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Grade of Service in End-To-End Service Quality of Service Broadband Networks

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Abstract: ***Grade of Service (GOS) is a measure of the success a subscriber is expected to have in accessing a network to complete a call. The grade of service is usually expressed as percentage of calls attempted by the subscriber during the busy-hour that are blocked due to insufficient network resources. The probability of a call's being blocked or delayed more than a specified interval, expressed as a decimal fraction, Grade of service may be applied to the busy hour or to some other specified period or set of traffic conditions. Grade of service may be viewed independently from the perspective of incoming versus outgoing calls, and is not necessarily equal in each direction. In telephony, the quality of service for which a circuit is designed or conditioned to provide, e.g., voice grade or program grade. Criteria for different grades of service may include equalization for amplitude over a specified band of frequencies, or in the case of digital data transported via analog circuits.***

Keywords— Grade of Service, Quality of Service, Network resources, Broadband network.

1. INTRODUCTION

In telecommunication engineering, and in particular teletraffic engineering, the quality of voice service is specified by two measures: the grade of service (GoS) and the quality of service (QoS). Grade of service is the probability of a call in a circuit group being blocked or delayed for more than a specified interval, expressed as a vulgar fraction or decimal fraction. This is always with reference to the busy hour when the traffic intensity is the greatest. Grade of service may be viewed independently from the perspective of incoming versus outgoing calls, and is not necessarily equal in each direction or between different source-destination pairs. On the other hand, the quality of service that a single circuit is designed or conditioned to provide, e.g. voice grade or program grade is called the quality of service. Quality criteria for such circuits may include equalization for amplitude over a specified band of frequencies, or in the case of digital data transported via analogue circuits, may include equalization for phase. Criteria for mobile quality of service in cellular telephone circuits include the probability of abnormal termination of the call.

2. MEASURING GRADE OF SERVICE IN BROADBAND NETWORKS

When a user attempts to make a telephone call, the routing equipment handling the call has to determine whether to accept the call, reroute the call to alternative equipment, or reject the call entirely. Rejected calls occur because of heavy traffic loads (congestion) on the system and can result in the call either being delayed or lost. If a call is delayed, the user simply has to wait for the traffic to decrease, however if a call is lost then it is removed from the system.The Grade of Service is one aspect of the quality a customer can expect to experience when making a telephone call. In a Loss System, the Grade of Service is described as that proportion of calls that are lost due to congestion in the busy hour. For a Lost Call system, the Grade of Service can be measured using Equation 1.

$$\text{Grade of Service} = \frac{\text{number of lost calls}}{\text{number of offered calls}} \qquad (1)$$

For a delayed call system, the Grade of Service is measured using three separate terms:

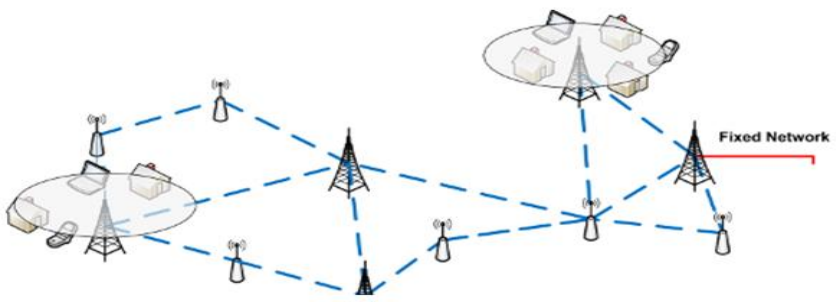

Figure 1. Grade of service provides the technology edge nodes to (many) points

The mean delay t_d – Describes the average time a user spends waiting for a connection if their call is delayed.

The mean delay t_o – Describes the average time a user spends waiting for a connection whether or not their call is delayed. The probability that a user may be delayed longer than time t while waiting for a connection. Time t is chosen by the telecommunications service provider so that they can measure whether their services conform to a set Grade of Service.

3. ABILITY GRADE OF SERVICE

The Grade of Service can be measured using different sections of a network. When a call is routed from one end to another, it will pass through several exchanges. If the Grade of Service is calculated based on the number of calls rejected by the final circuit group, then the final circuit group blocking criteria determines the Grade of Service. If the Grade of Service is calculated based on the number of rejected calls between exchanges, then the Grade of Service is determined by the exchange-to-exchange blocking criteria.

The Grade of Service should be calculated using both the access networks and the core networks as it is these networks that allow a user to complete an end-to-end connection Furthermore, the Grade of Service should be calculated from the average of the busy hour traffic intensities of the 30 busiest traffic days of the year. This will cater for most scenarios, as the traffic intensity will seldom exceed the reference level.

The grade of service is a measure of the ability of a user to access a trunk system during the busiest hour. The busy is based upon customer demand at the busiest hour during a week month or year.

4. CLASS OF SERVICE

Different telecommunications applications require different Qualities of Service. For example, if a telecommunications service provider decides to offer different qualities of voice connection, then a premium voice connection will require a better connection quality compared to an ordinary voice connection. Thus, different Qualities of Service are appropriate, depending on the intended use. To help telecommunications service providers to market their different services, each service is placed into a specific class. Each Class of Service determines the level of service required. To identify the Class of Service for a specific service, the network's switches and routers examine the call based on several factors. Such factors can include:

The type of service and priority due to precedence

- The identity of the initiating party
- The identity of the recipient party

In broadband networks, the Quality of Service is measured using two criteria:

1)The probability of packet losses or delays in already accepted calls.

2) The probability that a new incoming call will be rejected or blocked.

To avoid the former, broadband networks limit the number of active calls so that packets from established calls will not be lost due to new calls arriving. As in circuit-switched networks, the Grade of Service can be calculated for individual switches or for the whole network.

5. MAINTAINING A GRADE OF SERVICE

The telecommunications provider is usually aware of the required Grade of Service for a particular product. To achieve and maintain a given Grade of Service, the operator must ensure that sufficient telecommunications circuits or routes are available to meet a specific level of demand. It should also be kept in mind that too many circuits will create a situation where the operator is providing excess capacity which may never be used, or at the very least may be severely underutilized. This adds costs that must be borne by other parts of the network. To determine the correct number of circuits that are required, telecommunications service providers make use of Traffic Tables as shown below

5.1 ERLANG'S LOST CALL ASSUMPTIONS

To calculate the Grade of Service of a specified group of circuits or routes, Agner Krarup Erlang used a set of assumptions that relied on the network losing calls when all circuits in a group were busy. These assumptions are:All traffic through the network is pure-chance traffic, i.e. all call arrivals and terminations are independent random events There is statistical equilibrium, i.e., the average number of calls does not change Full availability of the network, i.e., every outlet from a switch is accessible from every inlet Any call that encounters congestion is immediately lost. From these assumptions, Erlang developed the Erlang-B formula which describes the probability of congestion in a circuit group. The probability of congestion gives the Grade of Service experienced.

Table 1. Erlang B Traffic T

3	Trunks	.001	.002	.01	.02	.05	.10	.20	.30	.40
4	1	0.036	0.072	0.364	0.735	1.895	4.000	9.000	15.429	24.000
5	2	1.647	2.352	5.493	8.045	13.727	21.436	36.000	52.156	72.000
6	3	6.978	8.954	16.397	21.679	32.378	45.748	69.478	94.793	125.273
7	4	15.814	19.261	31.299	39.321	54.886	73.634	106.027	140.056	180.757
8	5	27.436	32.395	48.988	59.657	79.865	103.719	144.376	186.799	237.439
9	6	41.253	47.707	68.725	81.932	106.571	135.304	183.911	234.488	294.865
10	7	56.830	64.744	90.034	105.675	134.561	167.983	224.287	282.832	352.793
11	8	73.848	83.180	112.592	130.574	163.547	201.497	265.291	331.653	411.079
12	9	92.070	102.777	136.171	156.410	193.329	235.671	306.781	380.837	469.631
13	10	111.314	123.355	160.602	183.024	223.765	270.381	348.659	430.306	528.389
14	11	131.438	144.775	185.757	210.295	254.750	305.536	390.852	480.003	587.309
15	12	152.330	166.926	211.536	238.130	286.202	341.065	433.309	529.886	646.359
16	13	173.899	189.720	237.858	266.455	318.056	376.916	475.986	579.925	705.516
17	14	196.069	213.085	264.661	295.210	350.262	413.045	518.853	630.094	764.762

order for a telecommunications network to continue to offer a given Grade of Service, the number of circuits provided in a circuit group must increase (non-linearly) if the traffic intensity increases.

5.2 CALCULATING THE GRADE OF SERVICE

To determine the Grade of Service of a network when the traffic load and number of circuits are known, telecommunications network operators make use of *Equation 2*, which is the Erlang-B equation.

$$\text{Grade of Service} = \frac{\left(\frac{A^N}{N!}\right)}{\left(\sum_{k=0}^{N} \frac{A^k}{k!}\right)} \qquad (2)$$

A = Expected traffic intensity in Erlangs, N = Number of circuits in group.
This equation allows operators to determine whether each of their circuit groups meet the required Grade of Service, simply by monitoring the reference traffic intensity.
(For delay networks, the Erlang-C formula allows network operators to determine the probability of delay depending on peak traffic and the number of circuits.)

6. CONCLUSION

The novelty of our work is that we are able to both accurately measure network QoS parameters and objectively assess application Grade of Service in parallel. This allowed us to quantify the relationship between QoS parameters and Grade of Service for two applications (file transfer and VoIP) and identify their QoS requirements. For file transfer, we observed the expected decrease of good put with packet loss. The dependency is linear and good put decrease is not very large in the range of 0% to 5% packet loss. For loss rates above 20%, good put indicates a transfer efficiency lower than 0.7. The transfer time performance graph has a negative exponential shape, showing that the time needed to transfer a file increases significantly with packet loss. For loss rates around 5% and low RTTs, the TTP is one order of magnitude smaller than the value obtained at zero packet loss. At 25% loss rate, the time to transfer has become several hundred times larger than in the case the loss rate is smaller than 5%. VoIP results show that for packet loss less than 10% and jitter below 20 ms the perceived speech quality is good. For jitter exceeding 50 ms the quality of the speech signal becomes unacceptable, the distortion of the speech signal being very large. Using our results it is possible to predict an application Grade of Service based on the corresponding measured network QoS parameters and understand the reasons of possible application failure. One can also determine the end-to-end network QoS requirements for an application to run with a desired Grade of Service level. Mapping high-level user requirements to network QoS conditions is also a key issue in service level.

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