DATA NETWORK PARAMETERS

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The Cable Television Industry has developed over the years many thousands of miles of coaxial broadband cable communications systems. The primary use of these systems has been for the delivery of entertainment services into the home. Even the limited data which has been introduced into our systems is used for control of entertainment offerings.

This paper will deal with the business applications of data networks and the parameters which will be viewed by the end user as critical to his data communications needs. These parameters will include: 1)end to end throughput 2)queuing delay 3)error correction 4)blocking probabilities 5)delay - throughput curves and many more which are inter-related to the network design.

The entrance into the business data communications arena will require us all to learn new skills to both design and market these services.

When dealing in the business of providing entertainment over our coaxial networks we have come to learn the parameters by which we are either accepted or rejected by the consumer. These parameters boil down to basically two: 1)picture quality and 2)reliability. These are, of course, subjective parameters but can be broken down into measurable units of performance such as noise, second and third order distortions, low frequency disturbances, failure rates, and a whole host of others used daily in our industry. By proper selection of the measured parameters the subjective ones viewed by the subscriber will be assured.

The same basic philosophy will hold true in the potential business user of data communications circuits. That is, he has his subjective values of the service provided and these values can be related to measurable parameters. Before we discuss these parameters, we must first realize that there are two primary types or classifications of users:

1. Those with high volumes of data traffic but limited destinations
2. Those with low volumes of data traffic but many possible destinations

While variations exist between these two extremes this paper will deal only with the extremes.

In case number 1, the solution is fairly simple in that direct full time circuits would most likely be established for this user. He would, in all probability, be very sophisticated in his network approach and only require the line provider to meet bandwidth and noise limitations.

Case number 2 is quite another story. From an economical stand point it makes sense to share the line amoungst many users thus take full advantage of the resources available to us.

It is interesting to note that with either classification of user the subjective performance of the system or network is the same "accurate data transfer with minimum response time available on a full time basis". The performance measures and considerations will be substantially different for the two classifications to achieve this subjective performance criteria. In case number 1 direct connection of Data Terminal Equipment (DTE) over a wide band, low noise circuit with redundancy will provide the desired results. In case number 2 an elaborate multiple access scheme with message processing will be required to serve all users.

PERFORMANCE MEASURES

In the following list of performance measures the first seven are applicable to both cases. The balance are more related to the multiple access networks.

1. Transfer Rate of Information Bits (TRIB)

This is the net rate at which information "BITS" can be transmitted across the network and be accepted by the sink. This is measured in bits per second and is closely associated with the bandwidth assigned.

2. Bit Error Rate (BER)

This is the number of bits which are changed by the network from those originally transmitted. This measure is closely associated with "noise" (both thermal and impulse) within the assigned bandwidth.

3. Residual Error Rate (RER)

The ratio of bits which are in error that have not been detected or corrected by the error correction process.

This is the true measure of the information transfer accuracy in any network.

4. Reliability

This is the probability that all of the devices in the network will perform without failure over a specified time or period or amount of usage.

5. Availability

This is the portion of a selected time interval during which the communications path is capable of performing its' assigned function. It is closely tied to reliability in that both mean time to failure and mean time to repair are considered. This is some times referred to as "on time".

6. Probagation Delay

The time taken by a one bit signal to move from the input of the network to the output. In wide area cable systems this will be variable with the distance to be covered.

7. Turnaround Time

The time taken for the circuits to reverse from transmit mode to receive mode. In two way cable systems, this is usually determined by the modem and is usually negligible.

8. Channel Establishment Time

The time required for the network to establish a connection between the source and destination DTE.

9. Response Time

The time interval from the instant that the last bit is sent from the source DTE to the instant the first bit is received at the destination DTE.

10. Message Delay

There are three ways of stating message delay:

a) End to End Delay

The time taken from input of the first bit in a message at the source DTE to the time the last bit in a message is received at the destination DTE.

b) System Delay

Has the same definition as response time.

c) Insertion Delay

The elapsed time from the transmission of the last bit of a message from the source DTE to the receiving of the last bit of the message at the destination DTE.

For the user the most meaningful is the end to end delay.

11. Blocking Probability

This is the parameter which indicates to the user that his message may be blocked due to other users occupying the capacity of the system. It is usually stated in percentage.

12. Buffer Occupancy

Since the load on the network is variable the capacity will be determined by laws of probability, thus "buffers" or storage areas will be used to handle the maximum foreseeable load. Messages will be lined-up or "Queued" for insertion into the system. During overloads the buffer may "overflow" causing messages to be lost. This can be stated as a probability or percentage.

13. Index of Utilization

This is the probability that the network is not idle.

14. Throughput

This parameter is, or should be, a collective statement of the system capability (much like channel loading of our distribution systems) to handle the traffic demands. While there are many ways to state this parameter the most meaningful is "Net Throughput Rate" which is in effect TRIB. This statement of throughput considers and nets out error correction delay and overhead bits. To make sense, this parameter must be stated at some finite delay.

This parameter can be stated:

$$TRIB = \frac{K_1 \ (M - C)}{N_T \ [\frac{M}{R} + \Delta T]}$$

Where:

K_1=Information bits per character

M =Characters per message

R =Characters per second (bit rate)

C =Overhead characters per message

N_T=Number of retransmissions *

T=Time between blocked transmissions

*ARQ (Automatic Repeat Request) error correction scheme.

Based on these parameters a potential customer for a multiple access data communications system would desire to see specifications such as:

Data Rate = 1.544 MB

TRIB = 80% Data Rate @ 2 message delay

BER = 10 - 6

RER = 10 - 10

Availability = 99%

Response Time = $<$ 2 second maximum

Blocking Probability = .01% maximum

Overflow Probability = .001% maximum

Index of Utilization = 60%

In addition to these parameters two other areas must be considered for multiple access networks:

1. Transparency

Messages sent over the network should not be mistaken for routing, flow control, or network control codes. This is accomplished by "bit stuffing protocols".

2. Security

The network must have the ability to protect the information being transmitted over it from loss, disclosure, or modification. This can be accomplished by authorization groups or by cryptograms.

In the design of the network the operator of the system desires totally different parameters than does the end user. For example, the operator desires to maximize the use of his resource (in this case frequency spectrum) thus he would hope for an index of utilization as close to 100% as possible while the end user desires minimum delay. Since the network will have widely varying usage over the period of a day, the end user would hope that the network design was for the absolute peak but the operator would like to design for the average. The realistic design approach is to use statistical analysis of the probable demands placed on the network.

When the analysis is done properly, you will find that as net throughput increases the delay will also increase. Random access network curves can be developed to display this characteristic of the network. When the error rate increases and additional transmissions are required for correction both the net throughput decreases and delay increases.

The most complete analysis of a network is to compare net throughput versus delay at various retransmissions. One such example has been done for a slotted ALOHA Multiple Access channel. As can be seen by the curves, a knee exists over which the system will head toward a condition of complete lock up allowing no traffic to enter. Designs should be such that the network, at its statistical peak, will not exceed the values at the knee. If higher levels are required then you must change the access scheme to be more efficient. This, of course, carries a cost penalty.

SUMMARY

When entering the multiple access business network market consideration must be given to both the customer needs and the operator needs and trade offs must be made if the cost of service is to be kept competitive or attractive compared to existing resources. Remember, the most important parameter which is being sold is the subjective customer evaluation just as in the CATV customer.