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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Variable bit rate calculations for ITU-T Recommendation G.767 Digital Circuit Multiplication Equipment (DCME)

Supplement 38 to
ITU-T G-series Recommendations

(Previously CCITT Recommendation)

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

For further details, please refer to ITU-T List of Recommendations.

SUPPLEMENT 38 TO ITU-T G-SERIES RECOMMENDATIONS

VARIABLE BIT RATE CALCULATIONS FOR ITU-T RECOMMENDATION G.767 DIGITAL CIRCUIT MULTIPLICATION EQUIPMENT (DCME)

Source

Supplement 38 to ITU-T G-series Recommendations, was prepared by ITU-T Study Group 15 (1997-2000) and was approved under the WTSC Resolution No. 5 procedure on the 13th of October 1998.

FOREWORD

ITU (International Telecommunication Union) is the United Nations Specialized Agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the ITU. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, the ITU had/had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

Supplement 38 to G-series Recommendations

VARIABLE BIT RATE CALCULATIONS FOR ITU-T RECOMMENDATION G.767 DIGITAL CIRCUIT MULTIPLICATION EQUIPMENT (DCME)

(Geneva, 1998)

This Supplement explains how the VBR equations were derived. The same notations of Recommendation G.767 are used here. The notation (X, Y, Z) shall be used to note that N_{16} = X, $N_{12.8}$ = Y and $N_{9.6}$ = Z, i.e. X QBs of the bearer carry traffic at 16 kbit/s, Y QBs at 12.8 kbit/s and Z QBs at 9.6 kbit/s.

In this combination, X+Y+Z QBs are used to support traffic from up to $X + \frac{5}{4}Y + \frac{5}{3}Z$ BCs.

If N_V is greater than N_{QB}, then VBR is required to create the additional overload channels. Creation of the extra channels can be done using several combinations of N_{16}, $N_{12.8}$ and $N_{9.6}$.

If, for example, there are 19 BCs that need bearer resources and 15 available QBs, then several combinations exist that use the available resources and support this traffic. Some combinations create more BCs than required, like (2, 4, 9) that creates 22 BCs or (1, 8, 6) that creates 21 BCs. These combinations support all traffic from all BCs but the average bit rate is not optimal since additional unused BCs are created. Obviously, a combination that creates too few BCs is not acceptable. Other combinations do not use all available QBs but still support all traffic, like (4, 4, 6) that uses only 14 QBs of the list to create 19 BCs, but, again, such combinations lower the bit rate as the bearer resources are not optimally utilized.

One exceptional case needs special attention: If N_{QB} is a multiplier of 3 and also $N_V = \frac{5}{3} N_{QB} - 1$, there is no combination that creates exactly N_V BCs and an additional unused BC must be created. For example, if $N_{QB} = 3$, it is possible to create 3 channels (each QB carries one voice channel at 16 kbit/s) or 5 channels (the 3 QBs carry five 9.6 kbit/s channels), but it is not possible to create exactly 4 channels.

To this point, an optimized combination is one that provides the highest bit rate and highest utilization supporting traffic from all BCs in the voice list. This means that no unnecessary additional BCs are created and all the QBs of the list are used.

Given N_V and N_{QB} there still may be more than one combination that meets these requirements. Advancing the above example, both (9, 0, 6) and (4, 8, 3) use all 15 QBs, create no unused BCs and provide the same bit rate – 1.58 bit/sample.

So another criterion is required to choose a unique combination. The criterion will be: Prefer creation of as few 9.6 kbit/s channels as possible. In the given example, the second combination is favourable since it uses less 9.6 kbit/s channels, even though it also uses less 16 kbit/s than the first combination. The motivation to use this criterion is that linear decrease of the bit rate might result in a steeper deterioration of speech quality so, when more 9.6 kbit/s channels are used, even when the average bit rate is maintained, the total quality decreases.

To sum, the criteria for choosing one unique combination of N_{16}, $N_{12.8}$ and $N_{9.6}$ are:

a) Maximize instantaneous average bit rate of the traffic while using available bearer resources.

b) Create enough channels for all BCs in the voice list.

c) Minimize the number of 9.6 kbit/s channels.

The formal representation of these criteria is:

a) $$\max\left(16\times N_{16}+12.8\times\frac{5}{4}N_{12.8}+9.6\times\frac{5}{3}N_{9.6}\right)$$

b) $$N_{16}+\frac{5}{4}N_{12.8}+\frac{5}{3}N_{9.6}\geq N_V$$

c) $$\min\left(N_{9.6}\right)$$

Another obvious requirement is:

d) N_{16} is an integer;
$N_{12.8}$ is an integer multiplier of 4; and
$N_{9.6}$ is an integer multiplier of 3.

The first criterion is satisfied when all bearer resources are consumed, so that:

a) $$N_{16}+N_{12.8}+N_{9.6}=N_{QB}$$

The special case, when an unused BC must be created, is handled in the following manner: If N_{QB} is a multiplier of 3 and also $N_V=\frac{5}{3}N_{QB}-1$, then N_V is adjusted by adding 1 to its value. After handling this special case, the second criterion is satisfied when exactly the number of required channels are created, so that:

b) $$N_{16}+\frac{5}{4}N_{12.8}+\frac{5}{3}N_{9.6}=N_V$$

In order to find the unique combination, the third criterion is handled first:

$N_{9.6}$ is an integral multiple of 3, say $N_{9.6}=3\times I_1$ where I_1 is an integer. Then exactly $5\times I_1$ 9.6 kbit/s channels are created. The maximum number of additional channels that can be created will be achieved if as many of these additional channels will be at 12.8 kbit/s and the rest at 16 kbit/s. The maximum number of channels at 12.8 kbit/s is $5\times\mathrm{int}\left(\left(N_{QB}-3\times I_1\right)/4\right)$ which leaves $\left(N_{QB}-3\times I_1\right)-4\times\mathrm{int}\left(\left(N_{QB}-3\times I_1\right)/4\right)$ channels at 16 kbit/s. It is required that the sum of the 9.6 kbit/s, 12.8 kbit/s and 16 kbit/s channels will be at least N_V:

$$5\times I_1+5\times\mathrm{int}\left(\left(N_{QB}-3\times I_1\right)/4\right)+\left(N_{QB}-3\times I_1\right)-4\times\mathrm{int}\left(\left(N_{QB}-3\times I_1\right)/4\right)\geq N_V$$

$$\Rightarrow 2\times I_1+N_{QB}+\mathrm{int}\left(\left(N_{QB}-3\times I_1\right)/4\right)\geq N_V$$

$2\times I_1$ is an integer. N_{QB} and N_V are also integers so all three quantities can be moved inside the parentheses and the equation is still valid so we get:

$$\mathrm{int}\left(\frac{5}{4}I_1+\frac{5}{4}N_{QB}-N_V\right)\geq 0$$

The minimal I_1 that satisfies this equation is:

$$I_1=\frac{4}{5}N_V-N_{QB}$$

Since I_1 is an integer, the solution is:

$$I_1 = \text{int}\left(\frac{4}{5}N_V - N_{QB}\right) + \alpha$$

where $\alpha = 0$ if $\frac{4}{5}N_V - N_{QB}$ is an integer (because this way the value inside the parentheses is exactly zero) or $\alpha = 1$ otherwise.

If I_1 is smaller than zero, then it is set to zero since the number of QBs cannot be negative.

After setting the value of $N_{9.6}$, the first two criteria are simply two linear equations with two variables, and their solution is:

$$N_{12.8} = 4\left(N_V - N_{QB} - \frac{2}{3}N_{9.6}\right)$$

$$N_{16} = N_{QB} - N_{12.8} - N_{9.6}$$

Example #1

Case of $N_{QB} = 10$ and $N_V = 13$

$$I_1 = \frac{4}{5}N_V - N_{QB} = \frac{4}{5}13 - 10 = 0.4$$

0.4 is not an integer therefore $I_1 = 1.4$

$$N_{9.6} = 3 \times \text{int}(I_1) = 3$$

$$N_{12.8} = 4\left(N_V - N_{QB} - \frac{2}{3}N_{9.6}\right) = 4\left(13 - 10 - \frac{2}{3}3\right) = 4$$

$$N_{16} = N_{QB} - N_{12.8} - N_{9.6} = 10 - 4 - 3 = 3$$

Assume IT=120 and BC=54. Then:

$P_V = (BC + IT) \bmod N_V = (120 + 54) \bmod 13 = 5$

And the VBR mapping is as follows:

$N_{QB} = 10$, $N_V = 13$	**BCs number**	**mapped to QBs number**	**at rate [kbit/s]**
$N_{9.6} = 3$, $N_{12.8} = 4$, $N_{16} = 3$	5	1	16
	6	2	16
IT = 120, BC = 54	7	3	16
$P_V = 5$	8, 9, 10, 11 and 12	4, 5, 6 and 7	12.8
	13, 1, 2, 3 and 4	8, 9 and 10	9.6

Example #2

Case of $N_{QB} = 15$ and $N_V = 18$

$$I_1 = \frac{4}{5}N_V - N_{QB} = \frac{4}{5}18 - 15 = -0.6$$

–0.6 is smaller than zero, therefore $I_1 = 0$

$N_{9.6} = 3 \times \mathrm{int}(I_1) = 0$ (creation of 9.6 kbit/s channels is not required)

$$N_{12.8} = 4\left(N_V - N_{QB} - \frac{2}{3}N_{9.6}\right) = 4\left(18 - 15 - \frac{2}{3}0\right) = 12$$

$$N_{16} = N_{QB} - N_{12.8} - N_{9.6} = 15 - 12 - 0 = 3$$

Assume IT = 79 and BC = 136. Then:

$$P_V = (BC + IT) \bmod N_V = (79 + 136) \bmod 18 = 17$$

And the VBR mapping is as follows:

	BCs number	**mapped to QBs number**	**at rate [kbit/s]**
$N_{QB} = 15$, $N_V = 18$	17	1	16
$N_{9.6} = 0$, $N_{12.8} = 12$, $N_{16} = 3$	18	2	16
	1	3	16
IT = 79, BC = 136	2, 3, 4, 5 and 6	4, 5, 6 and 7	12.8
$P_V = 17$	7, 8, 9, 10 and 11	8, 9, 10 and 11	12.8
	12, 13, 14, 15 and 16	12, 13, 14 and 15	12.8

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