THE AGT TOLL NETWORK RELIABILITY OBJECTIVES

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ABSTRACT
Network reliability plays an important role in enabling traffic flow in the network. This paper describes the derivation of AGT's toll network reliability objectives. These objectives are used as a guide for network planning, design, and operations to ensure that the toll network will continue to be reliable, regardless of the emergence of new technologies that may influence the future network configuration.

I. INTRODUCTION
To enable traffic flow between a pair of nodes in a telecommunications network, a set of paths between them is required. A path between the two nodes consists of a set of network components, which includes the two nodes, connected in series. If failure occurs in any one of the components in the path, the path is said to have failed and can not be used for carrying traffic until it is repaired. The duration that a component, a path, or a set of paths remains failed is called the down time. Obviously, during the down time of the set of paths between the two nodes, no traffic can flow between them and traffic congestion is a certainty. From the viewpoint of the customers, no service can be received if traffic congestion is encountered, whether it is due to traffic overload or due to failure of the set of paths between the two nodes [1]. Therefore, when network traffic is considered, network reliability can not be ignored.

Like other telephone administrations, Alberta Government Telephones (AGT) takes advantage of the emergence of new technologies. This may require a change in its network configuration. No matter what the future network configuration may be, however, AGT's policy is to continue to have a reliable network to serve its customers. In order to do so, AGT has established network reliability objectives to guide network planning, design and operations. For convenience, the AGT network may be divided into two parts: local and toll. This paper describes the derivation of its toll network reliability objectives.

II. DEFINITIONS
For the purpose of this paper, the probability that a component, a path, or a set of paths will fail is called the unavailability of the component, the path, or the set of paths. It is defined as follows:

\[ \text{Unavailability} = 1 - \text{Availability} \]

\[ = \frac{\text{Mean Down Time}}{\text{Mean Down Time} + \text{Mean Up Time}} \]  

(1)

where the up time of a component, a path, or a set of paths is the duration that the component, the path, or the set of paths can be used for carrying traffic until failure occurs. The availability of a set of paths between two end-nodes in a given network is called the point-to-point reliability between them. In practice, for economic reasons, the point-to-point reliability between two nodes depend on the distance between them and the main-station density in each of them. As pointed out in a previous paper, traffic can be forecasted based on main-station densities and distance [4]. Therefore, it may be appropriate to define the total network
reliability as the traffic weighted average of the point-to-point reliabilities over the entire network.

The AGT network follows the North American Hierarchical principal with the end-nodes of its toll network as class 4 offices. Since its local network reliability objectives have accounted for the traffic flow within each class 4 office serving area, it follows that the total AGT toll network reliability is,

\[ R = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} A_{ij} E_{ij}}{\sum_{i=1}^{N} \sum_{j=1}^{N} E_{ij}} \]  

where \( A_{ij} \) is the point-to-point reliability between class 4 office \( i \) and class 4 office \( j \); \( E_{ij} \) is the amount of traffic flow from class 4 office \( i \) to class 4 office \( j \); and \( N \) is the number of class 4 offices in the AGT network.

III. NUMBER OF OBJECTIVES

To plan and design the network, a reliability objective is required to guide the selection of reliable network components. In AGT, such an objective is called the design reliability objective. A network component may be made up of equipment supplied by one or more manufacturers. The reliability of equipment is usually specified and standardized by the manufacturer. Therefore, the design reliability objective may also be regarded as the design reliability standard.

After the network component is installed and is in operation for service, experience shows that there are always some external causes (e.g. cable cuts) besides the intrinsic equipment failure to disrupt the traffic flow. Thus, actual network reliability provided to the customers must be measured on an operational basis. Therefore, there is a need for establishing an operational reliability objective, which takes into account both intrinsic equipment failures and external disruption of traffic flow.

It should be noted that it is convenient to have a total network reliability objective for monitoring the reliability of the entire network. However, to guide network planning, design and operations, the point-to-point reliability objectives are useful for ensuring that a set of paths between two end-nodes is sufficiently reliable. Thus a set of four objectives is required:

(1) Point-to-point design reliability objective,

(2) point-to-point operational reliability objective,

(3) total network design reliability objective, and

(4) total network operational reliability objective.

IV. ESTABLISHMENT OF OBJECTIVES

The policy of continuing to have a reliable network implies that the future network must be as reliable as the present one. Therefore, to establish the network reliability objectives, the existing network may be used as the base. In 1979, when the network reliability study was made, the AGT toll network had 12 class 4 offices, 2 class 3 offices, and one class 2 office. These offices also have telecommunications paths connected to offices outside the province of Alberta, Canada. To simplify the task of establishing the AGT toll network reliability objectives, only the class 4 to class 4 offices within the province of Alberta were considered.

At the time when the network reliability study was made, there were no point-to-point reliability statistics for the AGT toll network. Fortunately, reliability standard values were available from the manufacturers' equipment specifications, and network component operational availabilities were available from AGT's operational records. Since the class 4 offices in the AGT toll network are the end-nodes, the point-to-point reliability is the availability of having at least one path for traffic to flow between a given pair of class 4 offices. Thus, if failure of the network components are assumed to be independent of each other, both point-to-point design reliabilities and point-to-point operational reliabilities can be estimated for the AGT toll network.

If the point-to-point design reliabilities are applied to equation (2), the resulting \( R \) is the total network design reliability. Similarly, if the point-to-point operational reliabilities are
applied to equation (2), the resulting \( R \) is the total network operational reliability. To estimate the total AGT toll network reliability, however, the class 4 to class 4 traffic information as indicated in equation (2) is also required. To speed up the process of establishing the objective, the point-to-point class 4 office traffic \( E_{ij} \)'s were obtained from the output of the AGT toll network traffic planning tool (C4UP•GTF computer program) [5]. The point-to-point reliabilities and the total network reliability was computed using the AGT network reliability planning tool (C55.REL computer program) [5]. Thus, the tool provided fast computations and accurate results. The outputs from the planning tools for the design reliabilities and operational reliabilities are shown in Figs. 1 and 2, respectively, and have been plotted against the traffic in units of CCS (36 CCS = 1 erlang). Figs. 1 and 2 show that, for 1979 AGT toll network, the lowest point-to-point design reliability was 0.999913; the total network design reliability was 0.999983; the lowest point-to-point operational reliability was 0.999755; and the total network operational reliability was 0.999915.

For the future AGT toll network to be as reliable as the present one, the objectives should have values as close as possible to those found in 1979. Therefore, the values calculated in 1979 were used as the basis of the objectives and, then, were rounded downwards. They were rounded downwards for the following reasons:

1. The results of the 1979 study were produced one year after the data for the study was obtained. Since it was assumed that the network was not improved during this time - a worst case assumption - the reliability of the network would have deteriorated due to aging. It was realistic, therefore, to choose minimum reliability objectives lower than the 1979 values. The degree of rounding was such as to have no practical significance.

2. The objectives were rounded off for ease of use.

Note that minimum values have been adopted for the point-to-point reliability objectives regardless of distances and main-station densities since the effect of distances and main-station densities have been accounted for in the total network reliability objectives.

For ready reference, the reliability values for the objectives and those found in the 1979 AGT toll network have been tabulated as shown in Fig. 3.

V. CONCLUSION

In conclusion, toll network reliability objectives have been established for AGT. They are not only realistic and economically achievable, but will also serve as a measuring stick to ensure that the future AGT toll network continues to be highly reliable.

ACKNOWLEDGEMENT

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REFERENCE

Fig. 1 Design Reliabilities In 1979 AGT Toll Network

Fig. 2 Operational Reliabilities In 1979 AGT Toll Network
<table>
<thead>
<tr>
<th></th>
<th>1979</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum point-to-point design reliability</td>
<td>0.999913</td>
<td>0.999900</td>
</tr>
<tr>
<td>Minimum point-to-point operational reliability</td>
<td>0.999755</td>
<td>0.999750</td>
</tr>
<tr>
<td>Total network design reliability</td>
<td>0.999983</td>
<td>0.999975</td>
</tr>
<tr>
<td>Total network operational reliability</td>
<td>0.999915</td>
<td>0.999900</td>
</tr>
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</table>

Fig.3 AGT Toll Network Reliability Objectives.
Summary of Questions/Answers

Date: 13 June 1983
Session: 2.3
Paper: 4

Q.1 (K. Kodaira)

How do you deal with partial circuits down, if the unavailability between i and j, which you defined, corresponds to all circuits down? Especially, partial down during low traffic hours?

A.1 (L. Lee)

Yes, the unavailability between i and j corresponds to all circuits down. Partial circuits down is not considered in this paper. However, this topic has been discussed in the previous ITC's, and should be encouraged to report further research results to ITC (in my opinion) in the future.

Q.2 (R.H. Laufenburger)

Your paper deals with reliability as defined by availability of a Path/Component. Does availability definition include Sonalin /Supervision and Transmission Capability or just Path Connection? If so, how are actual results obtained for comparison?

A.2 (L. Lee)

Availability definition includes just path connection. Actual results are obtained from operational records.

Q.3 (R.H. Laufenburger)

Manufacturers predictive reliability estimates are mean failure rates whereas in practical application variance is introduced thru manufacturing process and component value distributions. How do you weight variance into your estimates?

A.3 (L. Lee)

Your are right, variance should be considered. However, for simplicity, availability is usually used and may be defined as 'Mean failure rate X Mean down time per failure'.

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Q.4 (J.R. De Los Mozos)

In your article you mention a computer program for network reliability calculations. Can you briefly describe the objectives, input and output of this planning tool?

A.4 (L. Lee)

The inputs for the reliability planning tool are (i) point-to-point traffic, (ii) the network component availabilities. The outputs from the tool are (i) point-to-point reliabilities for every pair of the end nodes in the network, and (ii) the traffic weighted average point-to-point reliability for the entire network.

Q.5 (M. Crozier)

If certain objective value could be achieved in 1979 is it justified to specify lower objective value for 1980 based on aging? Would this not lead to a downward trend of network performance in AGT Network.

A.5 (L. Lee)

No. In practice, when network components are selected, the resulting point-to-point reliability is usually better than the specified objective.