenario that is risk-free as possible and leaves sufficient headroom for service planning errors. For the purposes of this discussion, the network traffic model in ITU-T Recommendation G.8261[3] was selected as a reference. Approved in 2008, G.8261 deals with the timing and synchronization of packet-based networks, and is based on 3GPP traffic models. The recommendation proposes two mobile traffic backhaul models, one voice-centric, the other data-centric. As timing and synchronization are heavily dependent on the network performance in terms of actual packet throughput, jitter, and delay, this recommendation specifies various packet sizes as in two basic traffic models as follows:

### Traffic Model 1 (Voice-Intensive)

In this model, 3GPP describes a network in which 80-90% of the traffic is conversational, and in which the average call duration is 1 to 2 minutes. In order to simulate the traffic in this model, 80% of the load should consist of small constant-bit-rate packets, with the remaining 20% containing a mix of medium and maximum size packets.

[3] ITU-T Recommendation G.8261, *"Timing and Synchronization Aspects in Packet Networks,"* April 2008

The packet size profile is:

- 80% of the traffic load contains minimum size packets (64 octets)
- 15% of the traffic load contains maximum size packets (1518 octets)
- 5% of the traffic load contains medium size packets (576 octets)

### Traffic Model 2 (Data-Intensive)

This model is data-oriented, and contains larger packets than in Traffic Model 1. In order to simulate the traffic in this model, 30% of the load should consist of small constant-bit-rate packets, with the remaining 70% containing a mix of medium and maximum size packets.

The packet size profile is:

- 60% of the load contains maximum size packets (1518 octets);
- 30% of the load contains minimum size packets (64 octets);
- 10% of the load contains medium size packets (576 octets).

## Why Small Packets Are So Common

"Small packets are still highly common." With the increased data load found in mobile networks, this claim is counterintuitive and requires a short explanation. Small packets *still* represent the majority of packets in a network and a great deal of the actual load. These small packets are of different types but consist mainly of:

- Voice packets
- ICMP packets
- ACK messages

In order to help judge the efficiency of wireless networks, link capacity is measured in terms of actual Ethernet-level throughput, and not just by the symbol rate derived from the modulation scheme and channel bandwidth. When looking at wireless networks from this perspective, it is clear that there are significant benefits to be gained by reducing packet overhead, especially when small packets are transmitted. Among the header fields that can be eliminated are:

- Inter-Frame Gap (12 bytes)
- MAC Preamble and Start-of-Frame Delimiter (8 bytes)

The rest of the header fields amount to 18 bytes. In summary, an Ethernet message of 64 bytes carries only 46 bytes of payload, but has an overall length of 84 bytes! The inefficiency of small packets grows worse when the IP header is taken into account, as shown in Figure 1 below.

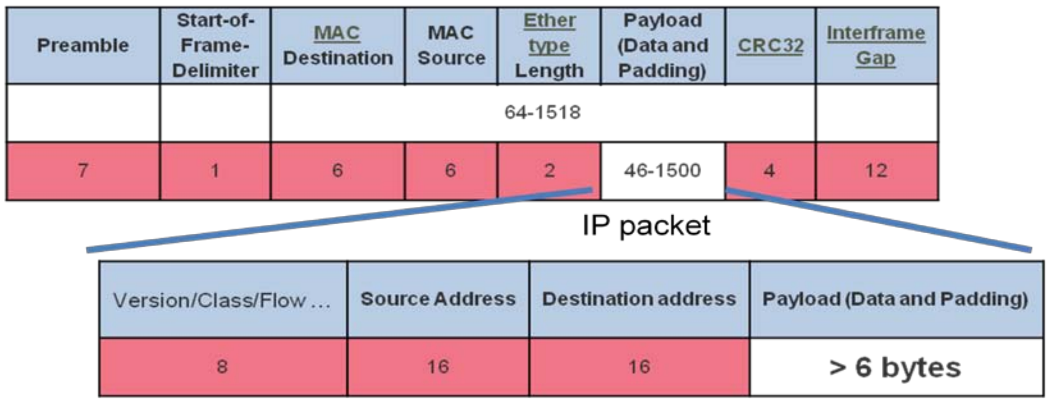


**Figure 1: Ethernet frame structure with embedded IP packet**

While the levels of overhead created by Ethernet, IP, and tunneling technologies are tolerable in fiber-based environments, they are far more difficult to absorb in a microwave-intensive backhaul network. Since fiber is not always available, or too costly, or too time consuming to deploy, microwave equipment must be able to reduce these overhead levels.

## Header Compression

Header compression significantly improves link utilization by eliminating information not needed in order to traverse the link. Each flow is assigned a code that allows the receiving side to reconstruct the original frame. Compression reduces Ethernet-level overhead from 44 bytes to just 4 bytes per frame. (Of course, there is additional overhead associated with transmitting packets over a wireless media). Since the header size is constant, there is an inverse relationship between packet size and relative capacity gain.

In addition to Layer 2 header compression, additional gains can be derived from compression of Layer 3 and Layer 4 headers. Table 1 below demonstrates the gain per packet size. Note that these multi-layer header compression results are for standard IPv4 packets.

| Ethernet Frame Size (bytes) | Ethernet throughput increase using header compression | | |
|---|---|---|---|
| | L1 Suppression only | MAC Preamble SoF Delimiter Interframe Gap | Multi-Layer Compression |
| **64** | **27%** | **45%** | **150%** |
| **96** | **18%** | **29%** | **84%** |
| **128** | **14%** | **22%** | **55%** |
| **256** | **7%** | **11%** | **23%** |
| **512** | **3.5%** | **5%** | **10%** |
| **1518** | **1%** | **2%** | **3.6%** |

**Table 1: Capacity Gain Comparison by Frame Size**

## Payload Compression

In addition to header compression, payload compression can be used to further reduce network load. Today's networks transport a great deal of compressed traffic, including voice, video and images. However, uncompressed payloads still amount to 50% of the traffic in mobile networks.[4] Lossless compression algorithms for text intensive applications, such as web browsing, mail, social media, and HTTP downloads, yield an additional 10% to 15% increase in overall link utilization.

## Overall link performance

If we apply the ITU-T Recommendation G.8261 voice-centric model on an Ethernet-based microwave system employing multiple compression techniques, we can expect significant gains. To illustrate this, we took a few examples relevant to different markets – 28 MHz channels and as well as 30 MHz channels (operating at 6 GHz). The following tables discuss the possible gains in these two scenarios, applying the two G.8261 models using a variety of modulation techniques:

[4] Allot Communications, 2010

| Band-width (MHz) | Modulation | Profile | Radio Capacity (Mbps) | Ethernet Capacity L2 Header Compression (Mbps) | | Ethernet Capacity Multilayer Header Compression and Payload Compression (Mbps) | |
|---|---|---|---|---|---|---|---|
| | | | | 64 Byte | 3GPP Traffic Model 1 | 64 Byte | 3GPP Traffic Model 1 |
| ETSI 28 | QPSK | 0 | 41 | 58 | 54 | 109 | 85 |
| ETSI 28 | 8 PSK | 1 | 55 | 78 | 73 | 147 | 114 |
| ETSI 28 | 16 QAM | 2 | 78 | 111 | 105 | 209 | 163 |
| ETSI 28 | 32 QAM | 3 | 105 | 151 | 142 | 284 | 221 |
| ETSI 28 | 64 QAM | 4 | 130 | 188 | 176 | 353 | 275 |
| ETSI 28 | 128 QAM | 5 | 158 | 229 | 215 | 431 | 336 |
| ETSI 28 | 256 QAM | 6 | 176 | 255 | 240 | 479 | 374 |
| ETSI 28 | 256 QAM | 7 | 186 | 268 | 253 | 505 | 394 |
| FCC 30 | 64 QAM | 4 | 142 | 205 | 192 | 385 | 300 |
| FCC 30 | 128 QAM | 5 | 162 | 234 | 221 | 441 | 344 |
| FCC 30 | 256 QAM | 6 | 183 | 264 | 248 | 497 | 388 |
| FCC 30 | 256 QAM | 7 | 198 | 287 | 270 | 540 | 421 |

**Table 2: Capacity Gains – 3GPP Traffic Model 1**

The following gains may be achieved when applying a data-intensive model on the microwave system:

| Band-width (MHz) | Modulation | Profile | Radio Capacity (Mbps) | Ethernet Capacity L2 Header Compression (Mbps) | | Ethernet Capacity Multilayer Header Compression and Payload Compression (Mbps) | |
|---|---|---|---|---|---|---|---|
| | | | | 64 Byte | 3GPP Traffic Model 2 | 64 Byte | 3GPP Traffic Model 2 |
| ETSI 28 | QPSK | 0 | 41 | 58 | 48 | 113 | 55 |
| ETSI 28 | 8 PSK | 1 | 55 | 78 | 64 | 152 | 74 |
| ETSI 28 | 16 QAM | 2 | 78 | 111 | 92 | 220 | 106 |
| ETSI 28 | 32 QAM | 3 | 105 | 151 | 124 | 295 | 144 |
| ETSI 28 | 64 QAM | 4 | 130 | 188 | 155 | 365 | 179 |
| ETSI 28 | 128 QAM | 5 | 158 | 229 | 189 | 447 | 218 |
| ETSI 28 | 256 QAM | 6 | 176 | 255 | 210 | 495 | 242 |
| ETSI 28 | 256 QAM | 7 | 186 | 268 | 221 | 529 | 256 |
| FCC 30 | 64 QAM | 4 | 142 | 205 | 169 | 385 | 195 |
| FCC 30 | 128 QAM | 5 | 162 | 234 | 193 | 441 | 223 |
| FCC 30 | 256 QAM | 6 | 183 | 264 | 218 | 497 | 251 |
| FCC 30 | 256 QAM | 7 | 198 | 287 | 237 | 540 | 273 |

**Table 3: Capacity Gains – 3GPP Traffic Model 2**

The compression-based performance gains detailed in the tables above far surpass those of the original 186 Mbps connection over a single 28 MHz radio channel. Even if we employ the more conservative data-traffic model, one can expect much more than 200 Mbps of throughput, while the voice intensive mode yields almost 400 Mbps per link. For 50 Mhz channels using Traffic Model 1, a link can deliver an Ethernet throughput of up to 718 Mbps, potentially providing huge benefits to network and capacity planners as they manage traffic growth.

## Summary

Planning for worst-case scenarios can be a costly strategy. While this model is widely accepted in public safety and utility systems, it lacks economic justification in commercial mobile and fixed services. The right decision can make a huge impact on network cost of ownership, but most importantly, can result in an excellent subscriber quality of experience, thus protecting the operator's revenue base.

When planning attractive new services for the broadband-savvy mobile user, header-compression capacity gains make a clear business case for the implementation of HSPA and LTE networks.

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