Effects of the Distinction between Long and Short Data Grants in DOCSIS Network

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Abstract. In this paper, we analyze the effects of the distinction between long and short data grants in the Data Over Cable Service Interface specifications (DOCSIS) protocol. According to DOCSIS specifications, the grants for a bandwidth request of a cable modem can be for either short or long data packets. The threshold value classifying a short and long data packet is a system operation parameter and is determined by a cable modem termination system (CMTS). We have tried to find the effect of the distinction at the point of efficiency and robustness. For this, we have checked the bit error rate and transmission efficiency for burst profiles defined in a commercial CMTS.

Keywords: CMTS, CM, DOCSIS, Bandwidth Allocation, Short and Long data grant.

1 Introduction

Since hybrid fiber coaxial networks provide economical access to broadband networks, many companies are exploring the support of digital interactive communications over cable television (CATV) networks [1], [2]. Data Over Cable Service Interface Specifications (DOCSIS) is a standard designed to support data communications over CATV networks. Recently, DOCSIS 3.0 was issued from Cable Television Laboratory, Inc. (CableLabs).

According to DOCSIS, the grants for a bandwidth request of a cable modem (CM) can be either for short or long data packets. The threshold value classifying a short and long data packet is a system operation parameter and is broadcasted by a cable modem termination system (CMTS). DOCSIS allows a short data grant to use forward error control (FEC) parameters that are appropriate to short packets, while a long data grant may take advantage of greater FEC coding efficiency [3]. This means that the distinction allows for the use of different levels of error correction overhead in order to provide a good balance of efficiency and robustness. However, providing such a balance is very difficult, as there are many combinations of physical parameters within the decision of system operation parameters. Therefore, using a real field system, we will check the effect of the distinction at the point of efficiency and robustness.

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2 Robustness of DOCSIS Upstream Channel

The modulation format of a DOCSIS upstream burst can be quadrature phase shift keying (QPSK), 8 quadrature amplitude modulation (QAM), 16QAM, 32QAM, 64QAM, or 128QAM. For a general performance analysis, we assume a Gaussian channel and a matched filter reception. In this case, the bit error rate (BER) for M-QAM, where $M = 2^k$ and k is even, is

$$P_b \approx \frac{4(\sqrt{M}-1)}{\sqrt{M}\log_2 M} Q\left(\sqrt{\left(\frac{3\log_2 M}{M-1}\right)\frac{E_b}{N_0}}\right), \tag{1}$$

where E_b/N_0 is the average signal-to-noise ratio (SNR) per bit [4] and can be applied as $(5/4)(S/N)(1/\log_2 M)$ in DOCSIS. When k is odd, we can use a tight upper bound,

$$P_b \le \frac{4}{\log_2 M} Q\left(\sqrt{\left(\frac{3\log_2 M}{M-1}\right)\frac{E_b}{N_0}}\right) \tag{2}$$

for any $k \ge 1$ [5].

The DOCSIS upstream FEC is able to provide Reed-Solomon (RS) Codes over GF(256) with T=1 to 16, or no RS coding for each burst type. It also provides the codeword length from a minimum size of 18 bytes (16 information bytes plus two parity bytes for T=1 error correction) to a maximum size of 255 bytes. In a (n, k, T) RS code, when an uncorrectable error pattern occurs, if the received codeword will be not modified and output by the decoder directly, then the symbol error density at the decoder output can be expressed as

$$P_S = \sum_{i=T+1}^{n} \left(\frac{i}{n}\right)\binom{n}{i} p^i (1-p)^{n-i} \tag{3}$$

where p is the RS symbol error probability at the decoder input.

3 Efficiency of DOCSIS Upstream Channel

To check the transmission efficiency of a DOCSIS upstream channel, we present its definition as

$$\mathit{Transmission\,Efficiency} = \frac{\mathit{Information\,Data\,Amount}}{\mathit{Assigned\,Bandwidth}}. \tag{4}$$

In order to obtain the transmission efficiency of (4), it is necessary to understand the bandwidth assignment mechanism for the DOCSIS upstream channel. Factors considered for the bandwidth assignment are mini-slot size, modulation format, symbol rate, FEC overhead, preamble length, and guard time. The mini-slot size is expressed as the number of 6.25 microsecond time-ticks. The mini-slot is used as the base unit for the bandwidth assignment. The example in Table 1 relates the mini-slot to the time ticks assuming QPSK modulation [3]. The symbols/byte is a characteristic of an individual burst transmission, not of the channel. A mini-slot in this instance could represent a minimum of 16 bytes or a maximum of 48, depending on the modulation format.

Table 1. Example Relating Mini-Slot to Time Tick

Parameter	Example Value
Time Tick	6.25 microsecond
Bytes per mini-slot	16 (nominal, when using QPSK modulation)
Symbols/byte	4 (assuming QPSK)
Symbols/second	2,560,000
Mini-slots/second	40,000
Microseconds/mini-slot	25
Ticks/mini-slot	4

The FEC is divided into the fixed codeword mode and the shortened last codeword mode in DOCSIS. The total data amount, D, including the FEC overhead for each mode is calculated as follows: For the fixed mode,

$$D = \begin{cases} q \times (k + 2T) & , r = 0 \\ (q+1) \times (k + 2T) & , r \neq 0 \end{cases}, \tag{5}$$

while for the shortened last codeword mode,

$$D = \begin{cases} q \times (k + 2T) & , r = 0 \\ q \times (k + 2T) + (16 + 2T) & , 0 < r < 16 \\ q \times (k + 2T) + (r + 2T) & , r \geq 16 \end{cases}, \tag{6}$$

where q and r are respectively the quota and remainder of *(m/k)*, and m is the total information bytes to be transmitted.

The preamble uses the QPSK constellation with preamble length 0, 2, 4,…, or 1536 bits (maximum 768 QPSK symbols). The guard time is the number of modulation intervals (e.g. symbols) measured from the end of the last symbol of one burst to the beginning of the first symbol of the preamble of an immediately following burst. Let M be the mini-slot size (i.e., time-ticks/mini-slot), T_S be the number of modulation symbols per time-tick (i.e., symbols/time-tick), S_P be the preamble length (i.e., symbols), S_G be the guard time (i.e., symbols) and B_{sym} be the number of bits per modulation symbols. Then, the required bandwidth (i.e., the number of mini-slots) for transmitting m bytes can be calculated as

$$N_{\min i-slot} = \left\lfloor \left\lfloor \left(\left\lfloor D \times 8 / B_{sym} \right\rfloor + S_P + S_G \right) / T_S \right\rfloor / M \right\rfloor, \tag{7}$$

where D is the number of transmitting data bytes from (5) or (6). Therefore, the transmission efficiency of (4) can be expressed as

$$TransmissionEfficiency = \frac{m \times 8 / B_{sym}\,(symbols)}{N_{\min i-slot} \times M \times T_s\,(symbols)} . \tag{8}$$

4 Comparison for Short and Long Data Grant

The burst profiles of Table 2 are three default modes defined in the ARRIS CMTS, which operates in the real field. Each profile for a short and the long data grant is compared at the point of error correction performance and transmission efficiency. The transmission efficiency is evaluated by (7) and the error correction performance is evaluated by (1), (2), and (3). In these evaluations, the assumed mini-slot size is 4 time-ticks and applied modulation rate is 2.56 mega-symbols/second.

Table 2. ARRIS CMTS Burst Profiles

Mode	1		2		3	
Profile	Short	Long	Short	Long	Short	Long
Modulation Type	qpsk	qpsk	16qam	16qam	64qam	64qam
Preamble length	84	96	168	192	104	104
Diff. encoding	No	No	No	No	No	No
FEC T bytes	6	8	8	10	12	16
FEC CW Size	78	220	78	220	78	220
Scramble Seed	0x152	0x152	0x152	0x152	0x152	0x152
Max Burst Size	15	0	8	0	6	0
Guard time size	8	8	8	8	8	8
Last CW short	Yes	Yes	Yes	Yes	Yes	Yes
Scramble	Yes	Yes	Yes	Yes	Yes	Yes
Interleaver Depth	1	1	1	1	1	1
Channel type	TDMA	TDMA	TDMA	TDMA	TDMA	TDMA

Figure 1 compares the BER performances of the short and long data grant profile for each mode. Generally, the BER performance required in DOCSIS is 10E-8. In order to obtain a BER of 10E-8, the required SNR for each profile of each mode is similar. In each mode, the short profile simply has an SNR gain of about 0.3 dB at 10E-8 BER. This result shows that the performance of short and long data grants are almost the same at the point of robustness. That is, the use of a long data grant with the higher coding efficiency for a long data packet is very appropriate.

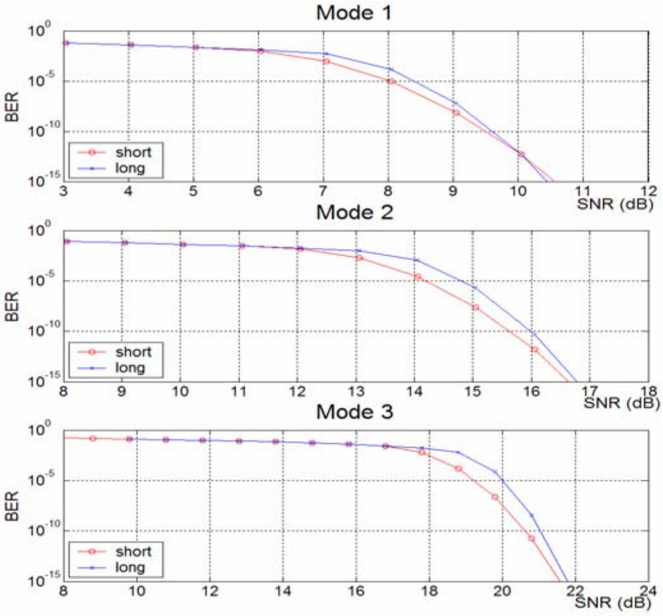

Fig. 1. BER performance comparison

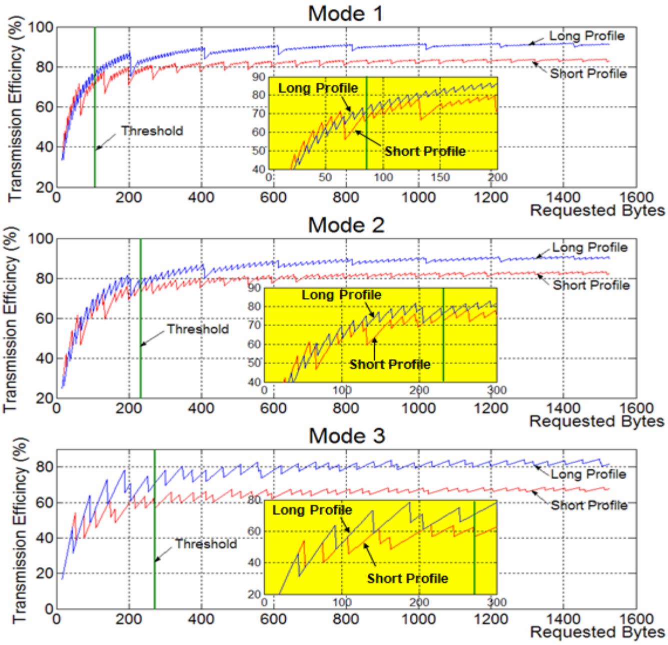

Fig. 2. Efficiency performance comparison

Figure 2 compares the transmission efficiency of short and long data grant profiles according to the number of transmitting bytes. In this comparison, when the number of transmitting bytes was small, the transmission efficiency of the short data grant profile was a little bit better. As the number of bytes increased, the transmission efficiency of the long data grant was more improved. Here, the point to pay attention to is the threshold, that is, the maximum burst mini-slot size of Table 2 classifying the short and long data grants. There exists a part in which the transmission efficiency of a long data grant is higher than that of a short one in the lower threshold. Also, the efficiency difference is very small in the lower threshold. That is, it shows that the use of a short data grant is not appropriate at the point of efficiency.

From the results of Figure 1 and 2, we have known that, without the distinction between long and short data profile, the use of one optimized profile with a high coding efficiency is effective because the advantage of using the short data grant could not be found at the point of the transmission efficiency.

5 Conclusion

From the comparisons described herein, we have found that the distinction cannot provide great effectiveness at the point of transmission efficiency. The object of the distinction is to provide a good balance of efficiency and robustness according to the packet length. But, in our analysis, the distinction provided very little benefit. Rather, it increases the complexity of the request and grant process. Therefore, we recommend that one optimized profile should be used for a data grant without a distinction between long and short. The use of one optimized profile is possible in the queue-depth based request of a DOCSIS 3.0 network.

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