# Communications for Time Sharing at Bell Telephone Laboratories

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ABSTRACT: The communications system proposed for provision of remote access to computers for users at Bell Telephone Laboratories is described with emphasis on the dial terminal arrangements. It is planned to offer time-sharing services from four large-scale computers located at the four major Bell Telephone Laboratories installations: three in New Jersey and one in Illinois. Provision of full flexibility of access is planned by utilizing the voice communications arrangements at each location to provide switching for the remote terminals and computer ports involved. It is proposed that the Bell Telephone Laboratories–Western Electric common control switching arrangement network (CORNET), which provides interlocation communication for users at the major locations as well as users at the various branch laboratory installations throughout the country, be utilized for this purpose.

Areas of primary consideration in planning communications for the system are discussed, and proposed implementations reflecting these considerations are presented. The considerations largely concern the use of a single communications facility to carry a heterogeneous load resulting from the integration of traffic with two distinctly different sets of characteristics.

A number of proposals toward making the most effective use of the telephone communications facilities to carry the two types of traffic simultaneously are described. These proposals are directed at specific equipment and program configurations utilized at the four Bell Telephone Laboratories locations studied. Specific implementations proposed herein include new central office arrangements, as well as new PBX configurations.

## Introduction

BELL TELEPHONE Laboratories (BTL) is planning the introduction of a time-shared computing capability at all BTL locations. It is intended to provide these services by use of four large-scale computer installations, one at each of the three major BTL locations in New Jersey (Murray Hill, Holmdel, and Whippany) plus one at the new laboratory in Naperville, Illinois (Indian Hill).

To make the services offered by these computers available to the maximum number of users, plans call for the installation of a large number of remote terminals at the various BTL locations. These devices will be used to gain access to the computers and thus provide time-shared computer services to users at the terminal location. The majority of these terminals will be teletypewriters, arranged, as much as possible, to operate in a manner similar to that of office typewriters.

To provide maximum flexibility in the system and to increase service reliability, it is proposed that the remote terminals be provided with switched access to the computers by use of the Bell System DATA-PHONE® service. Dialed-up connections to the computers would be established by use of the Centrex telephone switching facilities at each major location. It would be possible for interlocation as well as intralocation connections to be set up, thus providing any terminal in the system with the capability of accessing any of the four computer installations. Interlocation connections would be completed over facilities of the BTL–Western Electric Company common control switching arrangement network (CORNET), sharing these facilities with the normal voice connections.

This paper discusses some of the considerations involved in serving traffic of the sort generated by users accessing time-shared computer services for scientific and engineering development projects. Specifically, switching arrangements proposed for the four installations involved are described and the reasons for their selection are discussed. It should be emphasized that proposed arrangements appear, under the conditions extant at the locations studied, the most feasible ways of providing these services devoted to scientific and developmental work only. Other uses for time-sharing systems may result in system traffic characteristics that differ significantly from those expected at BTL, and it is these characteristics, together with geographical considerations, that are the major influence in selection of switching arrangements.

## System Operating Conditions

Functionally, the introduction of time sharing may be looked upon as an improvement in basic computer services, because it is expected to provide a wider variety of services and conveniences than presently offered. The entire concept should allow more and better use of computer services and thus enable the technical staff to more effectively perform their jobs.

The concept of time-sharing large computer systems allows users, operating terminals remote from the computer facility and connected to it by a communications channel, to obtain computer services at their own office location. Further, the number and types of services offered in this fashion could be greatly enlarged from those offered by present standard batch-processing techniques. To be effective, however, such services should be extremely reliable and easily accessible by all desiring to use them.

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There are a variety of alternate means available that would provide this reliability and allow flexibility in access and in usage of system storage capabilities to varying degrees. Review of all the factors involved led to the proposal of switched access for service to the remote input/output terminals for BTL.

Because of the number of remote terminals planned and their distribution, and because it is an integral part of the Bell System communications network, the Centrex telephone communications systems serving the BTL locations involved are proposed to provide the switched access. Further, it was felt that distinct economic advantages result from grouping voice and data traffic on the same switching network. As is well known, the Bell System offers DATA-PHONE service, in which the telephone network is used to interchange data between terminals. It is apparent that this service would provide an appropriate vehicle for time-sharing operations. It not only provides the flexibility required for reliability for "local" (on-location) users, but also allows interlocation access as well as access from branch laboratory sites, etc. In addition, switched access by use of DATA-PHONE services appears to allow efficient use of system storage facilities. Thus, specific programs or other information most often used or needed by users at any location could be maintained in the storage facilities at that location only. Remote terminals at other locations desiring access to this information could easily obtain such access by use of the switched interlocation telephone facilities.

Fig. 1 diagrams the communications network to be used (CORNET). Note that at the three major locations in New Jersey, the computer locations are interconnected by means of tie trunks, while Indian Hill and the branch laboratory locations are served via the CORNET switching offices. It is this network that would carry the time-sharing traffic.

The traffic situation, however, should not result in too large a load being placed on the CORNET switchers or on the tie trunk groups between New Jersey locations. It is presently estimated that approximately 90 percent of the time-sharing calls will be intralocation. This estimate takes into consideration possible computer failures and downtime as well as remote file and program access, which should be the reason for the bulk of the interlocation traffic. This paper considers proposals affecting only the local switching offices serving the four computer installations. Interlocation switching arrangements to accommodate this data traffic are considered only to the extent that these arrangements immediately affect the local switchers.

The local switchers of interest are the four PBX arrangements serving the four computer locations. The three New Jersey locations are each served by a No. 5 Crossbar (XB)Centrex-CO arrangement. A Centrex-CO PBX is one in which all the PBX switching equipment is located in, and is part of, the central office serving the area involved. The switching arrangements are similar in design and application at each of the three New Jersey locations and require attention to similar considerations at each for provision of time-sharing services. Interlocation

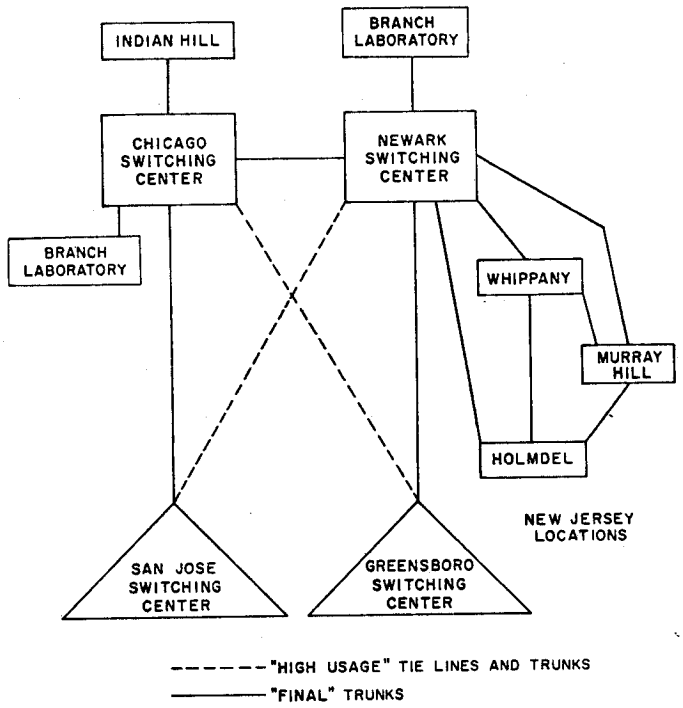



Fig. 1. CORNET layout. BTL time-sharing system.

connections involving these switchers, however, are somewhat involved, because of the interconnecting tie trunk groups. At Indian Hill, a No. 101 ESS Centrex-CU configuration has been installed, with the switching equipment located on the customer's (BTL) premises. Essentially, all interlocation connections involving Indian Hill will be accommodated via the CORNET network.

Local switching at the branch laboratory locations is not considered here because of the relatively small number of terminals expected at any one location (in comparison with the numbers expected at the major locations) and the fact that only switchers at the major locations would be used in serving the computer ports. Terminals located at branch laboratory locations would be provided with DATA-PHONE service and would access the computer of their choice by use of CORNET facilities. This traffic load, however, is expected to be quite small in volume in comparison to that generated at and served within the switching locations serving the computers. Thus, the areas where time-sharing traffic will have its most prominent effect will exist in the switchers serving the computer ports. This is true for the BTL case because of the characteristics expected in the offered traffic. With other types of switched access time-sharing traffic, the most prominent effects could arise elsewhere in the serving switching network.

In a research and development community such as BTL, time-sharing traffic typically is expected to be characterized by long holding time calls and fairly low per-terminal calling rates. While no precise data are now available, average holding times in the order of 45 minutes to one hour per call may be expected for at least some of the traffic, based on experience to date with Project MAC at M.I.T. In addition, the system will be engineered to

accept traffic loads in the order of 0.8 to 1 Erlang (30–36 ccs) that are expected on each computer port during the busy hour. It is these characteristics that most seriously affect switching office operation when combined with normal telephone traffic. It should be emphasized again that although these characteristics are probably typical of a scientific (research and development) community in time-sharing usage, they are probably not generally applicable for all time-sharing uses.

## The New Jersey Locations

Communications services for the computer installations at the three New Jersey locations will be basically similar in nature in that the same kind of communications switching device serves each location and the three locations are directly interconnected by means of tie lines. Further, the same variety of terminals is expected to be used. Teletypewriter devices, such as Teletype Corporation Model 37 machines, operating at both 100 and 150 words per minute, and IBM 1050 terminals, operating at about 135 words per minute, will comprise the vast majority of these terminals.

In addition to the above, a number of special on-line graphics terminals are planned for use with time-shared computer services. Bandwidth needs for these terminals in most, although not all, cases will be such that voiceband switching cannot be utilized. Thus, the majority will be directly connected to the computer serving their location, and can be considered computer adjuncts in the time-sharing sense rather than remote terminals. It is expected that those visual display terminals capable of using switched voiceband service will access the computer in the same manner as the teletypewriter terminals.

Fig. 2 illustrates the Crossbar (XB) Centrex-CO configuration that serves each of the New Jersey locations. In addition, access to CORNET by means of trunk groups to a four-wire No. 5 Crossbar private line central office in Newark and the interconnecting tie trunk groups are shown.

The wide variety of types of remote terminals planned for use results from the varying needs of the users plus the availability of the various units. Computer facilities to accommodate switched access for the three different specific terminal types mentioned previously are planned. Thus, a minimum total of three access hunting groups of computer ports will be required at each location. It would be desirable in the future to reduce the number of hunting groups to one, with a corresponding increase in communications and computer input/output efficiency. This reduction, however, will depend on an evaluation of terminal operation, standardization, and availability at some future date, and its outcome cannot be predicted at this time.

At the New Jersey locations, it is proposed to serve all remote terminals requiring switched access as normal telephone extensions from the switching office. Thus, all would appear as line link frame (LLF) terminations at the serving No. 5 Crossbar office. Fig. 3 illustrates this arrangement. It is also shown that most computer ports would be

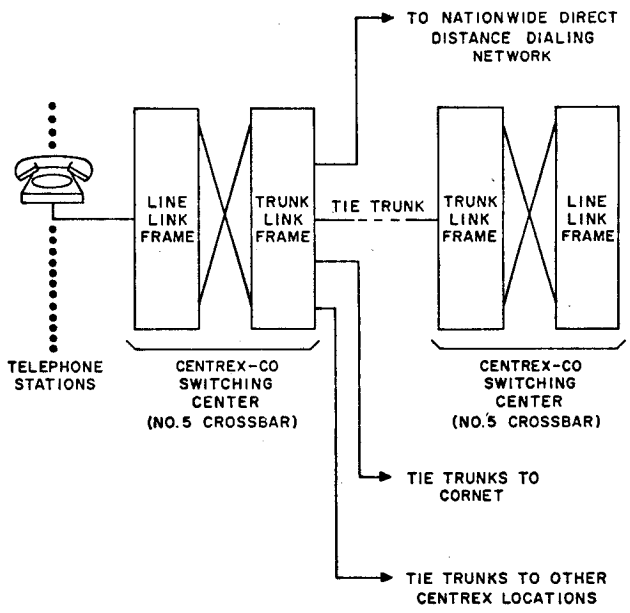



Fig. 2. Simplified telephone switching arrangement for BTL New Jersey locations. BTL time-sharing system.

served directly from the trunk link frame (TLF). With this configuration, intralocation calls can be completed using a single pass through the switching network, instead of the two passes (LLF to TLF to LLF) normally needed on intraoffice calls between telephone stations served from the LLF. This arrangement saves one connection through the network for each call and results in greater network availability during the busy hour. Three-digit (1XX) codes would be used to provide this access.

Fig. 3 also shows some computer ports being served by means of LLF appearances. This configuration is needed for two reasons: to enable interlocation calls to be accepted without requiring tandem capability in a switching office, and to allow the computer to originate calls when needed. These latter calls are expected to be needed for maintenance reasons and, perhaps sometime further in the future, for delayed responses to terminal inquiries. The result of this configuration is to provide complete flexibility of access for all terminals, while at the same time allowing for some of the more probable future needs. As can be seen, the LLF computer-port appearances must be capable of accepting calls from any of the three types of terminals described previously. Thus, three hunting groups would be required here also, resulting in a minimum total of six hunting groups for each computer location. This arrangement, particularly with the small LLF groups (low traffic volume), could produce traffic handling inefficiencies long recognized by traffic engineers.

In order to minimize the possible influence at these inefficiencies, and in doing so, reduce the total number of data sets and active computer ports needed, it is proposed to implement an arrangement whereby the LLF appearances are multipled with TLF appearances. Under this configuration, only three hunting groups would be needed, as the multipled LLF appearances would be final choice

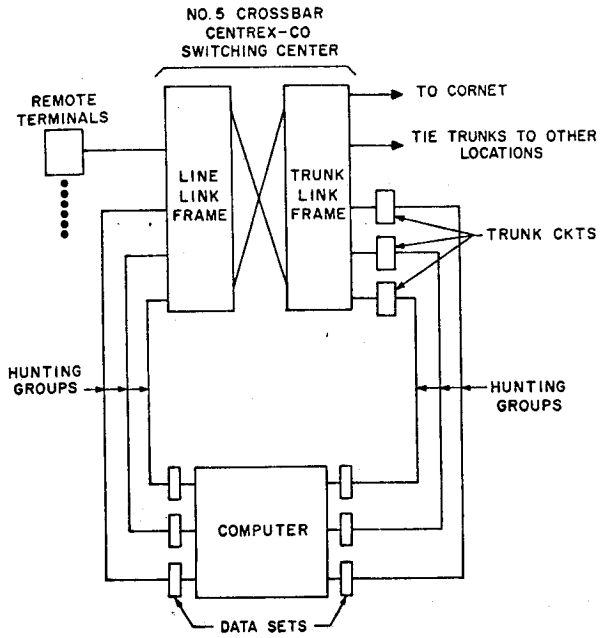



Fig. 3. New Jersey—Initial switching arrangement. BTL time-sharing system.

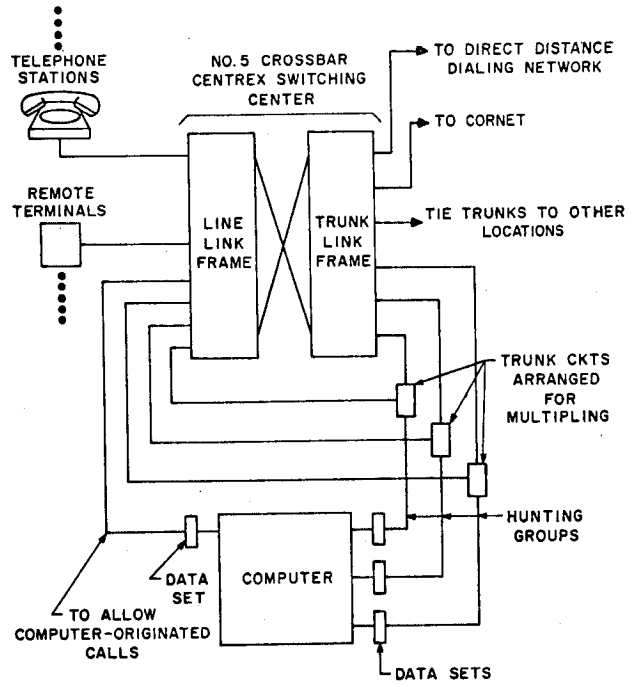



Fig. 4. New Jersey—Planned switching arrangement. BTL time-sharing system.

groups in each of the TLF hunting groups. Fig. 4 illustrates this arrangement. The configuration provides the full flexibility of access required while reducing the possibility of less efficient computer-port usage.

Under this proposal, traffic between New Jersey BTL locations would share, with the normal telephone traffic, the tie trunk groups provided between each local switching unit. These tie trunk groups would be increased in size to accommodate the expected additional traffic along with the telephone load; the amount of increase being predicted upon the expected 10 percent interlocation traffic. Both voice and computer traffic would be allowed unlimited access to the tie trunk groups involved.

Unlimited access, however, could result in the time-sharing traffic utilizing all trunks in a group, if, for example, a computer at one location was unable to accept any calls. Under this situation, users desiring service would be free to attempt to access one of the other computers at another location. If enough of these calls were completed, the resultant data traffic, because of its long holding time characteristics, could effectively monopolize the tie trunk group(s) involved and possibly block all interlocation telephone traffic. Thus, the traffic balance between normal voice traffic and time-shared computer traffic is of interest in system operation. A number of methods to control this balance are realizable, largely depending on system configurations. These methods require separate evaluation with respect to their possibility of use for each switching configuration involved. Initially, at the New Jersey locations, it is proposed to keep to a minimum the number of LLF computer-port appearances at each location, consistent with desired service. Since interlocation calls would only be able to access the computers via their LLF port appearances, this tends to limit the amount of data traffic able to be carried by a tie trunk group and would prevent complete occupancy of the group by these calls. However, some future modification of this plan will be required to prevent the overutilization of certain common switching equipment under all-ports-busy conditions.

Because a gradual phasing-in of the three computer installations is planned, some consideration was given to service during periods when only one or two of the three New Jersey computers were fully operational. During these periods, users at locations where computers were not yet operational would desire access to the operating machines. To provide this access, a number of plans were considered. The proposal selected involved the use of off-premises extensions for all off-location terminals desiring service during this interim period. While slightly more expensive than some other plans (estimated differences in cumulative monthly charges over all the periods were approximately $6^1/_2$ percent), the use of this procedure would allow complete access flexibility and would provide a numbering plan arrangement consistent with the ultimate system conception.

## Indian Hill

In comparison to the operations envisioned for the New Jersey laboratory locations, the planned Indian Hill Computation Center operation will be somewhat unique. A large fraction of the work expected to be handled by the Indian Hill computer will consist of assembly, compilation, and simulation of programs for use with electronic switching offices. This relatively specialized use is expected to result in little normal traffic between Indian Hill terminals and New Jersey computers, and vice versa. However, plans indicate that some terminals requiring access to the Indian Hill computer will be located outside the actual Indian Hill

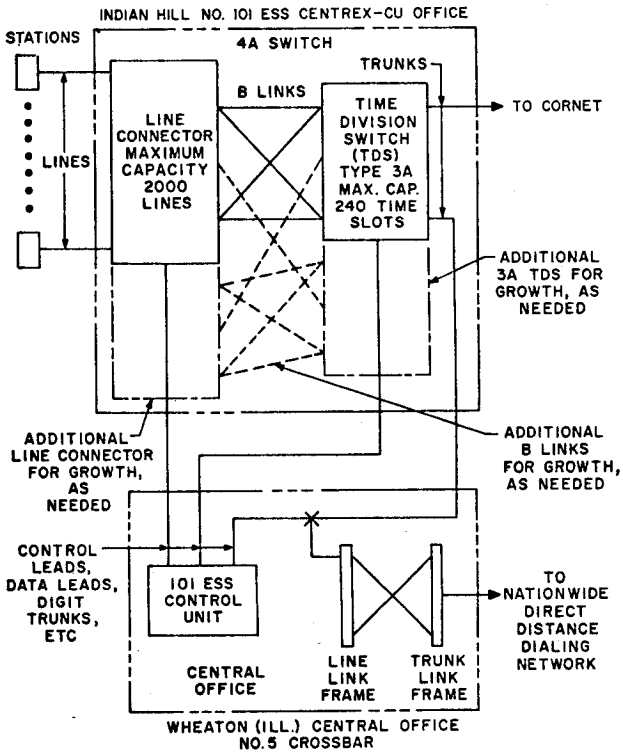



Fig. 5. Indian Hill—Planned switching configuration for telephone traffic. BTL time-sharing system.

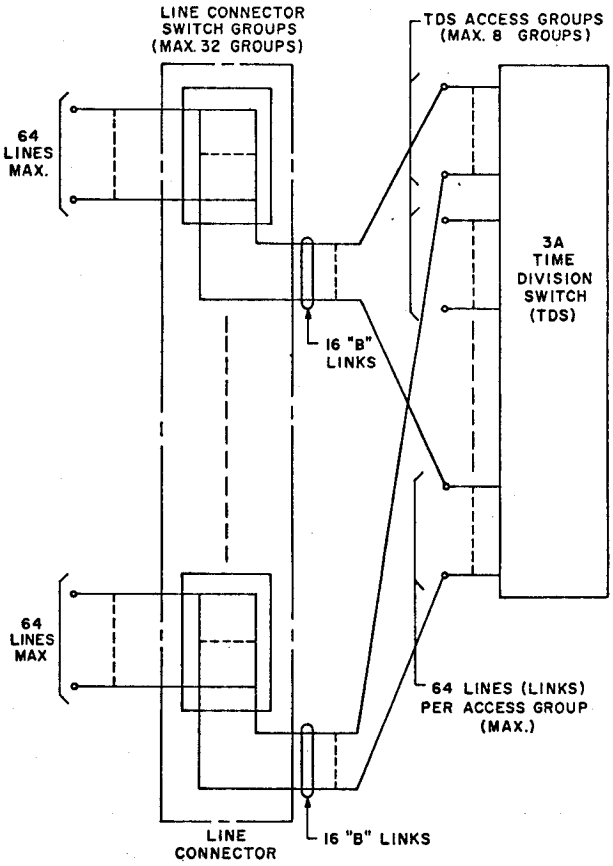



Fig. 6. Indian Hill—Concentration in line connector. BTL time-sharing system.

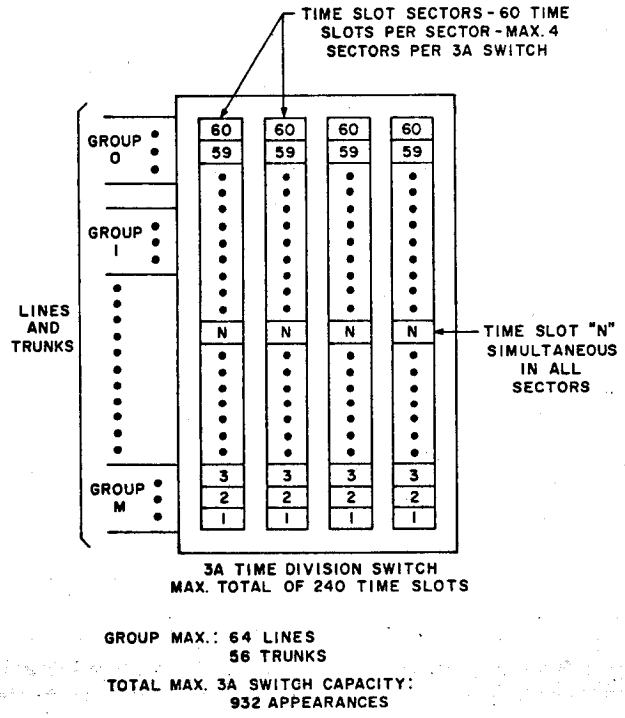



Fig. 7. Indian Hill—3A TDS, illustrating time-slot sectors and appearance groups. BTL time-sharing system.

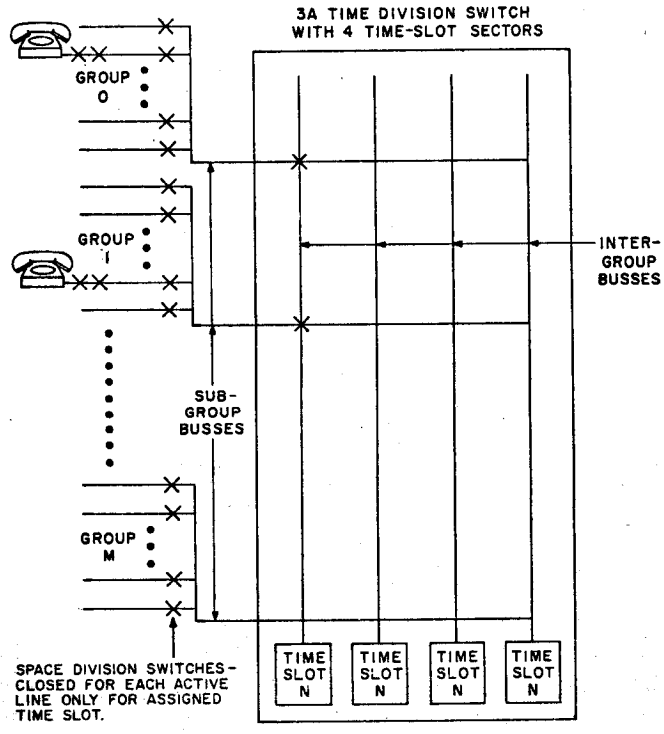
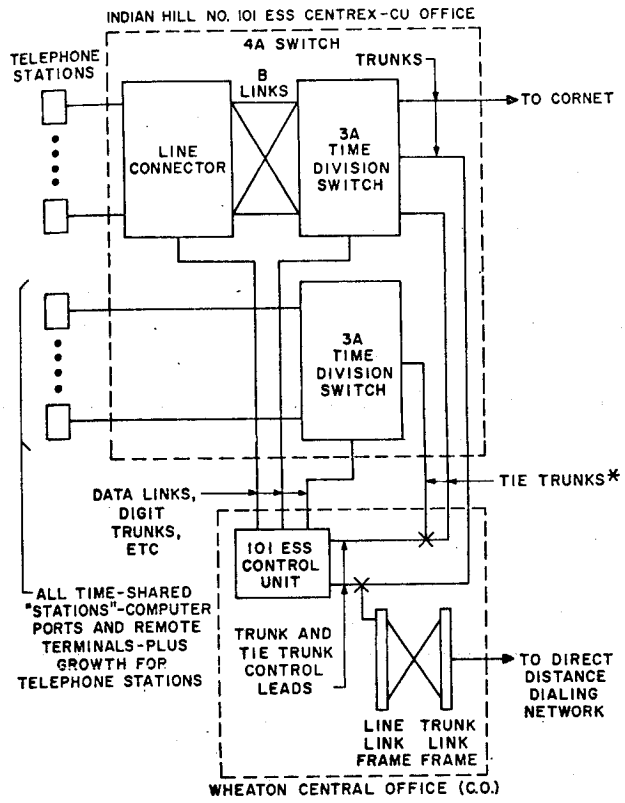



Fig. 8. Indian Hill—Configuration showing connection established between stations in Group 0 and Group 1 during time slot N. BTL time-sharing system.




* *Note:* Instead of looping the tie trunks through the Wheaton Central Office, it may be possible to control these trunks by use of a group of tie trunk control leads (one per tie trunk) between the No. 101 ESS control unit and the Indian Hill location.

Fig. 9. Indian Hill—Configuration illustrating the serving of time-shared "stations" from a separate 3A TDS. BTL time-sharing system.

building. Where traffic and geographic conditions warrant, it is planned to serve these terminals as off-premises extensions from the Indian Hill PBX arrangement. Remote terminals not served in this manner would obtain access to the Indian Hill computer by use of the CORNET switching network.

The No. 101 ESS presently serving as a PBX for Indian Hill utilizes the newly developed 4A switch to perform its switching functions. The 4A switch, a combination of space division and time division switching, can accommodate a maximum of 2048 lines. The space division portion acts as a concentrator and provides a maximum of 512 "B"-link inputs to the time division switch (TDS). The TDS, a type 3A, can provide a maximum of 240 time slots in four sectors of 60 slots each. It can accommodate from one to four time-slot sectors, depending on the switching need of the specific installation. At Indian Hill, initial installation of the TDS was made last spring with four sectors activated, thus providing the full switching capability of the 3A immediately.

The switching configuration used at Indian Hill for telephone service is shown in Fig. 5. This is a Centrex-CU arrangement where the actual switching is done outside the local central office. Control for the switching office is exercised by the No. 101 ESS Central Control Unit located in the local central office (No. 5 Crossbar) in Wheaton, Illinois. Connections into the nationwide direct distance dialing (DDD) network are shown as well as the CORNET interconnection. The figure also demonstrates the four-to-one concentration provided by the line connector. Fig. 6 demonstrates this concentration in more specific detail.

The concentration arrangement was engineered to accommodate telephone traffic exhibiting characteristics normally used in defining such traffic (i.e., average busy hour loads of 3 to 5 ccs or 0.083 to 0.14 Erlangs per connected line). As such, it is quite capable of switching a certain amount of traffic exhibiting the characteristics expected of BTL time-sharing traffic, since these characteristics are also routinely encountered in many PBX installations. To serve this traffic and to most efficiently utilize the B links between the line connector and the 3A TDS, it is proposed to distribute the computer ports and terminals over the line connector switch groups as widely as possible (see Fig. 6). This can be easily accomplished in the No. 101 ESS by making use of its inherent ability to define terminating hunting groups of almost any size, unrestricted as to line appearance location.

Thus, it is proposed to accommodate the computer traffic initially in this manner. As the number of remote terminals and activated computer ports becomes larger, the number of telephones requiring service will also increase. Sometime in the future, the line connector appearance (and traffic handling) capacity limit will be reached and additional switching capacity will be required. This additional capacity could be provided by the addition of a second 3A TDS to the system.

Before describing the larger switching configuration, some details with respect to TDS operation are needed. As illustrated in Fig. 7, a 3A TDS, when fully equipped as at Indian Hill, comprises four time-slot sectors containing 60 time slots each. The individual time slots are coincidental in each sector and space division separation is used to maximize the ability of the switch to provide four simultaneous connections in any one time slot.

In operation, lines (in a 4A configuration, these are B links) and trunks appear in access groups at the TDS. These are called subgroups and comprise a maximum of 64 lines or 56 trunks[1] each. The switch can establish connections between lines in the same, or different, subgroups. It does so by making a time slot available to the subgroup bus (or buses), which serves the lines requesting a connection. As shown in Fig. 8, as many simultaneous connections can exist for each of the total of 60 time-slot intervals as there are sectors in the TDS (four in the case illustrated). Each subgroup bus can carry only one connection during any one time-slot interval. Since this is so, any other lines attached to that same subgroup bus and desiring a connection must be served during different time-slot intervals, and thus the idealized "full" capacity of the TDS may not be available under all possible switch-

[1] Actually, 64 trunk positions are provided in each subgroup, but eight of those trunk positions are reserved for nontraffic handling purposes (digit trunks to the central control, etc.).

ing conditions. It should be emphasized that such conditions will seldom, if ever, be realized under normal telephone traffic loading.

Calls with long holding times, such as this form of data traffic, require that the line assignments be made in a manner similar to PBX lines carrying voice traffic with similar characteristics; that is, lines involved in these calls cannot be widely dispersed throughout the access subgroups. The lines generating this type of traffic should be bunched into a minimum number of access subgroups. Thus, these lines are competing for time slots essentially only among themselves, reserving time slots in other TDS sectors for other traffic on lines in other subgroups using other subgroup buses.

If, then, the second 3A TDS is added to the configuration, it is proposed to transfer all remote terminals and computer ports (within Indian Hill) to this new switch. Under this proposal, the ports and terminals would be served directly via a minimum number of access subgroups on the new switch. In addition, some selected telephone extensions could also be served directly from the new TDS. These latter stations would be selected on the basis of the most common community of interest. As shown in Fig. 9, common communities of interest among lines served by this TDS would decrease the traffic on the tie line group interconnecting the two TDS's involved.

Because of the particular growth structure involved, this configuration appears to be the most appropriate for Indian Hill. Its major advantages lie in the assignment of lines carrying the long holding time traffic on a TDS in such a fashion as to minimize any negative effects this traffic may have on normal switch operation. By these fairly simple means, fairly large volumes of time-sharing traffic can be accommodated by the No. 101 ESS in a most efficient manner, while retaining the system's extreme flexibility in carrying other traffic.

## Discussion

The intent of the arrangements proposed above has been to optimize the operation of a local PBX-type switching office under conditions resulting from the introduction of time-sharing traffic. If nothing else has been emphasized in the above, it should be clear that each individual situation requiring attention because of the introduction of time sharing must receive individual consideration. This is true of any large PBX with or without computer traffic. A large number of variables affect engineering decisions in each case, and each of these variables must be carefully analyzed with respect to its effect on a final system configuration. In the BTL arrangements discussed, some attempt was made to generalize the solutions (e.g., use of multipled LLF–TLF computer-port appearances to terminate interoffice calls rather than requiring tandem capability in an office) in the hope that the planning leading to the suggested configurations might serve as models for planning future systems of this type. The emphasis on planning is intended, because it is doubtful whether the specific arrangements suggested for the envisioned BTL system can be precisely applicable to other time-sharing system requirements.

It should be noted that applications exhibiting completely different traffic characteristics may well comprise as large an overall percentage of the total time-sharing use in the nation as that expected of the research and development function typified by BTL traffic. Another type of computer traffic may be characterized by extremely short holding times and large numbers of call attempts. It would place entirely different burdens on system designers, and its interaction with the other functions of switching systems would require attention to the relevant communications characteristics. The general end result should conform to the specific systems in such a way as to most efficiently carry the various kinds of offered traffic in a manner such that all types are treated equitably by the systems involved.

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