TRUNK NETWORK DESIGN—NETWORKS—GENERAL

TRUNK ENGINEERING

NETWORK OPERATIONS METHODS

1. GENERAL

1.01 This section face sheet is issued to assign its 9-digit number to Traffic Facilities Practices

Division G, Section 3-a(2), August 1976.

This is part of the conversion of all Traffic Facilities Practices (TFPs) to the 9-digit Bell System Practices (BSPs) series as described in GL-77-05-262 and GL-77-11-200.

1.02 When this section is reissued, all references to TFP numbers will be changed to the appropriate 9-digit BSP numbers.

1.03 Recommendations for changes, additions, or deletions to this section should be forwarded on Form E-3973 as specified in Section 000-010-015.

1.04 TFP to BSP cross-reference information can be found in GL-77-11-200 and in Section 780-400-005.

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TRUNK FACILITIES

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NETWORKS - GENERAL

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TRUNK FACILITIES

TRUNK NETWORK DESIGN

NETWORKS—GENERAL

1. GENERAL

1.01 This section contains a general discussion of the evolution of the message network and some of the concepts, philosophies, and considerations underlying network design objectives and methods.

1.02 Whenever this section is reissued, the reason for reissue will be listed in this paragraph.

2. TRUNK NETWORKS

A. Network Definition

2.01 The term "Network," as used in this section, means an arrangement of switching systems interconnected by trunk groups. The major thrust of this practice is toward the message network which handles the completion of calls generated by or for the general public. The two major subdivisions of the message network are the Metropolitan Networks and the North American Network. The former are essentially 2-level networks serving calls originating and terminating within a given metropolitan area; the latter is essentially a 5-level network serving the United States, Canada, Mexico, Bermuda and the Caribbean area. The North American Network and the various Metropolitan Networks discussed in this section are designed on a hierarchical basis (see 3.11).

2.02 There are various other forms of networks over which selected types of traffic are carried. Some of these are designed for specific types of calls, such as high-speed data. Others are designed with limited access for specific customers, such as federal or state governments. These networks may be hierarchical, similar to the message network, or they may be a form of symmetrical network in which switching systems have no rank and there are no homing arrangements.

2.03 With symmetrical networks, it is necessary that each call carry information along with it as it progresses through the network, regarding point of origin and destination, so proper routing can be provided. This can be accomplished by using a "traveling class mark" in addition to the called number. The traveling class mark can also be used to provide a priority status to insure that high-priority calls are completed.

2.04 Because of the complex engineering and administration of this type configuration, coupled with the requirement for expanded class marking of calls, its use has been restricted to private networks. As Common Channel Interoffice Signaling (CCIS) becomes available with its increased capabilities, some of the advantageous features of symmetrical networks will be incorporated into the hierarchical message network.

2.05 While the discussion within this practice covers networks in general, the major focus, as indicated earlier, is on Metropolitan Networks and the North American Network. Specific definitions of the various forms of networks are found in TFP Division G, Section 1-a(2).

B. Trunk Network Design Objectives

2.06 The basic objective of trunk network design is to determine the way in which network switching systems are to be interconnected. The specific objective is to determine how calls are to be routed, and how many trunks are required in a future period to meet a given service objective in an economic manner, when given a set of traffic loads.

2.07 Service objectives for trunk groups are found in TFP Division G, Section 1-d(1). They are normally stated in terms of the busy-season average network busy-hour percent NC on grade-of-service trunks groups, i.e., trunk groups without alternative routes. There is an obligation to design the trunk network to meet these blocking objectives, while at the same time efficiently loading all trunk groups.

2.08 Overall network design objectives, however, are more broad than this. There is also a responsibility to provide satisfactory service during those periods when changes in load levels or load distribution place a strain on the network. Within the appropriate economic constraints, a network should provide maximum flexibility in meeting the continuous variability of offered loads. This flexibility will ordinarily be provided by a network which has several ways of getting from point to point. Any network, of course, has the paramount requirement that it can be administered and managed as well as engineered.

2.09 In meeting this design requirement, there are criteria in addition to those related to the traffic considerations of probability of blocking, speed of connection, and length of traffic delay. To meet the overall quality of service objective, consideration must be given to:

- Transmission criteria concerned with the true reproduction of the original information at the distant end.
- Protection criteria concerned with safeguards against interruptions to service and with the rapid restoral of service.
- Maintenance criteria concerned with reliable performance and ease of repair.

C. Responsibilities of the Trunk Engineer

2.10 In keeping with the responsibility for the service and loading aspects of the message network and for routing within that network, the trunk engineer is principally concerned with the following activities:

(a) The accumulation, interpretation, and projection of load data for traffic handled or to be handled on the message network. In these activities, close working relationships are required with Network Administrators and other personnel involved in the scheduling, procurement, and delivery of trunk-group load-measurement data and point-to-point data.

(b) The determination of trunk requirements for construction program purposes. This requires the use of engineering techniques applied to the data mentioned in (a).

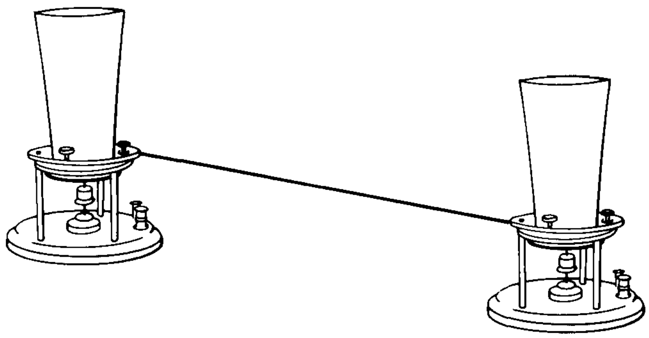
(c) The correlation of all matters concerned with routing of traffic, including the requirements for foreign area translation.

(d) Preparation for management of timely reports of network performance in terms of service and loading.

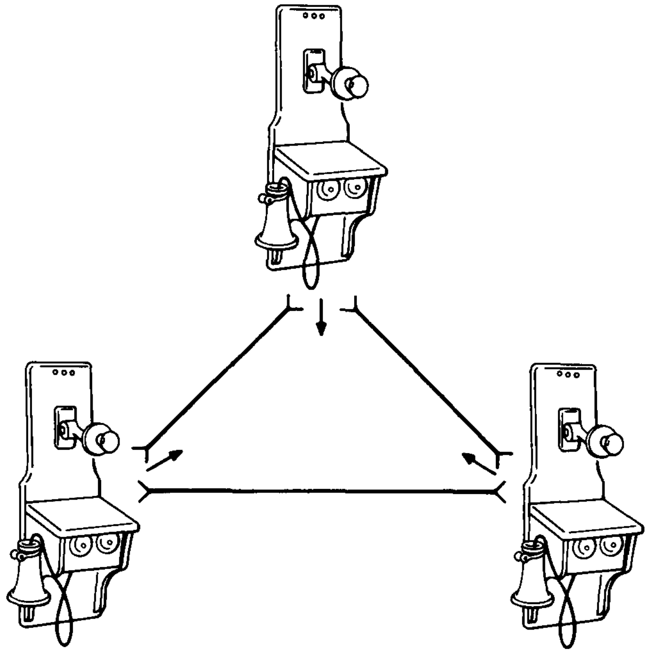
3. EVOLUTION OF NETWORKS

3.01 In trunking networks, the principal role of switching is to obtain economy in the provision of transmission facilities. This is done by concentrating small traffic items into parcels of traffic which are large enough to be trunked efficiently. This is accomplished by successive stages of concentration which have evolved as follows:

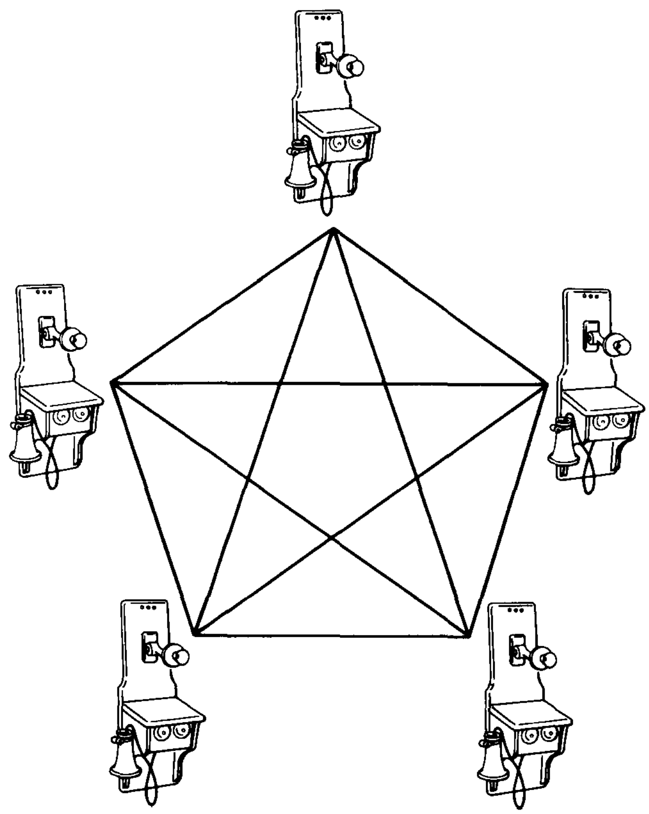
3.02 When Alexander Graham Bell had only two telephones, the routing problem was simple as illustrated in Sketch 1.



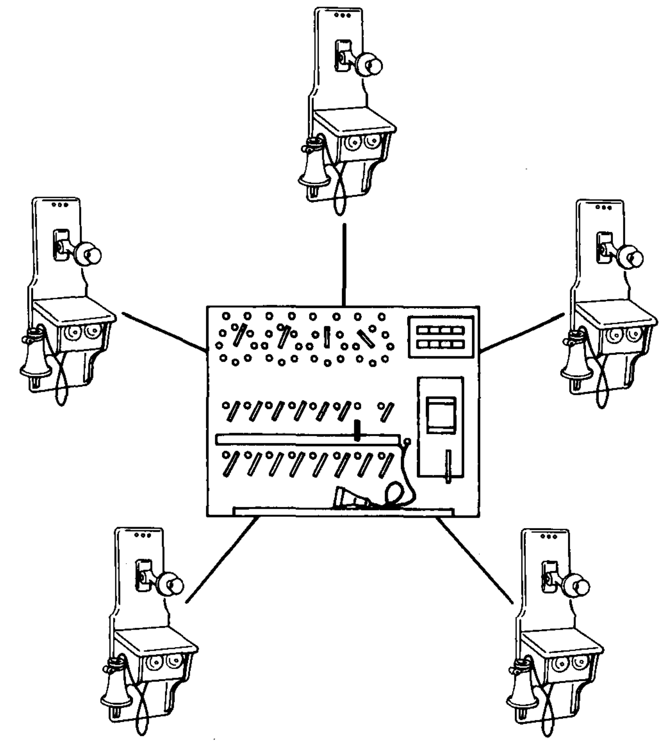
3.03 When the third telephone was added, two lines had to terminate at each telephone and a line selection and signaling device was made necessary as illustrated in Sketch 2.



3.04 As more telephones were added, the number of lines required to directly connect all of them began to be unmanageable, as illustrated in Sketch 3.

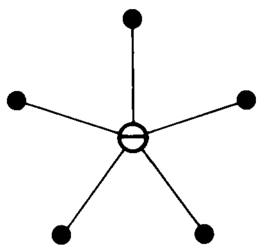


3.05 It then became economical to serve lines from a central switching system, as determined by a wire-centering procedure - first with a manual switching system or switchboard (1878) as illustrated in Sketch 4, and then with a mechanical switching system.

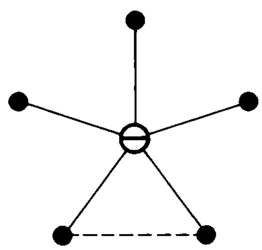


3.06 At this point, we may generalize and broadly define the network design function as one of "Determining the optimum economic balance between the provision of trunks and the provision of switching for a given set of demands and for a given set of service criteria."

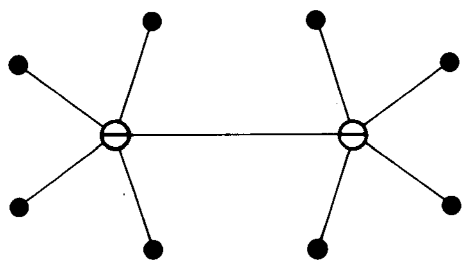
3.07 As required to meet this balance, additional stages of concentration are built up as follows. For a grouping of switching systems as illustrated in Sketch 5, a central location is chosen by wire-center study where another intermediate switching system can best be placed to most efficiently interconnect the other switching systems. This intermediate switching system is known as a tandem. This centering process saves trunking money by spending switching money.



3.08 The cost of a trunk path through a tandem is frequently higher than the cost of a direct path between the two switching systems. Even so, when the community of interest between two switching systems is low, traffic efficiency favors the tandem route. When the community of interest grows, however, a level is reached at which it is economic to provide both the direct and tandem routes as illustrated in Sketch 6.



3.09 Tandems, in turn, have communities of interest for the groupings of switching systems which they serve, and the process can start over again as illustrated in Sketch 7.



3.10 This second level of concentration may be adequate for the economic justification of direct trunking between tandems, such as those serving adjacent cities. As distances increase however, or where calling rates are low, a third level of concentration may be required in order to accumulate sufficient loads to economically justify direct trunking. This process continues with further increases in distance, or lower calling rates requiring a fourth level of concentration, for example serving an entire state or numbering-plan area. For nationwide calling, several states are normally grouped together to form a large geographic area served by a fifth level of concentration - the Regional Center. All Regional switching systems are directly interconnected.

3.11 As noted, trunk investment is saved by adding switching systems. Conversely, switching investment is saved by spending trunking money as in the establishment of direct trunk groups. Thus, the network design and implementation process is continuous with the trade-off between trunking and switching being dynamic, i.e., changing with traffic volume, traffic distribution, and technology. This trunking - switching trade-off is discussed further beginning with paragraph 4.01.

A. Network Hierarchy

3.12 For many years, the interconnection of switching systems in the nationwide network was accomplished by a single group of trunks between pairs of switching systems, whenever there was sufficient traffic to make such connection economically feasible. Lesser items of traffic were switched via "built-up" connections of two or more trunk groups in tandem. Transmission standards imposed certain limitations on the number of such groups in tandem, but beyond these there was little organization of the routes which switched traffic might take.

3.13 At the close of World War II, steps were taken to develop a system for handling message traffic on a high-speed automatic switching basis. This required a new concept of trunking, the development of sophisticated switching systems, and the full exploitation of the then new transmission facilities. Originally, operators directed long distance traffic over the new system but it was so designed that direct dialing of this traffic by customers could be accommodated as suitable automatic routing and billing equipment became available.

3.14 This call-handling system evolved separately for "toll" traffic and for "local" traffic. This distinction, however, depends largely on tariff arrangements and as the nature of the tariffs changed, and engineering methodology made the network configuration more similar, the local-toll network distinction became less clear. As a result, the term "message network" now covers the general combination of trunks and switching sytems serving the general public. There are two major subsets, the North American Network (generally five levels) and Metropolitan Networks (generally two levels). Definitions of these and other network subsets are covered in Division G, Section 1-a(2). Our primary concern here is with the design aspects of the trunking and switching arrangements of the message network.

3.15 The message network employs a definite pattern for routing traffic between switching systems over interconnecting trunk groups, provided in such a manner as to assure efficient and economical use. The network provides for a low incidence of blockage for traffic during the average busy-hour of the various network busy seasons. This is achieved by the pooling of trunk group capacities in handling many traffic items, through the use of automatic alternate routing, and appropriate techniques for allocating loads between first and alternate routes.

3.16 There are various classes of switching systems in the network, each identified by a class number. The class number always indicates the highest switching function performed, but higher class switching systems can, and generally do, perform lower switching functions. A definition of "class" and "switching function" may be found in Division G, Section 1-a(2), and further discussion of these terms will be found in Section 3-b.

3.17 Trunk groups which interconnect the switching systems in the network are basically of two types from a traffic-routing standpoint, grade-of-service and high usage.

3.18 Grade-of-service trunk groups perform a unique function in the switching pattern. Each is the route of last resort between its terminals. These trunk groups may be "finals" if other trunk groups overflow to them, or they may be only-route trunk groups. A series of grade-of-service trunk groups, connected in tandem, constitutes a last-choice route chain and thereby defines the network hierarchy. A grade-of-service trunk group is engineered for a low incidence of blockage (NC encountered) in its appropriate busy-season average busy-hour, and it has no alternate route. Calls failing to find an idle trunk in the trunk group are blocked and are then either abandoned or retried by the customer.

3.19 In addition to the grade-of-service trunk groups discussed in 3.18, high-usage trunk groups may be provided between any two switching systems, regardless of class or location, whenever the volume of properly routed traffic between those switching systems makes direct handling economical. A high-usage trunk group is designed to overflow to an alternate route a predetermined part of the busy-hour traffic offered it. Hence, a high-usage trunk group may be said to short-circuit the last-choice route chain. The location of high-usage trunk groups, and the number of trunks in each such trunk group, are determined by engineering study and procedures which are discussed in other sections of Division G.

3.20 Specific definitions of the various types of trunk groups are included in Division G, Section 1-a(2).

B. Network Numbering Plan

3.21 In addition to the hierarchy previously discussed, another essential element of the message network is an addressing system in which each main station is assigned a unique number convenient to use, readily understandable, and identical in format to those of all other main stations connected to the network. With such a numbering system, operators or customers, wherever located, may use this number to reach the desired destination through the network. This is called destination code routing.

3.22 The routing codes for dialing within the North American Numbering Plan consist of two basic parts:

(1) A 3-digit Area or Numbering Plan Area (NPA) code.

(2) A 7-digit number made up of a 3-digit Central Office (CO) code plus a 4-digit station number.

Together these ten digits comprise the network "address" or "destination code" for each main station.

3.23 Calls between any two main stations in the same NPA can be completed using only the 3-digit central office code plus the 4-digit station number. When the switching system at the originating location receives the seven digits dialed by the customer or operator, the 3-digit central office code directs the switching system to select the proper outgoing trunk group and route the call to or toward the destination. The seven digits, or that part of the seven digits required by the distant switching system, are sent forward. If the distant switching sytem is a tandem, it translates the code received, selects an outgoing trunk group, and spills forward either the full seven digits to another tandem, or four or more digits as required to the called end office. The procedure of translation, selection, and spill forward is followed from tandem to tandem until the call reaches its destination, making use of high-usage or grade-of-service trunk groups, as necessary within the routing pattern established for each call.

3.24 Calls between locations in different NPAs are handled similarly using the full 10-digit destination code. Both the originating end office and tandem switching systems make use of the 3-digit NPA code to direct each call to a particular trunk group to, or toward, the called NPA. Once a call reaches the called NPA, only the last seven digits are needed to advance the call.

3.25 For calls within the network between operators or test desks, a separate set of system codes using a specialized format is employed, as described in Section 11 of Division G.

C. Routing

3.26 In the preceding discussion of the network hierarchy, reference was made to a basic routing pattern. The aim of the routing pattern is to carry as much traffic as is economically feasible, over direct trunk groups, between pairs of switching systems low in the hierarchy. This is accomplished by application of routing procedures to determine where sufficient load exists to justify high-usage (HU) trunk groups, and then by application of alternate routing principles which effectively pool the capacities of HU trunk groups with those of final trunk groups, to the end that all traffic is carried efficiently and at a low overall probability of blocking in the average busy-hour of the busy-season. These routing procedures are discussed in detail in Division G Section 3-e.

3.27 The Trunk Engineer starts with the premise that the homing arrangements of all switching systems have been determined by prior study, for the engineering period for which trunk requirements are being estimated. The type of equipment to be used for each switching system and its capabilities for automatic alternate routing and for 6-digit translation are known. Most of this information is available in current records and any differences in future arrangements must be recognized.

3.28 With a knowledge of network homing arrangements, switching system capabilities, and point-to-point load information, the Trunk Engineer is able to determine where high-usage trunk groups should be planned. This is accomplished by routing the point-to-point traffic in accordance with a standard routing discipline and determining where sufficient load exists for direct trunking.

3.29 Generally speaking, network structure is determined by first route loads. For proper sizing of the network trunk groups, however, it is necessary to properly account for overflow traffic. This involves load allocation between direct and switched routes. The choice of an alternate route for a high-usage trunk group is similar to the choice of a switched route for a point-to-point item of traffic. Since the same rules apply to the selection of both a first route and an alternate route, the alternate route for a trunk group is the route the point-to-point traffic item between the two trunk-group terminals would take if the HU trunk group did not exist. The routing procedures discussed in Section 3-e describe how to select all first choice routes and alternate routes.

D. Load Allocation

3.30 In the preceding discussion, reference was made to load allocation between direct and switched routes. In the field of high-usage trunk engineering, this refers to the process of determining the portion of a given load offered to a high-usage trunk group which should be carried by that group and the portion which should be overflowed to an alternate route. The aim of this process is to provide a number of trunks in both the high-usage and alternate routes, such that the traffic between a given pair of switching systems will be handled at the least cost consistent with service objectives.

3.31 Conceptually, the procedure requires certain basic information concerning the existing or prospective high-usage trunk group, as follows:

- Average offered load between terminals.
- Relative costs of the high-usage trunk group and each leg of the alternate route.

In the simplest case, where the busy hour on all the first route and alternate route legs is coincident, the Trunk Engineer is concerned with the cost ***ratio,*** i.e., the ratio of the incremental cost of the alternate route path to the incremental cost of the direct path.

3.32 To determine the most economical trunking arrangement, it is necessary to relate the costs and efficiencies of the high-usage and alternate routes. This is done by calculating the amount of load which the last (least efficient) trunk in the high-usage trunk group should carry.

3.33 Once the objective last trunk CCS has been calculated, standard capacity tables or formulas can be used to determine the number of high-usage trunks required.

3.34 When the least efficient trunk in the high-usage trunk group is carrying the required load, the cost per CCS carried is optimal. In theory, any deviation from this load, whether up or down, would result in a more costly arrangement. Studies have indicated, however, that total network costs are not particularly sensitive to last trunk CCS. Deviations of up to 40 percent do not cause a significant change in network ***costs.*** These deviations in LTCCS can, however, produce a significant change in the placement of trunks with a resulting impact on network administration and on service during periods of overload.

3.35 As mentioned in 3.31, the procedures described above are particularly applicable to the simple case where all busy hours are coincident. In practice, these loads are often noncoincident and a procedure called multihour engineering has been developed to determine the optimum LTCCS in these cases. Multihour engineering is described in detail in Section 3-c.

3.36 This discussion has related to the broad ***concept*** of load allocation between direct and switched route paths, a network arrangement that provides the capability of both improving service and lowering costs. It provides the capability of melding busy hours and busy seasons within the network. To apply this concept, however, requires knowledge of a number of related factors. Section 1-e(1) includes discussion of the effect of day-to-day variations, Section 1-e(2) discusses the effect of peakedness within alternate route networks, and Section 3-c provides a detailed discussion of the application of load allocation concepts.

E. Network Concept of Trunk Engineering

3.37 The following paragraphs deal with a concept called "network engineering," under which the number of trunks required in a given trunk group is dependent upon the load offered to it in a busy-season and busy-hour characteristic of the "network clusters" of which it is a part. A thorough understanding of this concept is necessary for the proper use of basic trunk-group load measurements and message volume data in the detailed computations involved in determining the number of trunks required for each trunk group. The network engineering concept provides a means of pooling trunk-group capacities to handle the meld of many items of traffic (with varying busy hours and busy seasons) through the use of automatic alternate routing. It results in an economically efficient use of facilities for a given grade of service. Division G Section 1-d(2) provides discussion of this concept in detail.

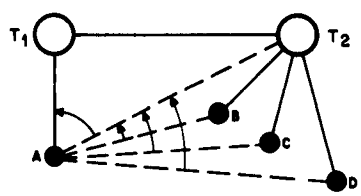
3.38 The design approach used is to subdivide the overall network into network clusters, each capable of being designed independently. A network cluster consists of a final trunk group and all the high-usage trunk groups having at least one terminal in common, for which the final trunk group is in the last-choice route chain. Both ends of the final trunk group must be considered. It is unsuitable to view a network cluster in terms of a single reference office looking out, since this may reflect only part of the high-usage trunk groups overflowing to the final.

3.39 Every high-usage trunk group, then, is a part of two network clusters. This is true without regard to whether the trunk groups operate one way or two way, or whether the network cluster in question is a part of a Metropolitan Network or the North American Network.

3.40 Effective use of the network engineering principle depends upon taking into account not only the network cluster arrangements, but also all of the significant load-time relationships. These include the offered first route and overflow loads on the various actual and potential trunk groups, the level of that load in the busy-season busy-hour of each network cluster involved in carrying that load, and the relationship between the various network clusters with respect to the incidence of their busy seasons and busy hours. The accuracy with which these relationships are identified and evaluated, and the wisdom with which they are used in developing future trunk requirements, determine the efficiency and the economy of the trunking arrangements.

3.41 The network engineering process is designed to provide, within each network cluster, for a low incidence of final route call blocking during the average busy hour of the network busy season. A service objective, expressed in terms of a probability of blocking such as B.01, is selected and used as the busy-season busy-hour service objective for forecasting and servicing final trunk groups. The attainment of that objective will result in a blocking rate for some traffic items which is somewhat lower than the blocking objective, because of the leverage of the attempts carried on high-usage trunk groups of a nonblocking basis. However, it will insure an acceptable grade of service for that traffic which does not have access to high-usage trunk groups, and an adequate margin for handling peak loads.

3.42 From a blocking standpoint, the best service is attained when calls are handled end-to-end over high-usage trunk groups. In a given network cluster, the average blocking level to a large extent is a function of the calls handled over high-usage trunk groups, as illustrated in Sketch 8 and the tabulation that follows:



TRUNK GROUP	CALLS OFFERED 1st ROUTE	OFL RE'CD	TOTAL	CALLS CARRIED	CALLS OVERFLOWED	CALLS BLOCKED	% NC
A — B	300	—	300	270	30	—	—
A — C	300	—	300	270	30	—	—
A — D	300	—	300	270	30	—	—
A — T2	410	90	500	450	50	—	—
A — T1	950	50	1,000	990	10	10	1
Total Cluster	2,260			2,250		10	.4

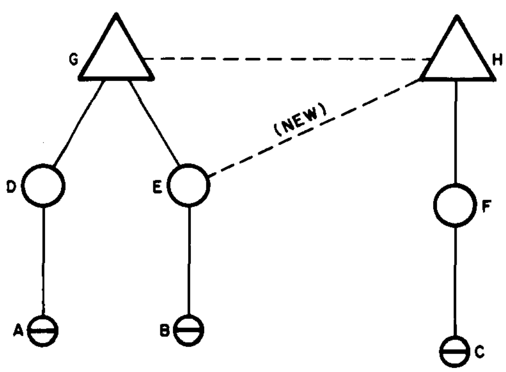
3.43 If all 2,260 calls had been offered to the final trunk group with one percent blocking, more than twice as many calls would have been blocked. The chart depicts the NC condition for the A-T1 cluster only. From an end-to-end service standpoint, there is also a probability of NC within each network cluster encountered.

4. TRUNKING VS. SWITCHING CONSIDERATIONS

4.01 The dynamic nature of network loads and profiles requires a continuous reevaluation of the trunking - switching trade off. The following paragraphs discuss some additional considerations.

A. Load Splintering

4.02 Normally, new trunk groups are economically justified when the cost of carrying the load on the direct group is lower than the cost of switching the load via a tandem. One significant consideration is the fact that establishing any new trunk group involves a splintering of loads between at least two trunk groups. Some trunks are then available to fewer customers and there is less network flexibility to handle changes in load characteristics. Also, the total trunk requirements are larger than with the combined trunk group, causing some loss in trunking efficiency. Sketch 9 illustrates this load splintering consideration.



4.03 Assume a trunk group exists between G and H to handle all the intersectional area traffic. As this traffic volume grows in time, a trunk group can be justified E-H, saving switching at G and replacing E-G-H facilities with E-H facilities. When this is done, however, it causes a reduction in the size of the G-H and E-G trunk groups. Customers served by switching sytems A, D, and G consequently have a smaller number of trunks serving their calls to the H sectional center area, and customers served by switching systems B and E have fewer trunks to G. In other words, a splintering has taken place.

4.04 While the creation of new trunk groups generally is desirable in order to conserve switching and facilities, some other factors need to be carefully weighed before a final decision is made. Among these are:

(a) The busy-hour busy-season characteristic of the load on the proposed new group and the tandem switching system from which the load will be removed. If these busy hours are divergent, no switching capacity may be required specifically to carry the load even if the high-usage trunk group is ***not*** established. (In effect, the load gets a free ride on switching capacity provided for other loads in other hours.) Where this occurs, the switching-cost portion of the costs used to develop the appropriate objective LTCCS is effectively zero. As a result, the high-usage trunk group may not actually prove in. Where cost ratios are used to develop objective LTCCS values and busy hours are assumed coincident, this situation may not be apparent.

(b) The facility paths to be utilized for providing the new group. Where route costs are developed by basing facility costs on airline miles, a trunk group may appear justified. If the actual facility route, however, is via the location through which the traffic was previously handled, the high-usage and alternate route costs may be nearly identical, indicating that no savings will result from establishing the high-usage trunk group. Where this situation exists, the trunk group should be not be provided.

(c) The busy-hour busy-season characteristics of the proposed new trunk group and the trunk groups presently carrying the load. If the loads have widely divergent busy hours or busy seasons, the proposed trunk group load may not be significant to the engineering of the network. To size the group for this load may unnecessarily duplicate facilities.

(d) The variability of loads on the trunk group involved. While trunk groups are normally sized to meet a network busy-season load, the trunk engineer should be aware of load characteristics outside that time frame to insure that those loads can be handled economically and within approved service levels. This consideration is of particular importance when busy seasons have been preestablished, or when nonbusy-season data is not available.

(e) The reliability of the data used to indicate that a new group is required. It should be ascertained that the projected load on the new group stands a good chance of being realized.

B. Vulnerability

4.05 Larger switching system capacities in terms of the ability to accommodate increasing numbers of lines and/or trunks are advantageous in many ways. The larger switching systems generally present the possibility for better service at lower costs because, with the concentration of larger loads, more direct trunking can be justified. The result is reduced tandem switching requirements.

4.06 However, this increased concentration also results in increased vulnerability. A larger portion of the network load can be affected by a single trouble or failure. Also, because of increased efficiency and higher average loads per trunk, there is less capability for absorbing surges in traffic.

4.07 The trunk engineer should be aware that the achievement of increased efficiency and lower costs through the increased concentration capability of larger and larger switching sytems is accompanied by an increased vulnerability which inescapably accompanies such a development.

C. Capital Constraints

4.08 Trunk group sizing procedures involve load allocations on the basis of assumed incremental costs. This assumption presumes that any number of trunks can be added to a trunk group for the average cost of all similar trunks. In reality, this ignores the fact that installations of both transmission and switching facilities are made in discrete units and that significant capital expenditures are required when basic relief or expansion of the facilities is required. In some specific situations, the addition of more trunks in a high-usage trunk group might require basic facility relief. It may be practical to defer such relief by increasing the amount of overflow to the alternate route, or reducing overflow from subtending trunk groups if facilities in these routes can be augmented.

4.09 Similar expedient arrangements may be possible to temporarily defer the expansion of a final trunk group beyond some point requiring basic facility relief. Overflow to the final trunk group can be reduced by augmenting subtending high-usage trunk groups or,in some cases, it may be possible to advance the implementation of one or more new direct high-usage trunk groups. The inception and implementation of these new high-usage trunk groups, however, involve certain first costs or getting started costs which need to be considered as offsetting, to some extent, the advantage gained by deferring plant additions elsewhere in the network. Thse costs are for such items as the initial switching system arrangement to accommodate a new trunk group, arrangement for the procurement of traffic usage data and PCO data, and the necessary routing changes.

D. Need for Flexibility and Adaptability

4.10 The base data and growth projections upon which estimates of future traffic loads are based seldom lead to projections which are realized exactly. The degree of dispersion may vary from small to very significant, as factors such as presumed economic trends are or are not realized. Assumptions made regarding the distribution of traffic over the day, and its other characteristics such as peakedness, are subject to change. Further, assumptions relative to homing arrangements and traffic transfers are often modified. In addition to these factors, neither the likelihood of surges in traffic nor the magnitude and duration of such surges from natural or other causes can be accurately predicted. It is equally difficult to be sure that costs and cost projections which are assumed in the study process are indeed those which will be realized.

4.11 Because of these uncertainties, it is most important to strive toward a network design which has some degree of latitude in its tolerance for the inherent variance involved in the forecasting process. Generally alternate routing networks, designed as recommended in these practices, provide a degree of tolerance because of their flexible routing capability.

E. Growth

4.12 The continuing requirement for accommodating growth is that of achieving a proper balance between splintering and concentration. One factor that complicates the achievement of such an objective is the dynamic nature of the problem. An optimum solution for a specific distribution of traffic loads may very well fail to meet objectives for the same loads with distributions altered by the passage of time.

4.13 The best solution for current problems is one which is consistent with reasonable solutions for anticipated future problems. An orderly program toward long-term objectives helps to avoid the necessity for expensive crash programs to "put out fires" which occur when expedient and short-term solutions fail to accommodate requirements increased and altered by the passage of time. The trunk engineer, then, should not assume an infinite flexibility of outside plant, but should smooth transitions betweeen forecast years.

F. Finite Switching Systems Capacities

4.14 The trunk network design process is interdependent with the switching design process. The message network utilizes many different types of switching systems including step-by-step, crossbar, and electronic. Each of these types has a group of finite design capacities and finite installed capacities. The overall capacity is composed of finite translation and termination capacities in addition to call carrying and attempt limitations. More detail on switching system capacities is contained in Division G, Section 3-g.

4.15 In general, trunk forecasting is done sufficiently early for switching systems or switching system additions to be made available to meet the forecast need. The routing logic and procedures dicussed in Section 3-e are used to identify the traffic switching patterns within the network. The trunk forecast logic and procedures discussed in Section 8-c are used to identify the first-routed and alternate-routed traffic loads on trunk groups and the resulting load on the various network switching systems.

4.16 These switching loads must lie within the finite capacities of the switching systems involved. They must also lie within a reasonable growth range of the installed capacity. If either of these conditions is not met, the forecast of switching loads should be re-examined.

4.17 The rerouting of traffic merely to take advantage of installed capacity at a different switching system, sometimes called "capacity chasing", is not recommended. While capacity chasing provides the illusion of improved plant utilization, the reverse is often true. Capacity chasing may cause significant outside facility construction to take advantage of the spare switching capacity. It may lead to significant trunk-order work, resulting in a temporary loss of trunks while the plant rearrangement work is in progress. It leads to difficult interpretation and use of trunk-group measurements. Capacity chasing also leads to a more uniform exhaust date at the various switching systems in a given network. This may lead to a disordered construction program and to continuously excessive rearrangements and changes.

4.18 There are some actions trunk engineers may take, however, to extend the life of switching systems. Among these are:

(a) In certain switching systems, the splitting of 2-way trunk groups into one-way directional groups to conserve trunk terminations. The penalties inherent in such splitting, as discussed in section 3-f, should be carefully evaluated before this action is taken.

(b) The advance building of subtending high-usage trunk groups to save switching. Care should be exercised to insure that such groups will be justified on their own merit, within a reasonable time frame so that the penalty, if any, is merely one of advancing some construction.

G. Network Engineering, Administration, and Management

4.19 Just as there are economic constraints relative to network design, there are also administrative and management constraints. The administrative constraints relate to the ongoing trunk servicing process and the management constraints relate to the managing of the network on a dynamic basis. It is important to test theoretical solutions to trunking problems against the requirements for administering and managing the network. For example, the theory supporting objective LTCCS determination might dictate a full and frequent recalculation. This could cause a change in overflow loads. Implementing such changes constantly could significantly increase plant and dial administration work, keeping the network in a state of flux and making trunk administration a difficult task. As previously stated, network costs are not particularly sensitive to LTCCS variation, therefore, there is no need to overtune the calculations.

4.20 Caution should be exercised in the use of ECCS values in the range of 24 or more. Designing high efficiency into high-usage trunk groups by increasing the loading also decreases the ability of the trunk group to absorb overloads or surges in traffic. When this condition is compounded by commonality to a number of high-usage trunk groups overflowing to a common final trunk group, the effect on service can be severe under relatively minor overload conditions.

4.21 In a somewhat similar vein, it is desirable to maintain a consistent network trunking plan. Care should be taken that trunk groups are not established until justified, and that once justified, they should remain unless the ***long term*** outlook indicates removal. Trunk groups should not fall into a cycle of in, out, in, out, etc. The trunk forecasting process discussed in Section 8-c provides a different threshold for continuing an existing trunk group as compared to establishing a new trunk group. This approach minimizes unnecessary plant rearrangement, and enables better interpretation of trunk usage data, with resulting improvement in network administration.

4.22 The trunk network is provided to meet an ***average*** load in the busy season, allowing for some variations about this value. However, there may be days throughout the year when busy-hour offered loads will exceed the expected values by significant amounts. Under these conditions, the Network Management organization, through the use of available tools and techniques, attempts to maximize completion of offered calls. To the degree that the network is designed and established in accordance with System Standards, this management job is made less complex.

H. Rearrangement Constraints

4.23 In designing the network to meet growth, there is often the need to perform network rearrangements such as those occasioned by the provision of new switching systems, new outside plant facilities, or load transfers to keep within existing limitations. Of concern is the managerial problem of stabilizing and smoothing out the work force needed in the future. Rearranging the network to accommodate growth and change constitutes a very labor-intensive activity. Experience indicates that the amount of rearrangements required is sensitive to the particular growth strategy employed. This being the case, labor consuming rearrangement activity becomes an important factor in decisions regarding network design.

4.24 In considering alternative ways of serving a given demand, there are typically solutions that are of comparable economic worth, but which differ substantially in their capital-labor mix. Because labor and capital tend to be inversely related, a capital consuming plan is likely to be less demanding of labor, and vice versa. The optimum capital-labor trade-off is often related to the timing of the rearrangement. The options, however, must be clearly identified before the choice is made.