Factors Influencing the Call Completion Ratio

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ABSTRACT

This paper begins with a brief description of network call completion statistics obtained by special processing of automatic message accounting data. In this paper "completion" is simply the ratio of answered calls to total attempts. Illustrative results are then presented for the total U.S.A. telephone system and for several individual Bell System operating companies. Seasonal variations, residual month-to-month variability, and problems resulting from abnormal traffic are discussed.

It is well known that the terminating customer's state (busy/does not answer) and the originating customer's response when a call attempt is not successful (retrial/abandonment) are the major factors influencing call completion percentages. Under present U.S. service standards, these factors serve to mask network effects, including blocking and equipment failure. This paper shows that the called party class of service distribution (i.e., numbers of residence, business, multiline hunt, PBX lines, etc.) provides a basis for calculation of an expected completion rate for each central office in a large administrative area. A computer model which has been developed to identify candidate offices for potential completion improvement is described.

Procedures to detect the causes of low completion ratios and possible methods of improvement are discussed. An example of a significant shift in network completion, resulting from a tariff change, is presented, and the cost/effectiveness of completion ratio improvement activities is discussed.

1. INTRODUCTION

Since late 1971, the automatic message accounting (AMA) records collected on the first Wednesday of each month have been specially processed by each regional accounting office in the U.S.A. and transmitted in summary form to AT&T, where Network Completion Reports (NCR) and various special reports are generated. The NCR outputs include total attempts, total completions, and percent completion. Calls to directory assistance are excluded. Any call not returning answer supervision counts as an incomplete attempt. These results are available on an originating basis, i.e., from every Numbering Plan Area (NPA), identified by an Area Code, to the system and to every other NPA, and in greater detail as terminating statistics: from the total system, to each company, to each NPA, and to each end office (NEO). The terminating statistics are recorded separately for traffic which originates within the same NPA, identified as home NPA (HNPA), or from other NPAs (FNPAs). FNPA statistics have received more emphasis than other completion results, because problems with incoming calls are hard to detect at the terminating offices and terminating FNPA results include the results of incoming failures.

It should be noted that the AMA completion ratio (CR), which is total completed calls divided by total call attempts into a specific area, does not represent the probability of completing a call as seen by any individual customer. The completion rate seen by each customer depends upon his selection of called numbers and his persistence in placing reattempts when calls are not completed. However, CR is important to the telephone companies since its inverse is the average number of network attempts per completed call.

Two other statistics, which could be obtained at a much greater expense from the original AMA data, would better represent the customer's view of call completion performance:

a) First attempt completion ratio - Typical results for this quantity are approximately 75 percent. If the first attempt is unsuccessful, subsequent attempts will not have a high completion probability, because the terminating line status (or, less likely, a network condition) which caused an earlier attempt to fail may be unchanged.

b) Revenue completion ratio - This statistic, also of interest to the telephone companies, is defined as the probability of an eventual completed call (within 24 hours) given a first attempt. Average values of this quantity are approximately 85 percent.

2. LARGE SCALE RESULTS

When the NCR data first became available, it was found that measured percent completion results, by company, varied over a wide range from 55 percent to 70 percent. Within an NPA, terminating office completion results vary from less than 10 percent to greater than 90 percent, and an individual office (especially a small one) may exhibit similar variations on a month-to-month basis. On a one-office basis, random and systematic day-to-day variations may account for much of the observed variability, but for the total system, with more than 45 million (FNPA + HNPA) attempts and 30 million completions per day, other factors are more important.

Figure 1 shows the total system FNPA completion ratio results each month for the 1972-1974 period. A seasonal variability is apparent, and Figure 2 shows a (12-month) sine wave plus linear trend regression fit to the data and the 95 percent confidence limits of the residuals about the regression (dotted lines). More complex seasonal models have been examined. The results are harder to interpret, but do not fit the data much better. During this three-year period, despite significant efforts on the part of the operating companies to improve completion, the best fit linear trend line indicates an improvement of 0.06 percent per month. After removing this linear trend and the .83 percent peak amplitude sine wave component,
the residual month-to-month variability of this measurement has a 0.45 percent standard deviation. It is clear that the small monthly changes in completion cannot be detected in the short term in the presence of large residual variability of month-to-month results. (The 95 percent confidence limits which reflect this variability are ± 0.9 percent.)

Similar analyses for each operating company provided similar residual variation, with some differences in the degree of seasonal effects. In some cases, a long-term linear trend was also significant. Four examples of company results are shown in Figures 3 to 6. The solid squares for 1975 results are plotted against extensions of the curves, assuming zero linear trends, since there is no basis for predicting shifts in the level of completion. As seen, the processes affecting completion are quite stable.

One other salient characteristic of percent completion results should be noted, i.e., the presence of outliers. A number of factors can reduce the achieved completion ratio on a given day. For example, natural disasters, such as tornadoes, earthquakes, or heavy winter storms, cause major increases in the offered attempts (any may, at the same time, reduce the network capacity if there is damage to facilities). The residual effects of the New York Telephone February, 1975, fire (see Figure 6) are large enough to show up not only in that company’s total results but also in the total Bell System completion performance for March, 1975. On any given day, a number of similar but less dramatic factors will probably exist. This raises the problem of when to discard data because a completion measurement is not representative of "normal" performance.

One simple statistical technique to facilitate detection of long-term trends in the presence of these factors (seasonal effects, month-to-month variability, and occasional outliers) is the calculation of a running twelve-month median percent completion result. Any analysis of month-by-month completion results must recognize the residual variability shown on the preceding figures. The 1973-1974 FNPA completion trends for eight companies and the system are shown in Figure 7. The median completion measure changes slowly but does reflect real changes in network completion. For example, the change in the median for New England shown in Figure 7 is consistent with the slope of the long-term trend shown in Figure 5.
3. INDIVIDUAL CUSTOMER COMPLETION RESULTS

At the other end of the spectrum, the System Called Line Report (SCLR) provides completion results for specific terminating customers. This report was developed for the purpose of identifying those customers with large numbers of incoming attempts and low completion rates and can be used to help find specific problems, such as PBX trunk shortages or undermanned operator positions. To avoid generating unmanageable volumes of output data, the SCLR program is normally run with cutoff thresholds (for example, results may be requested for terminating numbers with more than 25 FNPA attempts and completion less than 70 percent). While indeed limiting the volume output, use of thresholds in this manner discards more than 90 percent of the total attempts and obscures the impact of most customers on overall completion.

To obtain a better picture of what is happening, special studies, not practical on a routine basis, have been made with thresholds set to process all attempts. Figure 8 illustrates the results for NPA 304 (West Virginia) for September 3, 1974. Note that 30 percent of the total attempts terminated at telephone numbers which received only a single attempt and also that this set of terminating customers provided an 80 percent completion rate. Moving up this figure to lines with more calls, it is seen that completion rates drop and then increase again as the number of incoming attempts increase, with a minimum completion in the five to nine attempt per day interval. A further breakdown of these results by broad terminating class of service, i.e., residence-business is shown in Figure 9. As shown, business completion is everywhere better than residence completion, and most residence lines received small numbers per day of incoming long distance (FNPA) attempts. While residential completion decreases as the number of attempts increases (reflecting successive resubmission of failed incoming calls), business completion improves with attempt volume (reflecting the existence of multiline business customers, hunt groups, PBX operators, etc.).

A somewhat different breakdown of completion data by detailed class of service is shown in Figure 10. These results are quite stable month-to-month and company-to-company. Based on such information, it should be possible to predict an achievable completion rate for a given office. It should also be feasible to set objectives for NPAs and companies by weighted combinations of the expected completion of the end offices. Unfortunately, the data presented in Figure 10 were obtained by an arduous clerical process, and a breakdown by detailed terminating classification as shown is not available elsewhere in the System on an NNX basis.

However, a greatly simplified statistical model has been constructed, restricted to readily available office characterization. The model formulation finally selected is as follows:

![Figure 7](image1.png)

![Figure 8](image2.png)

![Figure 9](image3.png)
NNX Completion = \( C_0 + C_1 \log(\text{Attempts}) + C_2 (\text{PBX Stations} / \text{Attempts}) + C_3 (\text{Centrex Stations} / \text{Attempts}) \)

A computer program based on this model operates on the actual completion rates for a group of offices and their respective characteristics to calculate values for \( C_0, C_1, C_2, \) and \( C_3 \). A representative value of the multiple correlation coefficient, \( R \), is approximately 0.5. More elaborate models do not fit much better. The fit obtained to the achieved individual NNX completions and corresponding characteristics within an NPA is used to calculate a completion improvement potential for each office. Improvement potential is defined as the average daily attempt volume times the difference between statistical and actual completion rates for a group of offices and their companies in mid-1975 as an optional adjunct to the NCR and CLR programs and is now in use. A sample output is shown in Figure 11.

4. OTHER CONSIDERATIONS

It is important to recognize that AMA completion statistics do not identify the causes of incomplete attempts. However, it is known that Don't Answer and Busy are the major causes for incomplete attempts.

Special studies of AMA data by hour provide the initially surprising result that completion probability is usually highest during the busy hour. This occurs because the business-residence traffic ratio is highest at that time. For the same reason, the weekday completion rate is much higher than the weekend rate when business calling is practically non-existent. Special studies on weekends and major holidays, such as Christmas and Mother's Day, also show the reduced completion rate attributed to mostly residential calling.

Other factors which might be expected to affect completion rates have not been found to be significant. For example, terminating switching machine type, i.e., step-by-step, crossbar, electronic, does not matter. And office size, measured as line or number fill, does not provide a better basis for predicting completion ratio than does total attempt volume (because attempt volume and fill are closely correlated).

5. CONCLUSIONS

Based on studies the results of which have been briefly summarized above, it may be concluded that network completion as determined from AMA data exhibits significant seasonal variations (on a company basis) as well as inherent day-to-day variability. When they do occur, real changes in network completion ratios are generally small and take place gradually.

The primary causes of incomplete attempts are DA/YN terminating line conditions whose effects are amplified by originating customer reattempts. Business customers complete better than residence customers and large (multi-line, non-Centrex) customers complete even better. The achieved completion rates for NPAs or for companies are determined primarily by the relative quantities of terminating customer classes and may, therefore, be expected to differ. The detailed customer information which would be needed to set completion goals is not available. However, it is possible to identify offices within an NPA which are candidates for completion improvement by comparing their achieved results with one another using a simple statistical model.

Although it has been generally difficult to achieve even modest improvements in the network completion rates, it is appropriate to devote resources toward completion improvement under the appropriate circumstances, such as:

a) The existence of high trouble or blocking rates - in this case calls are actually being lost in the network itself; revenue is lost due to abandonment; additional network costs are incurred to handle re-_attempts; and poor service is provided to the customer. Here completion improvement may be considered a fringe benefit resulting from necessary service improvement activities.

b) Measurement of low-completion rates for certain large business customers - These may be the result of insufficient lines, inadequately attended PBX or Automatic Call Distributor (ACD) positions, or equipment problems. The significant improvement in INWATS* performance, beginning in January, 1975, is attributable to a tariff change requiring a minimum of two INWATS lines (see Figure 12). Compared to message service, INWATS exhibits little seasonal variation but has a large month-to-month variability. Completion beginning in January, 1975, exhibits a marked improvement. Analysis of raw attempt and completed call data shows that the improvement here is the result of a reduction in the number of attempts required to achieve the same number of completed calls.

\* Incoming wide area telephone service - Free to the calling customer.
c) The availability of new service features - The best example is "Call Waiting" which does significantly reduce the incidence of incomplete attempts due to terminating line busy conditions. Other offerings, such as "Call Forwarding" or automatic answering sets may also have potential for improving both revenues and completion ratio.

It should be evident that there exist completion improvement possibilities which are economically unsound. For example, if it were possible to discourage multiple re-attempts, either by a customer education program or by tariff changes, the network completion ratio would increase toward the 75 percent first-attempt level. However, the total number of completed calls would be expected to decrease significantly as well, and in this unrealistic illustration, total revenue would also decrease.

It is necessary to carefully evaluate each approach with regard to total economics before embarking on a completion improvement program. Some cases would appear to be clear winners. For example, "Call Waiting" appears very attractive, provided that the tariff is compensatory, since the benefits from additional billed calls and reduced ineffective attempts will enhance both profitability and service.

The possibility that changes in completion rates result from changes in customer behavior not influenced by TelCo actions must also be considered. For example, the network completion ratios for many companies and for the total system improved in early 1975. This change appears to have been primarily the result of a change in the mix of business and residence calling. It is possible that the slowdown in the national economy may have had greater impact on residential calling than on business calling. However, other effects, such as the recent changes in long distance rates, are undoubtedly also reflected in completion statistics.

Because many factors, of which few are under direct operating company control, influence the network completion simultaneously, it is very difficult to observe the effects of programs undertaken to improve completion. Nevertheless, unless there are hidden costs, high completion rates are more desirable than low rates, and actions taken which are expected to improve completion which are in themselves profitable (i.e., Call Waiting or more PBX trunks) should be emphasized because of the added benefits which accrue from better completion.

Finally, it should be noted that, like Network Management, call completion activities propagate throughout the network. If completion is improved in one area, customers calling from other areas receive better service and their telephone companies receive additional revenue. As international calling grows, the effects of completion will be felt throughout the world.

* An ESS optional service which alerts a customer whose telephone is in use when another incoming call arrives.