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A Study of Network Performance and Customer Behavior During Direct-Distance-Dialing Call Attempts in the U.S.A.

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A survey was conducted throughout the Bell System in October 1974 to gather detailed information about Direct-Distance-Dialing call attempts. The dispositions, setup times, and customer abandonment times associated with DDD attempts are discussed in detail in this article to provide network performance and customer behavior characteristics to network planners and administrators and to designers of equipment and systems which use, and interact with, the telephone network. It is shown that both network performance and customer behavior affect the call dispositions and the total call setup time; however, customer-dependent failures to complete account for 85 percent of all failures, and customer-determined components of the call setup time make up 71 percent of the total setup time. It is found that traffic composition in terms of the relative mix of business and residential originations exerts a strong influence on call dispositions. Network performance affects the probability of equipment blockages and failures and the interval from end of dialing to receipt of a network response. These are both found to depend on calling distance, while the latter is also affected by the types of originating and terminating local switching.

I. INTRODUCTION

A complex sequence of interactions and reactions is initiated each time a person or machine attempts to call another person or machine via the switched public telephone network. In the case of local calls, the setup process involves station equipment, subscriber loops, at least one local switching office (end office) with its multitude of equipment, and perhaps interoffice trunks and local tandem offices with possible local alternate routing capabilities. Several local switching arrangements are illustrated in Fig. 1a and b. In the case of long distance (toll) calls, the switching arrangements are more complex because of a five-level switching hierarchy, and they are more flexible because of the extensive use of alternate routing.[1] A standard toll switching arrangement is illustrated in Fig. 1c. At one extreme of this switching arrangement, a toll call may encounter ten switching offices interconnected by seven final intertoll trunks and two toll connecting trunks; at the other extreme, a toll call may encounter two end offices connected by a single direct intertoll trunk. In between these extremes, a toll call may be established through several switching offices interconnected by a combination of toll connecting, final intertoll, and high-usage intertoll trunks.

In general, a toll call may be established in several different ways between the same two originating and terminating stations. In Fig. 1c, there are four separate routes which may be traversed. The toll switching algorithm establishes calls on a "link-by-link" basis. At a given office in the switching hierarchy, precedence is given to the trunk group which provides the most direct route to the terminating end office. If the trunk group associated with that route is busy, an alternate route is sought by assigning precedence to the next most direct trunk group. This process is repeated at each consecutive office in the switching path until a route is established or until the setup process cannot proceed due to a system blockage.

A telephone customer making a call attempt has no perception of this process as it occurs, but is aware of the results: namely, the "system setup time" required for the network to provide an identifiable response after completion of dialing, and the probability that the calls are routed to the number dialed ("system completion"). Beyond these network effects, calling and called customer characteristics such as the time required to dial a number, the abandonment behavior of calling customers during the call setup process, and the time required for the called customer to answer impact strongly upon the overall completion probability and the call setup time experienced by telephone customers.

The combined influence of network performance and customer behavior tends to mold customer attitudes about the telephone network and plays an important role in determining the amount of equipment needed to serve customer requests and the revenues which are realized

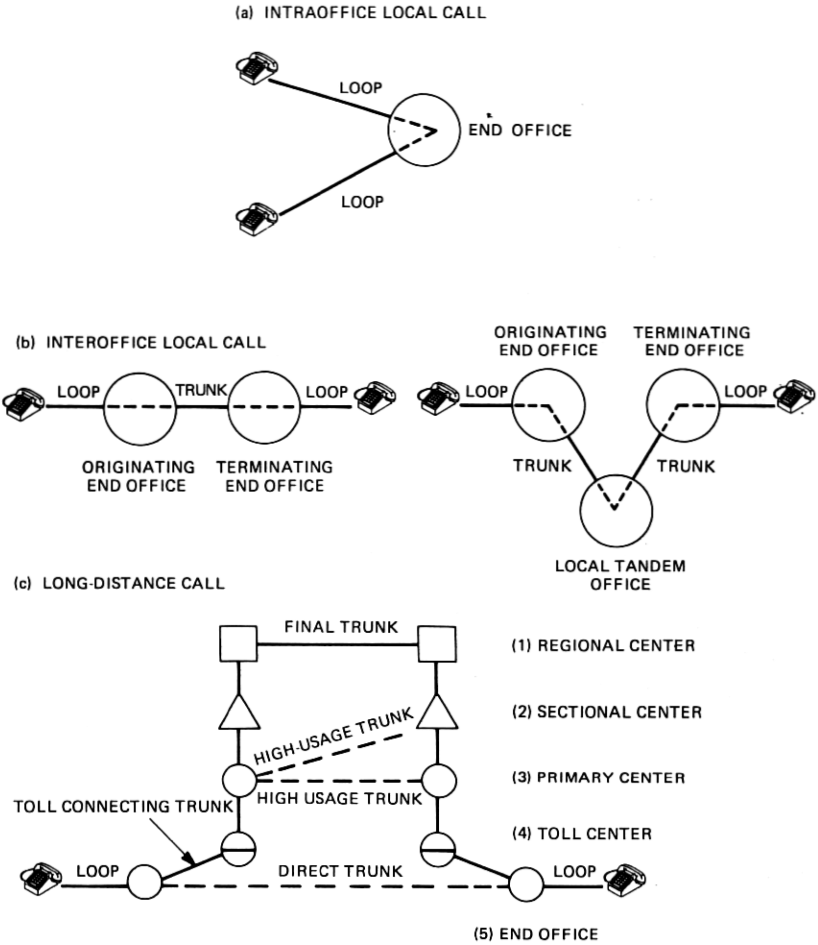

Fig. 1—Local and long-distance switching arrangements.

from successfully completed calls. As a result, the Bell System operating telephone companies continually collect detailed data on network performance and, to a lesser extent, customer behavior to identify and correct network problems and to be able to engineer the network properly to meet specified performance criteria.

Bell Laboratories has gathered a sample of these data using a sampling plan that provides a statistically valid systemwide characterization of the call setup process as seen by the calling customer. This article presents an analysis of the sampled data in the expectation that the information on overall network call setup performance and on customer behavioral characteristics which affect the call setup process will be useful to the planners and administrators of telephone networks and to designers of equipment which utilizes and systems which interact with the telephone network. For instance, the probability of a fast retrial following the occurrence of a no circuit/reorder signal or announcement, as presented in Table III, can be an important parameter in trunk group size engineering.

Several previous studies by Bell Laboratories have dealt with the call setup process.[2–5] All but the first of these are of such different emphasis that the points of comparison with the current study are limited to a few statements on customer behavior. The Larsen and McGill study[2] is the most similar of the studies, and like the current one, is based on service observing data. However, the data were obtained from a number of sites chosen arbitrarily and not according to scientific sampling procedures. Hence, the representativeness of its results is unknown; and in particular, the confidence interval calculations do not properly account for the complexity of the service observing process (see Section II). That study emphasizes time of day and day of week trends in the completion percentage and call setup time results; and while a direct comparison with the current study is difficult, the qualitative statements on these trends are borne out by the present work. The overall completion percentage in the Larsen and McGill study is slightly over 1 percent lower and the call setup time about 1 second higher than currently, but the confidence intervals in the current study overlap these results.

The discussion in this article pertains to Direct-Distance-Dialing (DDD) toll call attempts. Those attempts which are directly dialed by the calling party represent approximately 88 percent of all the long-distance calls established within the Bell System. The sample design used to gather the data is described in Section II. The network and customer call attempt characteristics derived from this survey are presented in Sections III and IV.

II. SAMPLE DESIGN

The term "sample design" denotes the entire process of planning a sample survey. That process includes (*i*) the definition of the population to be studied, (*ii*) the adoption of a sampling plan to collect the data, and (*iii*) the derivation or selection of appropriate statistical estimation formulas.[6] The Bell System call attempt survey described in this article was designed to provide a systemwide characterization of the call setup process utilizing data collected through an existing Bell System procedure. Therefore, considerable care was required in the design of the sample survey to properly account for the complex sampling scheme inherent in the established procedure. This design is discussed in detail in terms of the three features state above in the following subsections in order to demonstrate the statistical validity of the results.

2.1 Population

A distinction must be made between the target population and the sampled population. The target population is the collection of elements about which information is desired. In some situations it may be unattractive or even impossible to sample from the target population. In those cases, the population definition is modified for sampling purposes, and the modified population is referred to as the sampled population. The modifications should be carefully applied so that the sampled population does not deviate too greatly from the target population.

The target population for the Bell System Call Attempt Survey was defined to be all DDD call attempts originated by Bell System subscribers including attempts to toll directory assistance operators. This population definition was modified to take advantage of an existing data source, Dial Line Service Observing (DLSO). The sampled population is restricted to call attempts which originate from local switching offices which serve more than 3000 subscriber lines and consists basically of calls which are directed to a terminating switching office more than 25 miles from the originating switching office or to a different Numbering Plan Area (NPA). Exceptions to this general description are as follows: (*i*) calls to a different NPA which are dailed as a seven-digit number (permissible by protecting codes) are excluded unless the calling distance exceeds 25 miles, and (*ii*) calls to Inward Wide Area Telephone Service (INWATS) subscribers, or calls to toll directory assistance, which are generally dialed as NPA-555-1212, are included without regard to any milage restrictions. Operator-dialed toll call attempts and customer-dialed, operator-serviced toll call attempts are not included in this study. In general, partially dialed attempts are also excluded from this study because of the classification problems posed by insufficient or incorrect digits.

2.2 Sampling plan

The sampling plan defines the method used to gather the survey data. It was intended that the call attempt data include end-to-end information about the setup process and the final result of that process so as to enable the characterization of calling and called customer behavior and telephone network responses. Although test calling procedures and human factors tests can provide valid information about some aspects of network responses and customer behavior respectively, only "live" telephone traffic can provide real-life information of this type.

Dial Line Service Observing (DLSO) is a function performed daily at 425 bureaus geographically located throughout the Bell System to obtain nationwide information about the quality of the call setup process for telephone traffic. An ongoing sample of actual call attempts is observed in over 3500 local switching offices, and the data are summarized peri-

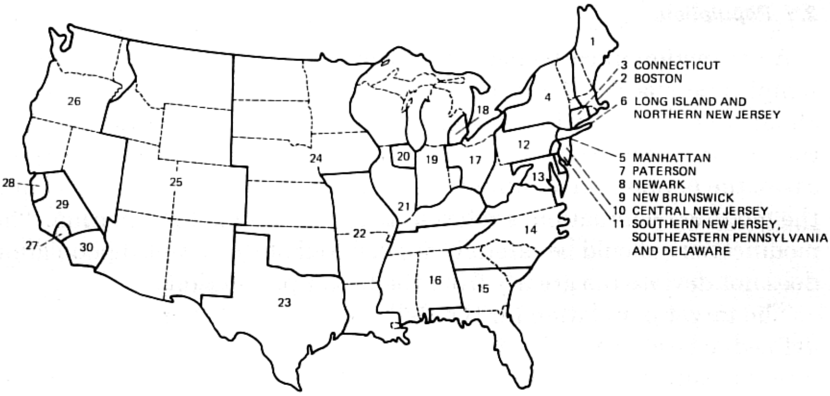

Fig. 2—Geographical stratification of the contiguous 48 states.

odically. Each observation begins at the instant the call attempt is originated and ends when the called party answers or when the calling party abandons. In the course of an observation, the call disposition and the timing sequence of call setup and abandonment events relative to the start of the attempt are recorded. These detailed records satisfy the survey criterion of end-to-end information, and the general application of DLSO satisfies the requirement for systemwide information. In addition, the DLSO definition of DDD call attempts agrees reasonably well with the target population definition for this survey. Therefore the sampled population definition in the previous subsection was intentionally designed to agree closely with the DLSO-DDD population in order to adopt DLSO as the data source for the Bell System call attempt survey.

The sampling plan can be briefly described as a four-stage selection process with stratifications imposed prior to selecting the first- and second-stage sample units. The first-stage units are DLSO bureaus. Prior to selecting the bureaus, the area of the contiguous 48 states was partitioned into 30 mutually exclusive geographical areas which are called primary strata. This stratification is illustrated in Fig. 2. Each primary stratum was designed to consist of a continuous geographical area and to be approximately the same size as the other primary strata with respect to the number of toll-call attempts originated from the area annually. The primary strata are much larger geographically in sparsely populated areas than in densely populated areas due to the second design criterion. This stratification guaranteed a dispersion of the sampled DLSO bureaus throughout the Bell System.

Five primary strata contained only one DLSO bureau. Those bureaus were selected as first-stage or primary sample units with a probability of one. Two DLSO bureaus were selected with replacement within each

Table I — Bell System call attempt survey primary or first-stage sample

Primary sample unit DLSO bureau	Primary stratum	Primary sample unit DLSO bureau	Primary stratum
Salem, Ma.	1	Cleveland, Oh.	17
Providence, R.I.	1	East Liverpool, Oh.	17
Boston, Ma.	2	Plymouth, Mi.	18
Bridgeport, Ct.	3	Pontiac, Mi.	18
New Haven, Ct.	3	Grand Rapids, Mi.	19
Glens Falls, N.Y.	4	Springfield, Oh.	19
White Plains, N.Y.	4	Blue Island, Il.	20
Manhattan, N.Y.	5	East Chicago, Il.	20
Brooklyn, N.Y.	6	Louisville, Ky.	21
Morristown, N.J.	6	Oshkosh, Wi.	21
Paterson, N.J.	7	Monroe, La.	22
Newark, N.J.	8	Saint Louis, Mo.	22
New Brunswick, N.J.	9	Fort Worth, Tx.	23
Asbury Park, N.J.	10	Houston, Tx.	23
Camden, N.J.	10	Salina, Ks.	24
Lansdowne, Pa.	11	Minneapolis, Mn.	24
Norristown, Pa.	11	Phoenix, Az.	25
Pittsburgh, Pa.	12	Las Cruces, N.M.	25
Fairmont, W.V.	12	Spokane, Wa.	26
Baltimore, Md.	13	Spokane, Wa.	26
Baltimore, Md.	13	Compton, Ca.	27
Athens, Ga.	14	Los Angeles, Ca.	27
Charoltte, N.C.	14	Oakland, Ca.	28
Delray Beach, Fl.	15	Oakland, Ca.	28
Melbourne, Fl.	15	Santa Ana, Ca.	29
Columbus, Ms.	16	Santa Ana, Ca.	29
Memphis, Tn.	16	Sacramento, Ca.	30
		Santa Cruz, Ca.	30

of the remaining 25 primary strata. Those selections were made with probabilities proportional to the sizes of the bureaus as measured by the number of annual toll call attempts which originated in the entities observed by the bureaus. Because sampling with replacement was employed to simplify the estimation formulas, four bureaus were selected twice. Two separate bodies of data were collected from each of these four bureaus. As a result of the first stage of sampling, the first-stage sample consists of 55 primary units which correspond to 51 distinct DLSO bureaus. The first-stage sample is listed in Table I. The analysis presented in this paper is based on 11,146 DDD call attempts observed by these bureaus during the study period.

Each DLSO bureau had the responsibility of observing between one and 124 local switching entities at the time the data were collected in October of 1974. A total of 3521 entities was being observed by the 425 DLSO bureaus in existence at that time for an average of approximately eight entities per bureau. Since the larger bureaus had a greater chance to be selected because the probabilities of selection were proportional to the sizes of the bureaus, there is an average of approximately 23 entities per DLSO bureau selected for the first-stage sample.

Somewhere between 20 and 100 service-observing loops were randomly assigned to groups of subscriber line appearances within each of these local switching entities. This assignment represents the second stage of sampling. The second-stage sample unit is a line group which is simply a collection of physically adjacent subscriber line appearances within a local switching entity. A line group varies in size from 50 to 600 subscriber line appearances depending upon the type of switching machine. Since the selection of line groups was made independently in each entity and since the entities associated with a DLSO bureau represented a partitioning of the bureau into mutually exclusive strata, the entities were treated as substrata in the sampling plan. The term "substratification" denotes a partitioning imposed within the first-stage sample units prior to selecting the second-stage sample. The second-stage sample units were randomly selected without replacement. In each line group belonging to the second-stage sample, the assigned service-observing loop was connected to a randomly selected subscriber line appearance. This selection of third-stage sample units generally was repeated within each local switching entity on a weekly basis during the month-long study. Observations of actual DDD call attempts on the selected subscriber lines formed the fourth-stage sample. These observations are referred to as sample elements since they comprise the last-stage sample and as such are members of the sampled population.

2.3 Estimation procedures

Because the Bell System call attempt survey data are not self-weighting, individual data items contribute differently to a system estimate. The complex sampling plan structure discussed in the previous subsection leads to varying probabilities of selection among the individual data items. The individual probabilities of selection are related to the amount of long distance telephone traffic a data item represents. Appropriate traffic weights, which are basically the inverse probabilities of selection for the data items, are used as sampling weights in all calculations to account for the individual contribution of a data item to a system estimate.

Ratio estimators of the form $r = x/y$, where r is an estimate of a population characteristic R and x and y are estimates of the population totals for two random variables X and Y, were used to calculate all system estimates. The distribution of such an estimate is approximately normal for sufficiently large samples. This assumption was used to calculate confidence intervals for the estimates presented in this study in the form $r \pm t\sigma_r$, where r is the ratio estimate, σ_r is the standard error, and t is the appropriate normal deviate. Since 90 percent confidence intervals are used consistently throughout this study, t has the value 1.65. Confidence intervals are not given when the sample size is too small for the normality assumption.

The confidence intervals indicate the precision associated with the population estimates. Precision is a measurement of the probable sampling error associated with a statistical estimate of a population parameter. It gives a measure of the reliability of an estimate with respect to sampling errors; it does not take into consideration nonsampling errors. The 90 percent confidence intervals in this article mean that if the study were repeated 100 times, then 90 out of the 100 confidence intervals which could be calculated for the 100 separate estimates of a given population parameter would be expected to contain the true value of the population parameter.

III. NETWORK RESULTS

Call attempt performance is characterized through the presentation of disposition probabilities, setup and abandonment time distributions, and some aspects of customer retrial behavior. The call disposition results summarize the outcomes of DDD attempts in terms of the relative frequencies of completion and various reasons for failure to complete. The setup time results show the speed of network response during the provision of system signals and intercepts. They also illustrate customer behavior while dialing and answering telephone calls. The abandonment time results illustrate customer behavior in terms of releasing telephone facilities prior to call completion. In some cases, the facilities are released after an explicit system indication of failure to complete, while in other cases, the facilities are released following a subjective judgment of failure to complete or a desire to terminate the attempt prematurely. The customer retrial results characterize retrials which are initiated within 60 seconds of a failure to complete. Attention is focused on each of these attempt characteristics individually in Sections 3.1 through 3.3, respectively.

3.1 Call disposition

A summary of DDD call attempt dispositions is given in Fig. 3. An estimated 70.7 percent of the attempts are completed satisfactorily. Approximately one out of every four attempts are incomplete due to a called customer did not answer (DA) condition, called customer line busy (BY) condition, calling customer dialing irregularity (CDI), or called station number change or disconnect (C/D) situation. These customer-dependent failures to complete account for 24.8 percent of all DDD attempts and 84.6 percent of all DDD failures to complete. The second largest category of failures is manifested by abandonments without system responses (NR—no response) after dialing valid telephone numbers; they account for 2.6 percent of all DDD attempts and 8.9 percent of all DDD failures

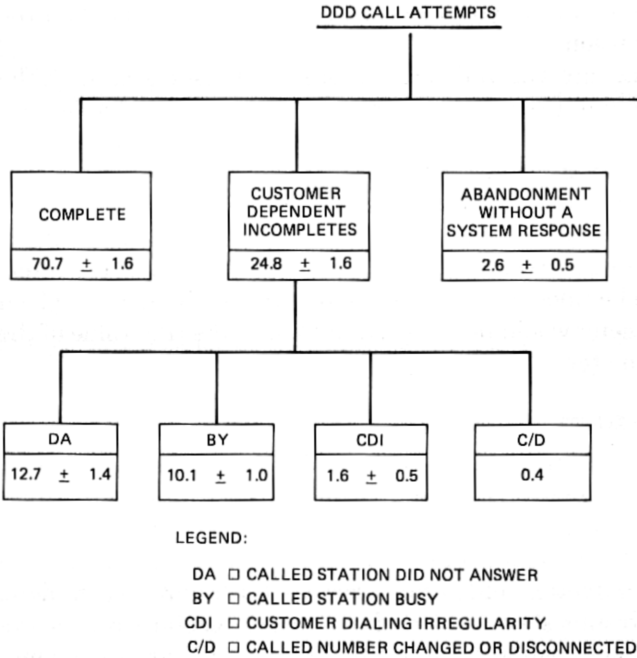

Fig. 3—DDD call attempt disposition percentage estimates with 90 percent confidence intervals.

to complete. These abandonments occur because the calling customer aborts prematurely or the network fails to respond properly to the request. The third and final category of incomplete attempts consists of equipment blockages and failures (EB & F). Since equipment blockages occur because of insufficient equipment to service the request and equipment failures are symptomatic of faulty equipment, the responsibility for these EB & Fs clearly belongs to the telephone network. These network failures account for 1.9 percent of all DDD attempts and 6.5 percent of all DDD failures to complete.

Complete attempts are calls properly processed by the switching and signaling network. They represent the ideal in call disposition since they fulfill the calling party service requests and generate revenues for the telephone companies. Customer-dependent failures (DA, BY, CDI, C/D) also are properly processed attempts from a switching and signaling viewpoint. While these attempts cannot be completed for reasons beyond network control, the calling party is informed about the nature of the failure. Therefore, the results in Fig. 3 show that at least 95.5 percent of all DDD attempts are properly processed by the telephone network. This percentage is a lower bound because a substantial number of abandonments without a system response are in fact premature disconnects

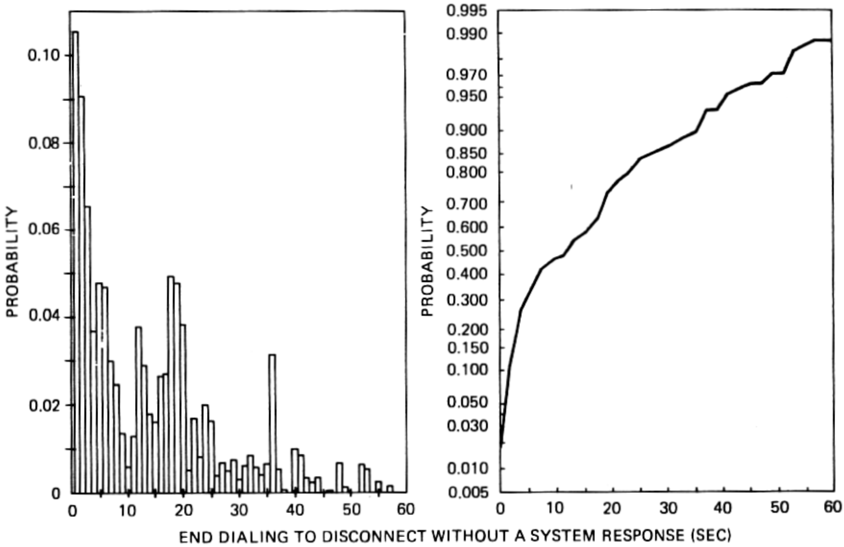

Fig. 4—Distribution of the time from end of dialing to abandonment without a system response.

on the part of the calling customers. A comparison of the distribution of time from end of dialing to abandonment without a system response in Fig. 4 with the distribution of time from end of dialing to the first system response in Fig. 5 illustrates that attempts abandoned within five seconds after dialing probably were intentionally prematurely disconnected by the calling parties, since the customers could have little expectation that a response should have been received during that interval. Only a few system responses are received within that time interval. This part of the distribution represents 30 percent of the NR conditions. At the other extreme of the distribution, it appears that about 14 percent of the NR conditions, or about 0.4 percent of all attempts, may be reasonably classified as network failures since very few system responses occur after 30 seconds. The remaining 56 percent of the NR distribution overlaps the system response distribution, and those abandonments cannot be easily classified as premature disconnects or network "high and dry" conditions.

While at least 95.5 percent of all DDD attempts are properly processed from a switching and signaling viewpoint, the disposition results also show that 1.9 percent fail to complete due to system blockages or equipment problems. This EB & F estimate is a lower bound for network failures since some of the abandonments without a system response, which were discussed above, represent network "high and dry" conditions. Individual estimates for blockages and equipment failures cannot be calculated because a common network signal, which is a tone inter-

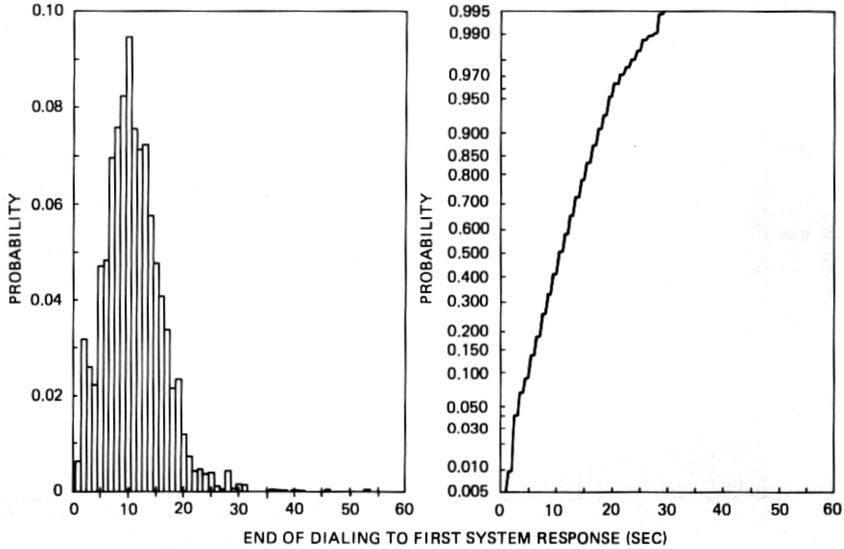

Fig. 5—Distribution of the time from end of dialing to the first system response after dialing a valid telephone number.

rupted 120 times per minute, is often issued for both failures. The telephone companies are responsible for providing and maintaining sufficient equipment to handle service requests within reasonable blockage and failure bounds. Since traffic loads are statistical in nature and equipment failures are random in nature, the system is continuously monitored and tuned to assure reasonable service within proper economic constraints. The EB & F estimate is an indication of the overall impact of system procedures for the provisioning and maintenance of equipment upon the DDD network response to customer service requests.

The reciprocal of the completion ratio gives the average number of attempts per successfully completed call. Using the DDD completion ratio of 0.707, this average is computed to be 1.4 attempts per successful completion. Substantial improvement in this average can only come about by a reduction in failures which are dependent upon calling and called customer behavior, since such failures account for about 85 percent of all DDD failures to complete. The occurrence of such failures can be reduced through the mutual cooperation of telephone companies and telephone customers. Reasonable service agreements in terms of the types and amounts of equipment required for individual customer communication requirements in conjunction with the application of new services made possible through the advent of Electronic Switching Systems (ESS) such as call forwarding and call waiting can produce a substantial impact.

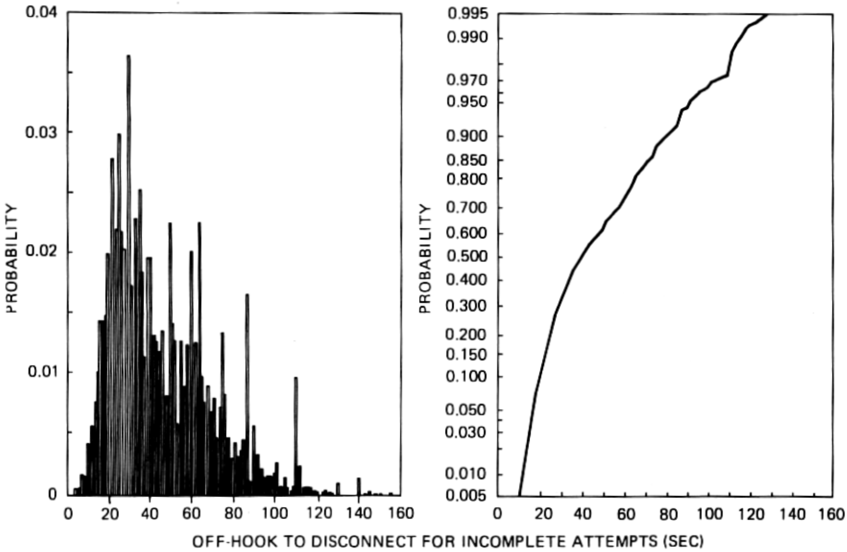

Fig. 6—Call attempt time for incomplete DDD attempts.

Complete eradication of all network failures would only decrease the average number of attempts per completed call by about 5 percent. Reduction of network failures is an area of continuing interest, and the historical record of EB & F reduction shows continuous improvement. Whenever practical, new technological advances continue to reduce network failures. For example, modern ESS offices will make a second attempt automatically if they are able to detect an irregularity in establishing the next link in a call.

3.2 Call attempt time

Call attempt time is defined as the nonconversational period which commences with calling station off-hook and terminates with called station answer for completed calls and with calling station return to on-hook for failures to complete. This usage of network facilities during the call setup process is absorbed as network overhead since revenues are not directly obtained. The average call attempt time with accompanying 90 percent confidence interval is 45.1 ± 1.8 seconds for incomplete attempts and 32.8 ± 0.7 seconds for completed calls. Call attempt times for incomplete attempts are not only longer on the average than those for completed calls, they are also more variable as is seen by the standard deviations of 24.7 and 11.0 seconds respectively. The distributions of call attempt time for incomplete attempts and completed calls are presented in Figs. 6 and 7 respectively. The overhead represented by these call attempt times amounts to an average of 50.8 seconds per

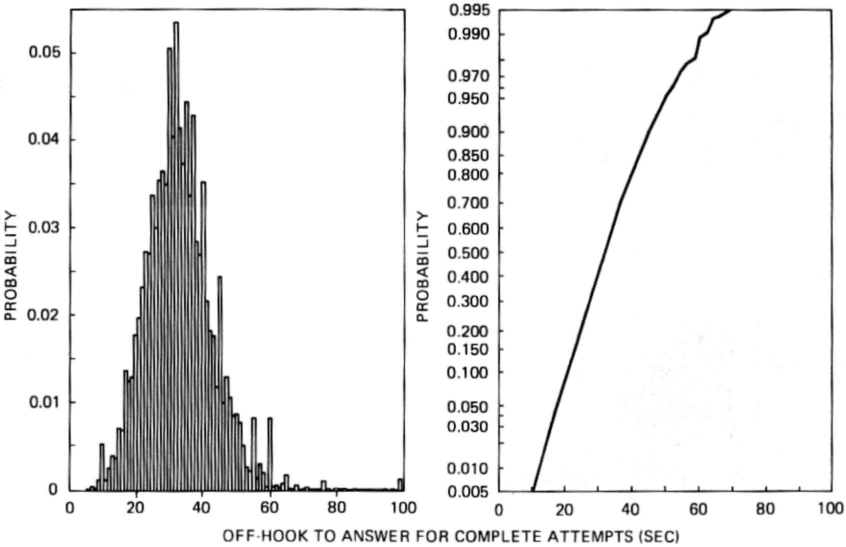

Fig. 7—Call attempt time (nonconversational) for successfully completed DDD attempts.

completed call, since 1.4 attempts are initiated for each successful attempt (32.8 + 0.4 × 45.1). If the time from off-hook to start of dialing plus start of dialing to end of dialing (13.8 sec) is excluded on the basis that it impacts mainly upon local facilities, the toll network overhead is 31.5 seconds per completed call (50.8 − 1.4 × 13.8).

Further insight into call attempt time is gained by considering the customer-controlled and network-controlled components. The components of the call attempt time interval are schematically illustrated in Fig. 8, which also contains the average holding time associated with each component. A more detailed statistical characterization, which includes the mean, standard deviation, and 10, 50, and 90 percent points of the cumulative distribution function, is given for each component in Table II. The calling customer components of call attempt time include the intervals from off-hook to start of dialing and from start of dialing to end of dialing, which are common to all attempts, and the intervals from the beginning of a system response to disconnect, from the beginning of an answer at the wrong station to disconnect, and from the end of dialing to abandonment without a system response for incomplete attempts. Called customer behavior is directly illustrated in two call attempt time components; namely, the intervals from the start of ringing to answer and from the end of dialing to answer with no audible ringing. These customer controlled components of call attempt time are discussed in Section 3.2.1 below. The network controlled components include the intervals from end of dialing to any of the various network signals, an-

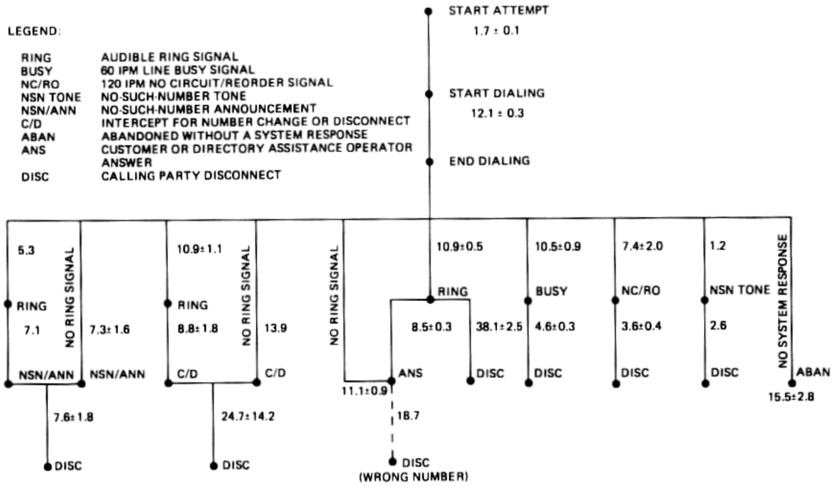

Fig. 8—Average DDD call attempt setup and abandonment times (seconds) with 90 percent confidence intervals.

nouncements, or manual intercepts, and they are discussed in Section 3.2.2 below.

3.2.1 Customer-controlled components of call attempt time

The intervals from off-hook to start of dialing and from start of dialing to end of dialing constitute the service request period of a call attempt. On the average, a request consumes 13.8 seconds of the overhead time per attempt. The type of dialing equipment at the originating location substantially impacts upon this service request time, since the average dialing time per DDD attempt is 13.7 seconds at rotary dial stations and 7.0 seconds at *TOUCH-TONE®* dialing stations. The interval from off-hook to start of dialing is also slightly longer for rotary dial customers than for *TOUCH-TONE* customers. The end result of these differences due to dialing equipment are rotary-dial service request times on the average of 15.5 seconds which are almost twice as long as the *TOUCH-TONE* service request times, which average 8.6 seconds.

In addition to influencing the service request phase of the call attempt process, calling customers also influence the speed of abandonment associated with incomplete or incorrectly completed attempts. Customers generally abandon faster when there is a positive network indication of failure to complete than when a subjective judgment of failure is required. This finding is borne out by a comparison of the abandonment times following network indications of line busy (BY), no circuit or reorder (NC/RO), and no-such-number (NSN) conditions with the abandonment times associated with disconnects after receipt of audible

Table II—DDD call setup and abandonment time statistics

Call setup or abandonment interval	Mean (sec)	Std. dev. (sec)	Cumulative distribution percentage points (sec) 10%	50%	90%
Off-hook to start of dialing	1.7 ± 0.1	2.0	1	2	4
Start of dialing to end of dialing	12.1 ± 0.3	5.1	6	12	18
End of dialing to ring before answer or disconnect	10.9 ± 0.5	5.0	5	11	17
End of dialing to answer without a ring signal	11.1 ± 0.9	5.3	5	10	17
Start of ringing to answer	8.5 ± 0.3	7.2	3	6	15
Start of ringing to disconnect without an answer	38.1 ± 2.5	20.7	18	33	59
Answer to disconnect for wrong numbers	18.7	8.9	—	—	—
End of dialing to busy (60 IPM) signal	10.5 ± 0.9	5.2	5	10	17
Start of busy to disconnect	4.6 ± 0.3	3.7	2	3	8
End of dialing to no circuit/reorder (120 IPM) signal	7.4 ± 2.0	7.4	0	6	15
Start of no circuit/reorder to disconnect	3.6 ± 0.4	2.3	2	3	6
End of dialing to no-such-number (NSN) tone	1.2	1.4	—	—	—
Start of NSN tone to disconnect	2.6	1.7	—	—	—
End of dialing to ring prior to NSN Announcement	5.3	4.1	—	—	—
Start of ringing to NSN announcement	7.1	4.9	—	—	—
End of dialing to NSN announcement without a ring signal	7.3 ± 1.6	5.4	1	6	11
Start of NSN announcement to disconnect	7.6 ± 1.8	10.4	2	5	13
End of dialing to ring prior to intercept for number change or disconnect (INT)	10.9 ± 1.1	4.6	6	10	19
Start of ringing to INT	8.8 ± 1.8	6.3	3	9	15
End of dialing to INT without a ring signal	13.9	4.4	—	—	—
Start of INT to disconnect	24.7 ± 14.2	24.6	4	15	81
End of dialing to customer abandonment without a system response	15.5 ± 2.8	17.8	1	12	35

ringing for DA conditions and with disconnects without a system response for network "high and dry" conditions. The reasons for the relatively slow abandonment times associated with intercepts for number changes or disconnects (C/D) will be explained later. The BY, NC/RO, and NSN indications immediately signal failure and encourage the calling party to abandon; while in other cases, the calling party abandons only after judging that the called party had sufficient time to answer or that the network has had sufficient time to respond.

Calling customers also appear to differentiate between the various definitive network indications for failure. The NSN tone, which continuously varies in frequency, is quite different from the BY and NC/RO signals. It consistently encourages rather fast abandonments as can be seen by the estimates for the mean and standard deviation in Table II. Either the characteristics of the NSN tone itself or the unfamiliarity of the tone may cause this behavior. More surprisingly, however, customers also seem to distinguish between BY and NC/RO signals since both the mean and the standard deviations are smaller for abandonment times after NC/RO signals compared with those after BY signals. The main distinction between these signals is that the BY tone is interrupted 60 times per minute and the NC/RO tone is interrupted 120 times per minute.

Abandonments which follow definitive network signals for failure to complete occur faster than those which follow recorded, automatically composed (computer-generated) or manual intercepts. NSN announcements and C/D intercepts convey verbal messages, and this transfer of information requires additional time. While all NSN announcements were automated, one third of the C/D intercepts were manual. This partially explains the slower C/D abandonment time, since the average abandonment time for the manual C/D intercepts is approximately 10 seconds slower than for the automated C/D intercepts. In addition, the average abandonment time following automated C/D intercepts is almost twice as slow as the average for automated NSN announcements. In some instances an automated C/D intercept is followed by an "operator intercept cut-through" to provide the calling party with an opportunity to discuss the problem with a person. In such cases the time to abandon could well be even greater than for an immediate manual intercept. The occurrence of such cut-throughs are not recorded in the data base; however, if it occurred during a significant number of the automated C/D intercepts, it might well account for slower abandonment times. That some such cut-throughs occurred is suggested by the presence of several outlying values in the automated C/D abandonment time data. These outlying values along with several long holding times for the manual C/D intercepts inflate the confidence interval substantially and result in an average overall C/D abandonment time of

24.7 seconds which is quite larger than the median of 15 seconds. Excluding the automated C/D intercepts which appear to be followed by operator intercept cut-throughs, the average abandonment time for automated C/D intercepts is still longer than for NSN announcements. Since the standard messages which are conveyed are similar in length, this difference must be attributed to customer reaction.

While some type of system response is encountered for 97.4 percent of all DDD attempts, the remaining 2.6 percent are abandoned after dialing without a system response. They are abandoned because the calling party no longer desires to complete the call, is interrupted by some event, or perceives that the network has failed to respond properly to the dialed digits. Abandonments without a system response were discussed in Section 3.1 above. The conclusions were (*i*) about 30 percent clearly appear to abort prematurely, (*ii*) about 14 percent clearly appear to be network failures, and (*iii*) about 56 percent of the distribution for these abandonment times overlaps the distribution for the times from end of dialing to first system response.

The final calling customer abandonment characteristic to be discussed in this article pertains to the 19 wrong numbers which were observed during the survey. The average time from answer at a wrong station to abandonment is 18.7 seconds; however, this estimate is based upon a very small number of observations. The confidence interval for this estimate is omitted in Fig. 8 and Table II because the small number of observations negates the meaningfulness of the confidence interval calculation.

The large differences in average abandonment time among the various reasons for abandoning cause the high variability seen earlier for the call attempt times associated with incomplete attempts. The longest average call attempt time is associated with the single most frequent reason for failure to complete, called customer did not answer. The average call attempt time for DA conditions is 62.8 seconds, of which 38.1 seconds are consumed by the calling party listening to ringing. An average of between six and seven rings are received before the calling party abandons. Since over 99 percent of all DDD answers occur prior to the 38.1 second average abandonment time, it is meaningful to investigate possible benefits associated with an effort to change customer behavior through educational programs. Not only may it be beneficial to discourage very long holding times, it may also be beneficial to discourage very short holding times to give called customers more opportunity to respond.

At the other end of the abandonment time spectrum, abandonments following a busy signal occur rather fast. However, 30 percent of the customers who encounter a BY signal remain on the line over 5 seconds following the initial receipt of the tone. Since 10.1 percent of all DDD attempts result in busies, this excessive holding time represents a drain on network facilities without any possibility of completion.

Focusing attention at the terminating end of a call, one aspect of called customer behavior is provided by the following answer time results: (*i*) the average time from end of dialing to called station answer with audible ringing observed at the calling station is 19.4 seconds, and (*ii*) the average time from end of dialing to called station answer without the receipt of audible ringing at the calling station is 11.1 seconds. The substantial difference between estimates is mainly attributed to toll directory assistance calls. The first category, which represents 96.1 percent of all DDD calls (messages), contains relatively few calls to toll directory assistance (5 percent), while slightly over two-thirds of the calls in the second category are to toll directory assistance. The average time to answer for toll directory assistance operators is 7.4 seconds when ringing is heard at the calling station and 1.1 seconds when it is not. This suggests that in the former case the operators are busy when the call appears, and that in the latter case an idle operator answers almost immediately; therefore, ringing is not observed at the calling station. Customer answers take an average of 8.5 seconds when ringing is observed at the calling station and 4.2 seconds when it is not. These results along with the composition of the two categories described above account for about two-thirds of the difference between the 19.4 and 11.1 second estimates. The remaining third is explained by differences in connect times for toll directory assistance calls and other DDD calls. The average time to establish a connection from the originating local switching office to the called station is 3.8 seconds shorter for toll directory assistance calls than for other DDD calls.

About 71 percent of the average call attempt time is under customer control during the service request or answer and abandonment phases of the call attempt process. The service request phase represents 33 percent of the call attempt time, and the answer and abandonment phase represents 38 percent. The remaining 29 percent is under network control for the purpose of establishing a physical connection between the calling and called stations.

3.2.2 Network controlled components of call attempt time

Upon completion of dialing, the network attempts to route a call to the called station by establishing transmission and signaling paths between a number of local and toll switching offices. A successful connection may be established, whereupon audible ringing is normally returned to the calling station, or the network may be unable to reach the called station, whereupon a specific network indication of failure to complete is normally returned to the calling station. The first system response is defined as the first network signal, network intercept, or called station answer without audible ringing at the calling station which follows the end of dialing. The distribution of these response times is given in Fig. 5 and has an average time to respond of 10.9 ± 0.5 seconds with a standard deviation of 5.3 seconds. In Fig. 8 and Table II, summary statistics are listed for the individual system responses which include answer without audible ringing at the calling station, audible ringing, busy signal, no circuit or reorder signal, no-such-number tone or announcement, and intercept for number change or disconnect.

The average times from end of dialing to ring prior to answer or disconnect, busy, NC/RO, and NSN tone are 10.9, 10.5, 7.4, and 1.2 seconds respectively. The averages for ring and busy are relatively long because a connection must be established to the far-end local switching office and the called customer line must be tested before a ring or busy signal is returned to the calling station. A NC/RO signal is returned to the calling station when an equipment blockage or failure occurs. The average time from end of dialing to receipt of the NC/RO signal is shorter than the ring and busy averages because the signal is applied at the office in which the EB & F is encountered. That office may be the originating local switching office, an intermediate toll switching office, or the terminating local switching office. The average time from end of dialing to a NSN tone is the shortest of the four because the tone generally can be applied at the originating local switching office or the first toll switching office encountered in the switching path.

The two remaining responses which qualify as a first system response after dialing are recorded, composed, or manual intercepts for no-such-number conditions and number change or disconnect conditions. The NSN intercept is encountered near the originating end of a connection in a manner similar to the NSN tone. The C/D intercept occurs at the far-end of a connection. As a result of these distinctions, it is clear why the average time from end of dialing to C/D intercepts is almost twice as long as the average for NSN intercepts. Both types of intercept often are preceded by audible ringing at the calling station. Note that the average time from end of dialing to ringing prior to a NSN intercept is only 5.3 seconds. This clearly reflects the fact that NSN intercepts occur towards the near end of a connection. The average time from end of dialing to ringing prior to a C/D intercept is 10.9 seconds which is and should be in agreement with the average for ringing prior to answer or disconnect.

3.3 Fast retrials

In the event that an attempt is not successfully completed, the calling party must decide to permanently or temporarily abandon or to try again. The retrial probability and time to retry are completely determined by calling customer behavior under the influence of the various

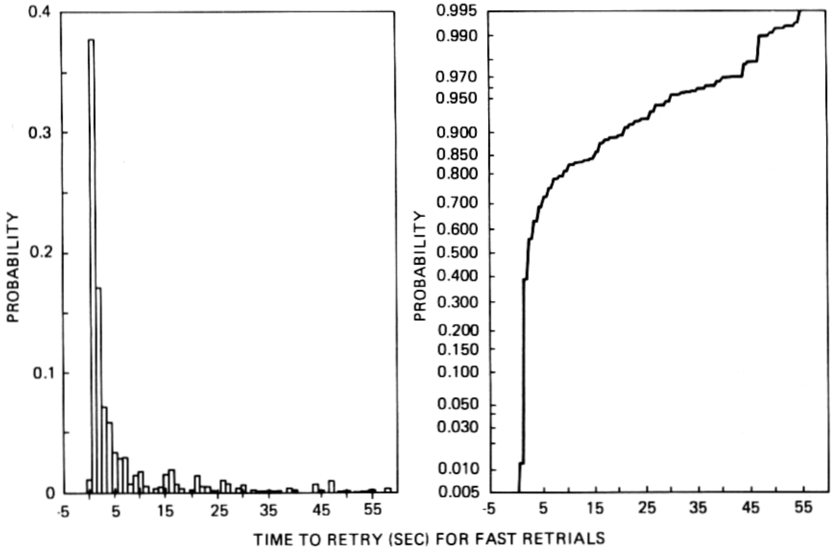

Fig. 9—Time to retry for retrials which occur within 60 seconds of a DDD failure to complete.

network indications for failure to complete. Retrial disposition is a function of both calling and called customer behavior, and to a lesser degree network behavior such as the persistence of NC/RO conditions.

An estimated 19.1 ± 2.5 percent of all DDD attempts which fail to complete are retried within 60 seconds of the failure, and 34.3 ± 5.4 percent of those retrials are successful. Over 50 percent of these fast retrials are initiated within two seconds of the abandonment time for the preceding failure. This time to retry is characterized by the distribution given in Fig. 9 for which the average is 6.7 ± 1.3 seconds and the standard deviation is 10.7 seconds. The substantial difference between the average and median times is caused by the high degree of positive skewness associated with the distribution.

Fast retrial statistics are summarized in Table III for the most frequent types of failures to complete. The fast retrial rates and the contribution to the overall fast retrial phenomenon for individual types of failures to complete are listed in the top part of the table. The major conditional disposition probabilities associated with retrials after failure to complete are given in the lower part of the table. Since these probabilities were derived from rather small samples, they are only intended to provide an indication of what happens to fast retrails, and are quoted without confidence limits. The sample size for the DA, BY, abandoned without a system response, NC/RO, and NSN results are 95, 183, 166, 66, and 85 attempts respectively.

Almost one-third of all DDD fast retrials follow a failure due to called

Table III — Retrial characteristics for retrials occurring with 60 seconds of an unsuccessful attempt

Unsuccessful call attempt dispositions	Percent which retry* (within 60 seconds)	Percent of retrials* (within 60 seconds)
Called party did not answer (DA)	5.2 ± 1.6	11.7 ± 3.9
Called party busy (BY)	17.3 ± 3.8	30.9 ± 5.1
Calling party abandoned without a system response (ABAN)	53.4 ± 6.5	24.4 ± 4.2
No circuit/reorder condition (NC/RO)	41.7 ± 13.8	11.2 ± 3.5
No-Such-Number condition (NSN)	55.5 ± 8.8	14.2 ± 4.7

Unsuccessful call attempt disposition	Conditional disposition probabilities (60 second retrials)		
Called party did not answer (DA)	Complete: 0.23	DA: 0.13	No order: 0.57
Called party busy (BY)	Complete: 0.20	BY: 0.61	
Calling party abandoned without a system response (ABAN)	Complete: 0.46	No order: 0.19	
No circuit/reorder condition (NC/RO)	Complete: 0.49	NC/RO: 0.40	
No-such-number condition (NSN)	Complete: 0.31	NSN: 0.23	No order: 0.24

Percent which retry—The percent of call attempts which fail to complete and are tried again within 60 seconds for the specific failures listed.

Percent of retrials—The percent of all retrials occurring within 60 seconds of a failure to complete which are attributable to the specific failures listed.

customer busy. These retrials are very likely to result in a second BY condition as is evidenced by the conditional probability for a BY following a BY of 0.61. The conditional probability for successful completion after a BY condition is only 0.20. While the fast retrial rate for called customer did not answer conditions is relatively low, such retrials account for 11.7 percent of all fast retrials because DA conditions occur relatively frequently on first attempts. Over half of these retrials which follow DA conditions are no orders, i.e., the calling party goes off-hook and back on-hook without dialing any digits or dials a partial number and returns to the on-hook state within 10 seconds after the end of dialing. The conditional probability for successful completion following a DA conditions is 0.23.

Fast retrial rates are relatively high for attempts which are abandoned without a system response or encounter NC/RO indications. The conditional probabilities for successful completion are also relatively high at 0.46 and 0.49 respectively. While less than 10 percent of the retrials after an abandonment without a system response also are abandoned without a system response, the reoccurrence of NC/RO having already received a NC/RO indication is very likely as can be seen by the conditional probability of 0.40 in Table III.

The fast retrial rate is also relatively high for attempts encountering NSN intercepts. The conditional disposition probabilities for fast retrial following NSN intercepts present a mixed picture. These probabilities are 0.31, 0.23, and 0.24 for successful completion, NSN intercepts, and no orders respectively. The latter two probabilities indicate substantial confusion on the part of the calling party, since the first suggests the customer again dials the incorrect number while the second indicates the customer is too uncertain to continue dialing.

Fast retrials comprise only a small segment of the complete retrial process, since hours and even days may elapse between a failure to complete and a legitimate retrial. The data collection scheme for the DLSO call attempt survey was not designed to capture information on other than immediate retrials; however, a systemwide survey to characterize the complete retrial process is currently in progress at Bell Laboratories.

IV. CORRELATION OF NETWORK RESULTS WITH SEVERAL ATTEMPT CHARACTERISTICS

Call disposition is strongly influenced by certain attempt characteristics such as class of subscriber service and calling distance. Call setup time also is influenced by these characteristics and by the type of switching which is encountered during the setup process. While the class of subscriber service effects are totally dependent upon customer influences, the calling distance and switching machine effects are also dependent upon network influence. Call disposition characteristics vary by day of week and time of day; however, the major causative influence for these variations is the relative traffic composition by class of subscriber service. The roles which class of subscriber service, calling distance, and type of switching play in the call attempt process, are explored in the following subsections.

4.1 Class of subscriber service

Service observing is restricted to originating attempts. While the originating class of service is known for most observations, the terminating class of service is unknown for all observations except for calls to directory assistance and INWATS calls. The survey results discussed in this subsection are predicated on originating class of service with the main service distinction being residential versus business. Substantial differences in customer behavior are clearly shown by the DDD completion rates of 76.6 ±2.2 and 66.9 ±2.5 percent for business and residential customers respectively. The primary cause of this 10 percentage point difference is attributed to called customer behavior in terms of did not answers and busies, since the business DA rate of 8.9 ±1.6 percent is approximately half the residential rate of 16.4 ±2.3 percent, and the business BY rate of 8.6 ±1.4 percent is approximately three-fourths the residential rate of 11.3 ±2.1 percent. Of the remaining dispositions, only customer abandonments without a system response border upon differing significantly. These estimates are 2.7 ±0.7 and 1.7 ±0.5 percent for business and residential attempts. Although the business abandonment rate is higher, business customers are as patient as residential customers in the sense that the median holding time prior to abandoning without a system response is 12 seconds in both cases. In addition, the distributions for the time from end of dialing to first system response are basically the same for business and residential traffic. These systemwide abandonment time and response time similarities for business and residential traffic seem to contradict the difference between the business and residential abandonment rates. The cause of this apparent contradiction is not known. It may be due to some characteristic such as routing for which the information is not available, or it may be due to sampling error.

Traffic composition in terms of the relative percentages of business and residential originated attempts exerts a strong influence upon overall DDD dispostion characteristics. In the following paragraphs it is shown that variations in the mixture of business and residential originations are responsible for many day of week, time of day, and calling distance trends associated with DDD call dispositions. In general, completion increases as the percentage of business originations increase because the occurrence of called station did not answer and busy conditions decline.

Weekend traffic is primarily residential in nature. Weekday traffic is almost evenly split between business and residential originations. As a result of this difference in traffic composition, the weekend completion rate of 69.1 ± 4.8 percent is lower than the weekday completion rate of 71.8 ± 1.8 percent. A high rate of DA conditions, which is typical of residential traffic, is the primary cause of the lower weekend completion rate.

In addition to this weekday versus weekend variation, traffic composition varies by hour of day. The percentage of business-originated DDD attempts by hour of day for weekday traffic is illustrated in Fig. 10 for the hours of 8:00 A.M. to 10:00 P.M. The business-residential composition is fairly constant during the *morning* hours of 8:00 A.M. to 12:00 noon. During the *noon* hour the business originations drop by about 10 percentage points. In the *afternoon* business originations initially jump to about 58 percent of the total traffic and then gradually decrease to about 49 percent of the traffic by 4:00 P.M. At this time a *transitional* period begins during which the business-residential mixture changes dramatically. By 7:00 P.M. the percentage of business originations is down to about 16 percent of the total traffic. The *evening* traffic from 7:00 to 10:00 P.M. consists of almost completely residential originated

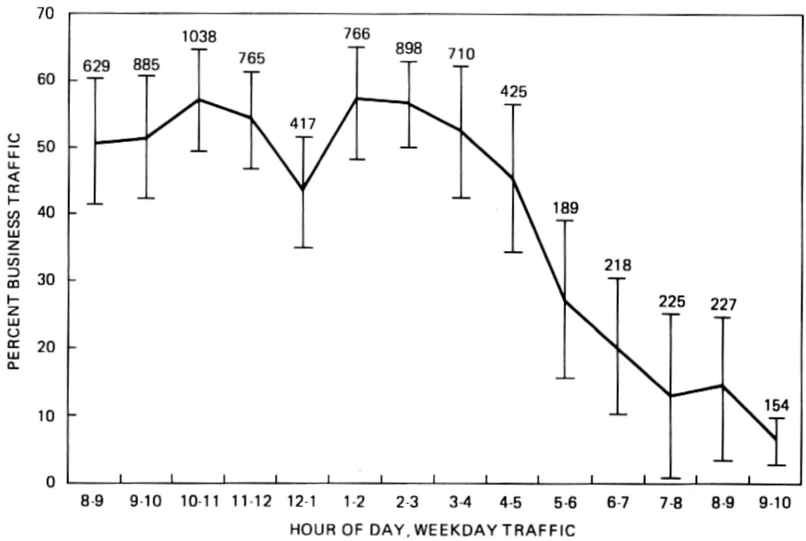

Fig. 10—Percent business-originated attempts with 90 percent confidence interval by hour of day.

attempts.

The variations in business-residential traffic composition are clearly evident in the disposition results for the five periods of day in italics above. The estimates for percent complete, which are listed in Table IV, increase and decrease along with the percentage estimates for business-originated attempts which are also listed in Table IV. These changes in completion are accompanied by corresponding changes in the opposite direction for the composite estimates of DA + BY conditions. While completion increases when the percent of business-originated attempts increases due to fewer DA and BY conditions, the increase in completion is not as great as the decrease in DA + BY conditions because the calling customer abandonment rate also increases with business-originated attempts. Considering the previous description of business and residential call disposition characteristics, it is clear that the time of day variations in call disposition are essentially caused by variations in the business-residential traffic composition throughout the day.

Business-residential traffic composition also varies with calling distance, which is defined as the airline distance between the originating and terminating local switching offices. While the majority (56 percent) of DDD attempts with calling distances between 26 and 400 miles originates from residential stations, the majority (also 56 percent) of the attempts with longer calling distances originates from business stations. This change in traffic composition contributes to several call disposition trends related to calling distances. Positive correlation of completion

Table IV — DDD call disposition estimates with 90 percent confidence intervals for five periods of the day for weekday traffic

Disposition	Percentage estimates by period of day				
	8–12 A.M.	12–1 P.M.	1–4 P.M.	4–7 P.M.	7–10 P.M.
Complete to desired station	74.1 ± 2.3	67.5 ± 8.3	72.0 ± 2.9	66.5 ± 5.0	59.1 ± 8.6
Called station did not answer	8.7 ± 1.5	15.2 ± 6.3	11.6 ± 2.1	13.6 ± 2.6	25.3 ± 9.0
Called station busy	9.6 ± 1.4	11.3 ± 6.2	9.4 ± 1.6	15.1 ± 5.5	11.5 ± 3.9
Calling customer abandoned without a system response	3.4 ± 0.8	1.7	2.3 ± 0.7	1.4	1.2
Percent business traffic	53.6 ± 6.2	43.5 ± 8.3	55.1 ± 6.2	33.2 ± 7.1	13.3 ± 5.8

with calling distance comes about because the business completion rate is higher than the residential rate and the percentage of business originations increases as calling distance gets longer. In a similar manner, negative correlation of the DA + BY rate with calling distance comes about because the business DA + BY rate is lower than the residential rate and the percentage of business originations increases as calling distance gets longer. The abandonment rate without a system response also is positively correlated with calling distance. In this case, the business abandonment rate of 2.7 ±0.7 percent appears to be invariant with calling distance, while the residential abandonment rates of 1.5 ±0.6 percent for attempts with calling distances between 26 and 400 miles and 3.0 ±2.1 percent for those with calling distances greater than 400 miles appear to be positively correlated with calling distance. These trends, along with additional call disposition trends which are related to calling distances but are not influenced by class of subscriber service, are discussed more thoroughly in Section 4.2.

Class of subscriber service plays only a minor role in determining call setup and abandonment times, since statistically, call setup and abandonment time results for business- and residential-originated traffic are similar with the exception of customer dialing times. The average residential rotary dialing time is 1.5 seconds longer than the average time for business customers. The average residential *TOUCH-TONE* dialing time is 1.3 seconds longer than the average time for business customers. Residential and business customers originate almost the same percentage of Home company, Home Numbering Plan Area (H-HNPA) attempts. Therefore, the differences in dialing times cannot be attributed to calling patterns in which one group is required to dial NPA codes more frequently than the other. Most likely, business customers have shorter dialing times because they use the telephone more frequently or are more familiar with the numbers they call. The only clear correlations of call setup and abandonment times with day of week or time of day once again is for customer dialing time for which the average dialing time on weekends is longer than the average for weekdays, and the average dialing time in the evening is longer than the average during the remainder of the day. These findings are in total agreement with the differences between business and residential dialing times and the traffic composition characteristics which were discussed previously. Namely, dialing times tend to be longer when the traffic is dominated by residential originations and shorter when the traffic is dominated by business originations.

4.2 Calling distance

Beyond the customer influences discussed above, there are additional network effects upon the call attempt process that appear in the calling

Table V—DDD call disposition percentage estimates with 90 percent confidence intervals as a function of calling distance

Disposition	26–400 miles	>400 miles
Complete to desired station	69.8 ± 2.0	72.0 ± 3.9
Called station did not answer	13.9 ± 1.6	10.9 ± 2.8
Called station busy	9.8 ± 1.3	9.0 ± 2.3
Calling customer abandoned without a system response	2.3 ± 0.5	4.0 ± 2.1
No circuit/reorder condition	1.4	2.5
No-such-number condition	1.7 ± 0.7	0.5
Other failures to complete	1.2 ± 0.5	1.1

distance discussion in this section and in the type of switch discussion in Section 4.3 below.

As stated previously, calling distance is defined as the airline distance between the originating and terminating local switching offices. Generally, as this distance increases, the call setup process becomes more complex due to additional toll switching, intraoffice processing, and interoffice trunking. This added setup complexity has considerable impact upon call disposition and setup times. It does not have much impact upon customer abandonment times.

Direct-Distance-Dialing attempts with calling distances of 25 miles or less are excluded from the following analyses because many such attempts do not belong to the sampled population for the DLSO call attempt survey (see Section 2.1). INWATS attempts are also excluded from the following analyses because the calling distances are not known for the intrastate, INWATS attempts. All remaining attempts to both customer stations and toll directory assistance operators are included in the calling distance analyses which follow.

Disposition results for attempts with calling distances between 26 and 400 miles and for attempts with calling distances greater than 400 miles are listed in Table V. As stated in the previous subsection, the completion and abandonment without a system response rates both increase and the DA + BY rate decreases as the calling distance becomes longer. The completion and DA + BY trends are primarily attributed to changes in business-residential traffic composition. The abandonment without a system response trend is attributed to a dependence of residential abandonments upon calling distance.

The occurrence of no circuit/reorder conditions increases as the calling distance gets longer. This trend is caused by the added complexity to the call setup process. The increase in toll switching creates more opportunities for failure to obtain the required facilities and for equipment irregularities.

The occurrence of no-such-number conditions decreases as calling distance increases due to the substantial difference between the 3.3 ±1.7

percent intra-NPA NSN rate and the 0.7 ±0.3 inter-NPA rate. While over three-fourths of the intra-NPA NSN conditions are due to the omission of the toll access code 1, which is required in many areas of the country, only about one-third of the inter-NPA NSN conditions are due to that reason. Apparently the presence of an NPA code in the called number reminds the calling party to dial the access code.

The impact of calling distance upon setup time is shown in Table VI. Average dialing times are greater for attempts with long calling distances because such attempts more frequently require an NPA code to establish a call. The interval from end of dialing to a ring or busy signal also increases as calling distances get longer because additional switching tends to slow down the setup time. The estimates for end of dialing to a NC/RO signal do not indicate any dependence upon calling distance. Because NC/RO conditions can occur at any intermediate office within the switching path and ring or busy are always returned from the terminating local switching office, the average time from end of dialing to NC/RO is shorter than to ring or busy, while the standard deviation is wider.

The last four intervals listed in Table VI represent customer abandonment times. The second and third of these intervals are for abandonments after positive indications of failure to complete; namely, busy and NC/RO signals. The results show that there is no correlation between calling distance and the time to disconnect after hearing a NC/RO signal. The results also indicate that there may be a positive correlation between calling distance and the time to disconnect after hearing a busy signal; however, the evidence for such a correlation is rather weak. The two remaining abandonment times for disconnect after receipt of audible ringing with no answer and disconnect without a system response are dependent upon calling customer judgments that the attempts would not complete satisfactorily. The time to disconnect after receipt of audible ringing without an answer is not correlated with calling distance. The time to disconnect without a system response may be positively correlated with calling distance; however, once again, the evidence for such a correlation is rather weak.

4.3 Local switching and call setup time

The average setup time from end of dialing to ring or busy varies substantially for attempts classified by the types of local switching. The average setup times with accompanying 90 percent confidence intervals and standard deviations are listed in Table VII for originating and terminating local switching classifications. Estimates for attempts which originate from rotary dial and *TOUCH-TONE* dialing stations are given separately for the originating local switching classifications.

Call attempts which originate from *TOUCH-TONE* dialing stations served by step-by-step (SXS) switching machines have a significantly

Table VI—DDD call attempt setup and abandonment time statistics as a function of calling distance

Setup or abandonment interval	26–400 miles Mean (sec)	26–400 miles Std. dev. (sec)	>400 miles Mean (sec)	>400 miles Std. dev. (sec)
Rotary dialing time	13.1 ± 0.4	4.6	14.4 ± 0.3	4.3
TOUCH-TONE® dialing time	6.9 ± 0.4	3.3	8.5 ± 1.0	4.4
End dialing to ring or busy	11.1 ± 0.6	5.2	12.5 ± 0.4	4.2
End dialing to no circuit/reorder	8.6 ± 3.4	8.7	6.9 ± 3.1	5.6
Start of audible ring to disconnect without an answer	39.9 ± 3.3	20.7	39.3 ± 4.2	21.1
Start of busy to disconnect	4.4 ± 0.4	3.5	5.8 ± 1.6	4.6
Start of no circuit/reorder to disconnect	3.8 ± 0.4	2.5	3.7 ± 0.9	1.7
End dialing to abandonment without a system response	14.8 ± 3.1	13.8	20.2 ± 7.3	27.9

Table VII—DDD call attempt statistics for the time from end of dialing to ring or busy as a function of originating and terminating local switching

Originating switch	Rotary dial customers		*TOUCH-TONE*® customers	
	Mean (sec)	Std. dev. (sec)	Mean (sec)	Std. dev. (sec)
PAN	13.6 ± 3.0	7.4	—	—
SXS	12.6 ± 1.6	5.8	16.5 ± 1.7	4.7
5XB	10.1 ± 0.4	4.4	10.8 ± 0.6	4.6
1XB	10.8 ± 0.8	5.8	12.3 ± 1.9	4.6
ESS	9.2 ± 0.6	4.6	9.5 ± 0.9	3.6

Terminating switch	All customers		Legend:	
	Mean (sec)	Std. dev. (sec)		
			PAN	Panel
SXS	12.7 ± 0.6	4.6	SXS	Step-by-step
CDO	12.8 ± 1.0	4.7	5XB	No. 5 crossbar
5XB	9.7 ± 0.7	5.0	1XB	No. 1 crossbar
1XB	9.5 ± 0.6	3.8	ESS	Electronic Switching System
ESS	7.9 ± 0.5	3.7	CDO	Community Dial Office

longer delay between the end of dialing and the beginning of audible ring or busy than attempts which originate from rotary dial stations served by SXS switching machines. *TOUCH-TONE* dialing signals, which are generated at a subscriber station, are stored and converted to dial pulses at a SXS office before the telephone number is processed. On the other hand, dial pulses, which are generated at a rotary dial station, directly drive a SXS switch during the dialing interval itself; therefore, the telephone number is almost completely processed at the end of dialing. These operational procedures account for much of the difference between the SXS estimates; however, unknown differences in calling distances, routing patterns, and toll switching may also contribute to the 3.9 second difference in average setup times. There are no significant differences between rotary dial and *TOUCH-TONE* results for the other types of switching.

The average setup time for attempts originating from customer stations served by SXS machines is significantly higher than the averages for those originating through No. 5 crossbar (5XB), No. 1 crossbar (1XB), and ESS machines. In the previous paragraph it was stated that the dial pulses generated from a rotary dial station directly drive a SXS switch, and hence, at the end of dialing the dialed number is almost completely processed by the originating SXS machine. This would tend to shorten the interval from end of dialing to ring or busy. However, the same SXS procedure occurring at the terminating switching office tends to lengthen the setup interval as is illustrated by the SXS and CDO estimates in the lower portion of Table VII. An estimated 50 percent of all DLSO-observed call attempts which originate through SXS machines also terminate through SXS machines. This terminating percentage is 20 to 30 percentage points higher than for the other types of switching machines. In addition to this influence, which tends to increase the length of the call setup interval, there is a second influence which comes into play: the calling distance distribution for DDD attempts originating from customers served by SXS machines is significantly biased towards longer calling distances relative to the distributions for attempts originating from customers served by the other types of switching machines. In the previous subsection it was shown that call setup time increases as the calling distance gets longer. Thus, the long setup times for rotary dialed calls handled by SXS machines are not caused by the originating SXS machines. They come about because of call destination and calling distance characteristics associated with the attempts. However, SXS machines at the terminating ends of calls do cause significantly longer setups.

In addition to the SXS findings above, the results in Table VII indicate that calls placed by customers served by panel machines have rather slow setup times and calls placed or received by customers served by ESS machines have rather fast setup times. Terminating ESS machines generally provide immediate ringing when a desired line is not busy, while other machines generally do not. This difference in procedures tends to shorten setup times for calls terminating through ESS machines. Other causes which underly these characteristics have not been uncovered. The precaution of not totally attributing these findings to the panel or ESS machines is exercised because of the absence of routing and toll switching information.

V. CONCLUSIONS

This survey has confirmed that both network performance and customer behavior play a role in determining the overall completion probability and call setup time experienced by telephone customers. In the area of completion performance, the percentage of equipment blockages and failures has been steadily declining in recent years due to extensive efforts throughout the Bell System to provide adequate facilities to achieve low blocking and to detect and correct equipment failures. As a result, customer-dependent failures now account for at least 85 percent of all failures to complete. Thus the greatest potential for improved completion performance lies in reducing such failures. This may be brought about, for instance, through the offering of new services made possible by the advent of Electronic Switching Systems which will serve to reduce the occurrence of called customer did not answer and called line busy failures.

One manifestation of the dominance of customer behavior on completions is the important influence of class of subscriber service. Many trends by day of week, time of day, and calling distance can be directly attributed to changes in the relative proportion of business and residence traffic.

The total call attempt time is made up of several components, most of which are customer-controlled, such as dialing time and time from start of ringing to answer by the called customer. The one network-dependent component, time from end of dialing to network response, represents about 29 percent of the total call attempt time. Calling distance and type of local switching have both been shown to affect this interval. The advent of common channel interoffice signaling is expected to reduce this component from its current value of 10.9 seconds to 2 or 3 seconds, which will reduce the overall call setup time by 20–25 percent.

Customer holding time after the onset of ringing and after a positive indication of failure to complete has a significant effect on total call attempt time and hence on network load. Programs directed toward encouraging faster customer abandonment or toward releasing network facilities more promptly after receipt of busy of no circuit/reorder signals would reduce this load on network facilities.

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