Use of Computer Programs for Trunk Forecasting

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ABSTRACT

The efficient design and operation of a network requires the coordinated efforts of a great many people. In order to gain high network efficiency they should be able to take advantage of sophisticated traffic theories, analyze and manage large quantities of data, and coordinate their individual efforts. To accomplish this for the more than 300,000 trunk groups which make up the Bell System message network, it has been necessary to develop a package of computer programs as a part of a Total Network Data System.

The four programs making up this package are the Common Update System which maintains the records which describe the network, the Traffic Data Administration System which provides for storage, summary and screening of traffic data, the Trunk Servicing System which develops the base year traffic loads and the Trunk Forecasting System which calculates growth ratios and provides estimates of future trunk requirements. This paper describes these systems, with emphasis on their capabilities and their interfaces with the people who must operate them. These programs have currently been installed in more than half of the Bell System's administrations with further conversions scheduled.

1. INTRODUCTION

A trunk forecast is an estimate of the number of trunks which will be required between each pair of switching systems at specified future dates. Preparation of this forecast requires an estimate to be made of the traffic which will be offered between these pairs of switching systems. It is then necessary to convert these traffic estimates to trunk quantities, recognizing the constraints imposed by the switching systems, the role of the trunk group in the network (high usage or final), the characteristics of the traffic and the economics of direct versus alternate routing. The Bell System must perform this task for a network consisting of approximately 18,000 switching systems, connected by over 5 million trunks arranged in more than 300,000 individual trunk groups. This task has taken the combined efforts of thousands of people using sophisticated traffic techniques.

While each of the steps involved in producing a trunk forecast can be performed manually, computers provide the only practical approach to solving this problem for a large, complex network. The volume of data which must be processed and the number of required calculations is very large. This results from the number of hours of data which must be analyzed for each trunk group, as well as the large number of trunk groups and the complexity of their interactions. The data come in a variety of forms and units; therefore, various types of conversion are required. Because growth must be forecast for an entire network simultaneously, iterative algorithms are utilized—algorithms that are quite complex mathematically and which vary to reflect local network configurations. Overflow traffic items must be tracked to each of several alternate route legs and the peakedness of the resulting loads determined. Alternative network designs and routing patterns must be analyzed in order to insure minimum cost design. Thus the forecasting task could not be accomplished without the aid of large computers and programming systems.

The use of computer programs for trunk forecasting also insures that standard methodology, producing comparable results, will be used by each of the administrations making up the Bell System. It also permits the rapid introduction of new techniques, e.g. multihour engineering, without a large, complex and difficult training program.

2. THE TRUNK FORECASTING PROGRAMS

The Bell System has successfully been using mechanized techniques as an aid in trunk forecasting for many years. With the development of the Total Network Data System (TNDS), a new set of trunk engineering programs have been developed. These are designed to be an integral part of the TNDS; sharing the record keeping, data collection and summarization functions. Future plans call for integration of the outputs of the trunk engineering programs with other TNDS programs which do transmission facility and central office equipment design.

Four of the TNDS programs are directly involved in developing a trunk forecast. These are the Traffic Data Administration System (TDAS), the Common Update System (CU), the Trunk Servicing System (TSS) and the Trunk Forecasting System (TFS). TDAS and CU are shared with other TNDS programs. The programs have been designed to permit an administration to install and operate these programs on an individual basis. However, all 4 are required to have a total trunk forecasting system.

TDAS provides for the storage, summary and screening of traffic data. TDAS accepts the data as they arrive by magnetic tape, paper tape, or punched cards and, in accord with user requests, sorts it, labels it in common language, stores it and finally, outputs the trunking data in the proper format for TSS. The design recognizes the variety of data measurement devices and schedules employed by the various administrations to match the data collection capabilities of their individual switching systems.

Attempt (PO), usage (U), overflow (O), all-trunk-busy (ATB) and last-trunk-busy (LTB) data are accepted in various combinations. TDAS can accept up to 24 hours of daily data for a 5-day week. Additional data can be accepted for Sundays or other special periods.

TDAS acts primarily as a warehouse for data and does not operate on the data other than to ensure proper labeling, ensure internal consistency, and test against preset range limits. Typically, TDAS might run once a week to process data gathered during the preceding week.

CU maintains the records which describe the network. It accepts data in the form of manually prepared punched cards or magnetic tape from other TNDS programs. An example of an input record is described in Section 3.2.4. CU stores data for TDAS, TSS and TFS. The design is intended to encourage frequent updating of the data base, instead of "crash" efforts to update or create files. Although the record base is common for an entire administration, each engineer can individually administer that portion of the network records for which he is responsible. The CU outputs can be used directly by the engineer for his records.
Most Bell System administrations produce forecasts every 4 months in order to match regular reviews of the construction program. Therefore, the TFS process is geared to this time frame. During this period a typical administration may use 50 hours of computer time and produce 20,000 pages of output. These outputs are error reports, updated records, special summaries and the trunk forecast itself. The costs of this operation are more than recovered by the reduction in forecaster clerical effort and the improved design of the network.

### 3.0 FUNCTIONS OF THE SYSTEM

Production of a trunk forecast requires the interaction of all of the programs described above. Because of this, and the ubiquitous nature of CU, the functional flow of the forecasting process can best be described by assuming only two systems, TBS and TFS. This approach will be followed in this section, except where a reference to CU or TDAS adds clarity.

#### 3.1 TBS FUNCTIONS

The forecasting process requires that base year trunk group loads be entered for each trunk group to be considered. These data are developed and analyzed by TBS using a 5 step process. These steps are:

1. Validate and assemble trunk measurement data
2. Select measurements for use
3. Calculate traffic loads
4. Combine study weeks' data to produce study period data
5. Compute current trunk requirements

This last step, the determination and reporting of overloaded and underloaded trunk groups is not required for the trunk forecast. It is used for current administration of the network.

#### 3.1.1 DATA VALIDATION

On receipt of measurement data from TDAS, TBS searches the CU files to find the necessary trunk group record.* It also verifies at this time that the files contain sufficient information for engineering the group, i.e., blocking objective, primary hour, etc. If a match cannot be made an error report is generated.

Each input measurement for each hour is checked for reasonableness by comparison with expected maximum and minimum values. Typical tests are:

- overflow count greater than attempt count,
- excessive discrepancies between data at the two ends of a group, 3 consecutive hours of identical data, etc.

Once the individual measurement validation has taken place, all measurements are placed in a weekly matrix (5 days, 24 hours). If the program cannot find a minimum of three acceptable data values in either a preselected primary or secondary hour then the entire week's data are discarded and an error message is generated.

#### 3.1.2 MEASUREMENT SELECTION

Since all data are not available for all hours, TBS must select the measurement data it will use. When a single trunk group's measurements for one week have been received and stored in the matrixes, a selection of which measurements will be used is made using a set of preference rules. (The primary or secondary hour is used in testing for the preference.) The preference is based on the number of days of data, the type of measurement and the type of trunk group.

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*The data contained in a Circuit (Trunk) Group Record are illustrated in Figure 1 and described in Section 3.2.4.
The following table is an excerpt from the preference rules for a final trunk group, ranked from most to least preferred.

<table>
<thead>
<tr>
<th>Valid Days</th>
<th>A</th>
<th>Z</th>
<th>Selected Measurement</th>
<th>Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>U/PC/O</td>
<td>PC/O</td>
<td>U/PC/O</td>
<td>01</td>
</tr>
<tr>
<td>5</td>
<td>PC/O</td>
<td>U/PC/O</td>
<td>U/PC/O</td>
<td>02</td>
</tr>
<tr>
<td>5</td>
<td>U/PC/O</td>
<td>-</td>
<td>U/PC/O</td>
<td>03</td>
</tr>
<tr>
<td>5</td>
<td>U</td>
<td>PC/O</td>
<td>U/PC/O</td>
<td>06</td>
</tr>
<tr>
<td>4</td>
<td>U/PC/O</td>
<td>PC/O</td>
<td>U/PC/O</td>
<td>07</td>
</tr>
<tr>
<td>3</td>
<td>U</td>
<td>PC/O</td>
<td>U/PC/O</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>U</td>
<td>-</td>
<td>U</td>
<td>19</td>
</tr>
<tr>
<td>5</td>
<td>U</td>
<td>PC/O</td>
<td>PC</td>
<td>36</td>
</tr>
<tr>
<td>3</td>
<td>ATB</td>
<td>ATB</td>
<td>ATB</td>
<td>37</td>
</tr>
<tr>
<td>3</td>
<td>LTB</td>
<td>LTB</td>
<td>LTB</td>
<td>42</td>
</tr>
</tbody>
</table>

3.1.3 CONVERSION TO TRAFFIC LOADS

Once the data have been assembled, traffic loads are calculated for every hour where the preferred measurement type is available. Sixteen distinct procedures are provided. The choice depends upon the type of trunk group and the data available. Nine of these procedures represent all possible combinations of the 3 measurement groupings (U/PC/O, U, PC/O) and the 3 trunk group types (primary high usage, intermediate high usage and final). The remaining 7 procedures are various combinations of non-network (receiving no overflow) final groups and measurement types.

All of the procedures incorporate the Wilkinson Traffic Theory, i.e., recognize day-to-day variation and peakedness. The TSS program computes the weekly average offered load and weekly average overflow load for each trunk group. The day-to-day variation, peakedness and average call holding time are calculated whenever sufficient data exist. These values are held for use as default values in other weeks when some data may be missing. For example, if only attempt data are available for a particular study period usage will be estimated using the product of measured attempts and historical holding time.

All of the calculated results are available as outputs and are stored in a weekly history file which contains 65 calendar weeks of data.

3.1.4 COMBINATION OF WEEKLY DATA

The Bell System bases its forecast on data averaged for a 4 week base study period. Therefore, in preparation for the forecast process, study period data are created from data received during a calendar span of up to 9 weeks selected from the 65 weeks of data available. (Only 4 calendar weeks are used for network trunk groups to insure data consistency.) From these 9 weeks the process selects the most recent 4 weeks of data and calculates a weighted average value for each load parameter for each hour of the day. The study period data are collected into an Administrative File which has space for up to 18 study periods for each trunk group.

The TSS process also identifies the hour and load critical to the network sizing process. For non-network trunk groups this is the hour with highest average study period load. For network groups this is the hour of the highest average load in the cluster. For final network groups the process also identifies the hour of highest blocking. For high usage groups, TSS determines by stepping down the network hierarchy, the significant hour to the network of overflow from each high usage trunk group. The highest of these hours is identified as the control hour and stored in the Administrative File.

3.2 TFS FUNCTIONS

The Trunk Forecasting System consists of 5 major parts. These are:

1. Common Record Update
2. Growth Data Analysis
3. Growth Factor Analysis
4. Trunk Group Analysis
5. Trunk Forecast

TFS can be run at any time using study period data obtained from TSS and the description of the network contained in CU.

3.2.1 COMMON RECORD UPDATE

The building block record for both TFS and TSS is the Traffic Unit Record. A Traffic Unit Record must be maintained for each location at which trunk groups terminate and/or for which growth factors will be required at any time period to be considered in the forecast. The Traffic Unit Record identifies the location, the responsible user, the start and end date of the unit, and permits modification of certain system parameters such as forecast distortion limits and minimum trunk group sizes.

3.2.2 GROWTH DATA ANALYSIS

For each traffic unit the forecaster must enter growth data. In the Bell System, the fundamental growth data are most frequently estimates of main stations (MS) and CCS/MS for each future forecast period by each class of service, e.g. business or residence, for which a separate growth rate will be required. Since most trunk groups will carry several classes of service, the forecaster may enter a table defining logical combinations of these basic data items. Thus the user need only put in the most basic data level and then use the table to identify a particular data combination. The system makes the necessary computations. TFS can use any of these inputs, including different combinations for different traffic units, to compute growth factors.

If the preferred data type is not available to the user he may input main stations, call rate and holding time, or total CCS, or total calls, or main stations and call rate, or total main stations, or simply a statement of the growth factor. TFS can use any of these inputs, to compute growth factors. Each time the traffic unit data are altered the system provides an updated record for the user’s files. It also reports any missing or duplicate data.

3.2.3 GROWTH FACTOR COMPUTATION

TFS uses the input growth data to compute growth factors for each traffic unit. The growth factor is the ratio of the total CCS at the future period (obtained by multiplying main stations by CCS/MS) to the total CCS in the base period. If other data types are provided as input, growth factors are developed using ratios of the available data. However, both the base year and forecast period data types must be consistent.
The output of the growth factor computation is a report which lists the input data and the computed growth factors for each traffic unit. The forecaster, on receiving the report must decide whether he can accept the computed growth factors or must make revisions. A revision is good only for the production of the next forecast. A permanent change would require inputs to the records update process and a rerun of the growth data analysis step.

3.2.4 TRUNK GROUP ANALYSIS

Prior to producing the trunk forecast, trunk group records must be entered (or existing records reviewed) for each trunk group in the network. This particular record contains a large portion of the total required input information. It is therefore described in some detail here to aid in understanding the system and to illustrate the content and format of an actual record.

One Circuit Group record input is required for each trunk group to be considered in the forecast. More than 60 data fields are involved in this record. A system worksheet is shown in Figure 1. This is used to add new trunk group records. Once a record is entered, the system produces reports which are nearly identical in form and which may be used as the forecaster's record and as a base to change or delete the record. The numbers in parenthesis on the form identify specific input forms to clerical personnel. The system evaluates each input record for completeness and consistency. Error messages identifying specific problems are generated and distributed to the forecasters. This step in the process may be run repeatedly until the record base is in an acceptable condition.

The 500 section of the form defines the start and end date of the record and provides the common language descriptive name of the trunk group.

The 501 area defines the factors to be used in engineering the trunk group. The projection code (PROJ-CODE) is a numeric value signifying 1 out of 12 formulae which are to be used for the projection of the trunk group primary load. Most of these formulae consist of arithmetic combinations of the growth factors computed for the traffic units (or weighted combination of units) at either end of the trunk group, e.g. AEC, A/5, TFS. Other selections available to the forecaster include a stated projection ratio, a compounded growth factor, a directly stated future CSS or a directly stated future trunk requirement.

The fields "GRTH-CD-A" and "GRTH-CD-Z" identify the data items which should be included in the growth factor calculations at the A and Z end of the trunk group. This generally reflects the combination of classes of service for the traffic items being carried on the trunk group.

The "CONF-CODE" identifies to TFS the formula to be used for converting traffic loads to trunk requirements. Eleven codes are provided identifying procedures which include Wilkinson, Erlang B, S&S Graded and CSS/Trunk among others.

The "CONF-CODE" field is used to identify special configurations such as divided groups. The "PROB-COND" field identifies the service objective for probability-engineered trunk groups. The "TECS" field identifies the economical objective load to be carried on the last circuit of a high usage trunk group. The "STIM-FACTOR" is an additional term which may be used in computing the projection factor to reflect anticipated special stimulation of growth to the traffic units. The last 3 fields are used to identify ownership of the circuit group when more than one administration is involved.

The 505 section of the form is used to identify, for high usage groups, the first alternate route path from the "A" end of the trunk group. Overflow traffic from the "A" end of the group will be offered on a first choice basis to this route. Up to 3 trunk groups can be identified. This is adequate to handle 95% of the situations occurring in the Bell network. The last tandem office encountered in this alternate route is also identified. This information is used to support one of the automatic load reroute options provided by TFS.

The 503 field is identical to the 502 field except that it describes the alternate route as seen from the "Z" end of the high usage group. The 510 and 511 areas contain information necessary for TFS, such as identification of the primary hour, number of circuits in service, historical holding time (if the computed value is to be superseded, etc.).

The 512 area allows the forecaster to state for each forecast period specific parameters which are to be used to supersede values that TFS would normally calculate. The two fields "OTHER TRUNKS" and "OTHER CSS" can be used to add to the trunk group a specified number of trunks or loads developed independently by another administration.

To be useful a trunk forecasting system must be able to evaluate the need for new trunk groups in the network. TFS allows for this by permitting inputs for both actual trunk groups and "pseudo" trunk groups. Two types of "pseudo" groups may be identified.

For the "Q" type all calculations are made as though the group was an actual trunk group. If the calculations show the group to be larger than the minimum acceptable size the group is removed and the network resized without it. Otherwise the group is reported in the final forecast. The "S" type "pseudo" group is for test purposes but can also be used to group a particular item of traffic separately from other items on a trunk group. Calculations are made in order to properly size the group and these data are reported to the forecaster. However, this group is not considered for inclusion in the network and its projected load is always added back into an existing group in the network before final sizing.

3.2.5 TRUNK FORECAST

Once the records are completed the base load data determined from TFS will be accepted and the forecast produced. For each trunk group TFS will accept study period base load data for up to 8 different hours. These are the network cluster busy hour, the hour of maximum blocking and the hours for which overflow to the alternate route legs must be determined. The forecaster must identify which of the hours is to be used in sizing the particular trunk group. The preferred data are offered and overflow load for each hour. However, TFS also allows the forecaster the flexibility of entering the first route offered load directly.

Since the network structure will change during the forecast interval, TFS is designed to accommodate 3 types of traffic transfers. These are transfer of traffic from one group to another, transfer from or to a specified route or transfer of traffic items from all completing groups of a tandem to a new bypass route. The system also allows groups to be started at any time during the forecast period. Prior to the start date the loads for the group are automatically distributed to the alternate route.

The first step in producing the forecast is to convert the offered base loads to first route loads by removing the accumulated overflows. These first route loads are then multiplied by the calculated projection ratios to get the first route loads for each trunk group for each future period. Non-network groups can be sized directly using these forecasting loads and the conversion method identified for the trunk group. Primary high usage groups may also be sized, and their overflow computed for each hour of interest. The system produces a route up the network from bottom to top, sizing each group for its combined first route and received overflow loads, as soon as overflows have been computed for those groups subtending it. Equivalent random theory is used for all groups receiving overflow traffic.
When all of the trunk groups have been sized, TPS produces a preliminary trunk forecast. In addition to estimates of trunk quantities, it contains detailed information about each trunk group and summary information for each switching system. One useful report identifies changes from previous forecasts. The forecaster may modify the preliminary forecast prior to producing the final forecast if external constraints, e.g., switching system maximum size, have been violated or in order to smooth the forecast if random period to period changes have been projected. These changes are entered and a final forecast is produced for the entire administration, sorted in a fashion to be most useful for other groups using the forecast, i.e., facility planners and switching system designers.

4.0 PLANNED ENHANCEMENTS

Although the Bell System is proud of its present trunk forecasting system, several major enhancements are already being developed. The most important among these is the introduction of an automatic routing system. This will reduce input requirements by automatically identifying new trunk group candidates and identifying their alternate route legs. The system will directly accept point-to-point data so that traffic transfers can be identified internally.

Once routing is installed it will be possible to automatically select the base loads for TPS within TBS. At present, this must be done manually because TBS cannot reflect network rearrangements when it determines base loads.

A schedule has also been set to introduce the new multi-hour sizing procedures to the system. Other techniques, involving dynamic routing through the network are also being considered.

Finally, a management reporting system, using an on-line time shared computer to access the data base is being developed. This will reduce the number of paper records required, while allowing easier record update and the production of specialized reports for improved management control of the trunk forecasting process.

REFERENCES

3. A 37 character code used to uniquely identify each trunk group. Two groupings of 11 characters each identify the end switching systems. The remaining 15 characters specify unique group characteristics.
5. TPS will automatically interpolate data for any period between the base year and the last forecast year if intermediate data are not input directly.