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Title: Factors affecting the multiplexing gain for VBR Voice.

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Abstract:
The multiplexing gain for VBR voice sources depends on the acceptable delay bounds, the voice activity factor, the mean burst length, the mean silence period, the total link capacity. Sensitivity analysis of these factors is presented here.

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1 Introduction:

In our previous contribution [ATMF97-0608], we presented an analysis of multiplexing gain for 64 kbps VBR voice transmitted on a 1.544 Mbps link. It was shown that for a cell loss ratio of 10-3, and end-to-end delay variation thresholds of 5 ms and 15 ms, about 50% of the available bandwidth could be used by statistically multiplexing silence suppressed voice. Even though there was unused bandwidth, using it for more voice connections lead to unacceptable voice performance. The left-over bandwidth can be used by lower priority data services (ABR and UBR). In this contribution we analyze the sensitivity of that result to all the parameters that were used in the study.

The multiplexing gain depends on the end-to-end delay thresholds, activity factor, the speech and silence intervals, acceptable cell loss ratio and compression.

2. The Network Model

As described in [ATMF97-0608], we use a network model consisting of n VBR VCs sharing a link between two switches. Each VC generates traffic using a two-state on-off Markov model. The number of cells lost and delayed are combined to produce a "degradation in voice quality (DVQ)" metric. A DVQ of 10-3 is considered acceptable.

The experiments here assume per-VC queuing at the switches. For all the factors, unless otherwise specified, we assume end-to-end delay bounds of 30 ms, an activity factor of 352/650 with 352 ms as the mean speech interval and 650 ms as the mean silence interval.

3. Simulation Results

We studied the multiplexing gain by varying the following factors.

a) End-to-end delay threshold and Buffering

If we relax the delay thresholds, we find an increase in the multiplexing gain. The delay thresholds in the network are guaranteed by bounding the network queues. An increase in the delay threshold allows an increase in the network queues, and thereby it reduces the cell loss ratio for the same number of sources. Hence, for a given DVQ, we can get a higher multiplexing gain.

The end-to-end delay threshold is related to the buffer sizing at the switches and hence cannot be studied independently. We performed a full-factorial experimental design consisting of all 6 combinations of two values for delay thresholds (30 ms and 60 ms) and three values for buffers (1 cell/VC, 2 cells/VC, 4 cells/VC). These results are shown in the table below as DVQxx-n, where xx is the delay and n is the number of buffers.

NS	DVQ30-1	DVQ30-2	DVQ30-4	DVQ60-1	DVQ60-2	DVQ60-4
20	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
30	0.001101	0.003585	0.004503	0.000333	0.000182	0.000000
35	0.001875	0.004897	0.005794	0.000713	0.000584	0.000346
45	0.004515	0.008838	0.009709	0.001818	0.001618	0.002688
50	0.008859	0.025664	0.029383	0.003218	0.002480	0.003853
55	0.023400	0.084997	0.094697	0.007871	0.005798	0.006871
60	0.057058	0.200083	0.231701	0.019538	0.015562	0.014716
65	0.113237	0.359139	0.413115	0.040189	0.034856	0.033958
70	0.184742	0.540436	0.608237	0.068059	0.063022	0.070239
75	0.272701	0.697129	0.760992	0.105709	0.101741	0.130685
80	0.370163	0.811582	0.861931	0.149899	0.147056	0.215805

Table 1: DVQ varying delay thresholds and buffer sizes

NS: Number of Sources

DVQ: Degradation in Voice Quality
DVQxx-n: DVQ for end-to-end delay threshold=xx and buffer size=n.

b) The activity factor (a)

In the two state Markov model, the speech and the silence durations follow an exponential distribution with means of b and s, respectively. The activity factor a, over very long periods is approximately equal to,

$$a = b/(b+s)$$

An increase in the activity factor indicates either an increase in the mean burst length or a decrease in the mean silence interval. Increased activity factor correspondingly reflects in lower multiplexing gain.

Table 2 shows the DVQ values for various activity factors. We find that increasing the activity factor also increases the degradation in Voice Quality (DVQ), and hence this lowers the multiplexing gain.

NS	300/650	400/650	600/650	650/650
20	0.000000	0.000000	0.000000	0.000000
30	0.001073	0.001110	0.001463	0.002047
40	0.002815	0.003337	0.015433	0.023168
50	0.004612	0.018544	0.154117	0.202521
60	0.021036	0.109409	0.398261	0.458655

Table 2: DVQ with different activity factors

c) Mean burst length and mean silence interval

To study the effect of the mean burst length(b) and the mean silence interval(s), we change these values while keeping the activity factor constant. The results are shown in Table 3 below. Notice that an increase in the burst length increases the burstiness in voice activity that is difficult for a network with small queues to handle. This increase results in an increase in cell loss. For a given activity factor, the loss increases with increase in the mean burst length, and hence there is a decrease in the multiplexing gain achieved.

This result shows that results obtained by fluid flow analysis are not valid since the fluid flow analysis is equivalent to assuming that the speech and silence durations are infinitesimally small. The increased burstiness is not captured in the fluid flow approximation of the system.

Table 3 shows the DVQ with on-off periods of 35/65, 175/325, and 350/650. The activity factor is the same for the three. However, we find that with increasing speech bursts there is an increase in the DVQ values for the same number of sources.

NS	35/65	175/325	350/650

20	0.000000	0.000000	0.000000
25	0.000038	0.000146	0.000271
30	0.000145	0.000600	0.001099
35	0.000271	0.001045	0.001862
40	0.000392	0.001653	0.003054
50	0.001219	0.004647	0.008566
60	0.026106	0.051234	0.056334

Table 3: DVQ variation with change in mean length of speech bursts

d) Total capacity of the link

Increasing the overall link capacity increases the network's capability to handle more fluctuations in the voice sources. The multiplexing gain increases with an increase in the total link capacity.

Table 4 shows the DVQ for various number of multiplexed sources under link speeds of 0.772 Mbps, 1.544 Mbps and 3.088 Mbps. We observed a near linear increase in the multiplexing gain with increase in the link speeds.

NS	0.772 Mbps	1.544 Mbps	3.088 Mbps
10	0.000136		
12	0.000385		
14	0.001033		
16	0.001628		
18	0.001978		
20	0.007576	0.000000	0.000000
25	0.056448	0.000271	0.000000
30	0.172028	0.001099	0.000000
35	0.323237	0.001862	0.000000
40	0.487546	0.003054	0.000000
45	0.634507		0.000000
50	0.761750	0.008566	0.000096
55			0.000347
60	0.915132	0.056334	0.000703
65			0.001178
70	0.973410		0.001411
75			0.002015
80			0.002437

Table 4: DVQ values for different link speeds

e) Acceptable Cell Loss Ratio

An increase in the acceptable cell loss ratio allows the network to drop more cells and still support "acceptable" voice. A higher acceptable CLR value clearly increases the multiplexing gain for the network.

The CLR as a number in itself does not capture the voice quality requirement. Voice quality also depends on the cell loss distribution. For instance, losing 10 cells in sequence will cause more degradation in voice quality than losing 10 cells spaced over a longer time interval.

f) Compression

Compressed voice greatly reduces the bandwidth required to support a single voice channel. All voice compression schemes are lossy, and hence lower compression rates mean a degradation in the voice quality. This degradation is without any cell loss. With cell loss, compressed voice will suffer more degradation than uncompressed 64 kbps PCM. There is more correlation between subsequent cells with increased compression.

The compression schemes also increases the coding and the packetization delay. The choice of the compression scheme chosen for a given network will depend on the its coding delay and the acceptable end-to-end delay.

Summary

The multiplexing gain improves with increasing link speed, decreasing voice rate, and decreasing speech interval. We found that for the same activity factor, the duration of speech has a significant impact on the multiplexing gain. Therefore, the results obtained by fluid flow analysis cannot be relied on since that analysis assumes infinitesimally small speech and silence intervals and ignores their effect.

References

[ATMF97-0608] J. Iyer, R. Jain, and S. Dixit, "Performance of VBR Voice over ATM: Effect of Scheduling and Drop Policies," , ATM Forum 97-0608, July 1997.

All of our contributions are available on-line at:
http://www.cse.wustl.edu/~jain