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2. A STUDY ON NETWORK PLANNING MODELS OF CANADIAN DATA NETWORKS AND THE IMPACT OF INTERCONNECTION AND INTERWORKING

by

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SUMMARY

The contract background statement for this study was "to provide DOC with the scientific information necessary to develop policy decisions and guidelines that will benefit users in Canada and insure a healthy competition between the carriers". The fundamental objective of the study was to develop a model for the tariff structure of each available data communications service so that statements could be made regarding:

- the conditions under which a particular service is most economical to a user,
- the changes that would occur if an interconnection of Infoswitch with the dial telephone network and/or interconnection of Datapac with the Telex network existed,
- the changes that would occur if interworking of the Datapac and Infoswitch networks existed,
- the most economical services for providing the data communications requirements of three specific user groups, namely, Electronic Funds Transfer Systems, COSTPRO, and the systems identified by the Government Telecommunications Agency.

In order to make statements about which data service is most economical it is necessary to relate the chargeable items of each service to the characteristics of the application. It was found that for a full comparison six

price
distance speed
volume technical
demand
time
institutional

parameters describing the user applications were needed. The tariffs for digital and analog leased lines, Datapac, Infocall, Infoexchange and DDD telephone were reduced to models based on these six parameters. From these models the most economical regions for each data communications service were evaluated.

In general, proceeding from high traffic volume to low volume, for all speeds, there is a digital leased line region, followed by Datapac, Infoswitch and the DDD telephone network in that order. To estimate the number of users in each region it was necessary to use information from the Datacom'76 survey data base. This survey only supplied three of the user parameters and the others had to be estimated from general knowledge of user characteristics.

For several major applications it was determined that Datapac was the most economical service. In the balance of the major applications Datapac and Infoswitch are competitive. Infoswitch and Datapac tend to occupy the region where currently leased line and DDD telephone costs are roughly equivalent, and hence these new services give the users a more economical service than was previously available.

It was found that an interconnection allowing dial telephone access to Infocall and Infoexchange would have little impact on the distribution of users if the choice between Infoswitch and Datapac were made on an economic basis.

A Telex-Datapac interconnection could significantly reduce user costs but if it were of the interworking type, it could result in Datapac capturing the Telex customer base.

The effect of interworking between Datapac and Infoswitch was considered by analysing the user costs for the various application area. For those applications where interworking seems useful there is insufficient cost differential between the two services to make interworking economically attractive to the users unless it is almost free. The major argument that we see for interworking is to insure competition by preserving user freedom of choice in those applications where Infoswitch and Datapac are competitive.

The study of Electronics Funds Transfer Systems was hampered by a lack of data on user characteristics. It is conjectured that Datapac and Infoswitch will be competitive for this application.

The systems identified by GTA are basically identical to general user time sharing and remote job entry activities. For both Datapac is the most economical service. Datapac also seems to be the most economical service for the COSTPRO system.

CONCLUSIONS

Tariff and user models.

- Tariffs for various communications services can only be meaningfully compared with respect to a particular communications application.

- Fair comparison of tariffs, and selection of the most economical data communications, service for a particular application, requires knowledge of up to six application dependent parameters. Currently available data typically contains only two or three of these.

- We recommend that all future surveys such as "Datacom'76" and "Survey of EDP Telecommunication Applications in the Federal Government" base the survey questions on the user model developed in this study.

Most Economical Service Regions

- In general, proceeding from high traffic volume to low volume for all speeds there is a digital leased line region, followed by Datapac, Infoswitch and the DDD telephone network in that order.

- In the Infoswitch region, Infocall is most economical at the lower speeds and Infoexchange at the higher speeds.

- For many applications the Infoswitch region is very narrow.

- Existing data on applications indicates more terminals are located in the Datapac region than in the Infoswitch region.

Interconnection: Infoswitch-Dial Telephone

- Telephone dial access to Infoswitch will be of economic benefit to approximately 10% of the terminal users in the time share and enquiry-response environment.

- Infoexchange-dial telephone interconnection service will be at least twice as expensive to a user as dialed Datapac 3101.

- Infocall-dialed telephone is competitive with dialed Datapac 3101 for local calls, but can be up to twice as expensive for non-local calls.

- Where Infocall-dialed telephone is competitive with dialed Datapac 3101, the cost difference is very sensitive to interconnect charges and non-tariff costs at the host computer.

Interconnection: Telex-Datapac

- A Telex-Datapac interconnection for long haul traffic would significantly reduce the long distance Telex charges.

- A full interworking interconnection, including local calls, would significantly reduce all user costs, but would probably result in Datapac capturing the Telex customer base.

- A Telex-Infocall interconnection would give customers a cost reduction similar to a Telex-Datapac interconnection.

Interworking: Datapac-Infoswitch

- Interworking between Datapac and Infoswitch appears necessary to preserve competition. Datapac is clearly best for many applications and competitive for most others.

- Interworking will preserve competition by reducing the tendency for all users in a given application area to adopt a single service for "compatability" reasons.

- The typical data communication cost of a user for whom interworking may be of benefit, is in the order of $100 to $150 per month per terminal.

- Provided there is no interworking charge, interworking would typically yield a saving of 10 to 20% where it gave a choice between services.

- If interworking charges exceed 25¢ per kilopacket of data the economic benefit to the user becomes questionable.

- The introduction of the Infogram service tariff will alter the above conclusions only if Infogram service is significantly less expensive to the user than Infocall or Infoexchange.

Application Areas

- For time share and enquiry-response users, Datapac and Infoswitch are more economical than the current leased lines and DDD telephone network. Datapac is on the average approximately 20% less expensive than Infoswitch in the asynchronous speed region, and 50% less in the synchronous speed region. Datapac is within 25% of Infoswitch in those areas where Infoswitch is less expensive; the converse is not true. Since Datapac is most economical for many applications, and competitive for the balance, there will be a tendency for the members of this user community to adopt Datapac because it is most economical overall. Interworking would eliminate this tendency, and would make this area more competitive.

- On-line banking terminals currently use analog leased lines. Datapac and Infocall costs are approximately the same as the leased line costs. Consequently Datapac and Infocall are both contenders for this application, especially if there is an increase in leased analog line rates. Without interworking, one carrier may capture a major fraction of this market, especially if "compatability" questions are raised due to Electronic Funds Transfer considerations. Interworking would eliminate this "compatability" requirement and increase competition.

- Air line reservation terminals currently use analog and digital leased lines. Conversion to Datapac would reduce costs for the analog line users but would make little change for the digital line user. This application will probably remain on leased lines unless there is a significant increase in leased line rates. Infocall costs would be twice those of Datapac and, consequently, the presence/absence of interworking will have little effect on user actions.

- For remote job entry (remote batch) applications Datapac is more economical than the current leased lines and DDD telephone network. Infoswitch is typically more than twice as expensive as Datapac. Therefore interworking would have little effect on user service selection.

Closed User Groups

- Based on the results obtained for the general user groups with similar characteristics to Electronic Funds Transfer Systems it is conjectured that Datapac and Infocall will be competitive for this application. The data communications cost will probably be in the order of $100 to $150 per month per terminal.

- The systems identified by the Government Telecommunications Agency have the same characteristics as general use time share and remote job entry traffic. For both applications Datapac is the most economical service.

- Based on COSTPRO traffic and terminal projections, Datapac is the most economical service for this application.

TABLE OF CONTENTS

SECTION 1. INTRODUCTION

The following sections present the details of a study of the tariffs for data communications services in Canada. The purpose of the study was to develop models for the tariff structure of each available service so that statements could be made regarding:

- the conditions under which a particular service is most economical to a user under existing tariffs,
- the changes to these conditions that would occur if an interconnection of Infoswitch with the dial telephone network and/or interconnection of Datapac with the Telex network existed,
- the changes that would occur if interworking of the Datapac and Infoswitch networks existed,
- the most economical service or group of services, for providing the data communications services of three specific user groups, namely, Electronic Funds Transfer Systems, COSTPRO, and the federal government communication systems identified by the Government Telecommunication Agency (GTA).

In order to make statements about which data service is more economical for a given user, it is necessary to relate the chargeable items (according to the tariff) of each service to the characteristics of the user. Then when two data services are compared, it should be possible to insure that the tariffs are being compared under identical and, hopefully, reasonable assumptions with respect to the characteristics of the user application.

It was discovered that available existing studies of this nature were carrier oriented, i.e., they were concerned with the optimum method of the carrier providing future data service, and it is not apparent that the analyses nor the conclusions are particularly relevant to users. Indeed, the studies ignore some items, such as access charges, which for some data communications users are the dominant service charge. Consequently, an investigation was made of the tariffs to isolate the various charging mechanisms.

which are these we used item 2

Upon study of the tariffs, and consideration of the data communications process, it became apparent that a user application could be described by eight parameters (of which only six are independent) and that the tariffs for the various services were based on various subsets of these parameters. Hence, in order to make a meaningful comparison of the cost of two data communication services for a specific application, it is necessary that

1) both tariffs be reduced to a function of these eight parameters, and

2) the values of the parameters for the application be available.

The first item has proved possible, although computationally tedious, and in Section 2 and 3 are presented the background and details of the resulting analytic models[1] for the various data communications tariffs. The second item has, however, proved to be a major problem. There are obviously two sources for obtaining the communications parameters of a user's applications - the public carriers and the user community. Neither source has been fruitful.

?
Implication on voicing [illegible]

The carriers do not appear to be in a position to provide significant data of the type required. This is, of course, partially due to the possibly sensitive nature of the information, either for their own business planning, or for their customers business activities. However it is also likely that they do not have information at the level required. While the type of information needed will be defined in Section 2, the problem might be illustrated at this time by an analogy from the voice telephone system. On the voice networks the carriers have a century of experience on call duration and base their tariffs on expected call duration. However, until recently, they had no reason to be interested in whether you talked fast, slow or not at all during that time. Hence they had little information of that type. For data communications an accurate model of the user requires not only knowledge of typical call durations but also of the amount of "talking", and given the very recent

Were they asked?

[1]It should be noted that the models are fits to "smoothed" tariff data and are valid for general comparisons and sensitivity studies. However they seldom reproduce any individual user charges exactly.

development of private and public data networks it is unlikely the carriers have a representative sample of all user parameters for typical applications. For example an analysis [6] based on the Eurodata Study did not consider line speed and was forced to assume a message length.

Now turning to the user community, very little general information is available. Most papers that discuss terminal user characteristics, or network performance, are more interested in estimating computer response time than in the details of the communications process. This is understandable since most of these studies were made for 300 bit/s (or lower) communications channels and the line utilization or cost was not a dominant consideration. However, even the recent Datacom'76 [1] survey only asked users for total traffic volumes and line speed, but not holding time, number of calls, average message length or communications intensity. Similarly, most computing centres record input/output data on which they bill, but not all the communications parameters. It might be noted that the lack of detailed information is not surprising; it is only required if the user has the option of choosing among several transmission schemes and this option is a very recent phenomena.

Consequently, in view of the lack of accurate knowledge of user application parameters, care must be taken in comparing the tariffs and in assessing the advantages to the user of various interconnection and interworking schemes. In the report an attempt is made to overcome this difficulty by considering the sensitivity of the results to the various parameters.

How Successful Evaluate

The following section, Section 2, discusses in detail the background to the development of the tariff models, and considers in detail the characteristics of a user application. Section 3 presents the models for each of the tariffs, and indicates how the cost to the user varies as a function of the various user application parameters. The graphical results presented give a general view of the tariff, and how it depends on the application parameters. In several cases behaviour that is counter intuitive is observed, i.e., improved service being less expensive. Section 3 concludes with a discussion of tariff sensitivity to certain parameters, particularly distance.

Section 4 compares the tariffs for the various user parameters, and contains graphical results indicating the regions (partitions of user parameters) for which each service is most economical. These partitions were generated for various sets of user parameters, each of which represents a typical user application, and which between them cover the anticipated range of user parameter values. Hence it is expected that, if a given application is not close to one of the cases presented, an interpolation between the bracketing cases would be possible.

Section 5 considers the effect of interconnection. It is shown that for a typical time sharing (service bureau) application that the Infoexchange-dialed telephone interconnection will yield no saving to the user, but that there are situations in which Infocall-dialed telephone interconnection is competitive with Datapac 3101. A Telex-Datapac interconnection would reduce costs to users, but could also substantially reduce the Telex share of revenue.

Section 6 considers the effect of interworking. The problem is approached by using the Datacom'76 survey data base to locate a large sample of users on traffic vs speed diagrams. This allows statements to be made regarding the optimum service for a given application and the cost differential between services. From this it is possible to indicate applications where interconnecting would improve competition, and to estimate some of the interworking economic factors.

[illegible]

Section 7 is a discussion of the three closed user groups, Electronic Funds Transfer Systems (EFTS), COSTPRO, and the systems identified by the GTA. For EFTS almost no information exists except for on line banking, hence the study is restricted to that application. For COSTPRO a full discussion is presented which indicates Datapac is most economic if the COSTPRO traffic data is valid. For GTA systems the data is insufficient to clearly indicate specific optimum applications, but there is a strong indication that Datapac is the most economical in many cases.

SECTION 2. TARIFF MODELS

2.1 GENERAL FORM OF MODEL

The total monthly cost of transmitting a certain quantity of data depends, in the first instance, upon the total volume of data, the speed of transmission, and the distance. In a fluid analogy, these are the volume transported, and the cross-section and length of a pipe. However, the various services available from the carriers, such as a leased line, circuit switching, and packet switching introduce additional parameters upon which tariff charges depend. The first task of the model is to collect the total costs for a month's operation under specified conditions, and to identify any additional parameters upon which the different techniques depend.

It is carrier practice to impose a monthly charge in order to obtain access to a data network. This access charge depends primarily on the speed of operation of the access channel and whether it is synchronous or asynchronous. Other considerations can play a part, such as various options and terminal equipment, but for the purposes of modelling we can consider that each end of a point to point communications link has an access charge, A(s), associated with it, that is only a function of the nominal line speed, s, in bits per second. Accordingly, the first term in the model is 2A(s) when both termini are operating

 Impact of Transmission ?

at the same service speed. It is recognized that some services, for example Datapac 3101, do not have the same access charge at the remote end. This and the question of special purpose non-carrier software and hardware, will be ignored until a later section.

The second component of the total charges depends on the amount of network usage measured in a manner appropriate to the service technique employed. In all cases, this measurement will involve at least the length of the communications link. In the case of a leased line, usage is charged directly in dollars per month depending upon the length and capacity of the line, regardless of the actual traffic transmitted. For packet switching, the usage charge is expressed as a rate in cents per kilopacket that depends on the distance, so that the total monthly cost will be proportional to traffic volume according to a packet count. In the case of circuit switching, usage is charged by the total circuit connect time during a month, according to a rate that depends upon the distance and the speed of the service. In the model, we designate these different usage functions and rates as U(d;....), where dependence upon variables in addition to distance is indicated in particular cases.

In order to add the usage to the access charges, the usage must be converted to dollars per month in all cases, by some factor, K, defined according to the service technique involved. The second term in the model is then $KU(d;...)$ dollars per month, where the factor K is most important in the comparison of different communication techniques for which the usage rates are defined differently.

In several cases of carrier services, K involves parameters that are unique to that one service only. This means that comparison among services, or between usage and access charges, depend upon the value of a unique parameter and hence can be made quite arbitrary. This question is considered in detail in Sections 2.4 and 2.5. Finally, in some cases there is a surcharge for each call set up according to some rate, N, which may be a constant per call (Datapac), or a function of distance (telephone). If N is in dollars per call, and the average number of calls per month is "n", then Nn becomes a third term in the model.

The basic tariff model consequently takes on the form:

$$\text{dollars/month} = 2A(s) + Nn + KU(d;...) \qquad [2.1.1]$$

2.2 MODEL PARAMETER DEFINITIONS

We now define the variables and parameters employed in the model, together with the units in each case. The total tariff is calculated in dollars per month ("$pm") for a particular application under specified conditions. The amount of data actually communicated during the month is the traffic volume, "u", in bits per month while the speed of the line used is "s" in bits per second. The distances between points on the network have been calculated as the direct (great circle) distances from their latitudes and longitudes. These are tabulated in an Appendix and are referred to as geographical distances, "d", in miles as distinct from circuit route distances. Thus, u, s, and d, are three important variables of the model for all data communications services. In addition, there are a number of parameters necessary to describe different types of applications. For packet switching we have the average packet length, "b", in bits per packet, while for circuit switching, the connection time, "c", in hours per month is the basis for charging.

Is this acceptable i.e. [illegible] ?

We have already defined the call density "n" in calls per month, to which we now add the average call duration, or the holding time, "t" in minutes per call. Because the analysis involves comparing different communication methods under a variety of application types, wherein some parameters appear only in some cases, we have found it essential to define an additional descriptive parameter called the "communication intensity" which is a dimensionless parameter "i". This parameter measures the extent to which a communication facility is used in comparison to its maximum capacity. The communication intensity is unity for a half-duplex connection used at rated line speed continuously without pause. (This definition was chosen since half-duplex protocols are used in most computer communications.

If a duplex channel is used at rated line speed in both directions simultaneously a value of two is obtained for i. However such applications are rare and we will proceed as if the maximum value for i is unity.) Thus we may define the communication intensity as the ratio of the time required for a communication at full rated speed relative to the actual call duration or holding time. In terms of the other quantities defined above, this is,

$$i = \frac{u/(60ns)\ \text{min/call}}{t\ \ \text{min/call}} = \frac{u}{60tns} \qquad [2.2.1]$$

An alternative definition is the ratio of the actual data per call to the capacity of a call of the same duration at full line speed; viz.,

$$i = \frac{(u/n)\ \text{bits/call}}{60\ ts\ \text{bits/call}} = \frac{u}{60nts} \qquad [2.2.2]$$

Through this intensity of line use parameter we arrive at an effective line speed, (is), which is the apparent line speed of a call in terms of its data content and holding time; namely,

$$is = \frac{(u/n)\ \text{bits/call}}{60t\ \ \text{sec/call}} = \frac{u}{60tn}\ \ \text{bits/sec.} \qquad [2.2.3]$$

Equations [2.2.1], [2.2.2] and [2.2.3] are the same, of course.

In all, we have defined eight quantities of interest; viz.,

(u, s, d, b, c, n, t, i)

However, they are not all independent because of equation [2.2.1]. In addition, there is a relationship implied by the definitions; viz.,

$$\text{connection time} = 60c = tn \quad \text{mins/month} \qquad [2.2.4]$$

Therefore, it follows that only six of these quantities may be specified independently, and of these, two must be the distance, d, and packet length, b, and of the remaining four there must be at least one of (t,n) and at most two of (c,t,n). Therefore, there are a total of eleven possible selections of four independent variables from the set of (u, s, c, n, t, i).

Sometimes, other descriptions may be derived from the above, such as the packet call length:

$$\text{packet call length} = u/(bn) \quad \text{packets/call}$$

Finally, the holding time, t, may be separated into a "communication time" which is (ti), and an "idle time" which is t(1 - i).

2.3 UNIT COST ISOGRAMS

The model of equation [2.1.1] represents the total tariff cost per month. This can be normalized to the same volume of transmitted data to make cost-effectiveness comparisons. Such a unit cost, in dollars per megabit is obtained from:

$$G = (\$pm)\ 10^6/u \qquad [2.3.1]$$

Considerable consideration was given to the choice of the parameter space for the display of cost and performance behaviour. We have selected the direct and obvious variables from the user's point of view rather than derived quantities; namely, the quantity of data to be processed, u, bits per month, and the speed of transmission, s, in bits per second. This space is shown in Figure 2.3.1, where both axes have logarithmic scales. Traffic volume covers the range from 10^5 bits per month (12,500 characters per month) to 10^{10} bits per month (1,250 million characters per month).

Now both axes represent variables in equation [2.2.1] so that every point in Figure 2.3.1 corresponds to a value of the products, (tin), or, (ci). Because of the log-log plot, contours of constant value for these products are straight lines as indicated in Figure 2.3.1. A constraint on the maximum value of ci of 730 hours per month, or the maximum value of tin of 43,800 minutes per month, places an upper bound on the available space on this diagram.

useful connection [illegible]

The cost per unit traffic for a given carrier service can be plotted on this volume-speed diagram. Especially interesting are contour lines of constant unit cost according to equation [2.3.1]. Such a diagram of unit cost "isograms" - lines of constant dollars per megabit - show the sensitivity of transmission costs to volume of business and line speed or performance.

Two abscissa scales are shown in Figure 2.3.1. Synchronous data transmission employs 8 bits/character, while asynchronous data transmission uses 10 bits/character. From the users point of view, therefore, the nominal line speed

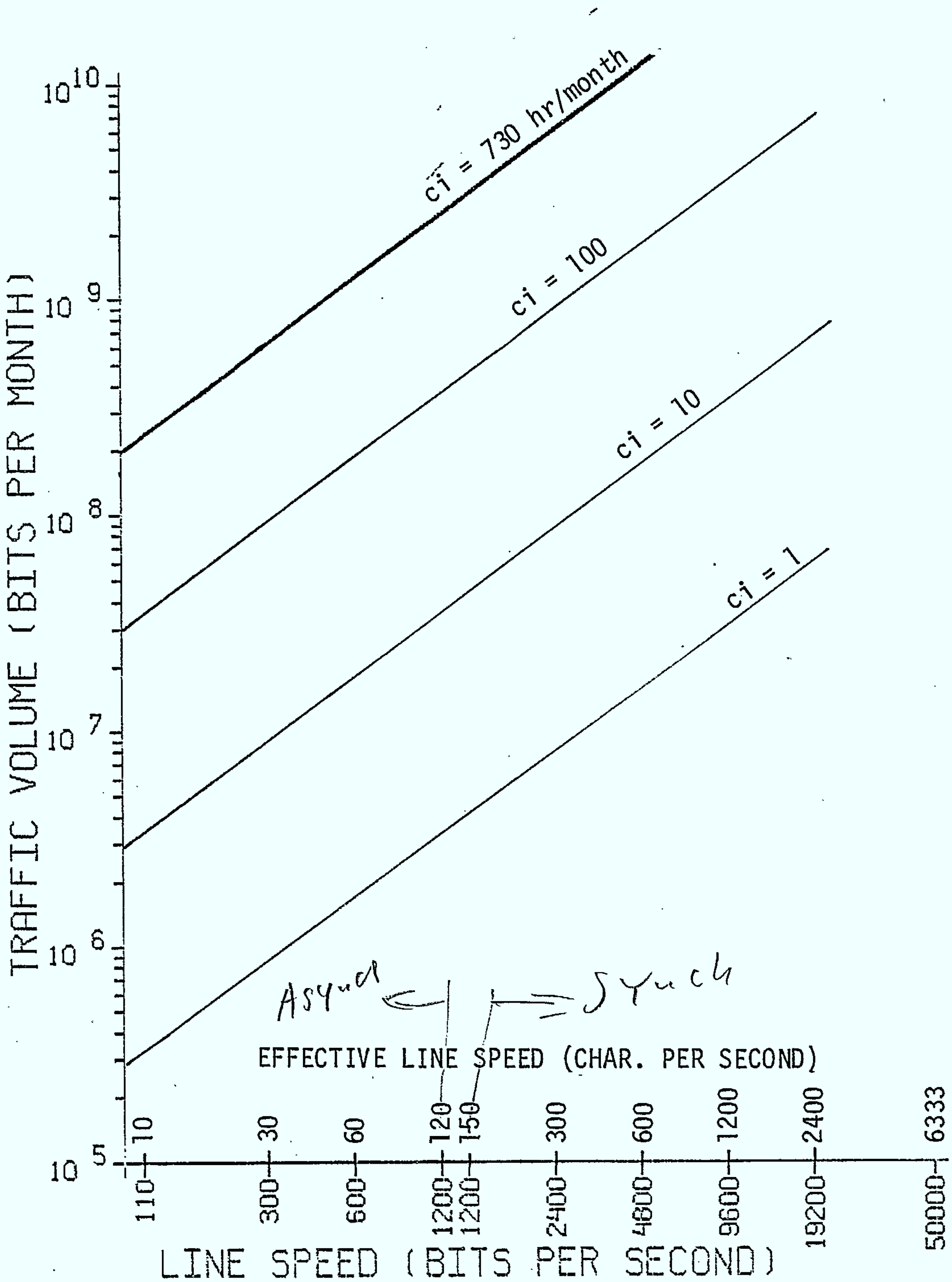


Figure 2.3.1: Traffic space

for asynchronous transmission must be derated to 80% to give comparable capacity. Accordingly, the asynchronous portion of the abscissa in Figure 2.3.1 has been moved an appropriate amount towards lower actual data rates. Alternatively, the abscissa may be regarded as a continuous (logarithmic) scale in characters per second, upon which are marked the nominal line speeds in bits/second for both synchronous and asynchronous modes. Equations [2.2.1], [2.2.2] and [2.2.3] now yield the following constraint on the variables:

$$u = 3600 \text{ cis} = 60 \text{ tins (synch: } s \geq 1200)$$

$$u = 2880 \text{ cis} = 48 \text{ tins (asynch: } s \leq 1200) \quad [2.3.2]$$

Moreover, the calculated values must lie in the allowed ranges. For example,

$$0 \leq i \leq 1$$

$$0 \leq c \leq 730 \text{ hours/month}$$

$$0 \leq tn \leq 43800 \text{ mins/month}$$

$$0 \leq s \leq 56000 \text{ bits/second}$$

$$0 \leq u \leq 1.5\ 10^{11} \text{ bits/month} \quad [2.3.3]$$

730*56000*3600

2.4 USAGE COEFFICIENT

We can now specify the usage term of the model, KU(d;...) in equation [2.1.1], according to the carrier method employed. As already noted, for a leased line, U(d,s) is directly in dollars per month so that $K_1 = 1$. The traffic variables are bound only by equations [2.3.2] and

[2.3.3]. For packet switching we have the usage, U(d) in cents per kilopacket so that it follows in this case that:

$$K_3 = u\ 10^{-5}/b \qquad [2.4.1]$$

Again, in circuit switching, the usage, U(d,s), is a rate in cost per connected minute each month. Hence we have in this case:

$$K_2 = 60c \qquad [2.4.2]$$

Finally, if a circuit switch network is charged on a traffic basis, say dollars per 10,000 characters, then a minimum amount of traffic will be assumed as a base for line occupancy. Therefore, the usage rate will depend partly on traffic and we have U(d,u,c) with , in this case:

$$K_4 = u\ 10^{-4}/8 \qquad [2.4.3]$$

Note that in each of these equations there are parameters which do not appear in the factor, K, for the other methods.

A comparison between different carriers, or different communications techniques can be made using the models of equations [2.1.1] or [2.3.1]. However, because of the unique parameters involved in the factor, K, the arbitrary assignment of the values of these parameters leads to an equally arbitrary comparison. Thus, any comparison of costs or performance which does not specify all the conditions must be regarded as incomplete.

Finally, if two such contour diagrams for different services are superimposed then the points of intersection of isograms of like value form a line that partitions the diagram into regions wherein one of the two services is the more economical.

The validity of such a partition depends upon equivalent conditions being assumed for the two services; and, this may require assigning values to parameters unique to each service. For example, circuit switching with an assumed average call duration can be compared with packet switching with an assumed average packet length. Clearly the equivalence of the assumptions is important. Moreover, a common parameter such as communication intensity will usually be kept constant in a comparison of services; but deeper insight might show that the intensity indeed is different for different services under the same application conditions.

The problem of adequate data on the values of a complete set of parameters which are sufficient to permit authoritative comparisons of tariffs and costs for well defined application types, has not had sufficient research. Sections 2.2 and 2.3 give the parameter set, and in the next section we indicate how representative values may be described for some applications.

2.5 APPLICATION SPACE PARAMETERS

We have seen that six quantities must be specified in order for presentations and comparisons between tariffs to be meaningful. Also, the calculation of unit costs involves unique parameters in some cases, such as, average packet length in the case of packet switching, that appear in the factor K in equations [2.1.1] and [2.3.1]. Accordingly, we describe an application of data communications by a point in the three dimensional "application space" of Figure 2.5.1 through typical values of the parameters (t, i, b).

Figure 2.5.2 lists values of these parameters for a number of common applications as examples. There are very few sources which give data that is complete enough for our purposes. For example, the only user usage variables recorded in the Datacom'76 [1] survey were "u" and "s".

Case (a) is used as a "central value" in the following Section 3 on tariffs to illustrate the analysis. Cases (b) and (c) are then used to show sensitivity to application type. Note the range of communication intensity values for Cases (a), (b) and (c). Cases (d) and (e) represent the same type of systems and a similar application, with the variation in parameter values apparently resulting from the heavier load on the one computer. Given such a variation within similar cases, the importance of more precise and complete user characteristics is apparent. Cases (a), (d), (e) and (f) are derived from published data wherein an attempt was made to hide the values by presenting only means and variances. However, the authors overspecified their results and it is possible to extract the required values. Cases (g) and (h) are typical of many sources which are not

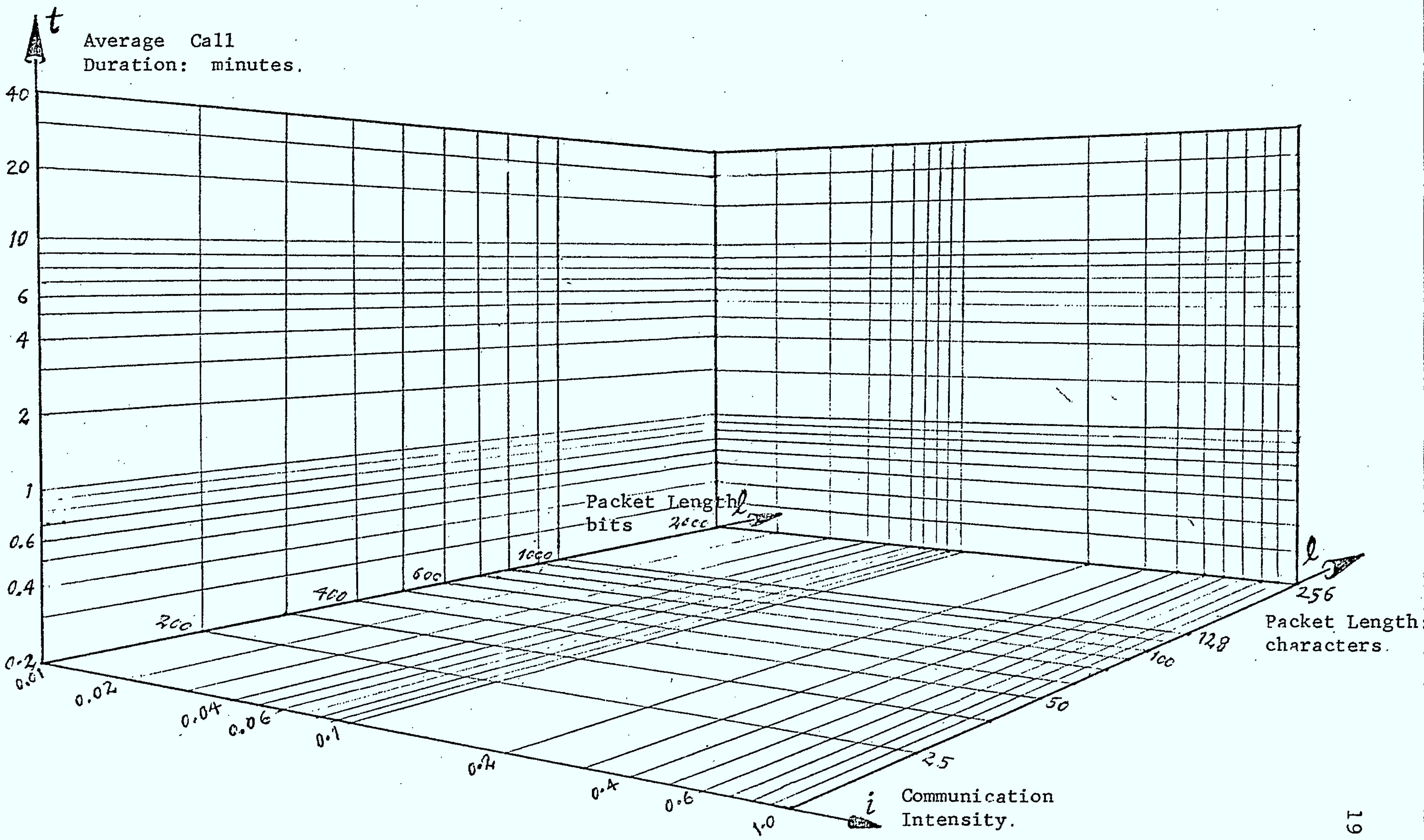


Figure 2.5.1: Data Communications "Application Space"

Note i varies all over the map!

adequate for present purposes because the specifications are incomplete.

Application Type		Average Packet Length in character	Average Call Duration in minutes	Communication Intensity (i)	Reference
(a)	Enquiry Response (light to moderate)	20	19	0.24	Fuchs & Jackson 1970 [2]
(b)	Remote Job Entry	256	45	0.80	Sec. 6.7
(c)	Costpro	210	2.3	0.01	Sec. 7.4
(d)	Scientific, Medium	45	17	0.36	Jackson & Stubbs, 1969 [3]
(e)	Scientific, Heavy	39	34	0.15	ibid.
(f)	Business, Moderate	16	21	0.40	ibid.
(g)	Point of Sale	128	1	n/a	Bell Canada [4]
(h)	Time Share	50	n/a	0.1	Nova Scotia Comm. Study, 1977 [5]

Figure 2.5.2 Application Parameters

With the choice of parameters (t, i, b) and variables (u,s), the quantities (c, n) can be calculated from equation [2.3.2]. The distance is required for the specification to be complete, which permits the sensitivity of the results to distance to be easily investigated.

It is a straightforward matter to employ the analytical models and derive alternative presentations to that one chosen above. For example, one might wish to display results on a diagram of holding time (t) versus line speed (s). However, for the results to be meaningful, one must also specify four of (u, d, i, n, c, b) including, "d", "b", and one of "u" or "i". In the following, we take a particular application to be defined by the parameters (i, b, t) and retain the variables (u, s, d) as the basis for display diagrams.

It is important to draw attention at this point to the use of average or typical values for the parameters (i, b, t), to define a point in the application space of Figure 2.5.1. A much better description of these parameters would be in terms of distribution functions, which would yield a volume probability density over a region in Figure 2.5.1. These would require extensive observations on the nature of data communications related to the various application categories. Several of the tariffs contain discontinuities, such as minimum charges and priority service, which could be more realistically brought into play if, for example, the distribution of call durations were available, rather than the average only. Similarly, the distribution of data packet lengths would provide a better description for the investigation of packet switching total tariffs than the average length. There are other types of packets required for call management that have different length characteristics and do not actually carry data payload. These essentially overhead communication requirements are not included as packets subject to tariff charges.

2.6 TARIFF MODELS

The tariffs for the various carriers' services have been modelled by analytical functions. This permits mathematical manipulation and general comparisons, as well as the investigation of the sensitivity of total unit costs to variations in selected parameters. The models use smooth analytic functions and therefore can only approximate the tariff tables. For example, tariffs are quoted for the standard line speeds, and these values may be fitted by a continuous curve. This curve has values for line speeds in the regions between the standard speeds, where, in fact, services are not generally available. Also in many cases, especially in dealing with distance, the rates are presented as piece-wise constant. The technique used here was to take midpoints in the intervals and the break points at their ends as comprising the "truth table" to be fitted.

The analytical functions employed are based primarily upon exponentials. In particular, tariffs generally saturate with distance, and comparisons are very easy in different cases since the constant in the exponential reveals the rate of saturation. (Note the anomaly in equation [3.5.8] compared with [3.5.7], [3.5.9], and [3.5.10].) The general technique was to make a simple first approximation which would give the essential shape of the relationship at a glance, and then to add a function to reduce the error to an acceptable value.

SECTION 3. DATA COMMUNICATIONS SERVICES

3.1 INTRODUCTION

In this section, each of the data communications services is analysed and the components of the tariff model identified. Analytic functions approximate the various tariffs and facilitate comparisons and manipulations. The tariff is calculated first in dollars per month from charges for line access, A(s), modems where applicable, M(s), call charge rate, N(d), and usage, U(d;...). The terms A(s), M(s) and nN(d) are directly in dollars per month where n is the number of calls per month. Finally KU(d) is added to the other terms where K is chosen in each particular case to make KU(d) have the units of dollars per month. Equation [2.1.1] is the result. From Section 2.3 and equation [2.3.1] we obtain the unit cost, G, in dollars per megabit transmitted.

The tariffs for usage charges divide clearly into asynchronous and synchronous line speed services. Generally, 1200 bits/second may belong to both, so that two tariffs may exist at this speed. In most cases, two analytic models are given, one for the asynchronous cases, namely, $A_a(s)$ and $U_a(d)$, and the other for synchronous line speeds, namely, $A_s(s)$ and $U_s(d)$. In those cases where the usage function is different for communication branches off the main mesh, the additional formula required to describe the off-mesh portion is designated, $U_o(d)$.

The geographic connections for each service are important in determining distances in particular cases. Maps give the connections or virtual connections for the different services. These maps follow from an examination of the published tariffs.

The tariffs are presented in graphic form as lines of constant unit cost, or isograms, on the u-s diagram. Beginning with at least \$1024 per Mbit, the values for "G" are decreased by the factor 0.707 for each step thereby yielding a logarithmic G-scale. The decreasing unit cost isograms occur with increasing traffic volume. Note that for

G = 1024 \$/Mbit

and a traffic volume of 10^6 bits/month, the monthly charge is \$1024 also. Similarly, the point corresponding to

G = 8 \$/Mbit

and a traffic volume of 10^8 bits/month has a monthly charge of \$800. In every case, the isogram graphs have been drawn for case (a) in Figure 2.5.2 and a distance of 300 miles. If these conditions are altered, the isograms may move. In a second diagram, a few lines of constant G are chosen and replotted at other distances (such as 30, 100, 1000, 3000 miles) to show the effect of distance. Again, keeping the distance at 300 miles, a few lines are replotted for cases (b) and (c) of Figure 2.5.2 to illustrate the effect of different application parameters. Further comments on sensitivity are found in Section 3.10.

3.2 DATAROUTE

Dataroute is a private leased line service provided by the Trans-Canada Telephone System for the transmission of digital data. Full duplex communications at speeds up to 50000 bits per second connect major cities or District Serving Areas (DSA). A Serving Area consists of one or more exchanges. Other channel leasing arrangements are available between exchanges, such as Multicom Service and a Wideband Service, but for the purposes of this study, it is the Dataroute Service which is important. Other data services may be required, for example voice or teletype-grade circuits, to enable exchanges outside the DSA's to access Dataroute Service.

The important feature of the Dataroute tariff structure is its independence of the volume of traffic since it is a line leasing service. The cost does depend upon speed of transmission and distance. The basic model is in the form of equation [3.2.1]:

$$\$pm = 2A + KU \qquad [3.2.1]$$

where the constant, K, does not depend upon the traffic volume directly as it does in packet and circuit switching systems. There are, however, three rate schemes:

a) a day rate (up to 13.75 hours/day)

b) a night rate that is 0.6 x (day rate)

c) a 24 hour rate that is 1.3 x (day rate)

In the model we have adopted the day rate, and set K = 1. Tariffs for the night rate and the 24 hour rate can be modelled similarly by setting K equal to 0.6 and 1.3 respectively. However, the daily connection time required at a given traffic volume, speed, and traffic intensity is

$$\text{hours/day} = \frac{u}{109512\ is} \quad \text{(synchronous)} \qquad [3.2.2\ a]$$

or,

$$\text{hours/day} = \frac{u}{87610\ is} \quad \text{(asynchronous)} \qquad [3.2.2\ b]$$

Therefore, if the value of the expression [3.2.2] exceeds 13.75 it becomes necessary to go to the 24 hour rate. This is done by setting K = 1.3 in the model, and the connection intensity parameter "c" can be used to determine the appropriate value of K as given in equation [3.2.3]:

$$\begin{aligned} &K=1 \quad \text{if } 0 \leq c \leq 418 \\ &K=1.3 \text{ if } 418 < c \leq 730 \end{aligned} \qquad [3.2.3]$$

When the expression [3.2.2] has the value 13.75, equivalent to a connection time of 418 hours/month, we obtain an upper boundary for the day rate region on the u-s diagram. (See Figure 2.3.1) The region is enlarged to the boundary line at 730 hours/month by switching to the 24 hour rate. The basic model will, therefore, have a discontinuity along the 418 hours/month line. Of course, the 24 hour rate could be employed throughout, but the resulting unit cost will be higher in that region where a day rate is also available. Similarly, if the region is below 297 hours/month, the night rate is available with K set at 0.6, if this would be a convenient service. This has not been done in the basic model.

Access to the Dataroute network involves a charge dependent upon line speed for both asynchronous and synchronous lines which can be approximated by:

$$A(s) = 314 + 185 \text{ Arctan } ([\log 6400][\log(s/6400)]) \ldots$$

$$\ldots - \frac{s}{10} \exp(-s/450) \qquad [3.2.4]$$

The approximation can be improved by separating synchronous access service, $A_s(s)$, and asynchronous access service, $A_a(s)$. The latter is then:

$$A_a(s) = 37.81 \exp(s/1605) \qquad [3.2.5]$$

and the access charge for synchronous service is, approximately,

$$A_s(s) = 3.2 + 179 \text{ Arctan}([\log 6784][\log(s/6784)]) \qquad [3.2.6]$$

The Dataroute tariffs provide circuit measurement tables for determining the distance to be used in calculating the usage charges. These can be compared with the geographical distances and the effective circuit map deduced. The result is shown in Figures 3.2.1 and 3.2.2. In any particular case, the circuit miles can be estimated by summing the geographic miles along the paths on these maps.

The usage charges for a leased line are independent of traffic volume and are a function jointly of line speed, and distance.

The model consists of two formulae for usage charges, one for asynchronous line speeds, U_a, and the other for synchronous line speeds, U_s. However, only one tariff exists at 1200 bit/sec, and it turns out that U_a is the better approximation at shorter distances (under 601 miles) and U_s at longer distances. For asynchronous speeds the equation is:

$$U_a = \frac{s}{600}[0.05d - 0.630 + 301\ (1 - \exp(-d/773))\ldots$$

$$\ldots + \frac{d}{21}\exp(-(d/3159)^2)] \qquad [3.2.7]$$

For speeds from 1200 to 50,000 bps, the rate table does not display a pattern that can be easily represented by a simple analytical expression. The method used, therefore, was to approximate the usage charge by a function designated "Z" of distance only which represents the usage at 9600 bps; that is,

$$U_s(d,\ 9600) \simeq Z(d)$$

This was then modified by expressions in both distance and speed as required to model the tariffs for line speeds from 1200 to 50,000 bps. The result is:

$$U_s = (V + WXY)Z \qquad [3.2.8]$$

where

$$V = \frac{1}{22.321} + \frac{s}{10.264 \times 10^3} + \frac{s^2}{4.63 \times 10^9}$$

$$W = \frac{1}{9600}[4800 + |s - 9600| - |s - 4800|]$$

$$X = 1.57334 + 0.28501 \log\ (d/300)$$

$$\log Y = [1.3163 - 0.1537|\log(d/300)|]\log(s/9600)\ldots$$

$$\ldots + [0.67378 + 0.26954|\log(d/300)|]\log|\log(9600/s)|$$

$$Z = 0.12d - 49.3 + 2182\,[1 - \exp(-d/511)]\ \ldots$$

$$\ldots + 58.42\exp(-d/39.2) + \frac{d}{401}\exp(-d/1436)^2) \qquad [3.2.8\ \text{end}]$$

Note the appearance of 300 miles in these functions. Differences taken in the original tariff rate table at any particular speed, also show a discontinuity at this distance. The minimum monthly charge is that for 16 miles, and therefore smaller distances may not be used in equations [3.2.8].

Unit cost isograms can be obtained from this model according to the equation:

$$G = \frac{10^6}{u}\{2A + KU\} \qquad [3.2.9]$$

Figure 3.2.3 shows contours of constant unit cost for a typical application. At a given line speed and distance, the unit cost is inversely proportional to the traffic volume alone, so that from equation [3.2.9] we have:

$$\log G + \log u = \text{constant}$$

and

$$\frac{\Delta G}{G} = -\frac{\Delta u}{u} \qquad [3.2.10]$$

Thus, the contours in Figure 3.2.3 are evenly spaced. The discontinuity at a connection time of 418 hours/month (the lower of the upper boundaries) results from the different values of K required according to equations [3.2.3] and [3.2.2] as explained above.

The fluctuation of these isograms with distance is shown in Figure 3.2.4 by superimposing lines for five different distances with the same unit cost. In Section 3.10 the sensitivity of the tariffs to distance is expressed by the vertical shift in a constant unit cost isogram caused by a change in the distance. For Dataroute equation [3.10.1] becomes:

$$\frac{\Delta u}{\Delta d} = \frac{K10^6}{G} \frac{\partial U}{\partial d} \qquad [3.2.11]$$

To express the fractional change in traffic volume that maintains the same unit cost under a change in distance, we have,

$$\frac{\Delta u}{u\Delta d} = \frac{K}{2A + KU} \cdot \frac{\partial U}{\partial d} \qquad [3.2.12]$$

Now the right hand side is independent of traffic volume and the fractional change on the left hand side means a constant interval in the logarithmic scale for u. Hence, the similar spreading of the isograms in Figure 3.2.4. It is also of note that $\frac{\partial U}{\partial d}$ decreases roughly exponentially with distance.

Similarly, in Figure 3.2.5, the variation of the unit cost lines over three different applications is an example of the effect of the application parameters. The leased line service is not sensitive to communication intensity at low traffic volumes, but at higher volumes and low intensity equation [3.2.3] may be brought into play. Thus in Figure 3.2.5, the 8 $/Mbit line must use the 24 hour rate at intensity 0.01.

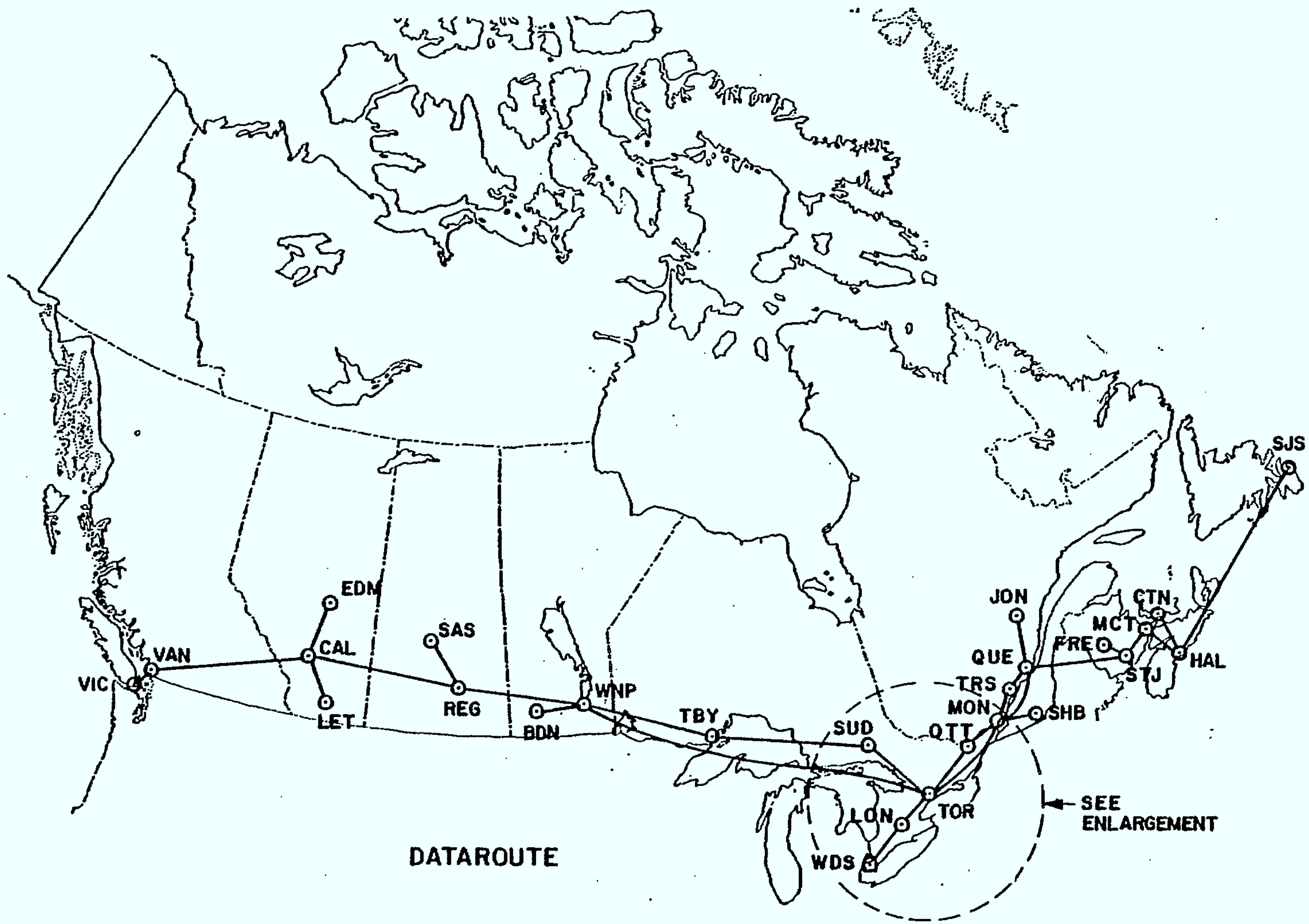


Figure 3.2.1: Virtual Dataroute Circuit Routes

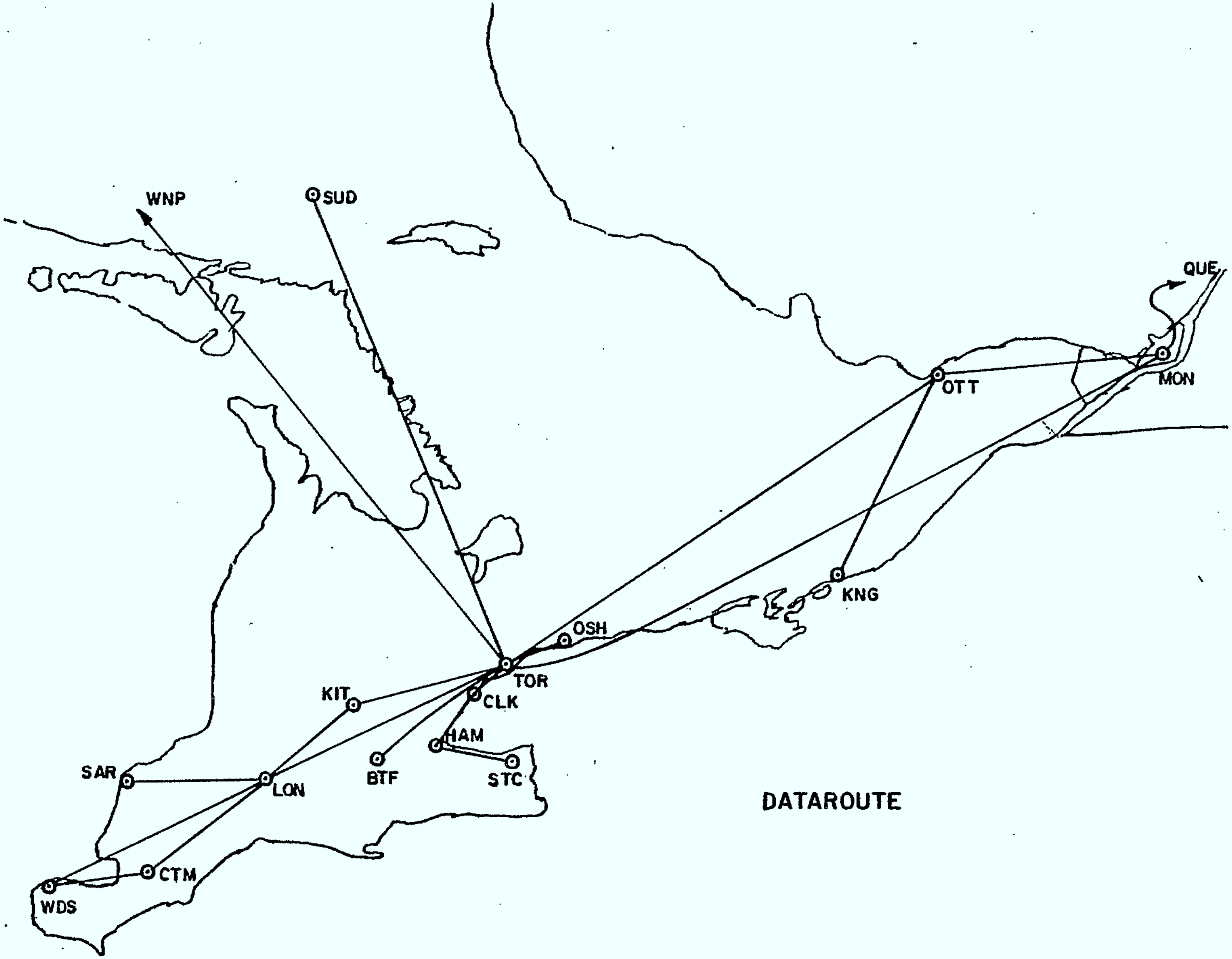


Figure 3.2.2: Virtual Dataroute Circuit Routes (Southern Ontario-Quebec)

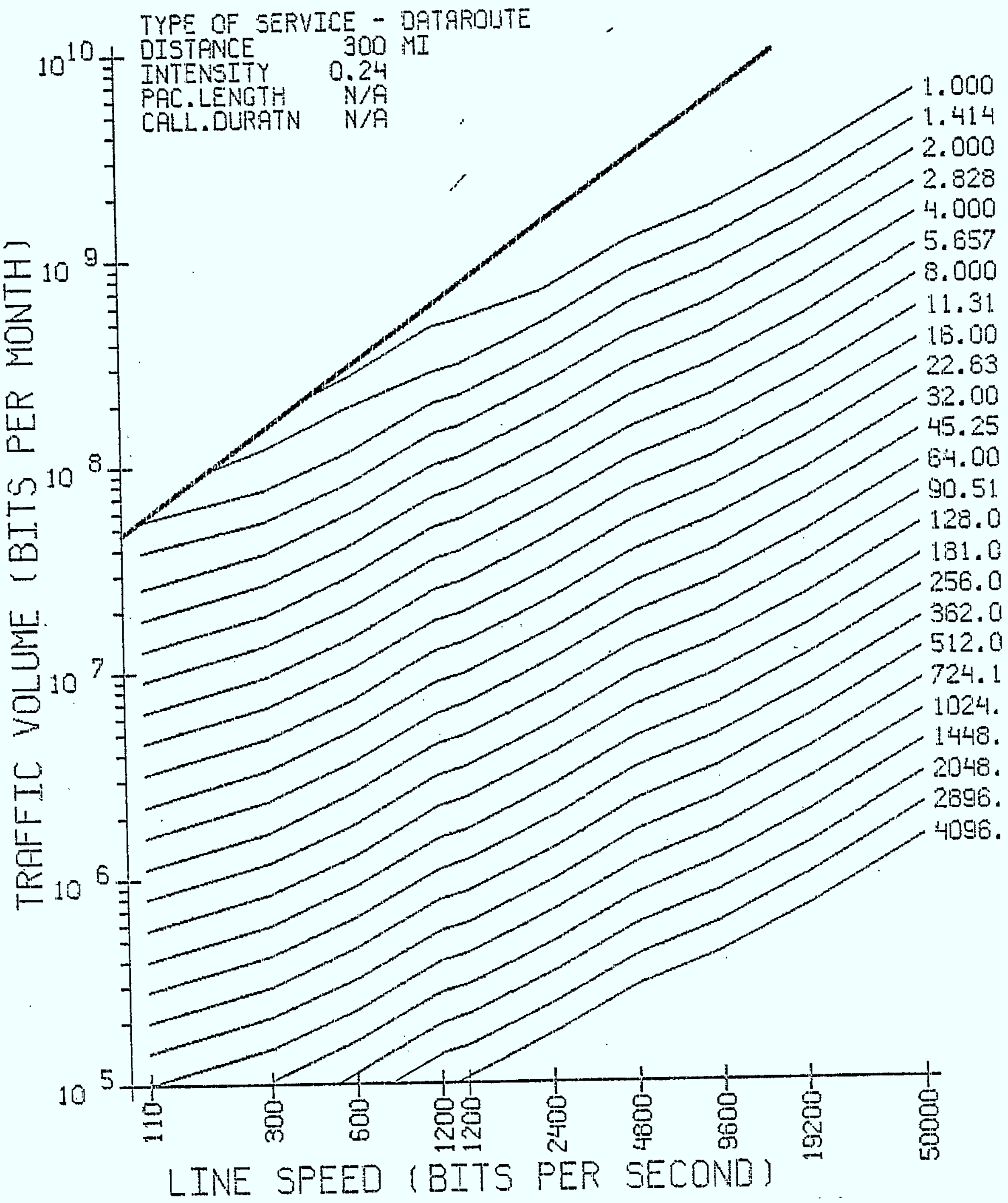


Figure 3.2.3: Isograms of constant unit cost

(dollars per megabit of data)

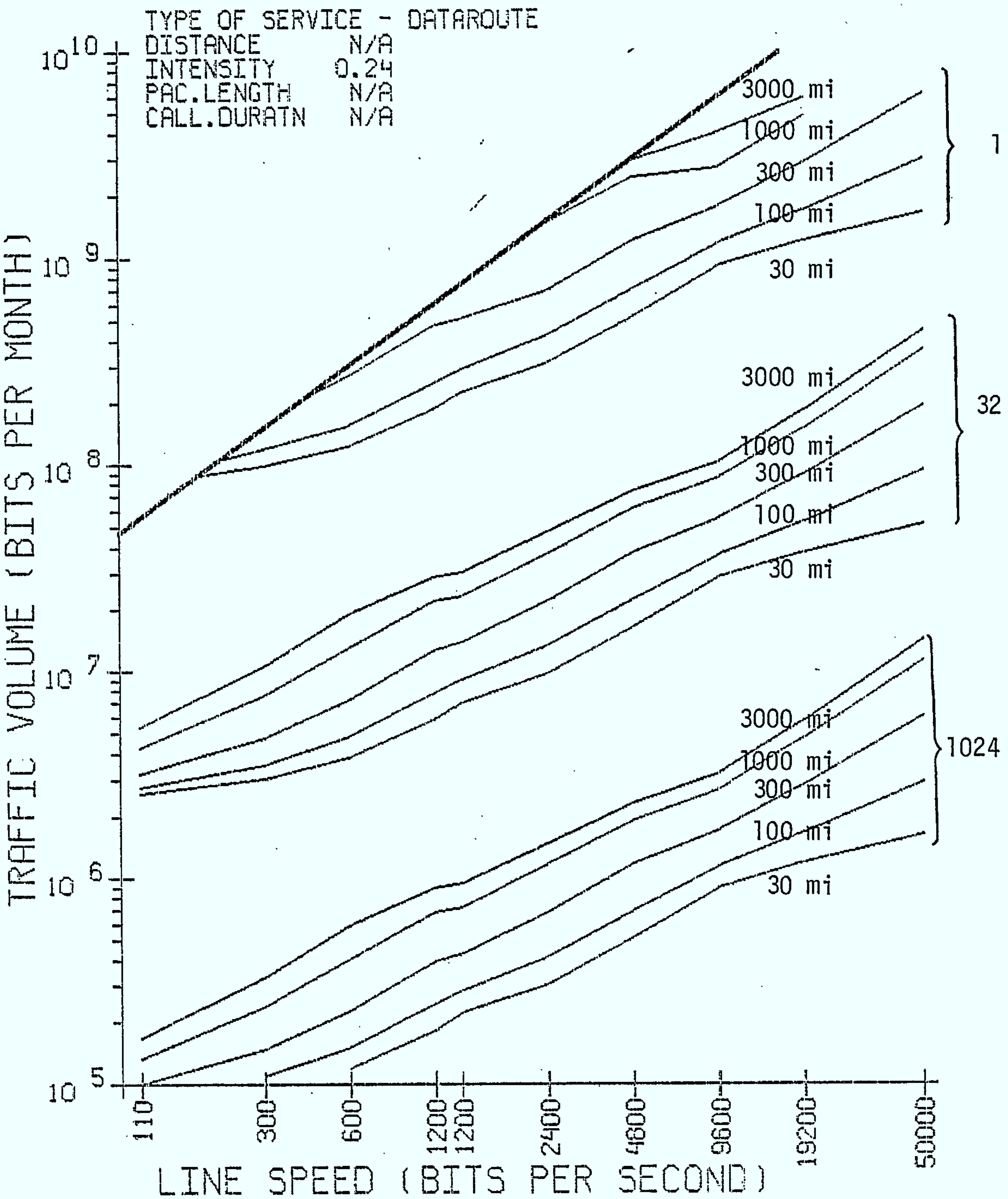


Figure 3.2.4: Variation in isogram lines with distance

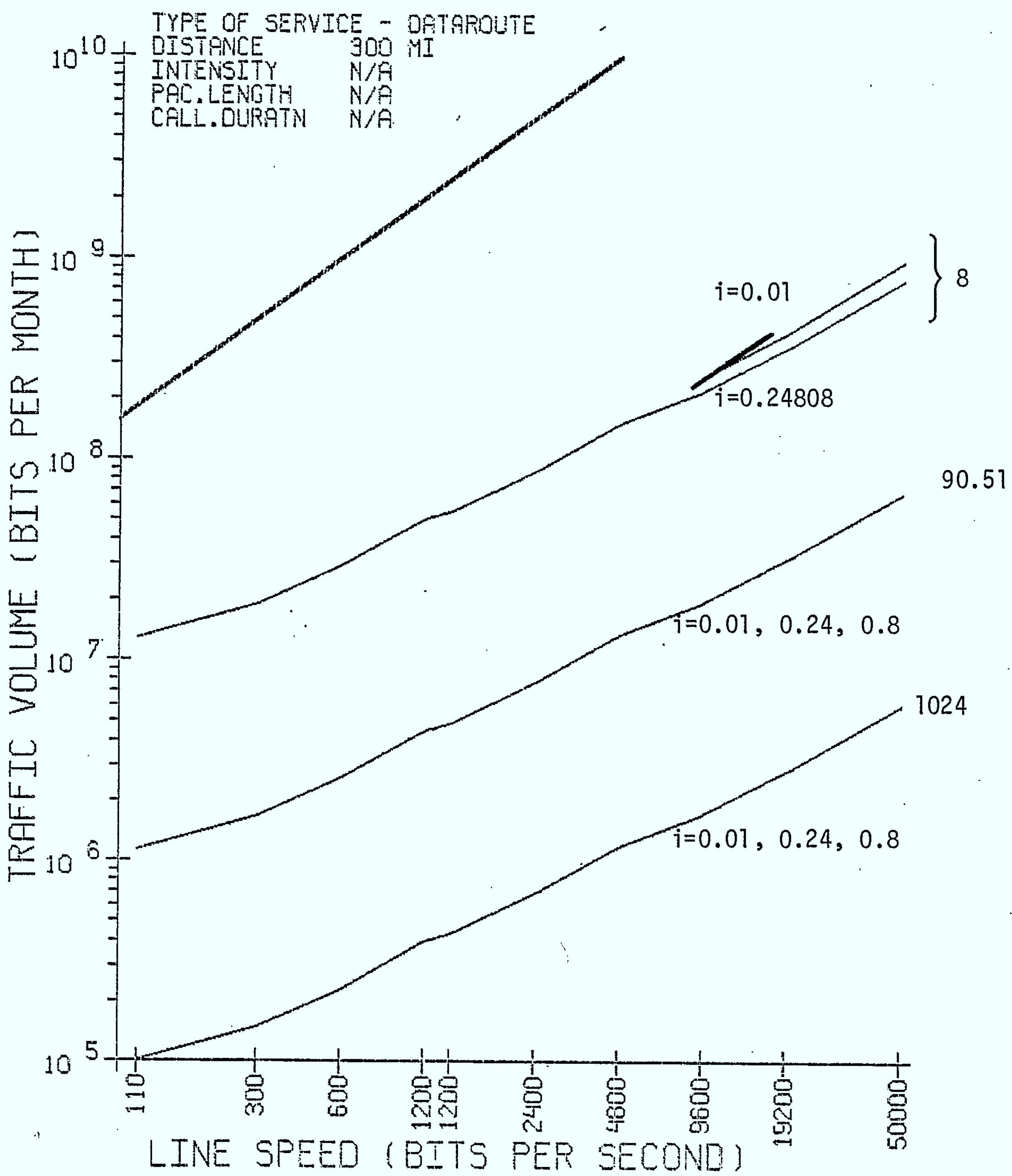


Figure 3.2.5: Variation in isogram lines for applications (i=0.01, b=1680, t=2.3), (i=0.8, b=2048, t=45) and (i=0.24, b=160, t=19)

3.3 INFODAT

Infodat is the leased line service of CNCP for the transmission of digital data. The cost is independent of the volume of traffic and depends upon the speed of the service and the distance.

The tariff rate structure is identical to that of Dataroute so that equations [3.2.1], through to [3.2.12] all apply to Infodat also. However, there are some differences between the two systems in the Serving Areas available, and in the actual connection paths available.

Again, the circuit measurement tables in the tariffs can be compared with the geographical miles and the effective circuit maps of Figures 3.3.1 and 3.3.2 deduced. Some differences in the cities served by each system can be observed by comparing these Figures with Figures 3.2.1 and 3.2.2. The path between Thunderbay and Sudbury is particularly noteworthy.

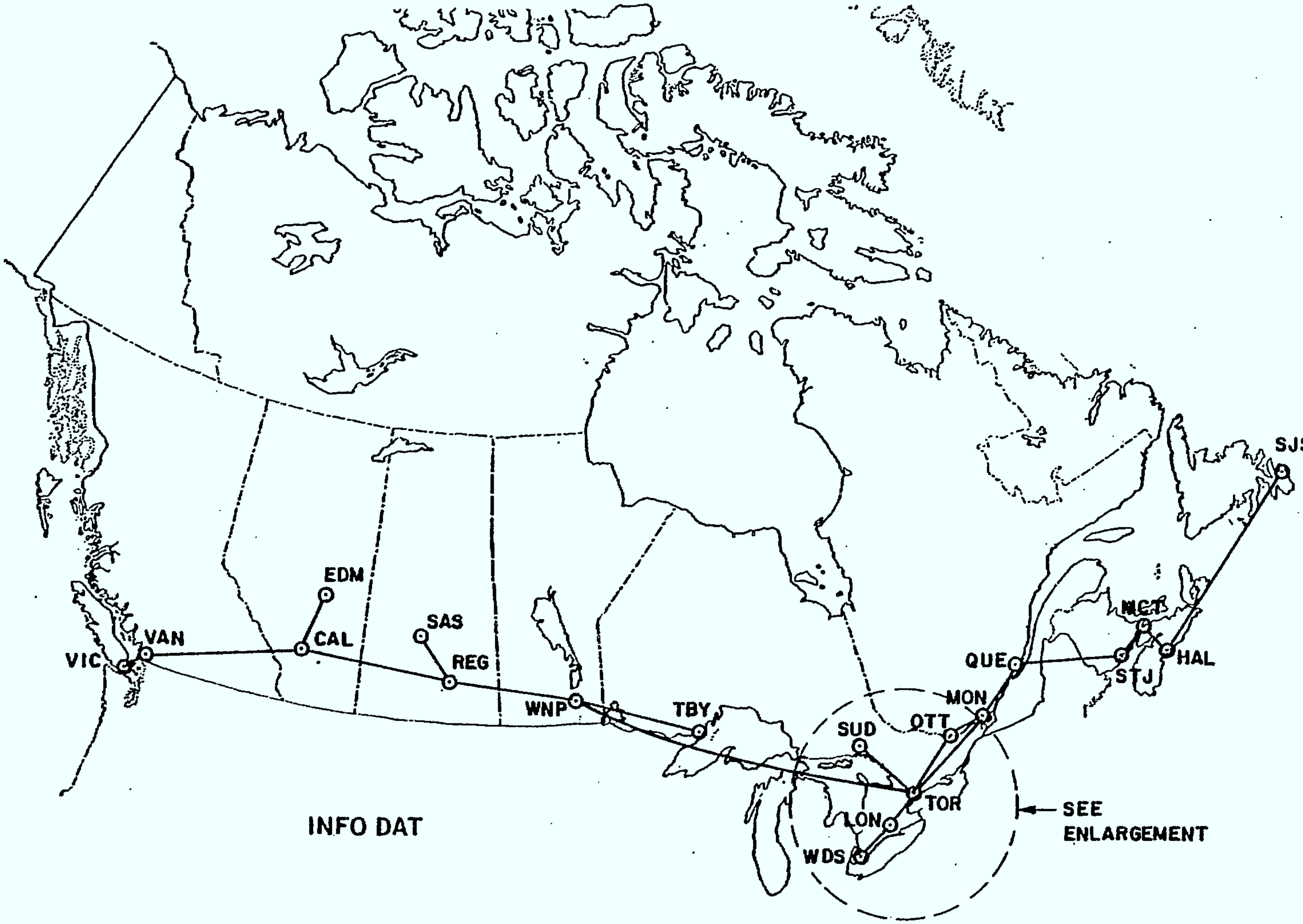


Figure 3.3.1: Virtual Infodat Circuit Routes

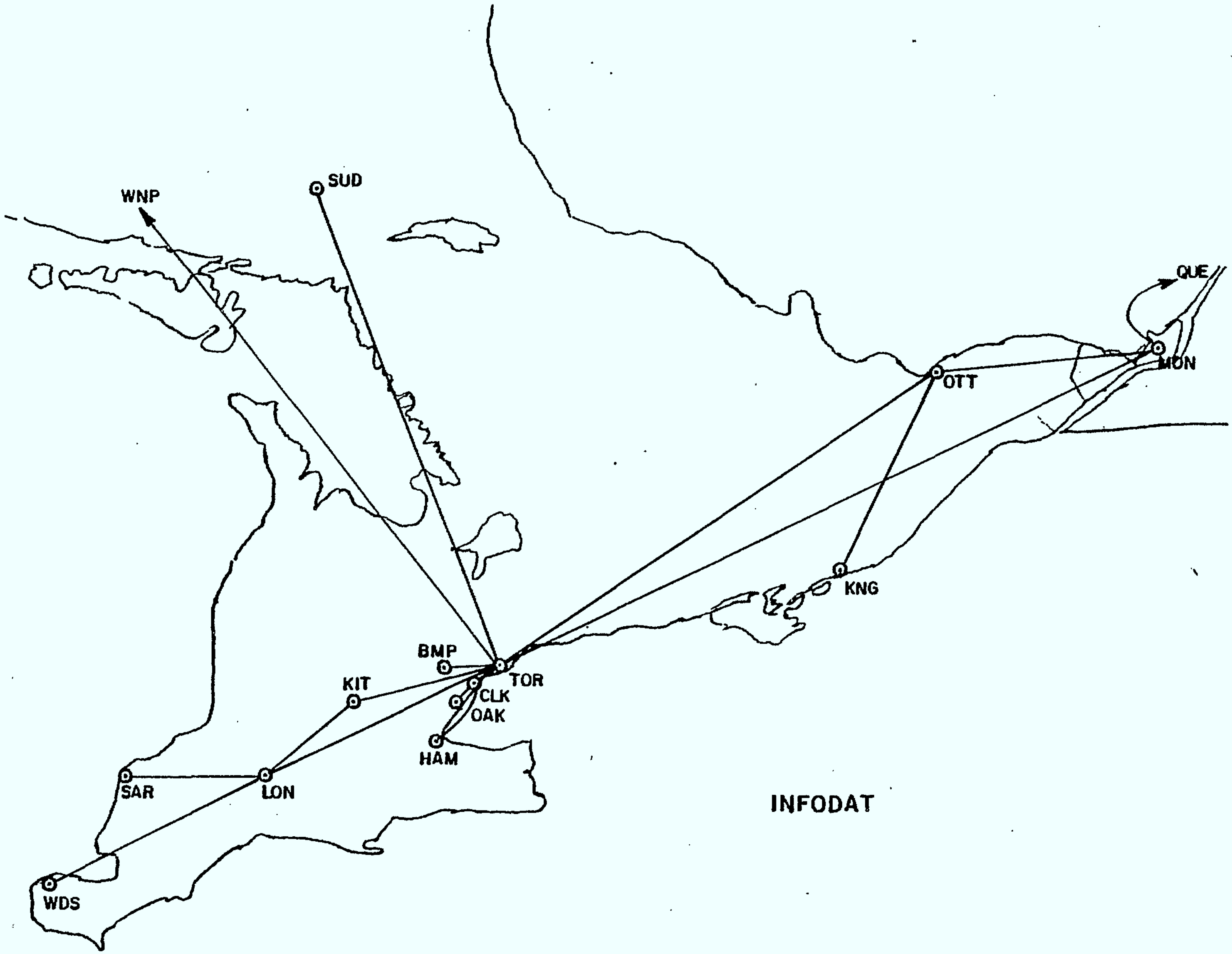


Figure 3.3.2: Virtual Infodat Circuit Routes (Southern Ontario-Quebec)

3.4 DATAPAC

The Datapac service is a shared data communications network employing packet switching techniques. The charge for the service is comprised of a monthly access charge based upon the speed of service, and a usage charge which depends upon the number of packets transmitted in a month and the distance of transmission. The usage charge does not depend upon the line speed and in this way it differs from the leased line and circuit switching methods.

The basic form of the model is given by equation [3.4.1]:

$$\$pm = 2A(s) + PKU(d) + Nn \qquad [3.4.1]$$

where A(s) is the access charge in dollars per month. The usage charge, U, is in cents per kilopacket (1000 packets of up to 256 characters each) and is itself the sum of two parts: one is a constant determined by the grade of the Datapac Serving Area; and the other is a function of geographical distance. The constant, K, in equation [3.4.1] converts the rate in cents per kilopacket to a monthly charge depending upon the traffic volume and the average packet length in bits. Thus for Datapac:

$$K = (u/b)10^{-5} \qquad [3.4.2]$$

The quantity n is the number of virtual calls established per month, while N is the fixed service charge in dollars for establishing a virtual call.

For regular service which applies up to 256 characters per packet, the factor "P" in equation [3.4.1] is unity. However, for "priority service", which is available on packets up to 128 characters, P is 1.25 to include the extra 25% charge. The basic model, in default of other specifications on priority service, assumes all packets are regular packets according to equations [3.4.3]:

For $1024 < b \leq 2048$, $P = 1$ only   i.e. 8×128 ⇒ 8×256

For $0 \leq b \leq 1024$, $P = 1$ regular service

$$P = 1.25 \text{ priority service} \qquad [3.4.3]$$

The Datapac network consists of 14 switching nodes; namely, Grades 1, 2, and 3, which are the higher volume centres equipped with digital facilities. These are virtually mesh connected since the model for the rate between any two includes the geographical distance only, and not the actual route. These rates are shown in Figure 3.4.3, and the distances in Figure 3.4.4. All other Datapac serving areas, (Grades 4, 5, and 6) are each connected to one switching node on the mesh and from thence to the message destination. These unique connections are shown in Figures 3.4.1 and 3.4.2, wherein the virtual mesh network is omitted. The route between any two areas will consist of at most three legs. Points within the same Serving Area, if it is a switching node area, require no map leg connection, but if it is an off-mesh area, two legs will be required, namely, to the switching node and back. Points in different switching node areas require one map leg connection, while points in different off-mesh areas require two or three map legs, depending upon whether they share the same switching node or not, respectively. Besides the usage charges for distances between serving areas, there is a usage charge for each port, sending and receiving, in each serving area along a route, including the ends, that depends on the grade of the area. For the purposes of the model, average figures are used, but they can be replaced by the actual charges in a case involving particular geographical locations whose grades are known. These points are illustrated in Figure 3.4.5 for the Saskatoon to Red Deer route which involves four areas of different grades.

An approximate model for Datapac access charges is given by equation [3.4.4]:

$$A(s) = 36.2 + \frac{s}{25.1}[1 + \exp(-(s/1237)^2)] \qquad [3.4.4]$$

? derivation

However, synchronous access is available for service speeds 1200 bps and above through Datapac 3000 Access Arrangement and the access charge in these cases is given by equation [3.4.5]:

$$A_s(s) = 35.8 + \frac{s}{25}[1 + \exp(1 - (s/892)^2)] \qquad [3.4.5]$$

? − [1 −

This applies to service points in Serving Areas which are on the mesh of switching nodes, and also to Grade 4 Serving Areas off the mesh, but not to Grades 5 and 6 Serving Areas.

Asynchronous access to Datapac is provided for under the "3101 Access Arrangement". Several options are available regarding the nature of the access. In the model of equation [3.4.6] below, dedicated access is assumed for line speeds of 600 and 1200 bps since this is the only service available at these speeds.

$$\begin{aligned} A_a(s) &= 115 && \text{for } s \geq 424 \\ &= 35 + u/3200si && \text{for } s < 424 \end{aligned} \qquad [3.4.6]$$

However, at 300 bps and below rather than the fixed rate of a dedicated access, equation [3.4.6] shows the charges dependent upon connection time appropriate to The fixed charge of $35 in this case represents the monthly charge for a business telephone and low speed modem (see Section 3.7). Due to this division of the asynchronous region into dialed access and dedicated access. there may be a discontinuity in the asynchronous access charges at the arbitrary speed of 424 bps. This will appear on graphs showing Datapac tariffs.

Access to the Datapac network is also available over a 1200 bps asynchronous polled-device channel under the "3201 and 3203" arrangements. The access charge and NIM rate vary with the protocol used, and in addition, for points outside a serving area, there is a monthly charge based upon the distance, i.e., independent of traffic volume and usage.

The Datapac usage rate cost, in cents per kilopacket, depends on the distance between the serving areas, the grade of the serving area, and the access mode. Although the tariffs include the NIM charge for asynchronous access as part of the access charge, the modél includes it with the usage, since it is a rate and the resultant charge depends upon the traffic volume. Consequently there are two usage equations, depending upon whether the access terminal is synchronous or asynchronous.

The usage charges are modelled by equations [3.4.7] and [3.4.8] for the mesh switching nodes.

$$U_s(d) = 20.4 + \frac{d}{100} + 55.86[1 - \exp(-d/407)] \ldots$$

$$\ldots - 0.0876\, d \exp(-d/243) \qquad [3.4.7]$$

$$PU_a(d) = PU_s(d) + 25 \qquad [3.4.8]$$

The 25 cents/kPac in equation [3.4.8] is the NIM charge, which is not subject to the priority rate. The constant term, 20.4, in equation [3.4.7], is an average over Grades 1, 2, and 3. The charge in a particular case of two cities can be obtained from Figure 3.4.3 and substituted in place of 20.4 in the model. The appropriate amount is the average of the two self-charges for the two cities involved.

Service areas off the switching node mesh are each connected to a mesh node, and over this branch a different usage model applies; namely:

$$U_{os} = 28.6 + 1.2\, d_o$$

$$PU_{oa} = PU_{os} + 25 \qquad [3.4.9]$$

equations [3.4.9] apply to Grades 5 and 6 serving areas and again the figure "28.6" is an average to be replaced by the appropriate value (25 or 30) in a particular case. Grade 4 usage charges (without a NIM) are according to equation [3.4.10]:

$$U_o = 20 + 0.4\ d_o \qquad [3.4.10]$$

The unit cost isograms will depend upon the service speed, the distance, the average packet length, and the traffic volume. If an average packet length is selected which is appropriate for a particular application, then the monthly cost for various access speeds, distances and traffic volumes can be calculated from equation [3.4.1]. Finally, the unit cost in dollars per megabit of data is obtained by dividing the equation [3.4.1] by the traffic volume, u, in bits per month:

$$G = \frac{10^6}{u}\{2A + PKU + Nn\} \qquad [3.4.11]$$

Lines joining points of the same unit cost on the "u-s" diagram show the effect on Datapac charges of changes in the line speed and traffic volume. Figure 3.4.6 shows a set of such unit cost isograms for a particular application in which the average packet length, b, is 160 bits or 20 characters.

At lower traffic volumes, the access charges dominate the right hand side of equation [3.4.11] so that the unit cost is inversely proportional to traffic volume and equation [3.2.10] applies. Thus the contours in the lower half of Figure 3.4.6 are evenly spaced. However, at high traffic volumes where usage charges dominate, the unit charge tends to become a constant based on the per packet rate. In other words, the surface represented by the unit cost contours becomes flat at an isogram value of

$$G \simeq 1Ø\ P\ U(d)/b \qquad [3.4.12]$$

which on Figure 3.4.6 has a value of $3.74.

The effect of distance can be illustrated by superimposing the same unit cost isogram for different distances as shown in Figure 3.4.7. In Section 3.1Ø, the sensitivity of tariffs to distance is investigated through the vertical displacement of the isogram contours that results from a change in distance alone. For Datapac, equation [3.1Ø.1] becomes:

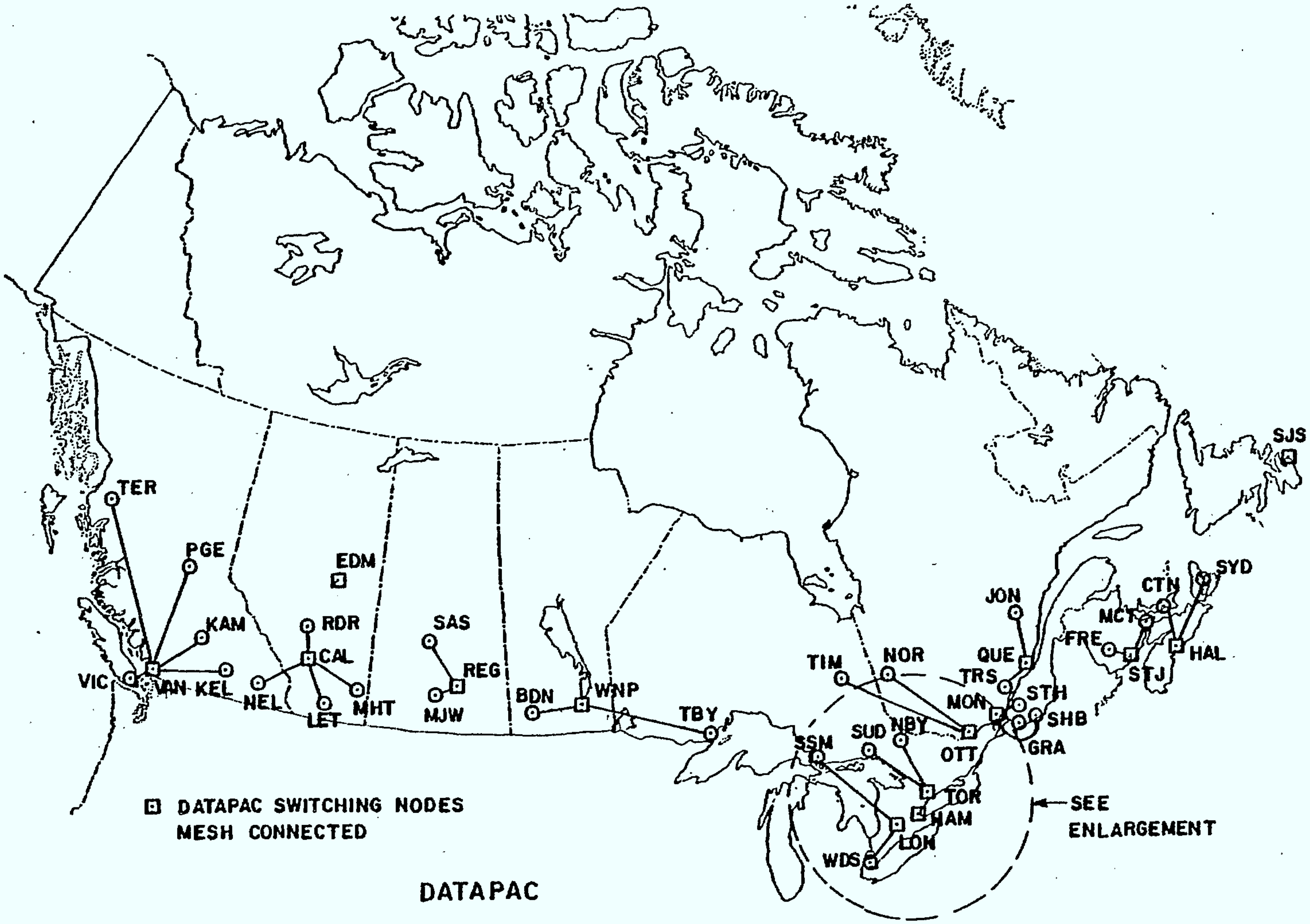
$$\frac{\Delta u}{\Delta d} = \frac{u^2}{2A(s)\ b \cdot 1Ø^5} \cdot \frac{\partial U}{\partial d} \qquad [3.4.13]$$

It is evident that the fractional change in traffic volume required to maintain the same unit cost under a change in distance, is proportional to the traffic volume itself. Consequently, a change in distance results in a spreading out of the movement of the isogram contours that increases with higher traffic volumes. Conversely, at low traffic where the distance-independent access charge dominates, the unit charge is less sensitive to distance.

In a similar way, the effect of increasing the average packet length from 2Ø characters to the maximum of 256, is illustrated in Figure 3.4.8 by superimposing the same isograms for the different packet lengths. In this case the vertical displacement (downwards) with an increase in packet length is

$$\frac{\Delta u}{\Delta b} = \frac{-u^2 U(d)}{2A\ b^2\ 10^5} \qquad [3.4.14]$$

It is evident that the fractional change is proportional to traffic volume, and also that it is more important at shorter lengths.



Figures 3.4.1: Virtual Datapac Circuit Routes

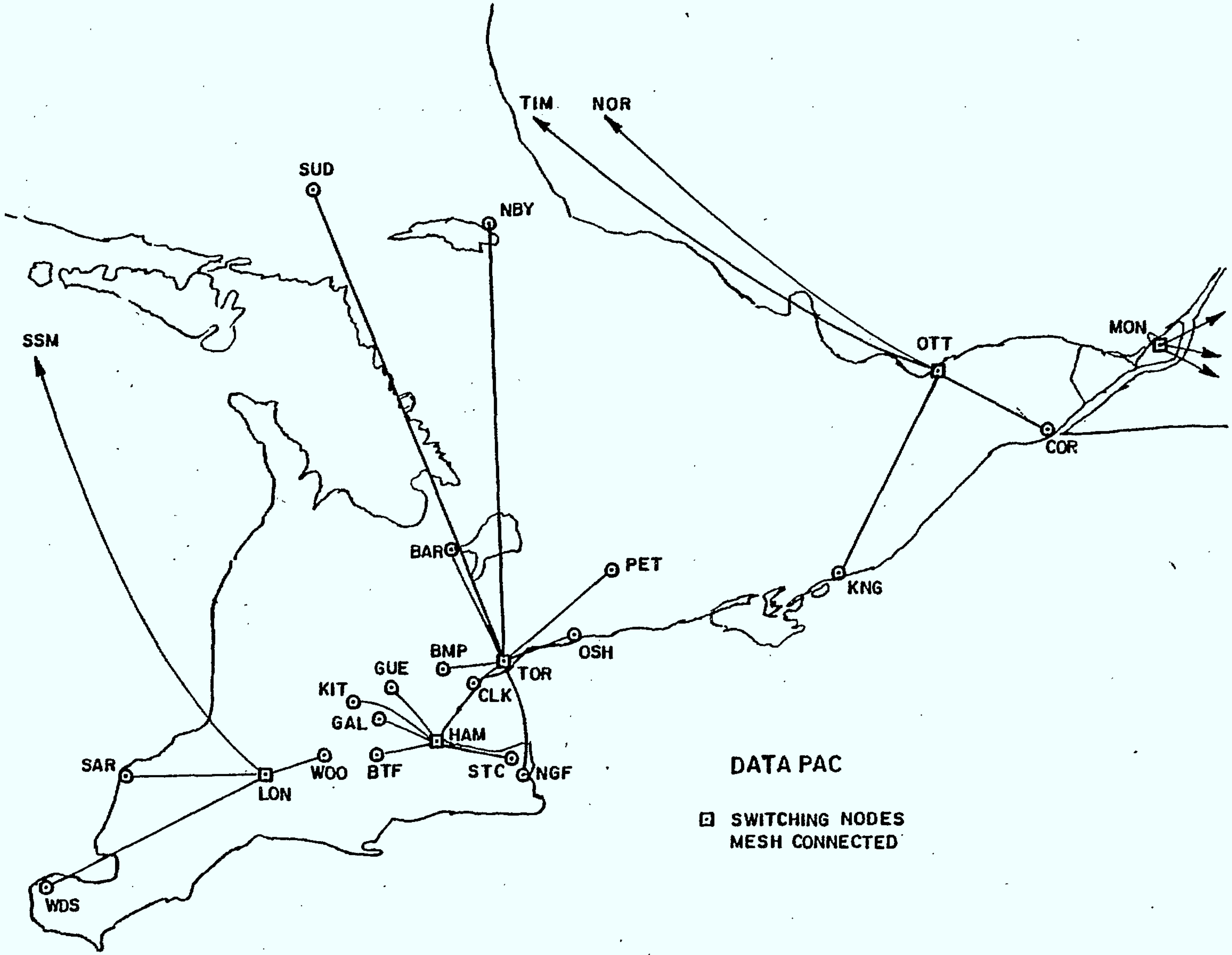


Figure 3.4.2: Virtual Datapac Circuit Routes (Southern Ontario-Quebec)

	CAL	EDM	HAL	HAM	LON	MON	OTT	QUE	REG	STJ	SJS	TOR	VAN	WNP
CAL	19													
EDM	33	19												
HAL	100	99	23											
HAM	93	93	76	23										
LON	92	92	78	29	23									
MON	91	91	58	47	52	15								
OTT	90	90	63	39	45	25	15							
QUE	96	95	55	62	65	31	38	23						
REG	54	56	97	88	87	88	87	93	23					
STJ	98	98	33	71	74	48	56	45	96	23				
SJS	103	102	65	90	91	79	81	78	101	69	23			
TOR	89	89	70	24	27	40	32	55	84	66	85	15		
VAN	53	60	104	97	96	95	94	100	74	102	107	93	19	
WNP	71	71	94	81	79	82	80	87	50	93	98	77	84	23

Figure 3.5.3: Switching Nodes Rate Chart (¢/kPac)

	CAL	EDM	HAL	HAM	LON	MON	OTT	QUE	REG	STJ	SJS	TOR	VAN	WNP
CAL														
EDM	175													
HAL	2333	2285												
HAM	1677	1677	812											
LON	1627	1632	884	72										
MON	1875	1844	489	347	417									
OTT	1786	1761	592	254	321	104								
QUE	1938	1895	396	487	556	144	235							
REG	414	432	1929	1264	1215	1465	1374	1533						
STJ	2207	2162	127	695	768	365	468	270	1802					
SJS	2692	2614	558	1341	1413	997	1098	867	2313	653				
TOR	1684	1679	784	36	104	314	218	453	1270	666	1309			
VAN	418	509	2749	2077	2023	2288	2197	2354	824	2624	3108	2086		
WNP	747	740	1598	937	892	1131	1040	1202	334	1472	2000	941	1157	

Figure 3.5.4: Switching Nodes Distance Table (miles)

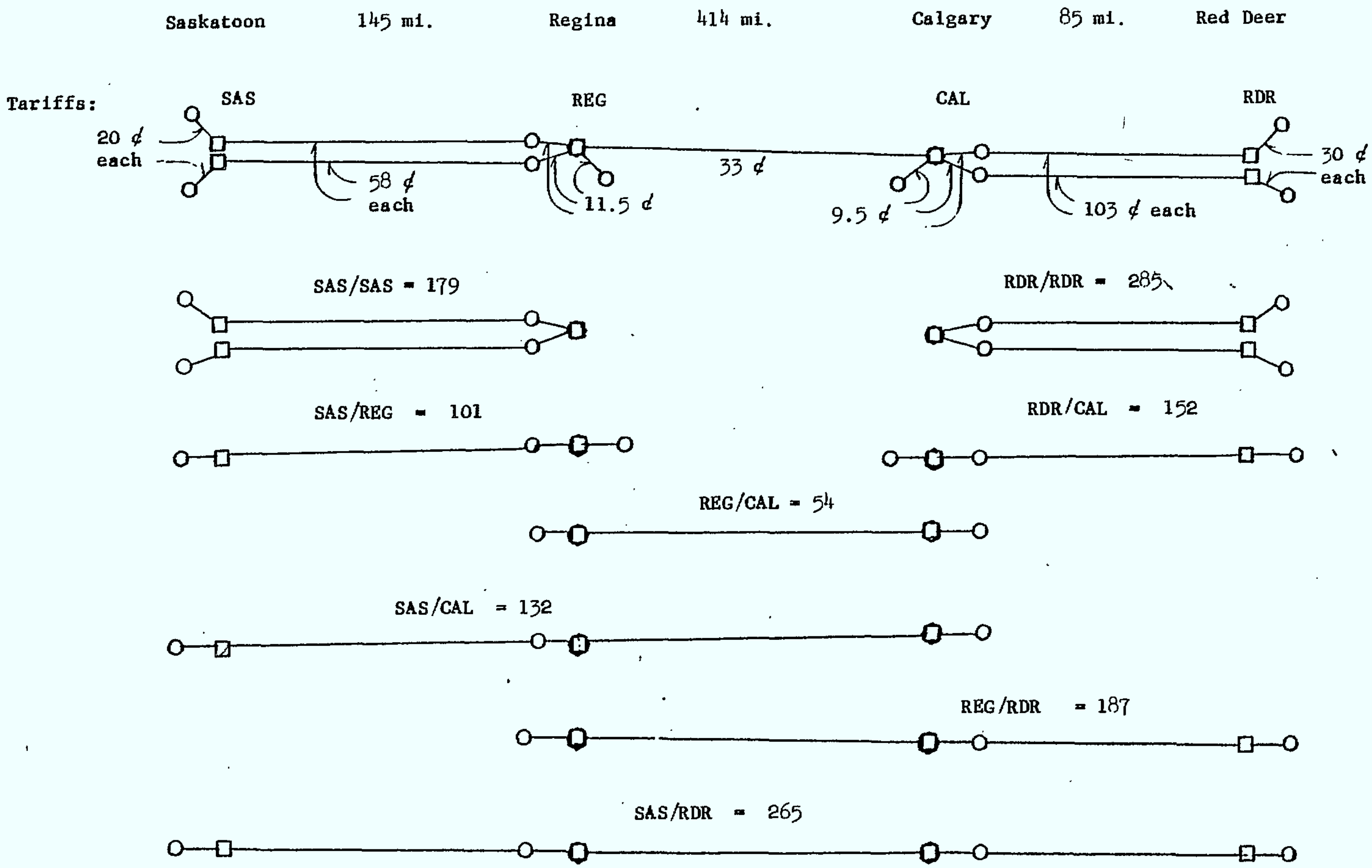


Figure 3.4.5: Sample Tariff Construction

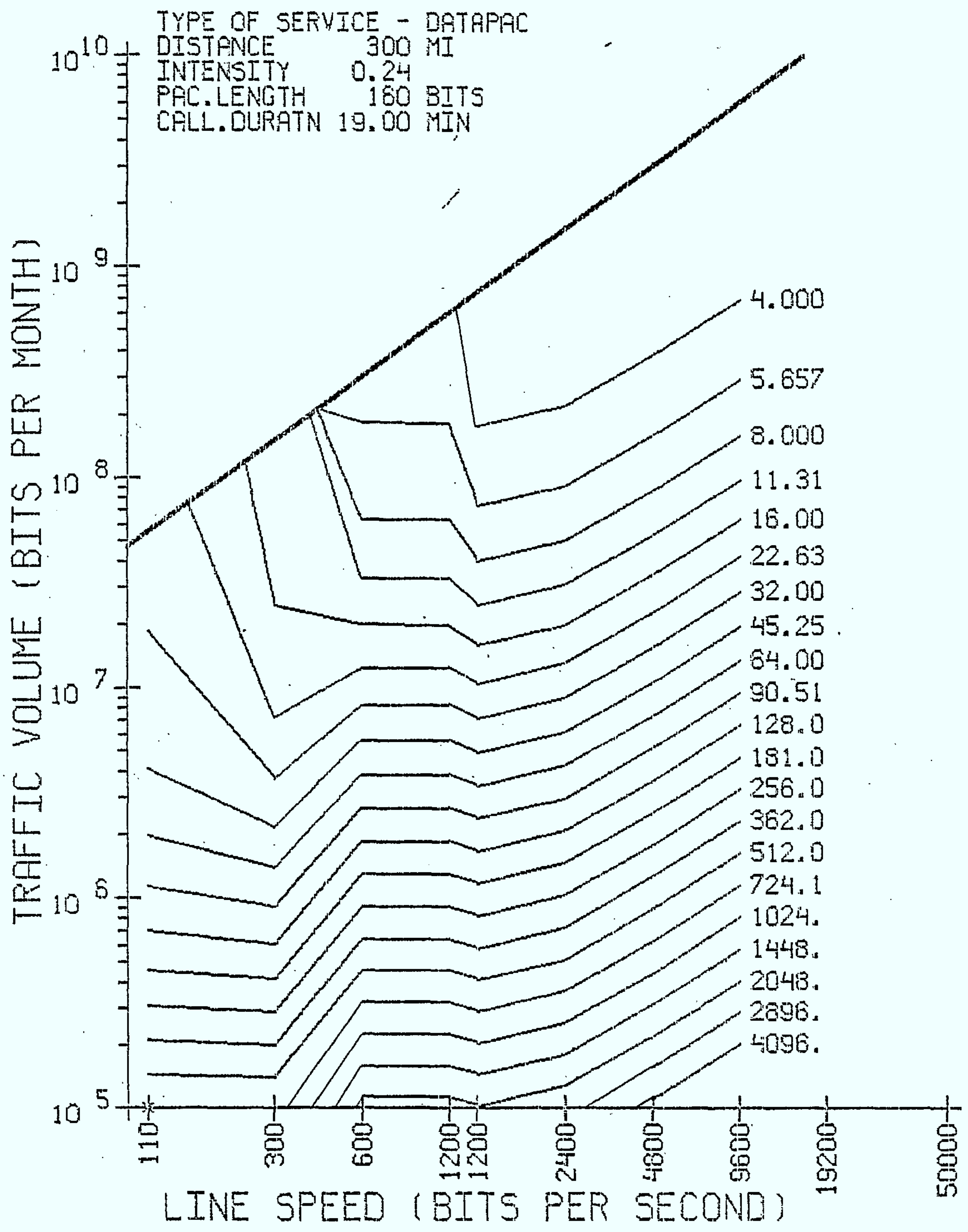


Figure 3.4.6: Isograms of constant unit cost

(dollars per megabit of data)

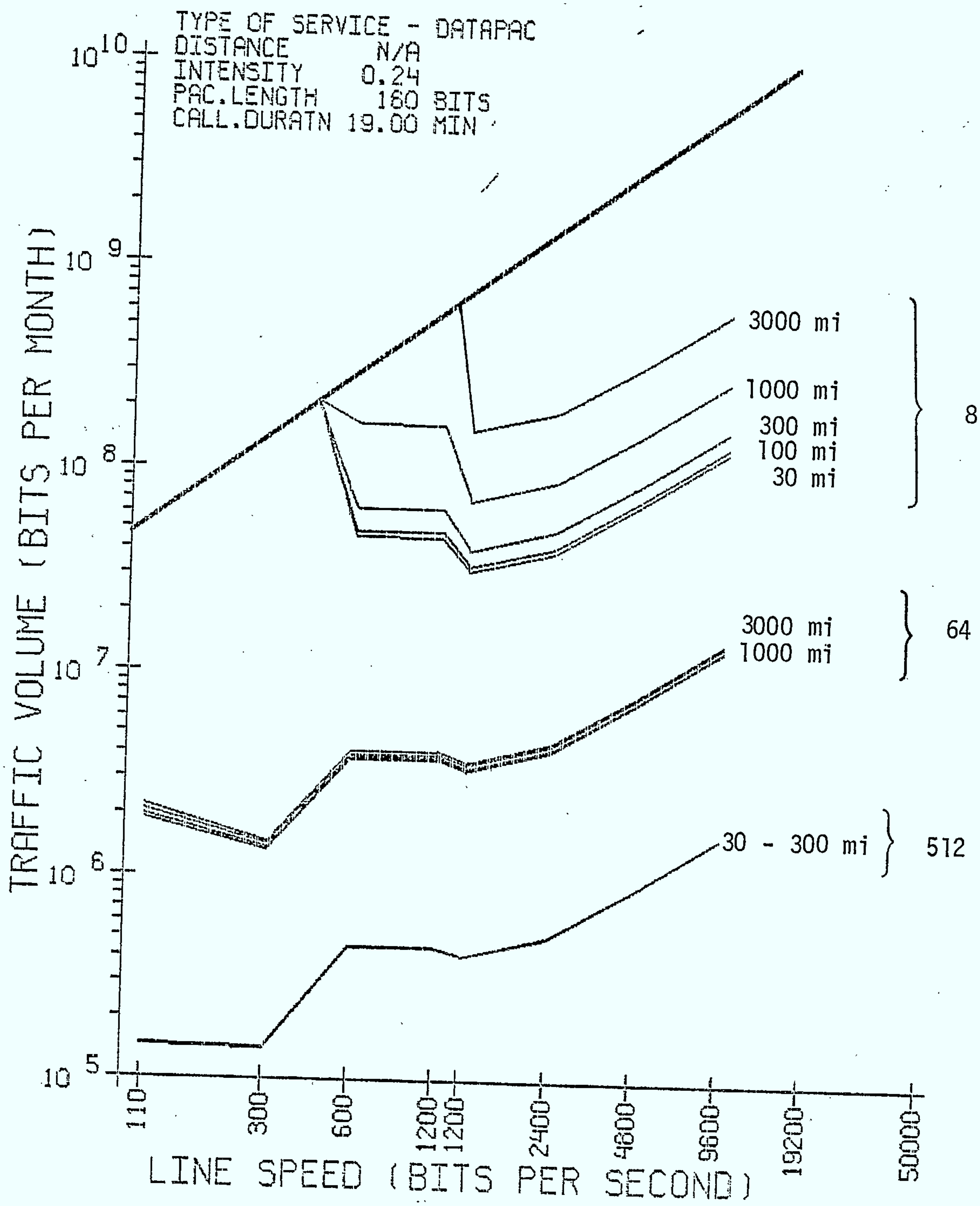


Figure 3.4.7: Variation in isogram lines with distance

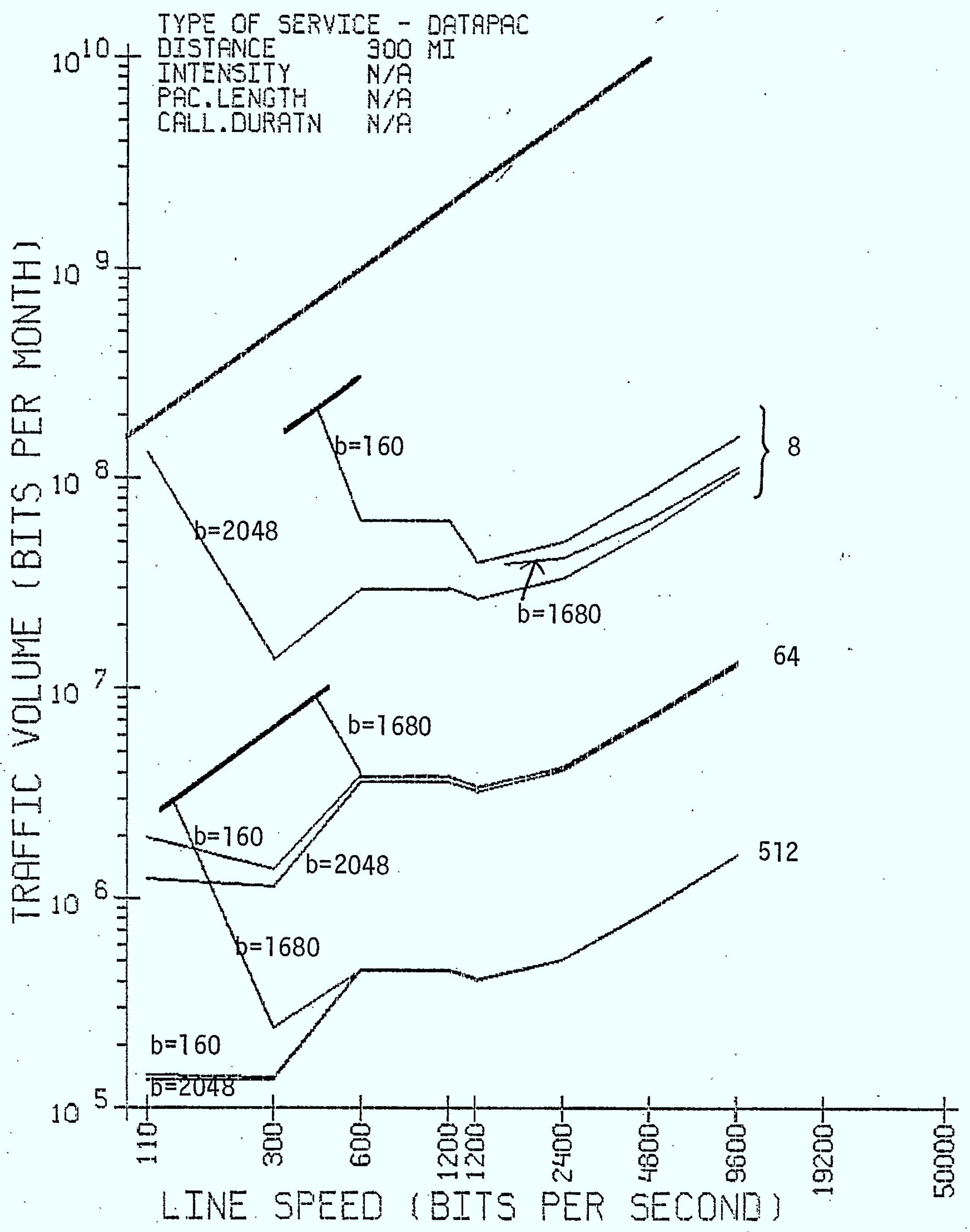


Figure 3.4.8: Variation in isogram lines for applications

(i=0.01, b=1680, t=2.3), (i=0.8, b=2048, t=45) and (i=0.24, b=160, t=19)

3.5 INFOEXCHANGE

The Infoexchange Service is the circuit switched portion of the hybrid circuit and packet switching network, Infoswitch. The charge for the service is comprised of a monthly access charge based on the speed, and a utilization charge based on circuit connection minutes per month, distance, and speed of service.

The basic form of our model is given in equation [3.5.1]:

$$\$pm = 2A(s) + KU(d,s) \qquad [3.5.1]$$

A(s) is the access charge in dollars per month and the usage charge, U(d,s), is expressed as a monthly rate per circuit connection minute. In this case, the monthly charge is obtained by taking K to be the connect minutes per month; hence,

$$K = 60c \quad \text{min/month} \qquad [3.5.2]$$

There is a minimum charge for each call based on an assumed minimum duration of half a minute. Since we are dealing with an average call duration and not a complete distribution of call durations, we can invoke the minimum charge only when the average call duration falls below the minimum. The minimum is obtained by setting K equal to (n/2) minutes per month. The charge is based upon the total minutes used in a month, and not on the number of messages or intensity of use when connected, nor the number of circuits set up in the network. However, there is a high volume rate that applies to those connect minutes in excess of 600 each month. This high volume rate is 2/3 of the basic rate rounded to the nearest cent. Within this round-off, the high volume rate is included in the model by replacing equation [3.5.2] by equation [3.5.3]:

$$K = 50c + 100 - 10\,|c - 10|$$

$$\text{if } 2t > 1\text{; otherwise } K = n/2 \qquad [3.5.3]$$

where $c = u/3600si$, synchronous

or $c = u/2880si$, asynchronous

The total chargeable minutes are averaged over the number of accesses provided in a collective number group to obtain "c".

The access charge, A(s), applies to levels 1 and 2 serving areas (mesh points), no specific charge being applicable to level 3 areas. Over a wide range of speeds (300 to 9600) this access charge can be represented approximately by equation [3.5.4].

$$A(s) = 27.50 + \frac{s}{32.8}\left[1 + \exp(1 - (s/945)^2)\right] \qquad [3.5.4]$$

However, the synchronous and asynchronous services have different charges at the same speed (1200) so that the model can be improved considerably by distinguishing between these two kinds of services. The access charge for synchronous service (1200 to 9600 bps) is given by equation [3.5.5], while that for asynchronous service (110 to 1200 bps) is given by equation [3.5.6].

$$A_s(s) = 100 + \frac{1}{65.3}[|s - 2400| + (s - 2400)] \qquad [3.5.5]$$

$$A_a(s) = 70 + \frac{1}{30}[|s - 300| - |s - 600|] \qquad [3.5.6]$$

The rate centres of the Infoswitch serving areas are shown on the maps of Figures 3.5.1 and 3.5.2. Levels 1 and 2 are derived from the Infodat network with the addition of Lethbridge, Brandon, Thompson, Fredericton, Jonquiere, Sherbrooke, and Oshawa. It has been assumed that the centres in Levels 1 and 2 are virtually mesh connected, and consequently, that the usage between any pair depends upon the geographic distance between them. The tariff indicates the so-called "Vertical and Horizontal method" is used to calculate the distance. We were informed this corresponds to geographical distance.

The Level 3 serving area centres are the "off-mesh" rate centres and are shown as being connected to a Level 1 centre. The off-mesh usage model applies only to the leg which joins to the mesh, after which the mesh usage model is used.

The usage function in the model depends on both access speed and distance. For points on and off the network mesh, it is a decreasing per mile charge with increasing distance. The mesh usage function for access speeds up to 1200 bps, both synchronous and asynchronous, can be modelled by the equation:

$$U_{12} = 0.0833 + 0.346[1 - \exp(-(d/650))] \qquad [3.5.7]$$

Similarly, the mesh usage functions for the higher synchronous access speeds, 2400, 4800, and 9600 bps, are modelled by equations:

$$U_{24} = 0.1142 + 0.565[1 - \exp(-(d/1155))] \qquad [3.5.8]$$

$$U_{48} = 0.1678 + 0.6957[1 - \exp(-(d/659))] \qquad [3.5.9]$$

$$U_{96} = 0.2058 + 0.865[1 - \exp(-(d/642))] \qquad [3.5.10]$$

These four formulae for mesh usage at synchronous speeds can be combined in the following equation as the mesh usage model:

$$U(d,s) = [0.14061 \log(s) - 0.3539] \ldots$$

$$\ldots + [0.5606 \log(s) - 1.3618] \,.\, [1 - \ldots$$

$$\ldots \exp(-d/(646 + (\log(s/2847))^{-4}/65))] \qquad [3.5.11]$$

Equation [3.5.11] is easily extended to all values of access speed, including asynchronous, by replacing the speed variable with the expression:

$$(s) \rightarrow [1200 + s + |s - 1200|]/2 \qquad [3.5.12]$$

The usage charge from off-mesh points to the nearest Level 1 rate centre depends both on access speed and distance. For the three synchronous speeds; viz., 1200, 2400, and 4800 bps, equation [3.5.13] can be used as a model.

$$U_o(d,s) = s^{0.707}\, 6 \times 10^{-4} + 0.049 \ldots$$

$$\ldots + \frac{d}{679} - 0.14 \exp(-d/16) \qquad [3.5.13]$$

Asynchronous speeds below 1200 can be included by replacing the speed variable with the expression in [3.5.12].

The unit cost isograms will depend on the service speed, the distance, and the monthly connect time. This last introduces the traffic volume, u, and the communication intensity, i, through the equation

$c = u/3600is$ hrs./mo. synchronous

$c = u/2880is$ hrs./mo. asynchronous [3.5.14]

In this way, the appropriate intensity is selected for a particular application, and then the connect time is determined for every point on the "u-s" diagram, and hence K by equation [3.5.3] in the model, [3.5.1]. Finally, the unit cost in dollars for each megabit transmitted is obtained by dividing equation [3.5.1] by the traffic volume, "u", to obtain a result identical with equation [3.2.9].

Figure 3.5.3 shows contours of constant unit cost, or isograms, for one set of application parameters as applied to Infoexchange. Again, at lower traffic volumes where the access charge is dominant, then equation [3.2.10] applies as shown by the unit cost isograms. However, at higher traffic volumes where the usage charge becomes important, the unit cost varies inversely with line speed, because a lower line speed means a longer connection time for a given volume of data. For negligible access charge, but ignoring the high volume discount rate, the fractional (i.e. per cent) changes in unit cost with line speed is, approximately,

$$\frac{\Delta G}{G}\frac{s}{\Delta S} \approx \frac{s}{U}\frac{\partial U}{\partial s} - 1 \qquad [3.5.15]$$

In the region below 1200 bits/sec line speed, the usage rate is constant for a given distance, and the access charge has two values only, one for 300 bits/sec and less, the other for 600 bits/sec and over. Accordingly, the slope of the unit cost isograms in these regions is,

$$\frac{\Delta u}{\Delta s} = -\frac{u^2 U_{12}}{120Ais^2} \qquad [3.5.16]$$

This quantity is negative in these regions and everywhere at higher traffic volumes where usage charges dominate and the increased connection time at lower speeds results in higher unit cost. Thus, at higher traffic, higher line speeds reduce unit costs.

The effect of distance on unit cost is illustrated in Figure 3.5.4. The vertical displacement in the isogram contours resulting from a change in distance is given by equation [3.10.1] which for Infoexchange becomes:

$$\frac{\Delta u}{\Delta d} = \frac{u^2}{120is\ A(s)} \cdot \frac{\partial U}{\partial d} \qquad [3.5.17]$$

Again, the fractional change in traffic volume required to maintain a given unit cost when the distance is increased, is proportional to the traffic volume itself. Thus, the corresponding contour spreads out more at higher traffic volume than in the region where the access charge dominates.

The sensitivity to different application types as described by the communication intensity parameter, i, is illustrated in Figure 3.5.5. A decrease in intensity requires a longer connection time for the same speed and volume, resulting in higher unit costs. If the unit cost is kept fixed as in Figure 3.5.5, then a decrease in intensity and its accompanying higher usage charges must be compensated for by a large increase in traffic volume, especially at low speeds, to reduce the per unit cost of access. In this service, the unit cost is strongly dependent on the communication intensity of the application, except perhaps when the intensity is close to unity.

This can be described approximately by a sensitivity relationship of the kind of equation [3.4.14] which for Infoexchange is:

$$\frac{\Delta u}{\Delta i} = - \frac{u^2 U(s,d)}{120A(s)si^2} \qquad [3.5.18]$$

or, since U(s,d) and A(s) vary only slowly with s,

$$\frac{\Delta u}{\Delta i} \propto - \frac{u^2}{si^2} \qquad [3.5.19]$$

Thus we find in Figure 3.5.5, that the displacement is larger at lower speeds, at smaller values of intensity, and at higher traffic volumes.

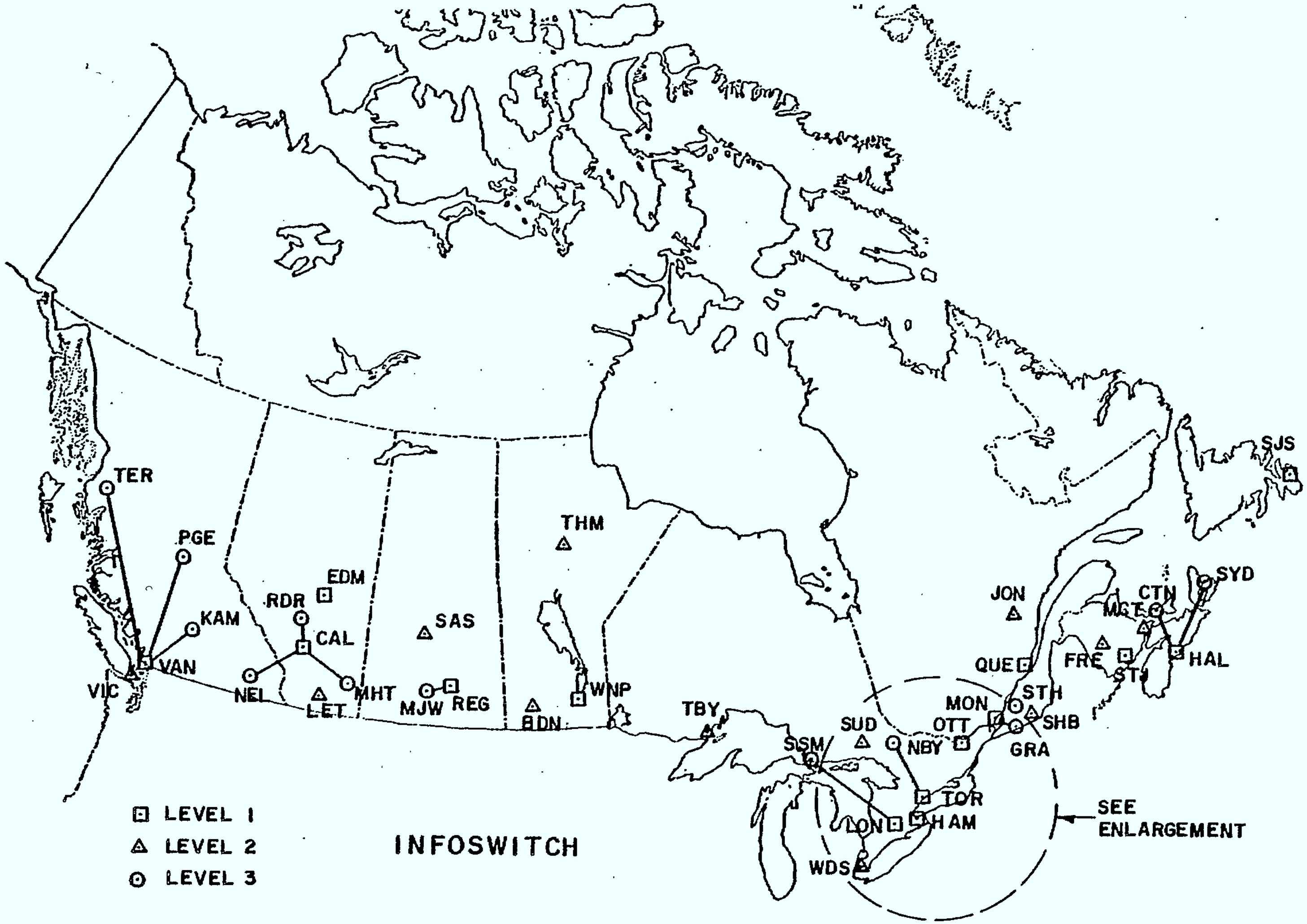


Figure 3.5.1: Virtual Infoswitch Circuit Routes

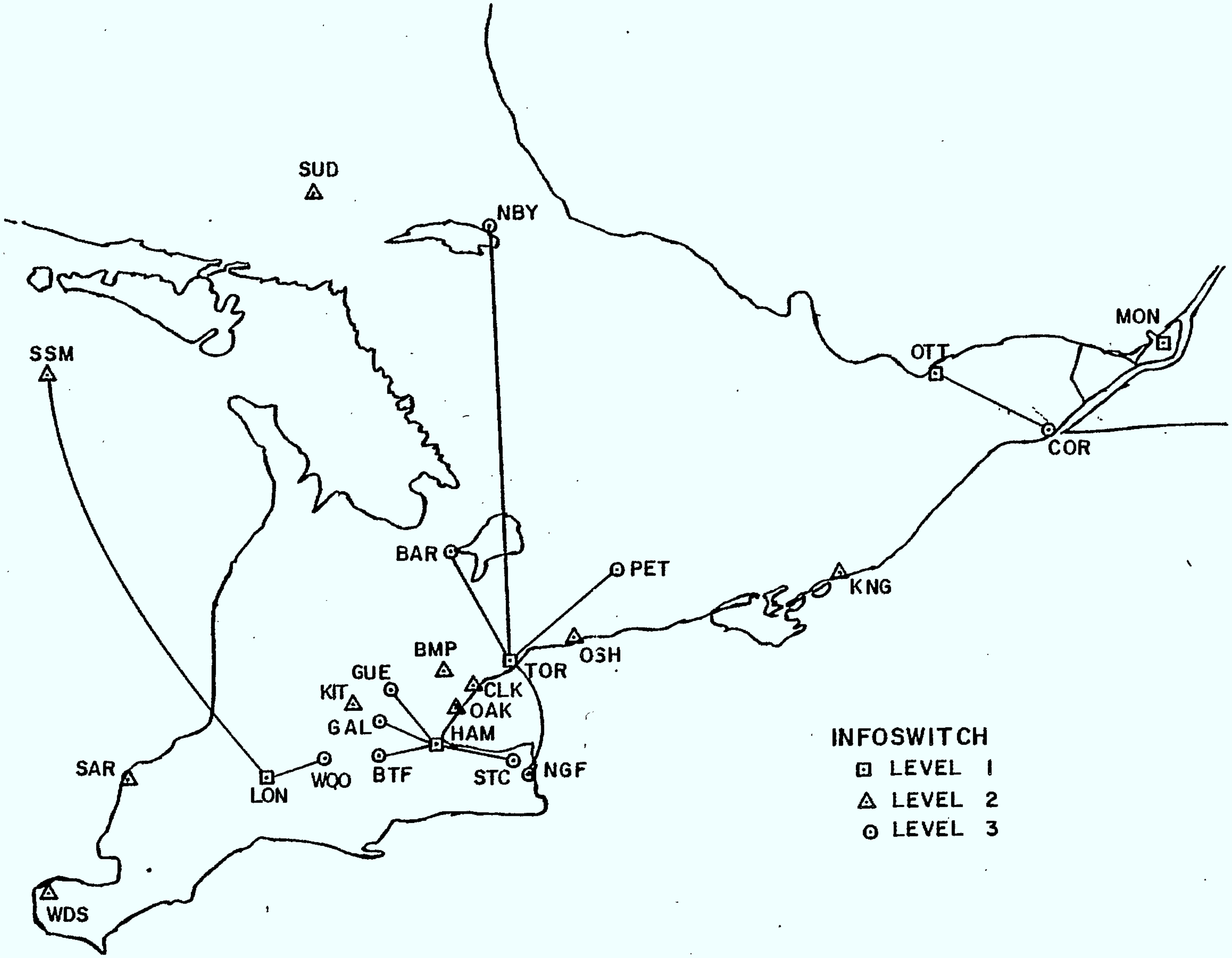


Figure 3.5.2: Virtual Infoswitch Circuit Routes (Southern Ontario-Quebec)

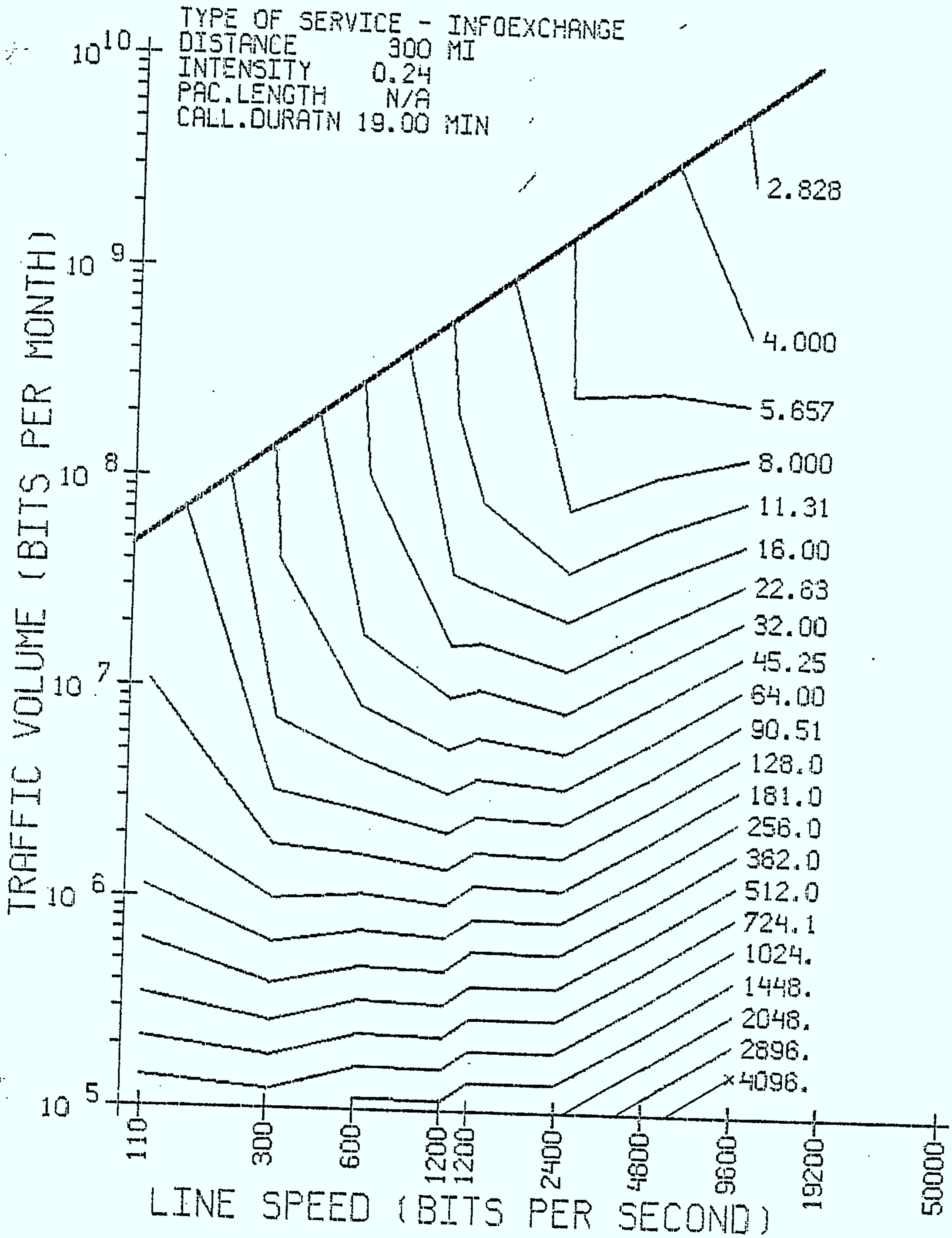


Figure 3.5.3: Isograms of constant unit cost

(dollars per megabit of data)

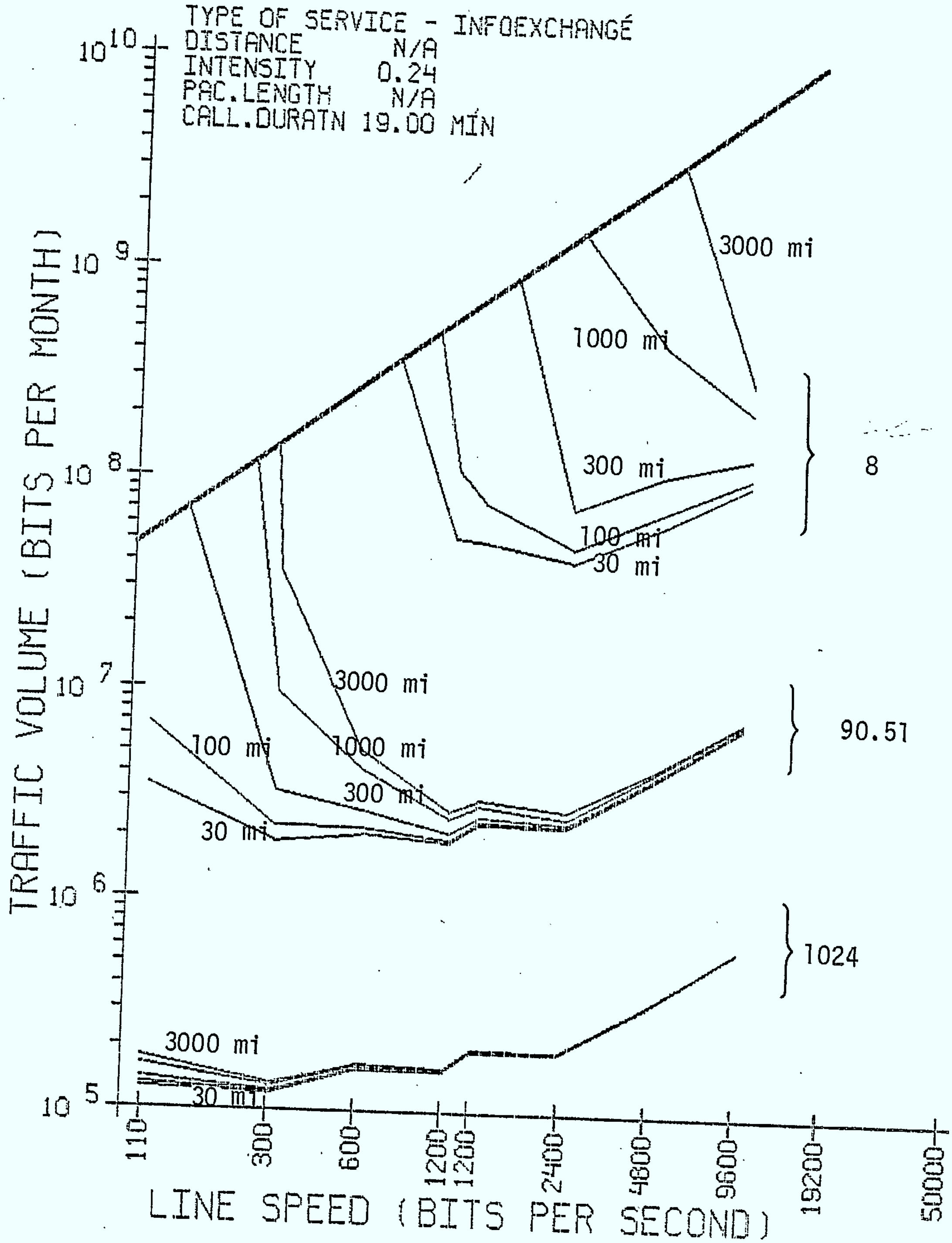


Figure 3.5.4: Variation in isogram lines with distance

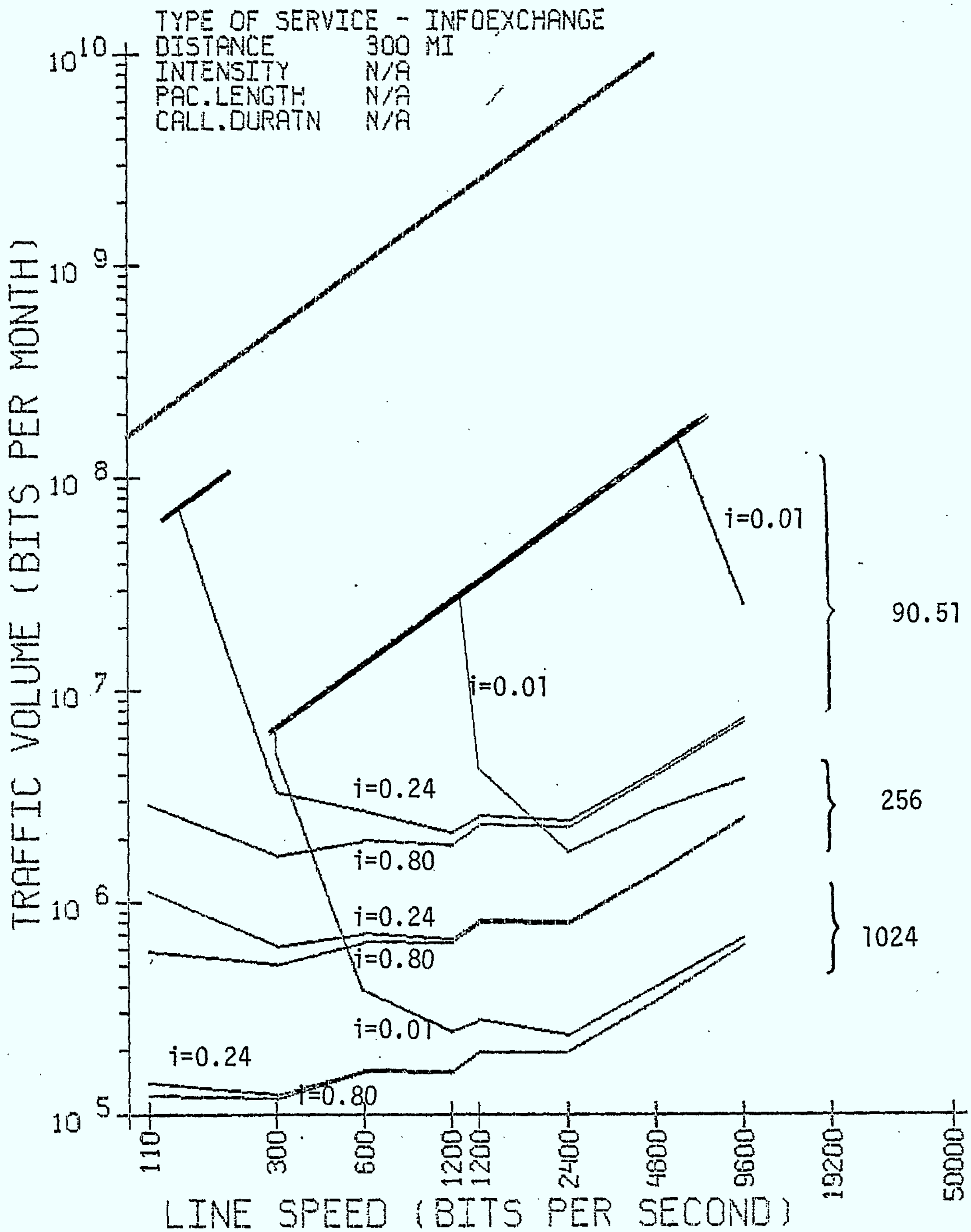


Figure 3.5.5: Variations in isogram lines for applications

(i=0.01, b=1680, t=2.3), (i=0.8, b=2048, t=45) and (i=0.24, b=160, t=19)

3.6 INFOCALL

The access charges for the Infocall service are the same as for Infoexchange. The model represents them by equations [3.5.4], [3.5.5], and [3.5.6].

Since Infocall charges on a character basis, for the purpose of our model we will take

$$10^4 K = u/8 \text{ characters/month} \qquad [3.6.1]$$

and include the minimum (no traffic) charge in the usage functions.

There are two usage functions for Infocall, U_a and U_s for asynchronous and synchronous transmissions respectively, between mesh points, and similarly for off-mesh points. The distance dependence is the same for synchronous and asynchronous transmissions, but the minimum traffic charges are different.

The mesh usage charges are given by the equations:

$$U_a = 0.40 + 0.80[1 - \exp(-d/631)] \ \ldots$$

$$\ldots + \frac{0.15}{2si}\,[|is - 30| - (is - 30)] \qquad [3.6.2]$$

$$U_s = 0.40 + 0.80[1 - \exp(-d/631)] \ \ldots$$

$$\ldots + \frac{0.15}{2si}\,[|is - 240| - (is - 240)] \qquad [3.6.3]$$

These include the distance dependence and also the minimum charge communication intensity. For example, in the synchronous case, the usage depends on the distance alone if the intensity is over (240/s). However, for intensities less than this minimum, there is an additional charge which is proportional to the difference between the actual and the minimum intensities. If the intensity (and hence the traffic volume) is set at zero, i.e., the no traffic condition, then equations [3.6.2] and [3.6.3] must be taken with equation [3.6.1]. The result for the usage term in the synchronous case then becomes:

$$KU_s \rightarrow 0.15 \frac{1800}{10^4} 60c$$

and in the asynchronous case:

$$KU_a \rightarrow 0.15 \frac{180}{10^4} 60c$$

The charges for off-mesh or Level 3 points can be treated similarly. The dependence on distance is different and applies to the connection to the Level 1 point in the mesh, after which the mesh charges apply. The expressions for usage on off-mesh distances, including the effect of the minimum intensity charge, are given by equations [3.6.4] and [3.6.5].

$$U_{oa} = 0.42 + \frac{d}{250} - 0.45 \exp(-d/20) \ldots$$

$$\ldots + \frac{0.15}{2si} [|is - 30| - (is - 30)] \qquad [3.6.4]$$

$$U_{os} = 0.42 + \frac{d}{250} - 0.45 \exp(-d/20) \ldots$$

$$\ldots \frac{0.15}{2si} [|is - 240| - (is - 240)] \qquad [3.6.5]$$

Here again equations [3.2.1] and [3.2.9] apply, and at the lower traffic volumes we have, again, equation [3.2.10]. However, at higher traffic volumes where the usage charge dominates, the unit cost tends to become a constant based on the per character charge rate. In other words, the surface represented by the unit cost contours becomes flat asymptolically to an isogram value of

$$G \approx \frac{100}{8} U(d) \qquad [3.6.6]$$

which on Figure 3.6.1 has a value of $8.78.

The effect of distance is again illustrated in Figure 3.6.2 and the results for Infocall are similar to those for Datapac. Equation [3.10.1] applied to Infocall yields:

$$\frac{\Delta u}{\Delta d} = \frac{u^2}{16 \times 10^4 A(s)} \frac{\partial U}{\partial d} \qquad [3.6.7]$$

and the figure shows the corresponding spreading out of the contours at higher traffic volumes.

The effect of different application types as described by the communication intensity, i, is shown in Figure 3.6.3 which is analagous to Figure 3.5.5 for Infoexchange. However, here, the unit cost is independent of the communication intensity provided that the latter exceeds the minimum intensity. This minimum is (240/s) for synchronous service and (30/s) for asynchronous service. Thus for an intensity of 0.01 or greater, the unit costs are the same if the line speed exceeds 24,000 bits/sec. Similarly for intensities over 0.24, the unit costs are the same for line speeds over 1000 bits/sec synchronous (i.e. all cases) and over 125 bits/sec asynchronous.

We can express this by defining the intensity below which the minimum charge is invoked, as:

$$i_m = 30/s \text{ (asynch)} \qquad [3.6.8]$$
$$= 240/s \text{ (synch)}$$

Then, the displacement of the isograms with changes in the communication intensity for different application types is:

$$\frac{\Delta u}{\Delta i} = 0 \qquad ; \; i > i_m$$

$$\frac{\Delta u}{\Delta i} \propto \frac{-u^2}{A(s)si^2} \qquad ; \; i < i_m \qquad [3.6.9]$$

Thus in Figure 3.6.3 we see the displacement, Δu, increase with traffic volume, and also increase at lower line speeds and very low intensities.

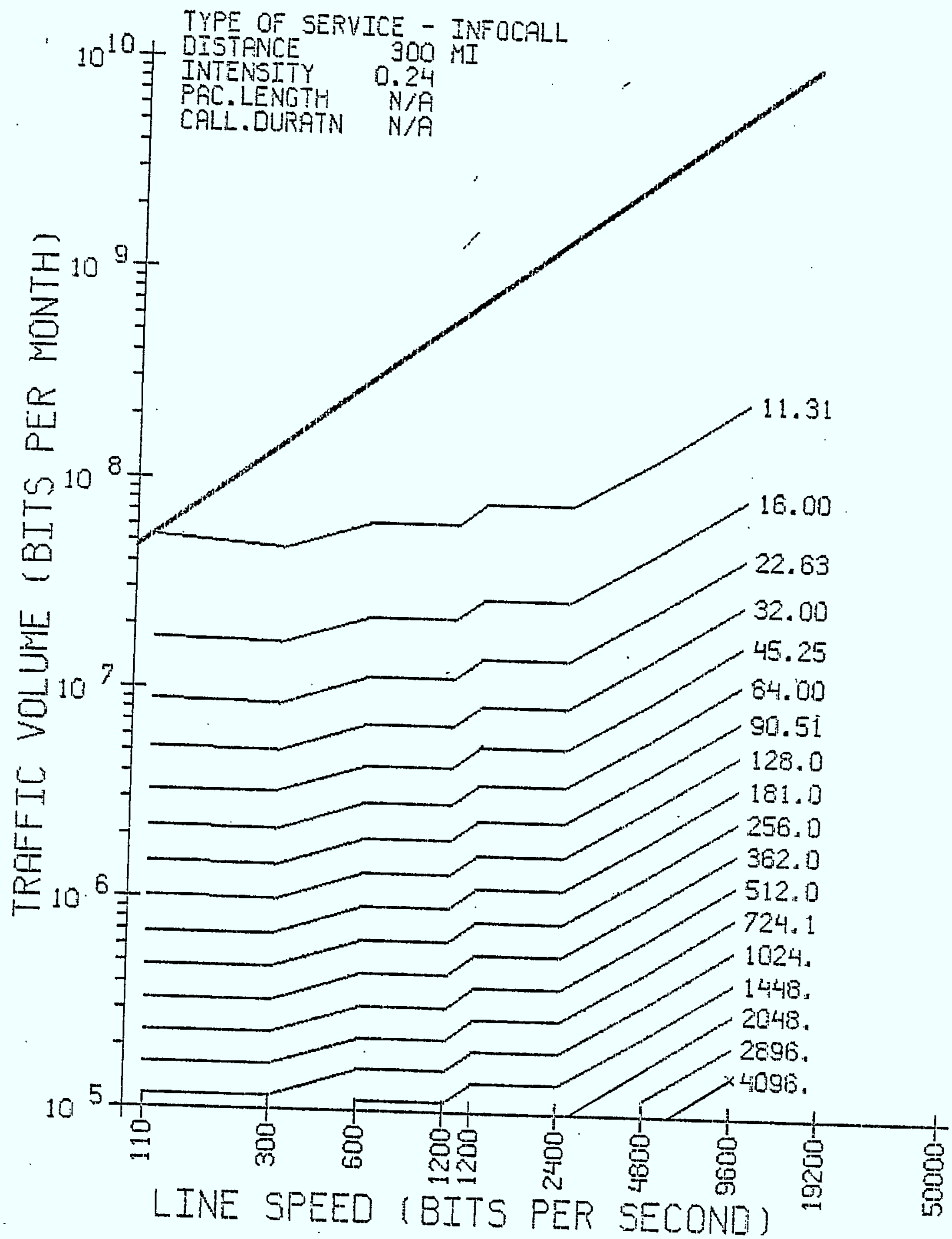


Figure 3.6.1: Isograms of constant unit cost

(dollars per megabit of data)

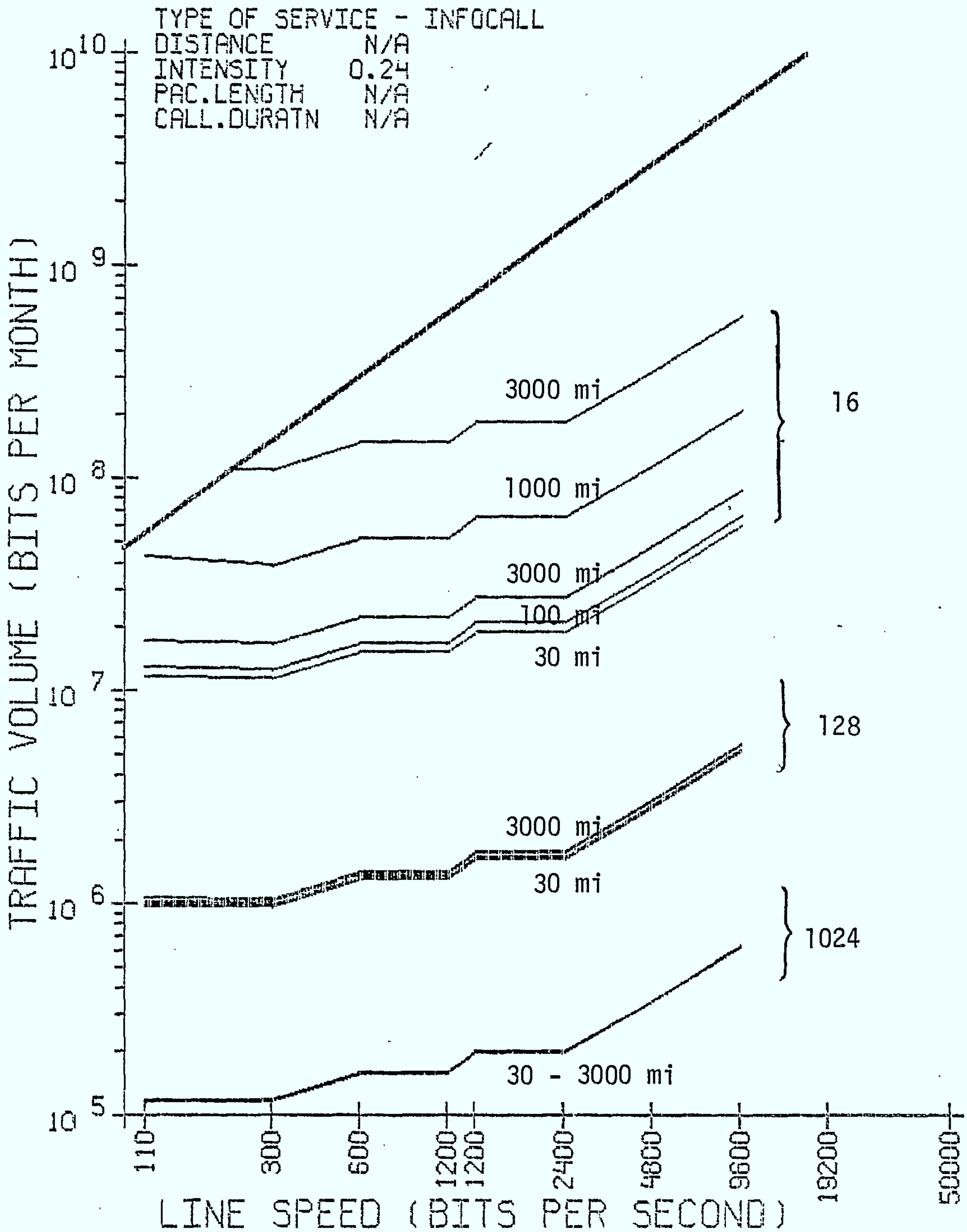


Figure 3.6.2: Variation in isogram lines with distance

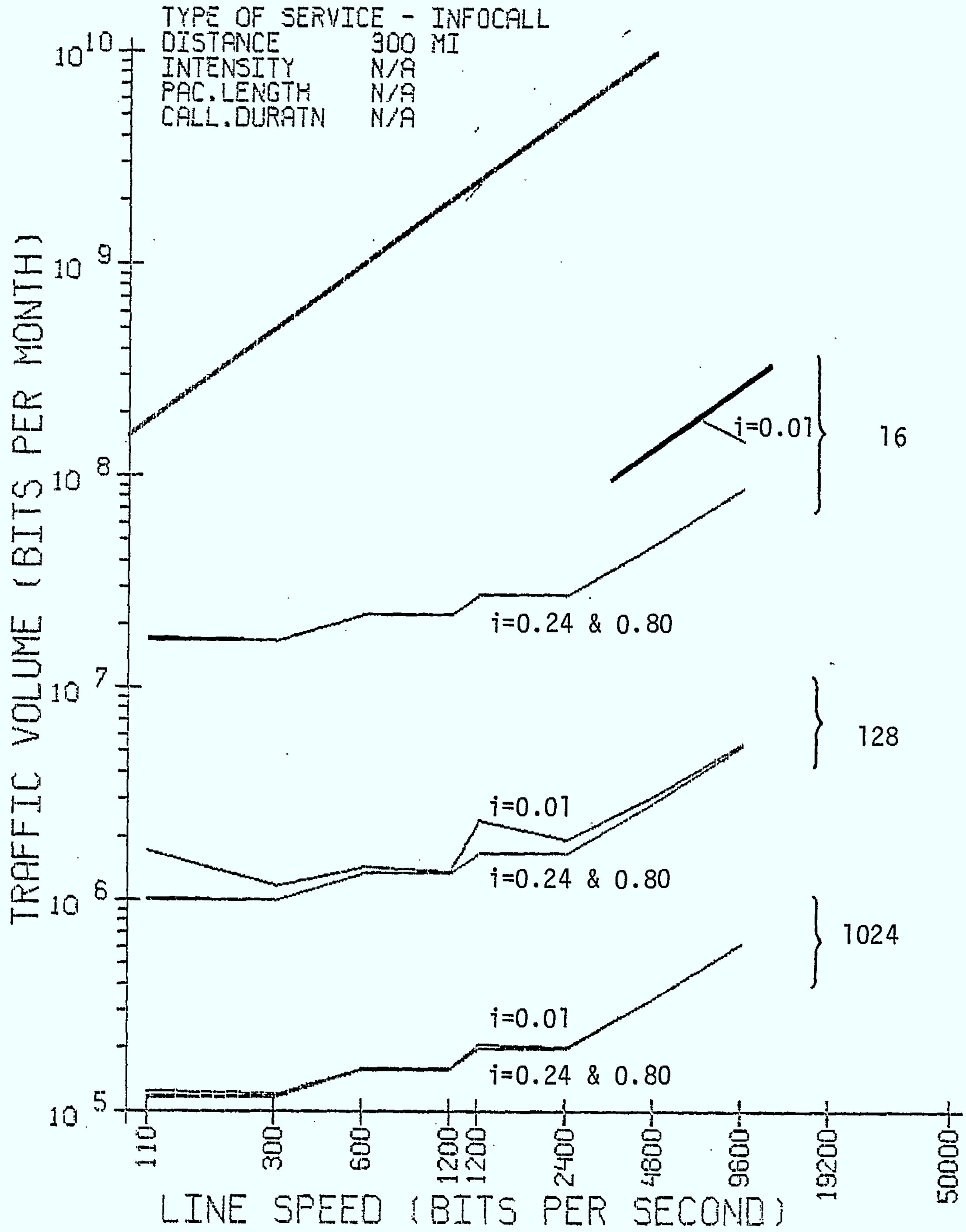


Figure 3.6.3: Variation in isogram lines for applications

(i=0.01, b=1680, t=2.3), (i=0.8, b=2048, t=45) and (i=0.24, b=160, t=19)

3.7 PUBLIC SWITCHED TELEPHONE NETWORK (DDD)

The public switched telephone network can be used to communicate data to and from computers at up to 9600 bits/sec speeds. In fact, it offers one of the most available, widespread, and standard access ports for many applications, although it suffers in some ways through the use of exchanges designed for voice rather than data. The speeds that can be achieved are related to the cost of the modem used to couple a terminal to a telephone. Speeds of up to 4800 bps are common, while higher speeds have a higher modem charge because of the communications complexity.

Accordingly it is necessary to include an allowance for the modem cost, which is an essential part of the access arrangement, along with the tariffs in order to make comparisons more realistic. Also, we follow the practice in this section of using twice the one terminal charge to account for both ends of a link, although in the case of telephone access to a computer facility, a one terminal charge may be more appropriate. Finally, we take

$$A = \$25$$

as a representative access charge in terms of monthly rental for a business phone, and add the modem cost

$$M(s) \quad \$pm$$

which, of course, is a function of line speed. From data on over 200 commercially available modems, we find, approximately,

$$M(s) = 10 + 60[\ln(s/2085) + |\ln(s/2085)|] \qquad [3.7.1]$$

although variations by a factor of two are quite common.

Taken with the other terms we have

$$\$pm = 2(A + M(s)) + N(d).n + K\,U(d) \qquad [3.7.2]$$

as the expression for the monthly charge. Since the usage, U(d), is a rate per connected minute, we have for this model:

$$K = \frac{u}{48si}[1 - [1 + |s - 2085|/(s - 2085)]/10] \qquad [3.7.3]$$

We have two sets of tariffs available; one for the Trans Canada rate schedule, and the other for the Ontario-Quebec region (except HF radio exchanges).

Thus for the Trans Canada telephone network N(d) and U(d) are modelled by equations [3.7.4] and [3.7.5] respectively.

$$N_1(d) = 0.108393 \exp(-d/152) \qquad [3.7.4]$$

$$U_1(d) = 1.05[1 - \exp(-d/516)] + \frac{d}{542}\exp(-(d/265)^2) \qquad [3.7.5]$$

For the Bell Canada region in Ontario and Quebec, N(d) and U(d) are modelled by equations [3.7.6] and [3.7.7] respectively.

$$N_2(d) = 0.10 - \frac{(d + 16)}{963}\exp(-(d + 16)/143) \qquad [3.7.6]$$

$$U_2(d) = 0.50[1 - \exp(-d/103)] + \frac{d}{362}\exp(-(d/70)^2) \qquad [3.7.7]$$

The minimum charge of $0.20 per call has been ignored on the assumption that calls from terminals will exceed either two minutes or ten miles (<u>or</u> <u>both</u>). The unit cost equation in dollars per megabit is now:

$$G = \frac{2(A + M) + Nn + KU}{u} 10^6 \qquad [3.7.8]$$

Contours of constant unit cost, the isograms, are displayed in Figure 3.7.1 using the Trans Canada rate model, and in Figure 3.7.2 using the Ontario-Quebec rate Model. Over large regions, the slope of these contours is negative indicating a lower unit cost at higher line services. This is because the access and modem charges are constant through the asynchronous region, so that higher line speeds mean shorter connection time for a given volume of data. In the synchronous region, usage charges dominate at high volume, but at lower traffic volumes the increased cost of high speed modems results in a positive slope to the isograms.

The sensitivity of these two services to distance is illustrated in Figures 3.7.3 and 3.7.4. In both cases the displacement of the contours in the vertical direction ($\Delta u/u$ on a logarithmic scale) is proportional to (u/is); that is,

$$\frac{\Delta u}{u \Delta d} \propto \frac{u}{si} \qquad [3.7.9]$$

Thus we see that the displacement is greater at lower line speeds and higher traffic volumes.

Similarly, the sensitivity of these two services to application type as described by the communication intensity is shown in Figures 3.7.5 and 3.7.6. Here the fractional change (per cent) in isogram displacement with fractional change in intensity, is proportional to, but opposite in sign to, the connection time; that is,

$$\frac{\Delta u}{u} \cdot \frac{i}{\Delta i} \propto \frac{-u}{si} \qquad [3.7.10]$$

Again, the Figures show a greater displacement at lower line speeds and higher traffic volumes.

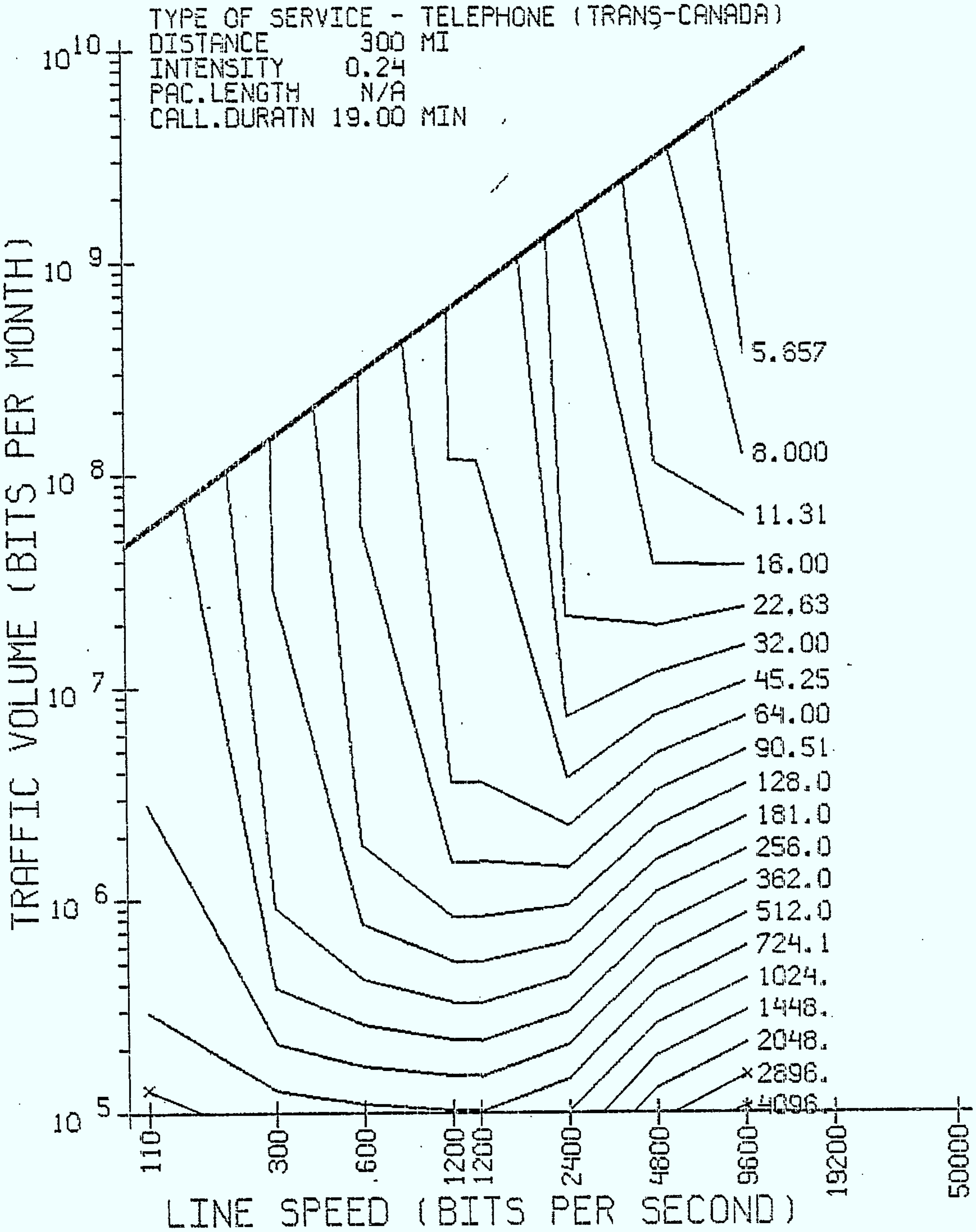


Figure 3.7.1: Isograms of constant unit cost

(dollars per megabit of data)

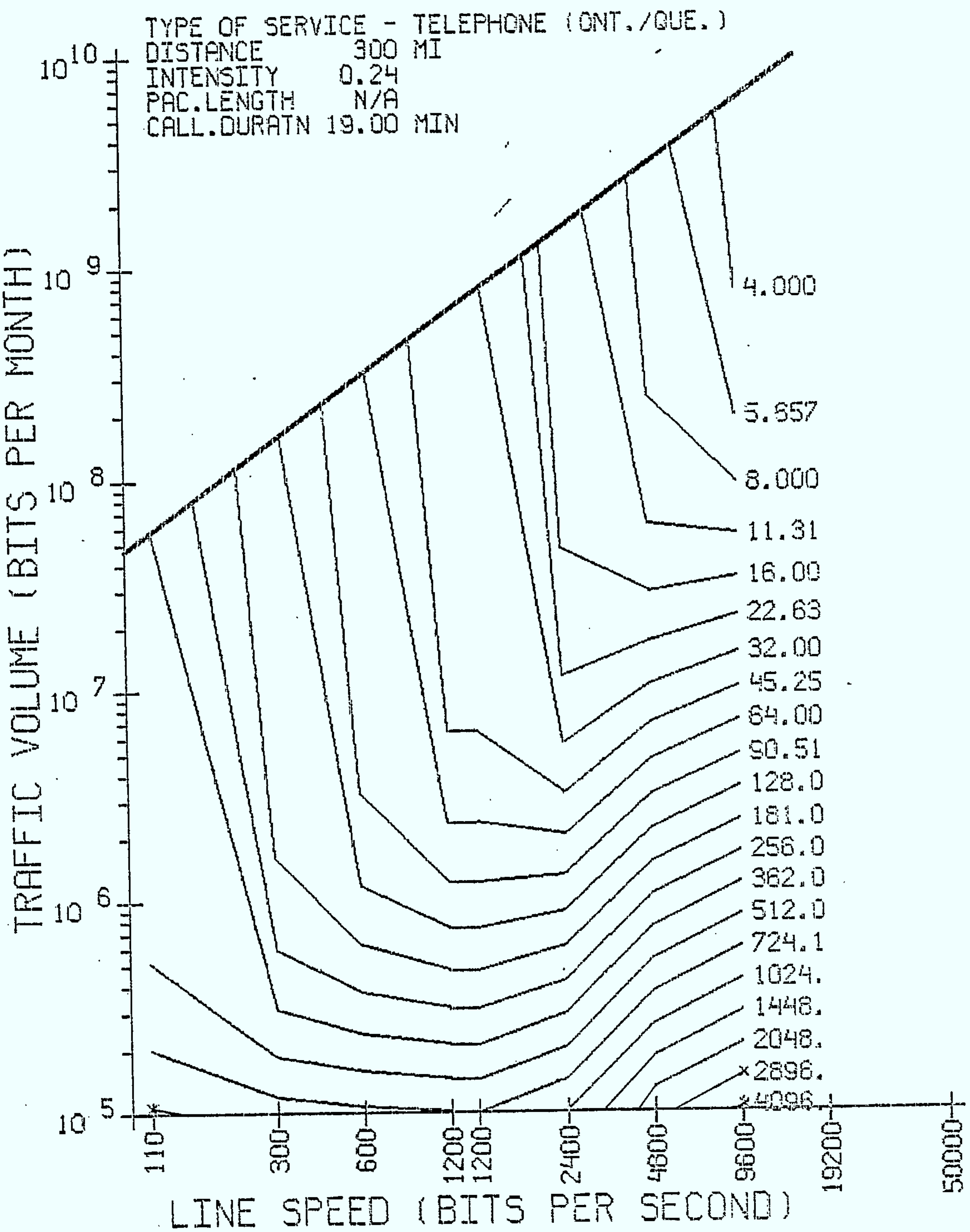


Figure 3.7.2: Isograms of constant unit cost

(dollars per megabit of data)

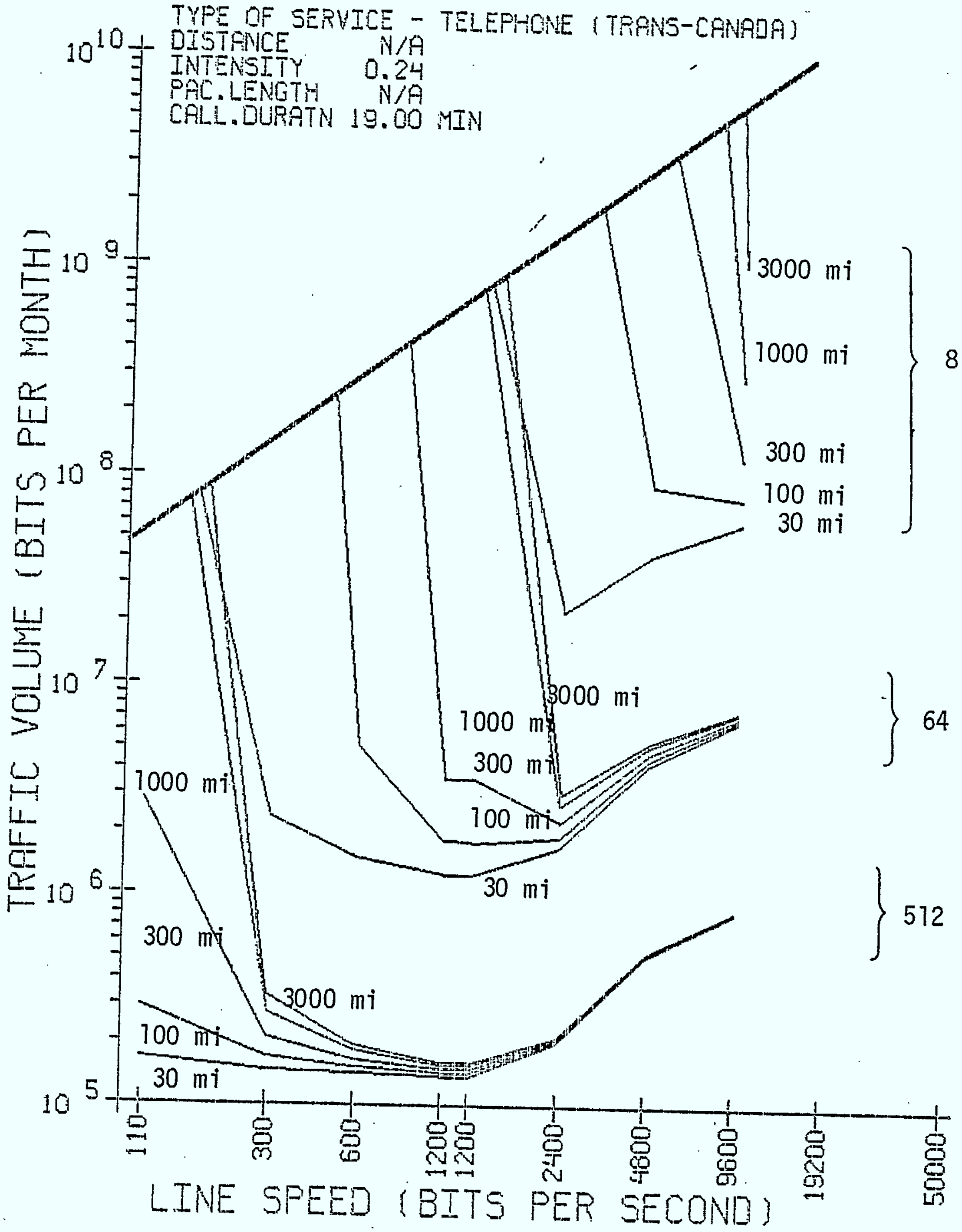


Figure 3.7.3: Variation in isogram lines with distance

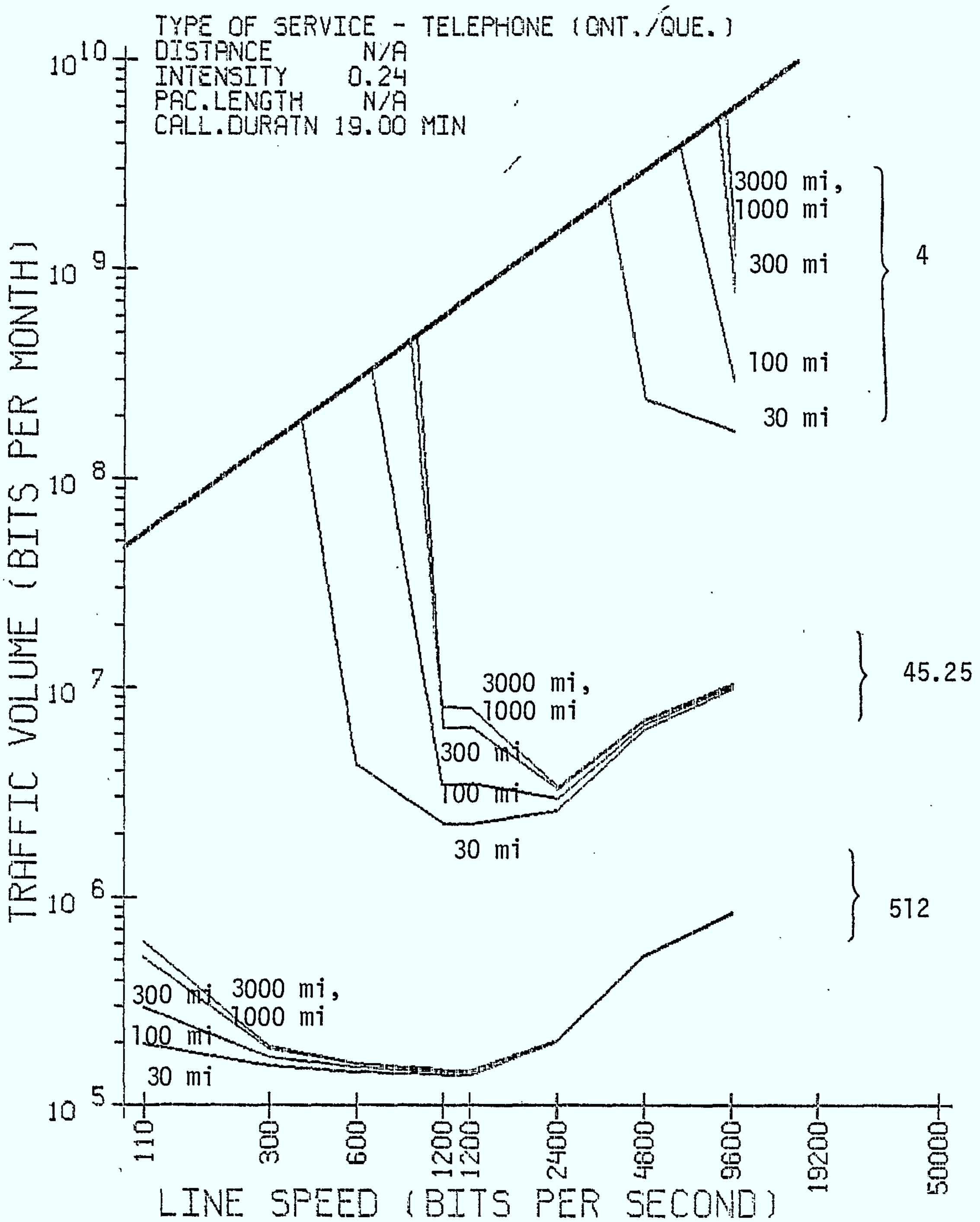


Figure 3.7.4: Variation in isogram lines with distance

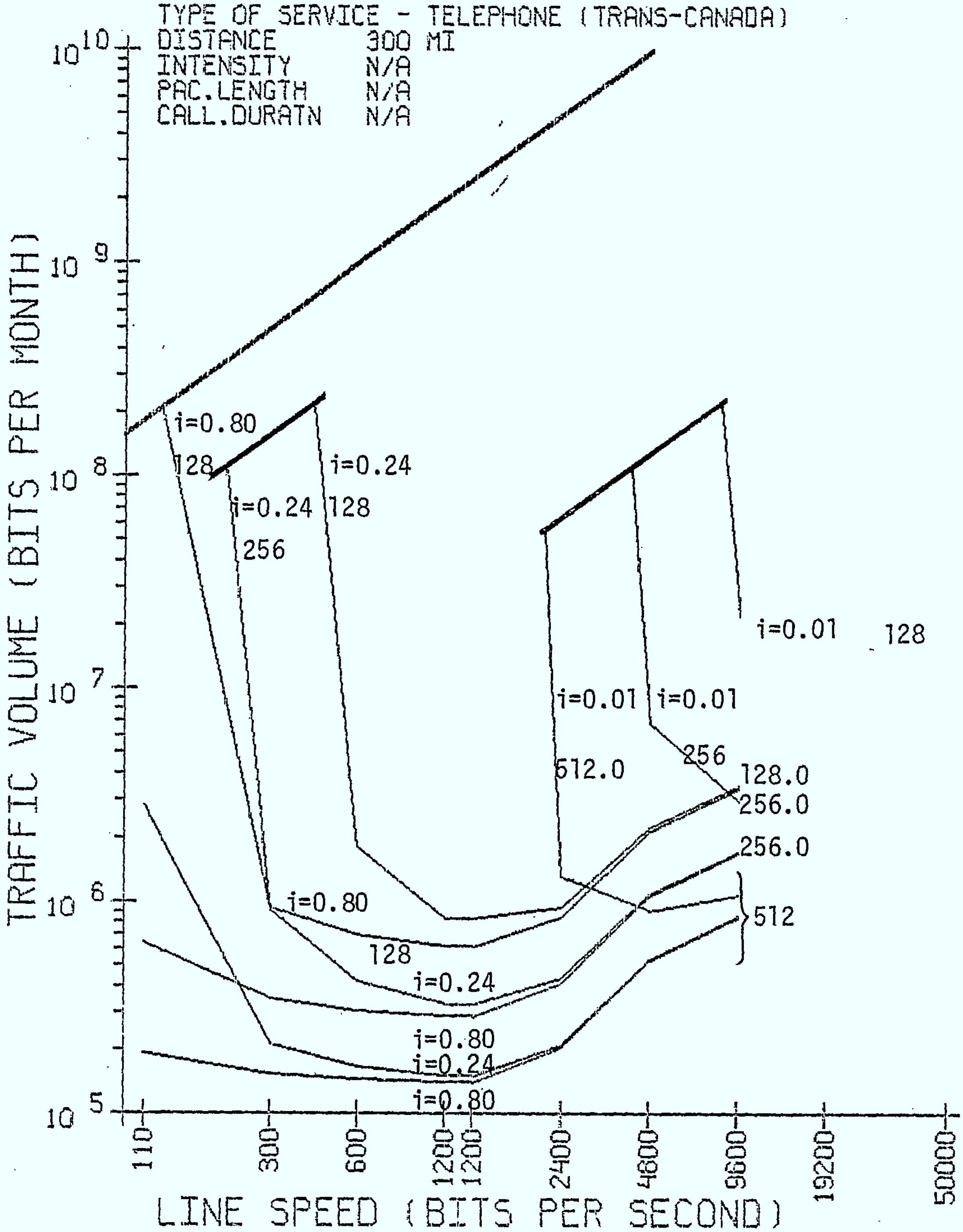


Figure 3.7.5: Variation in isogram lines for application (i=0.01, b=1680, t=2.3), (i=0.8, b=2048, t=45) and (i=0.24, b=160, t=19)

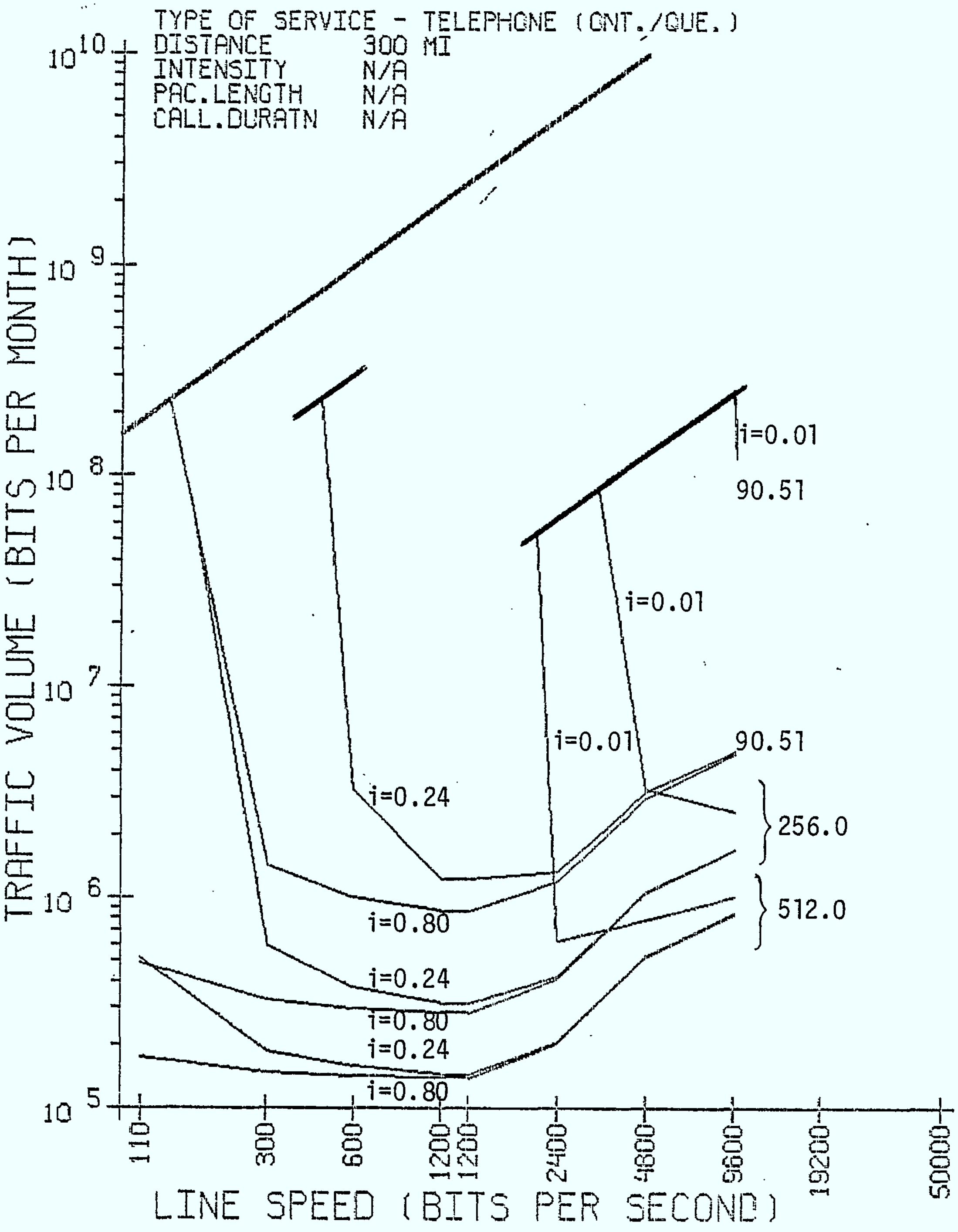


Figure 3.7.6: Variation in isogram lines for application (i=0.01, b=1680, t=2.3), (i=0.8, b=2048, t=45) and (i=0.24, b=160, t=19)

3.8 LEASED ANALOG LINE

Voice grade inter-exchange channels are circuits available with a bandwidth sufficient to carry telephone speech, or modem and data. The bandwidth is wider than that used for teletype circuits.

A modem is necessary to access leased voice lines, so that equation [3.7.1] is used here also. The usage charge is independent of traffic volume, line speed employed, and call frequency or duration, and depends only on the distance or length of the line. Two tariff rate schedules are available: (1) Trans Canada Telephone System, and (2) Bell Ontario-Quebec rates.

For TCTS we have:

$$U_1(d) = 20 + 2970[1 - \exp(-d/606)] + \ldots$$
$$\ldots\ 1.5d \exp[-(d/113)^4] + \ldots$$
$$\ldots\ 0.63[|d - 400| + (d - 400)] \exp[-((d - 400)/707)^2] \qquad [3.8.1]$$

Also, for the Bell Ontario-Quebec region we have:

$$U_2(d) = 32 + 2800[1 - \exp(-d/606)] + \ldots$$
$$\ldots\ 3.1d \exp[-(d/113)^2] + \ldots$$
$$\ldots\ 0.40[|d - 600| + (d - 600)] \exp[-((d - 600)/850)^2] \qquad [3.8.2]$$

The unit cost equation for this service becomes simply:

$$G = \frac{10^6}{u} (2M(s) + U(d)) \qquad [3.8.3]$$

Contours of constant unit costs are shown in Figure 3.8.1 using the TCTS rates, and in Figure 3.8.2 using the model for Bell rates for Ontario and Quebec. Now from Equation [3.7.1] it is evident that M(s) is constant below 2000 bits/sec, so that from [3.8.3] the isograms are the horizontal lines

$$u = 10^6 \, (2M + U)/G \qquad [3.8.4]$$

At higher line speeds, the isograms are essentially linear on a log-log plot with a positive slope of:

$$\frac{\Delta u}{u} \frac{s}{\Delta s} = \frac{500400}{2M + U} \qquad [3.8.5]$$

This means an increase in per unit cost resulting from the higher modem cost.

The sensitivity of these services to distance is illustrated in Figures 3.8.3 and 3.8.4. In both cases the fractional displacement in the vertical direction ($\Delta u/u$ on a logarithmic scale) for a distance interval, Δd, is

$$\frac{\Delta u}{u \Delta d} = \frac{1}{2M(s) + U(d)} \frac{\partial U}{\partial d} \qquad [3.8.6]$$

Again, this will be constant for line speeds below 2000 bits/sec, and will decrease at higher speeds.

Equation [3.8.3] involves only the three variables (u, s, d) and none of the application type parameters (t, i). Hence this service is insensitive to communication intensity and Figures 3.8.1 and 3.8.2 apply for all and any "i".

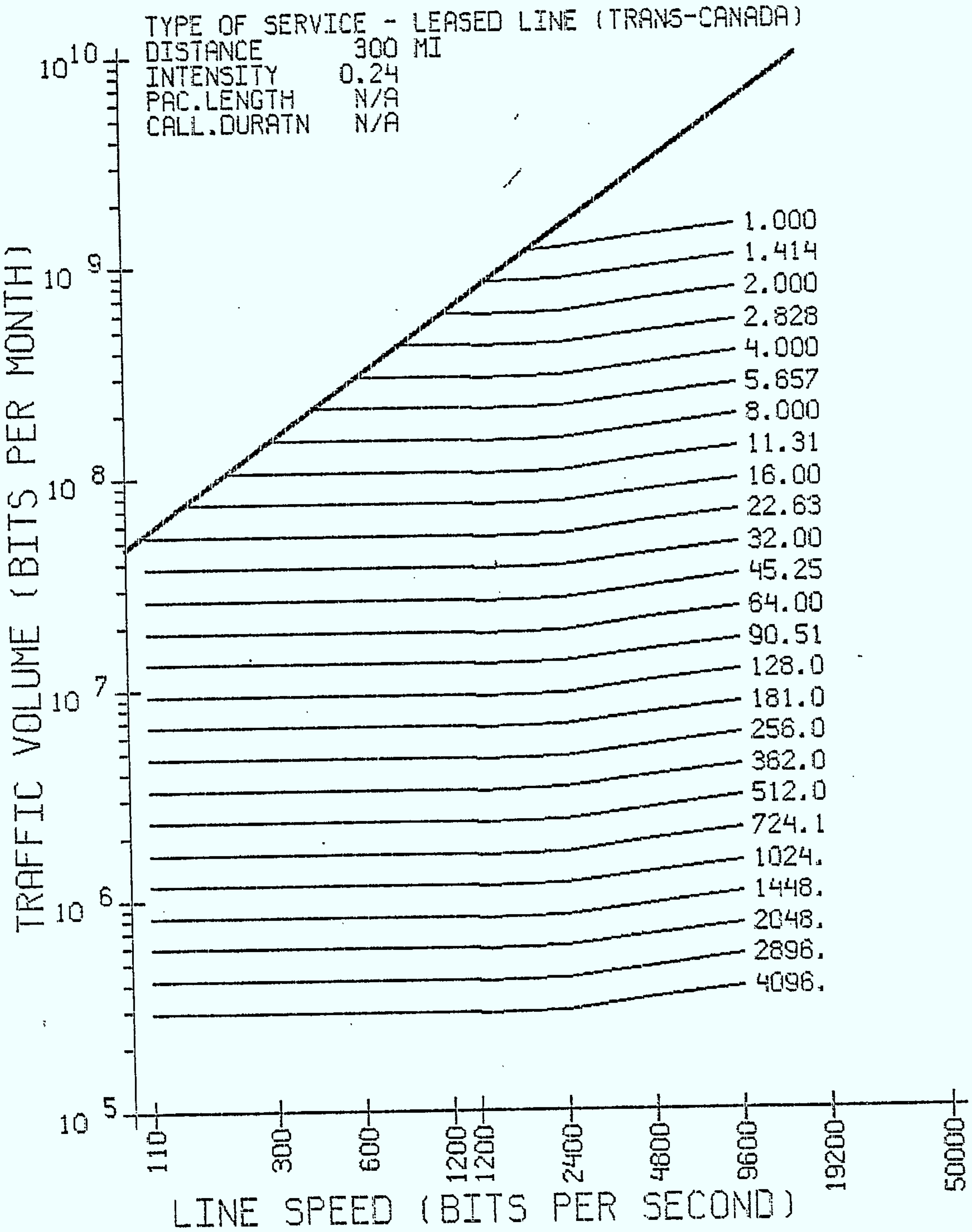


Figure 3.8.1: Isograms of constant unit cost

(dollars per megabit of data)

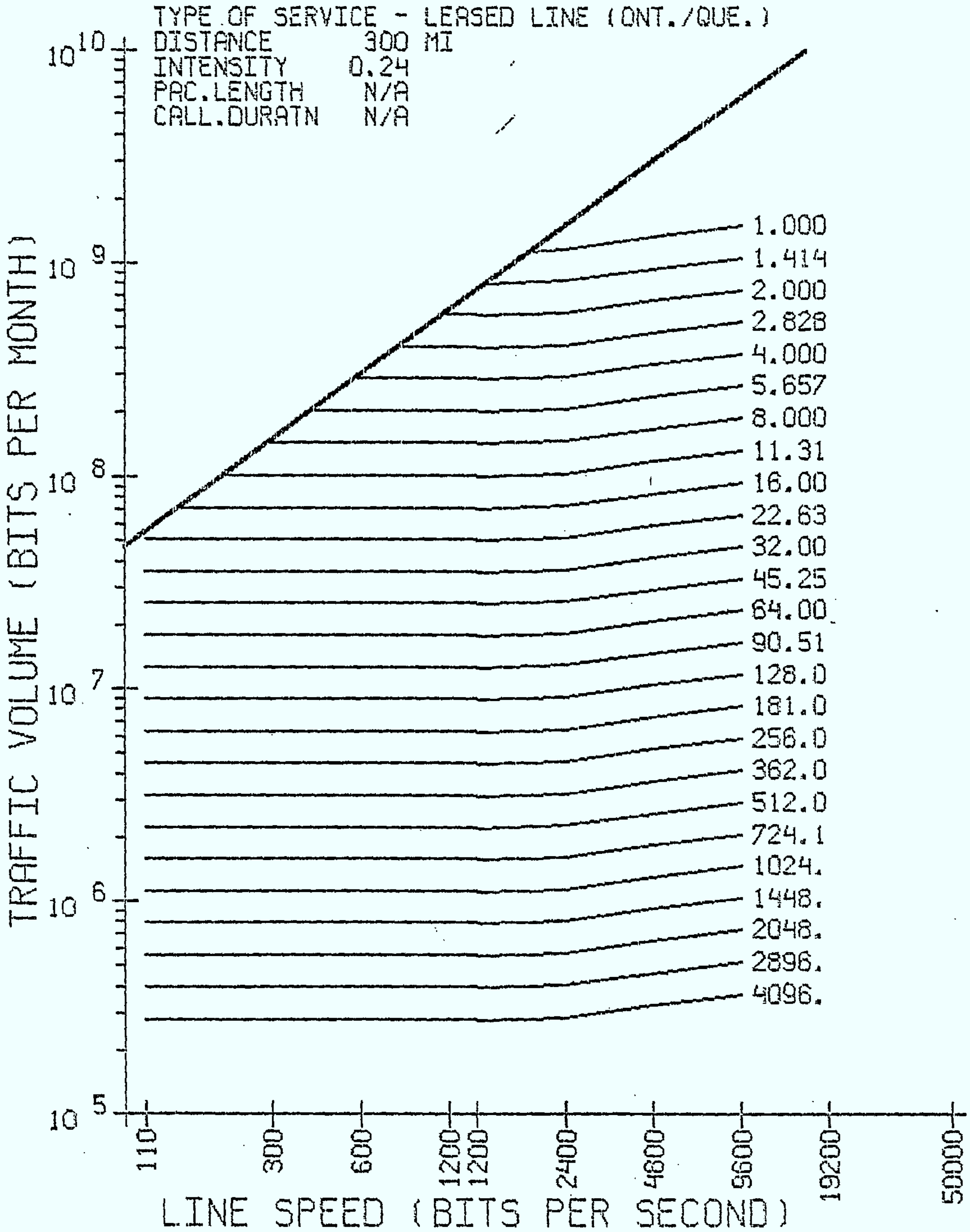


Figure 3.8.2: Isograms of constant unit cost

(dollars per megabit of data)

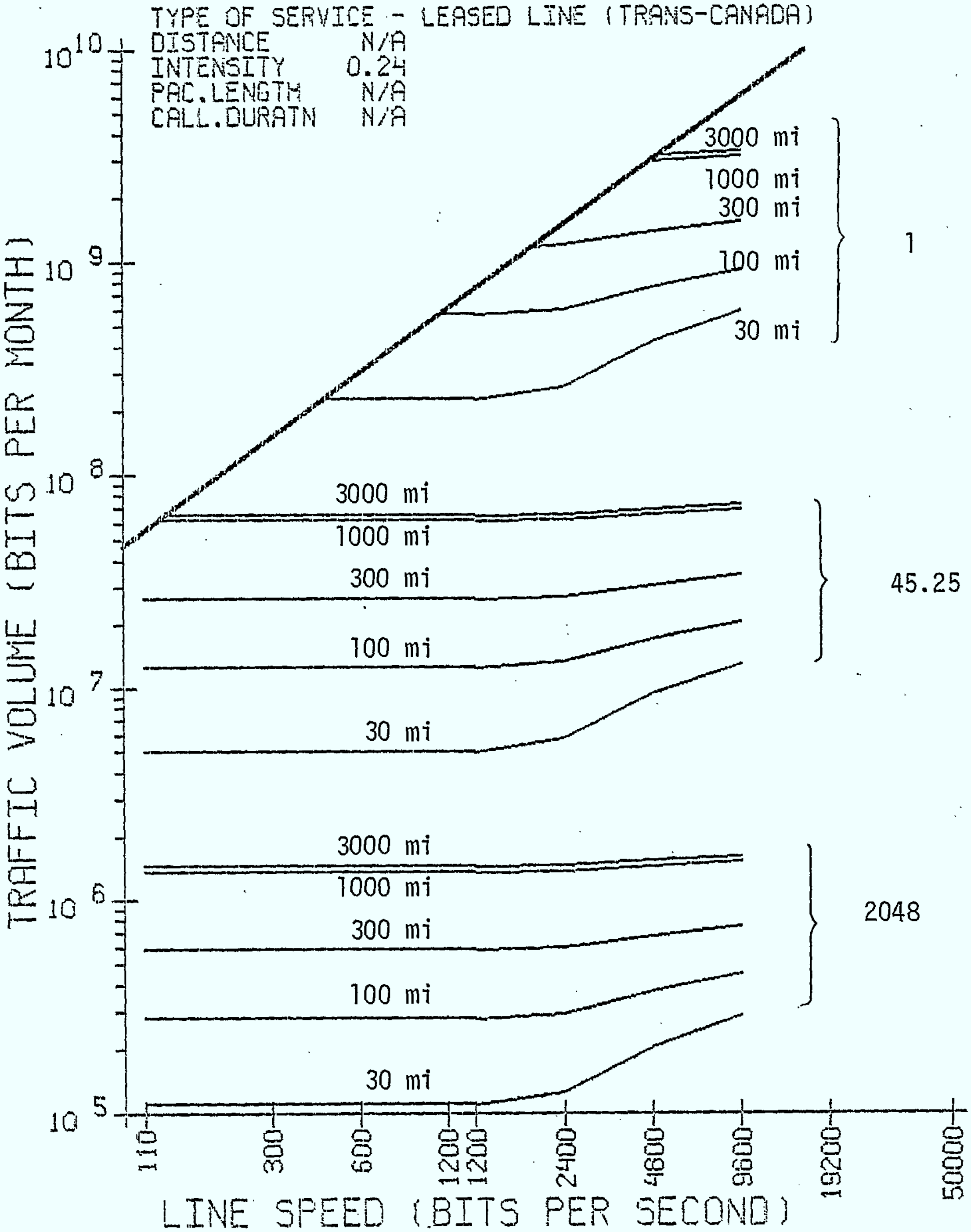


Figure 3.8.3: Variation in isogram lines with distance

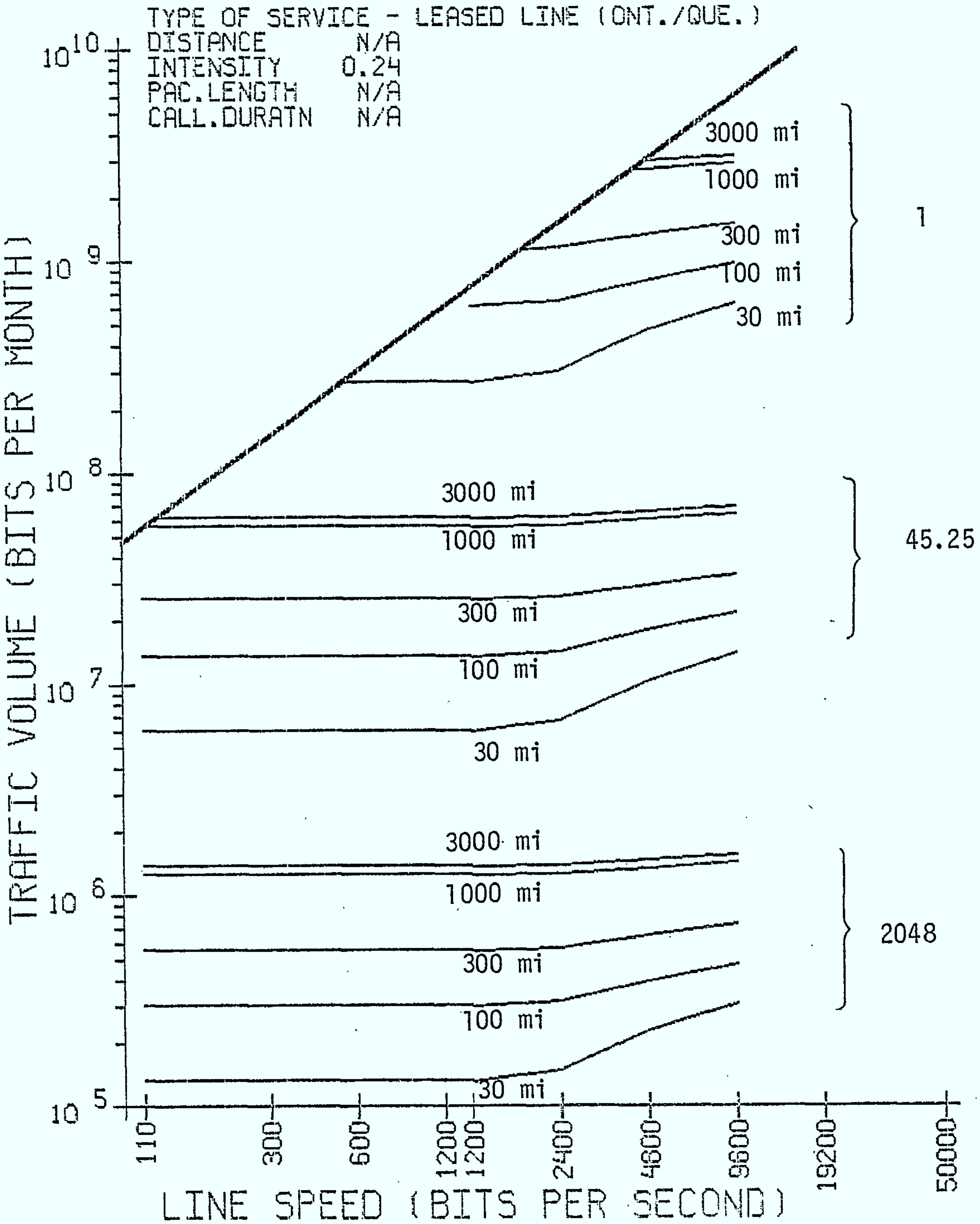


Figure 3.8.4: Variation in isogram lines with distance

3.9 TELEX AND TWX

Teletype facilities are usually considered as a low speed keyboard type of data terminal. This may be suitable for a local user who wishes access to a data network; on the other hand, it may also be suitable for long distance communications depending on the characteristics of the user's data traffic. For this reason, the distance-usage function is of interest.

Teletype tariffs offer a wide variety of access and terminal options that depend on choices not directly related to an operational variable of data traffic such as speed. The speed range for standard teletype access is 110 bps and less. A generally useful analytical access model for this service is not possible, so that terminal access is represented by a constant monthly rental.

However, usage charges vary with distance, and a simple functional representation permits comparisons with other services. Therefore, we can approximate unit charges with the model:

$$G = \frac{10^6}{u}[A + KU(d)] \qquad [3.9.1]$$

As usual, the distance function charges less per unit distance over longer hauls.

In the Telex network of CNCP a basic access charge would have a minimum of \$107 per month which includes a teletype; but this could be increased substantially through a variety of options and supplementary equipment. The usage charges are those of a circuit switching system, so that we have:

$$K = u/48si \quad \text{min/month} \qquad [3.9.2]$$

together with a usage function, U(d), which is in dollars per connected minute. The distance dependence for the usage is given by equation [3.9.3], which approximates the published tariffs in airline miles.

$$U(d) = 0.94[1 - \exp(-(d + 69)/819)] \qquad [3.9.3]$$

The toll charges are also published between 23 rate areas which apparently represents a geographic grouping application of the distance table.

The telephone systems also provide a variety of local and long distance teletype services. Half-duplex teletype-grade leased lines are one option whose distance dependence can be represented through equation [3.9.1]. Here the constant, K, depends on two factors, one is the day or night or 24 hour service and the other is the Schedule of service. These are given by equations [3.9.4] and [3.9.5] respectivly.

$$K = K_1K_2 \text{ where } K_1 = 1 \text{ if } 0 \leq c \leq 418$$
$$K_1 = 1.2 \text{ if } 418 < c \leq 730 \qquad [3.9.4]$$

$K = K_1K_2$ where K_2 is taken from:

	Ont. Que	Trns. Can.
Sch. 1	1.00	1.00
Sch. 2	1.09	1.08
Sch. 3	1.26	1.16
Sch. 3A	1.68	1.59

[3.9.5]

The usage function in the Ontario-Quebec region (Bell) is approximated by:

$$U_2(d) = 0.20d + 604[1 - \exp(-(d-23)/339)] \qquad [3.9.6]$$

Similarly, the usage function for the Trans Canada Telephone System is:

$$U_1(d) = 0.12d + 720[1 - \exp(-(d - 41)/417)] \qquad [3.9.7]$$

The telephone system also offers a "Teletypewriter Exchange Service" (TWX) for teletype communication on a message basis. In this case, usage charges depend upon circuit connect time, and hence equation [3.9.2] applies. The distance usage function is very coarsely quantitized in the rate tables. There are about ten different rates which are used to describe the charges between the telephone area code regions of Canada. Nevertheless, by employing representative average distances among these regions, the distance dependence can be modelled. (This will not, of course, reproduce the rate table without geographical regionalization and gross quantization of charges.) The resulting analytic expression for usage is:

$$U_3(d) = 0.308 + d/3250 - [|d - 253| - (d - 253)]/1680 \qquad [3.9.8]$$

If the usage is high so that the access charge can be neglected by comparison in equation [3.9.1], and taking a line speed of 110 bits/second, we can derive the high traffic asymptote for unit cost; namely,

$$G \simeq 189\, U(d)/i \qquad [3.9.9]$$

Obviously, line use intensity should be close to unity to minimize unit cost when connected.

3.10 TARIFF SENSITIVITIES

Given a user profile as a point in the (i, b, t) space of Figure 2.5.1, and a distance, d, the analytic models have been employed through equations [2.1.1] and [2.3.1] to draw contours of constant unit cost (dollars per megabit), or isograms, on the u-s diagram. As a starting point, we have taken the "Enquiry/Response" characterization from Figure 2.5.2(a) and a distance of 300 miles as the "central values". Then, for each of the tariff models in the previous sections, a set of G-isograms was drawn on the u-s diagram using these centre values for application type and distance. These show clearly the variation of unit cost with traffic volume and rated line speed for a given user profile. Although the lines are drawn continuously for convenience, only the points corresponding to actual rated line speeds can occur in practice.

The first question asked is about the sensitivity of the tariffs to distance. This has been clearly shown by the movements of the isograms when distance alone is varied. To do this, we select one isogram, (a value of G) and a value of the rated line speed (a value of s) and ask for the displacement of the isogram in the direction of the ordinate, u, resulting from an increment in the distance. This is the quantity:

$$\frac{\Delta u}{\Delta d}$$

In the sections on the tariffs, this was done by superimposing isograms with the same G value but for other distances as well as for 300 miles, giving the set (30, 100, 300, 1000, 3000) miles.

In general, the sensitivity to distance is given by equation [3.10.1]:

$$\frac{\Delta u}{\Delta d} = \frac{K\partial U/\partial d}{G10^{-6} - U\partial K/\partial u} \qquad [3.10.1]$$

We have neglected the call set-up charges for Datapac and public telephone services and used the simpler form of [3.2.9]; viz.,

$$G = (2A + KU)10^{6}/u \qquad [3.10.2]$$

Now we observe that there are two possibilities for the usage conversion factor, K; namely, it is independent of traffic, say K_o, as in the case of Dataroute and Infodat; or it is proportional to traffic volume, say ku, as in the cases of Datapac and Infoswitch. Thus,

$$K = K_o \text{ and } \partial K/\partial u = 0 \qquad [3.10.3a]$$

$$\text{or} \quad K = ku \text{ and } \partial K/\partial u = k = K/u \qquad [3.10.3b]$$

The appropriate values of k can be obtained from equations [3.4.2], [3.5.3], and [3.6.1] along with [3.10.3]. Equation [3.10.1] now reduces to two cases corresponding to [3.10.3]; namely,

$$\frac{\Delta u}{\Delta d} = \frac{uK_o}{[2A + K_oU]} \frac{\partial U}{\partial d} \qquad (a)$$

$$= \frac{u^2k}{2A} \frac{\partial U}{\partial d} \qquad (b)$$

$$[3.10.4]$$

The former becomes [3.2.11] for Dataroute and Infodat, while the latter yields equations [3.4.13], [3.5.17] and [3.6.7] upon substitution of the appropriate value of k as noted above. In all cases, the sensitivity to distance depends on the sensitivity of the usage function itself to distance; namely,

$$\frac{\partial U}{\partial d} = \frac{\Delta G}{\Delta d} \frac{u}{K10^6}$$

and this decreases with increasing distance approximately exponentially. Equation [3.10.4] also shows the increase of the distance sensitivity with the traffic volume, an effect that has been noted under the individual tariffs.

Equations [3.10.3] distinguish between two classes of services depending on whether usage is proportional to traffic volume or not. This in turn, determines the relative dominance of access charges and usage charges, and leads to an analysis of the shape of the unit cost contours which is important when comparing services. The unit cost isograms in Figures 3.2.3 , 3.4.6 , 3.5.3 and 3.6.1 are for equally spaced intervals on a logarithmic scale for G; that is, each line is an increase of G by a factor of 1.4142. The corresponding change in the traffic volume, or vertical increment is given by

$$\frac{\Delta u}{\Delta G} \text{ or, } \frac{\Delta u}{u} \frac{G}{\Delta G} \quad \text{on logarithmic scales}$$

If we use the form [3.10.2], we obtain:

$$\frac{\Delta u}{u} \frac{G}{\Delta G} = \frac{-1}{1 - \frac{U}{G} \frac{\partial K}{\partial u} 10^6} \qquad [3.10.5]$$

We see immediately that for case [3.10.3a], equation

[3.2.10] follows; viz.,

$$\frac{\Delta u}{u} = -\frac{\Delta G}{G} \qquad [3.10.6]$$

and the isograms are evenly spaced throughout (see Figure 3.2.3). For the services included in case [3.10.3b], equation [3.10.5] reduces to

$$\frac{\Delta u}{u}\frac{G}{\Delta G} = -\frac{[1 + KU]}{2A} \qquad [3.10.7]$$

which depends upon the ratio of usage to access charges. Consider first the low usage case where access charges dominate, say below one megabit per month of traffic. Then [3.10.7] approaches [3.10.6] and we obtain evenly spaced isograms. Secondly, consider high traffic volumes for which

$$KU >> 2A$$

Now the separation between isograms becomes very large as G tends to a constant or asymptotic value which is derived from the per unit traffic tariff. From equation [3.10.2] and [3.10.3b], this high traffic asymptote is

$$G = 10^6 kU \qquad [3.10.8]$$

which yields equations [3.4.12] and [3.6.6], and [3.9.9], upon appropriate substitutions for k; namely, $(P/b10^{-5})$, $(10^{-4}/8)$, and (1/5280i), respectively.

Another question of interest is the sensitivity of the tariff structures to different application types and user profiles. Again, this can be clearly illustrated by the movement of the isograms as a point is moved in the (i, b, t) application space. In the sections on tariffs, this was done by fixing the distance at 300 miles, and superimposing selected isograms with given G-values but for different points in the application space. For example, besides the enquiry-response point of Figure 2.5.2(a), we used the remote job entry values of Figure 2.5.2(b) and the Costpro value of Figure 2.5.2(c). These three applications cover a range of communication intensity, of call duration, and packet length.

The usage conversion factor, K, is directly related in most cases to the parameters of the application type. When K is a constant as in Dataroute, then the unit costs depend only on line speed, distance and traffic volume. See Figure 3.2.5. We can investigate other cases by using equation [3.10.3b] and calculating

$$\frac{\Delta u}{\Delta k} = \frac{u^2 U}{2A} \qquad [3.10.9]$$

For example, by substitution from equations [3.10.3b] and [3.4.2] we can derive equation [3.4.14] for Datapac sensitivity to packet length. For Infoexchange, we take

$$\frac{\Delta k}{\Delta i} \approx \frac{-1}{60 i^2 s}$$

with equation [3.10.9] to obtain equation [3.5.18]; viz.,

$$\frac{\Delta u}{\Delta i} = \frac{-u^2 U}{2A60i^2 s} \text{ or } \frac{-u^2 U}{3A60i^2 s} \qquad [3.10.10]$$

where the second expression applies for traffic volumes great enough to invoke the high volume discount. The sensitivity of the isograms, that is, the vertical displacement Δu, increases with traffic, with lower intensities, and with lower speeds. These points are illustrated in Figure 3.5.5.

The sensitivity of the tariffs to changes in various quantities can be expressed in other ways; such as the resulting increments in the per unit cost, or in the charges per month. Comparable results can be derived from the analytic models given here. The method of ths section has been to display the sensitivity as a displacement of the constant unit cost contours.

SECTION 4. COMPARATIVE SERVICE PARTITIONS

4.1 PARTITION DIAGRAMS - BACKGROUND

The ability to produce unit cost diagrams from the analytic models permits comparison of the various data communication services at any point on the u-s diagram for a given user profile and distance. Then, if we superimpose the sets of isograms for two different tariffs and identify the points where the isograms with the same value intersect, we obtain a boundary which is the projection of the intersection of the two tariff surfaces. On opposite sides of this boundary, the two different tariffs have the lower unit cost. In this way, we can partition the u-s operating diagram into regions according to which communication or carrier tariff is the most economical.

This partitioning will depend upon the application characteristics (b, t, i) and the distance (d). In Section 4.3, we show examples of such partition diagrams for the same conditions of user profiles (Figure 2.5.2) and distances as were used in Section 3. The sensitivity of the partitions to distance is investigated by repeating the exercise for 30 and 3000 miles under otherwise identical conditions. Similarly, the sensitivity to application characteristics is investigated by repeating the partitioning for cases (a), (b) and (c) of Figure 2.5.2, all at 300 miles.

The partition boundaries may be quite sharp where the tariff surfaces intersect at a steep angle. This is generally the case at the higher traffic volumes. On the other hand, at lower traffic volumes and lower speeds, the intersection angle of the surfaces is generally small, so that the position of the boundaries is much less precise. Indeed, it can happen that several services differ in tariff cost by amounts well within the modellin errors, and hence are indistinguishable (see Figure 4.3.5)

The analytic models of Section 3 form the basis for these partition diagrams. The partitions are less sensitive to distance than the isograms because all usage charges saturate with distance in a similar way. On the other hand, the application parameters which were introduced in Section 2.5 appear in any investigation of the partition boundaries, and again, the values for the set must be specified completely for any comparisons to be valid.

4.2 PARTITION BOUNDARIES

In order to show the qualitative dependence of the partition boundaries upon traffic volume, line speed, and the application parameters, it is useful to have an approximate description which uses only the main terms of the tariff model equations. Using equation [3.10.2] we define the charges for tariff "i" in excess of those for tariff "j" under the same conditions to be

$$E_{ij} = (G_i - G_j)10^{-6} \quad \$/\text{bit} \qquad [4.2.1]$$

Then by setting $E_{ij} = 0$ we obtain an equation for the tariff boundary. The values for i and j in the subscripts are according to:

i,j = 1 Dataroute/Infodat

2 Infoexchange

3 Datapac

4 Infocall

Dataroute and Datapac may be compared, for synchronous speeds, by:

$$E_{31} = \frac{U_3}{b10^5} - \frac{U_1}{u}$$

As an approximation we can, from equation [3.2.8], take:

$$U_1 \approx \frac{s}{9600} Z(d)$$

so that the partition boundary, is

$$u_{31} \approx 10bs \frac{Z}{U_3} = 10bs/D_{31} \qquad [4.2.2]$$

where D_{31} is a function of distance only, and U_3 is of the order of 0.05 for distances over 100 miles. From this, we expect the boundary to have unit positive slope on the log u vs log s diagram, and to move towards higher traffic volumes for applications with longer average packet lengths.

Roughly, we have for synchronous line speeds,

$$u_{31} \approx 200bs \qquad [4.2.3]$$

Some sensitivity to distance will appear at shorter distances where D_{31} increases, until [4.2.3] becomes

$$u_{31} \approx 50bs$$

which represents a downwards displacement of the partition line by a factor of 4 in traffic volume.

Infocall and Infoexchange have the same access charges and equation [4.2.1] becomes (using equation [3.5.2]):

$$E_{24} = \frac{U_2}{60is} - \frac{U_4}{8x10^4}$$

which yields a vertical boundary at

$$s_{24} \approx \frac{4000}{3i} \ln(s/300)D_{24} \qquad [4.2.4a]$$

$$\approx \frac{2310}{i} D_{24} \qquad [4.2.4b]$$

where (a) is for line speeds in the synchronous region and (b) for line speeds in the asynchronous region. Again D_{24} depends weakly on distance (increasing with increasing distance) and is of the order of 0.2. Note that the partition line is a vertical line on the diagram and that the line speed separating the Infocall and Infoexchange regions varies inversely with intensity. This assumes the intensity exceeds the minima given by equation [3.6.8], otherwise minimum charges will apply in Infocall which further decreases the boundary value of s.

The boundary between Datapac and Infoexchange is more complicated because the access charges are different so that the distance usage charges cannot be combined as in the above two cases. Setting $E_{23} = 0$ we obtain:

$$2(A_3 - A_2) = \frac{uU_2}{60is} - \frac{uU_3}{b10^5}$$

which reduces, with some approximations, to

$$u_{23} \approx \frac{600is(1+s/500)}{U_2 - \frac{6siU_3}{b10^4}} \qquad [4.2.5]$$

From this, we expect the Datapac-Infoexchange boundary on the log u vs log s diagram to have a positive slope between one and two in the interval of synchronous line speeds. Finally, if we equate equations [4.2.2] and [4.2.5] we have the condition for a vanishing Datapac region at a particular line speed. When this occurs at high traffic volume and line sped, then the Datapac region vanishes into a Dataroute-Infodat to Infoexchange partition boundary. It turns out that this applies to all line speeds above that so obtained, and that the threshold line speed is proportional to the ratio (b/i). We observe the evident basic significance in describing a user profile of the ratio (b/i). It occurs again in Equation 4.2.7 below and will be noted again in Sections 5 and 6. Accordingly, the intersection of Dataroute-Infodat, Datapac, and Infoexchange boundaries are at a point whose s-coordinate moves with this ratio, as well as being dependent to some extent on distance.

If the boundary given by [4.2.4] is above 1200 bits/sec, then there will also be a Datapac-Infocall partition boundary for synchronous speeds. Setting $E_{34} = 0$ we obtain for the boundary:

$$u_{34} \simeq \frac{2\times10^5[A_3 - A_2]}{\frac{10U_4}{8} - \frac{U_3}{b}} \qquad [4.2.6]$$

This boundary depends upon line speed which appears in the difference between the access charges.

At low traffic volumes, the partition boundaries become vertical lines representing a separation based primarily upon access charges. This yields Datapac below 300 bits/sec and Infoswitch above 1200 bits/sec. At a line speed of 600 bits/sec, Dataroute-Infodat have the lowest access charges, but to these must be added the distance usage charges which apply regardless of traffic volume. Consequently, the amount by which the Dataroute-Infodat region penetrates into the Infoswitch region at 600 bits/sec depends upon the distance, for distances over 110 miles. At distances less than this, Dataroute usage and access are less than Infoswitch access at all traffic volumes.

The upper limit on traffic volume is given by equation [2.3.2] and yields the diagonal boundary with unit slope on the u-s diagram. The partition boundary between Dataroute-Infodat and Datapac also approximates a unit slope line given by equation [4.2.3]. Thus under some conditions these two may coincide and the Dataroute-Infodat region will vanish. By equating equations [2.3.2] and [4.2.3] we find that the condition is long packets or low intensity according to:

$$b \geq \frac{3tin}{10} = 18ci \qquad [4.2.7]$$

If [4.2.7] pertains, the leased line services will be uneconomical in the synchronous region.

4.3 PARTITION DIAGRAMS

The expressions given in Section 4.2 for the partition boundaries are only approximate, and are intended to show how the various boundary lines depend upon the parameters of the application type or user profile, and distance. In the synchronous line speed region as the traffic volume increases, the appropriate service generally is Infoexchange (circuit-switching) then Datapac (packet-switching) and finally Dataroute-Infodat (leased line). The leased-line region may vanish for long average packets and short intensity according to equation [4.2.7] as shown in Figure 4.3.5. Similarly, from equations [4.2.3] and [4.2.5], we expect that Datapac region to vanish for high speeds and Infoexchange to be bounded by the leased line services when the average packet length is short as in Figure 4.3.1 but not when it is long as in Figure 4.3.4. The set of Figures 4.3.2 to 4.3.5 have a region superimposed on them wherein it is economical to employ the Trans Canada telephone system and the required modems. The boundary of this region is subject to the assumptions regarding modem costs and is therefore much more approximate than the other partition boundaries shown. It is noteworthy, nevertheless, that in many cases (Figures 4.3.1, 4.3.3, and 4.3.4) the telephone region essentially covers the Infoswitch region.

The lower traffic volume asynchronous region is more influenced by access charges, which generally favour the Datapac model (equation 3.4.6) at speeds of 300 bits/sec and less, leased line services at 600 bits/sec and under 110 miles, (Figure 4.3.2) and Infoswitch over 110 miles for higher traffic and for asynchronous line speeds over 600 bits/sec. In all cases, if the traffic volume and intensity are high enough, the leased line becomes the most economical.

Examples of partititon diagrams are presented for those cases in Figure 2.5.2 and for the distances used in Section 3 to illustrate unit cost contours. Thus, Figure 4.3.1 is for user profile Figure 2.5.2(a) and 300 miles. Figures 4.3.2 and 4.3.3 are under the same conditions but at shorter and larger distances respectively. Finally, Figures 4.3.4 and 4.3.5 are both at 300 miles, but for cases of Figure 2.5.2(b) and 2.5.2(c). These figures illustrate the sensitivity of the partition boundaries to distance and application type. They are drawn from the analytic models of Section 3, not the expressions in Section 4.2. Nevertheless, some of the features deduced in the previous subsection are illustrated. The boundary at a particular speed between Infocall and Infoexchange which is expected from Equation 4.2.4 appears as a vertical boundary in Figures 4.3.1, to 4.3.4 inclusively. Again, these same figures show that the Datapac-Infoexchange boundary is steeper in the synchronous region as expected from Equation 4.2.5 than the Dataroute-Datapac boundary above it, according to Equation 4.2.2.

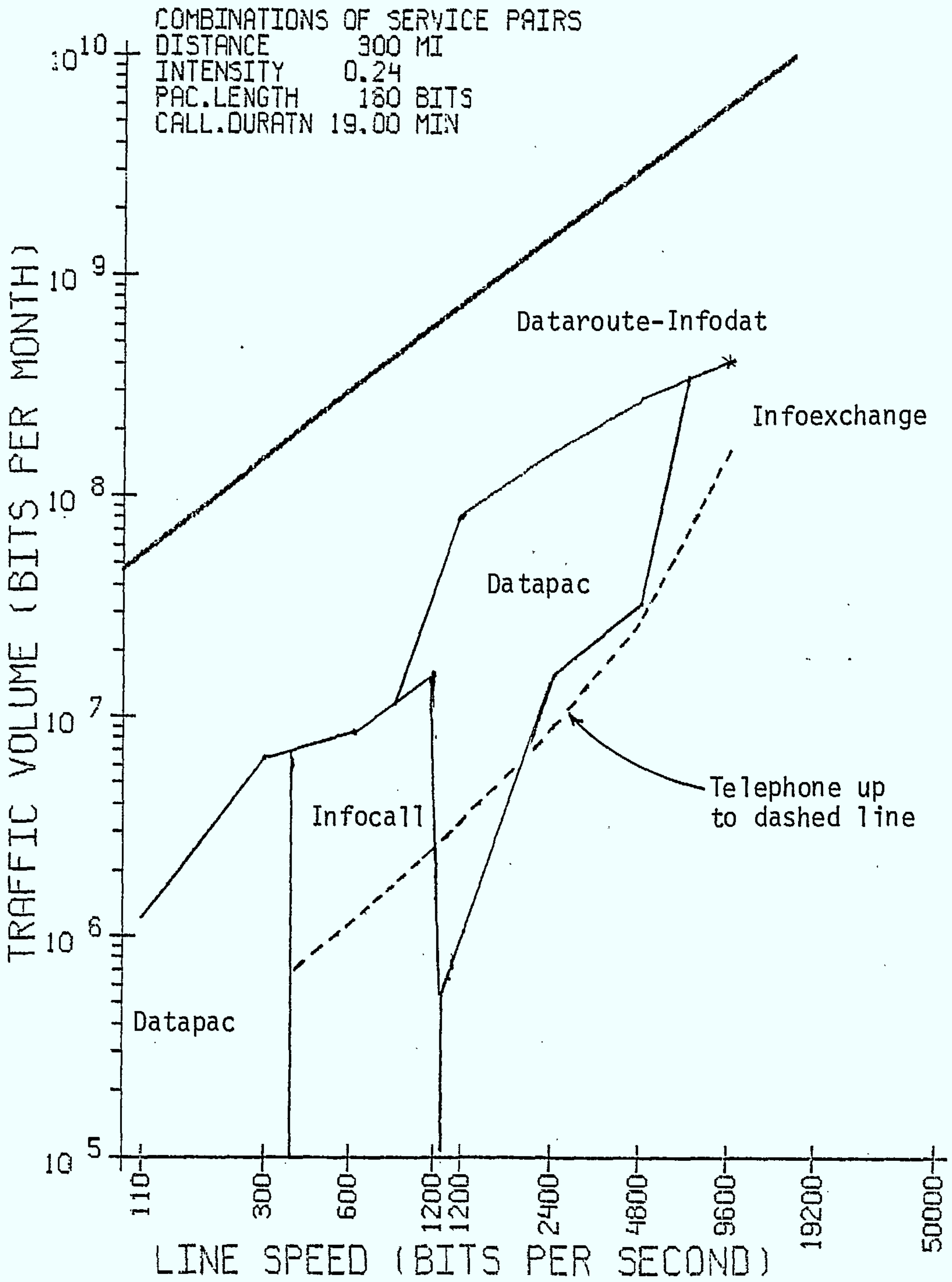


Figure 4.3.1: Most economical service partitions
(Time Share/Enquiry-Response, Figure 2.5.2(a), 300 miles)

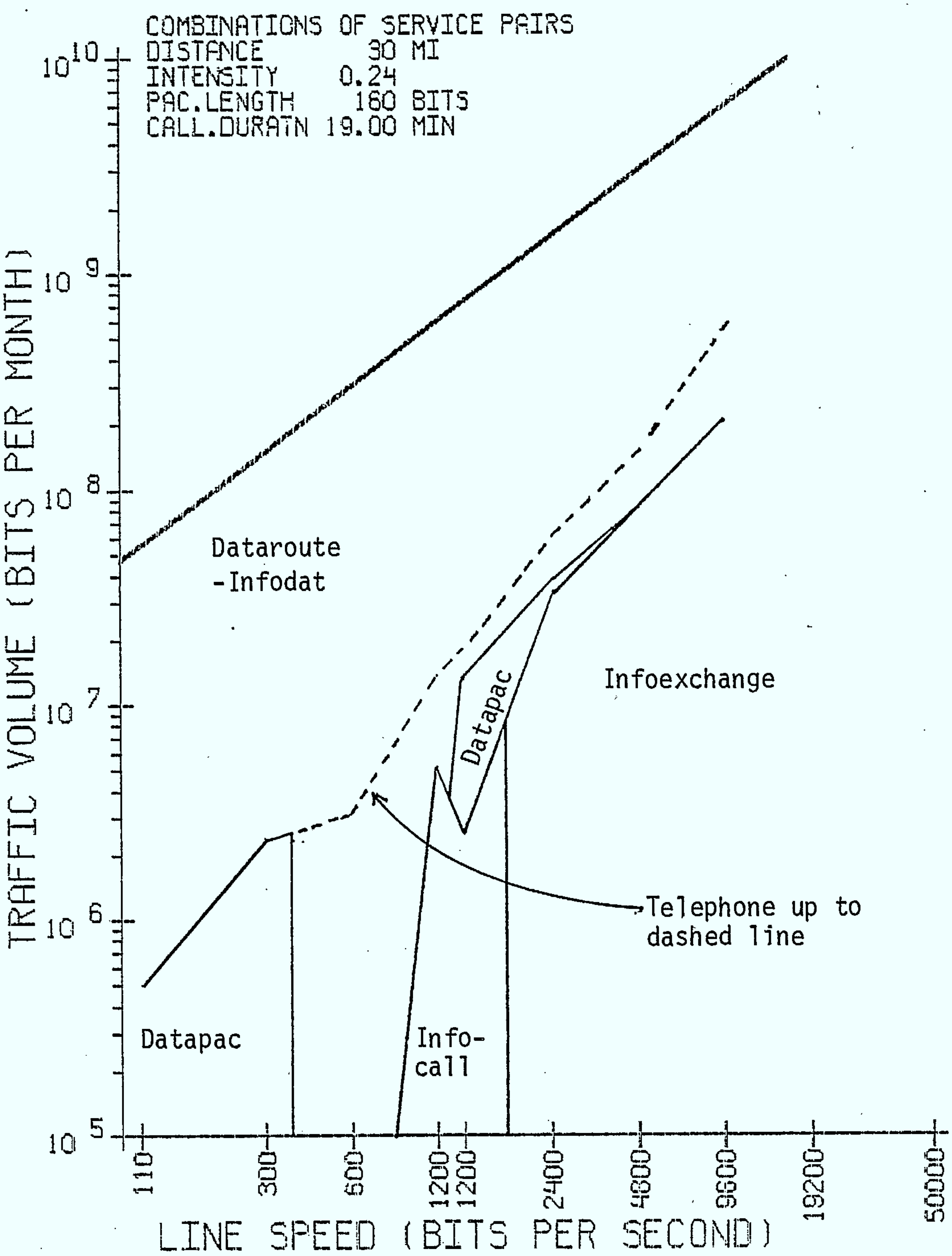


Figure 4.3.2: Most economical service partitions
(Time Share/Enquiry-Response, Figure 2.5.2(a), 30 miles)

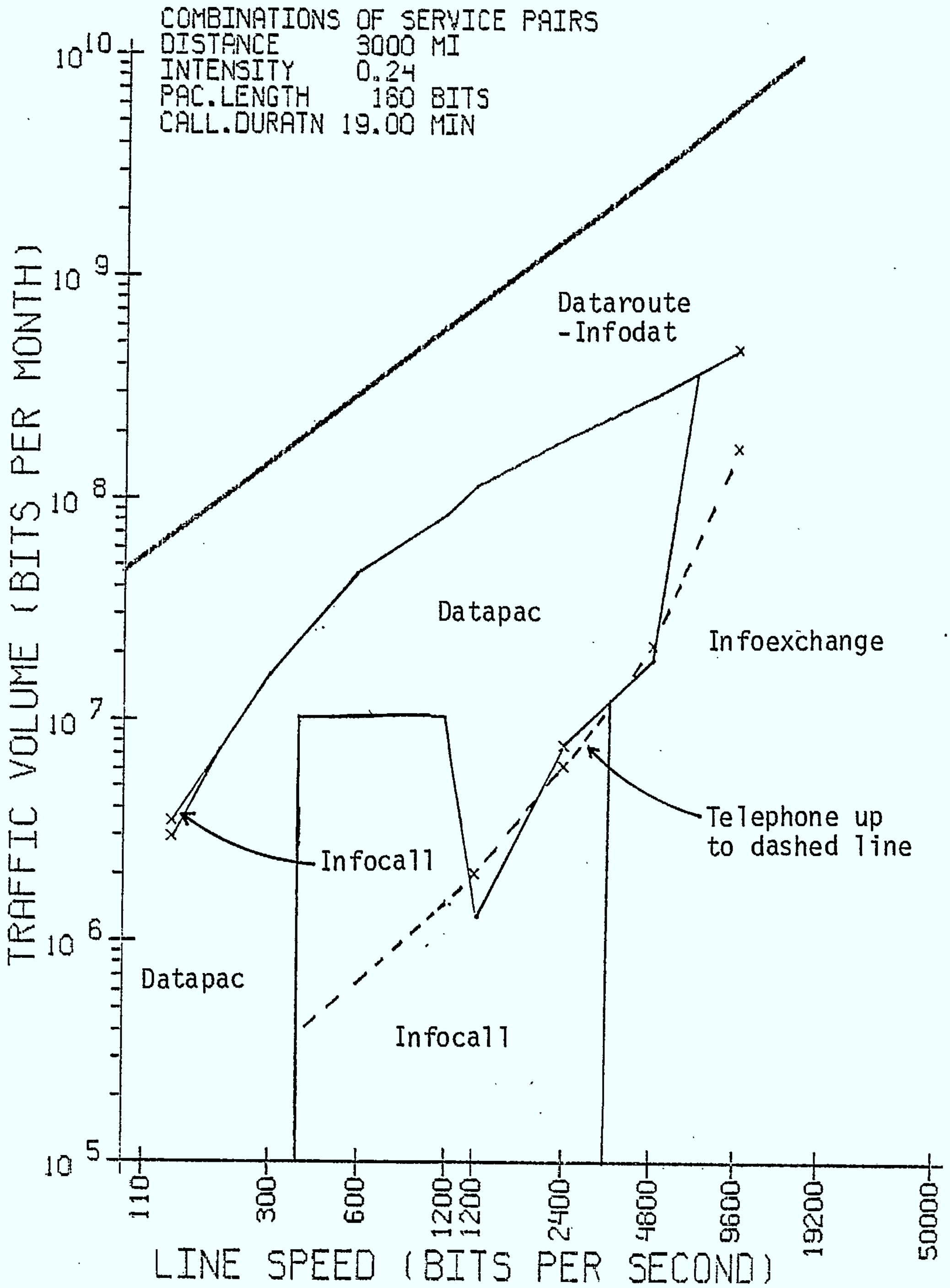


Figure 4.3.3: Most economical service partitions
(Time Share/Enquiry-Response, Figure 2.5.2(a), 3000 miles)

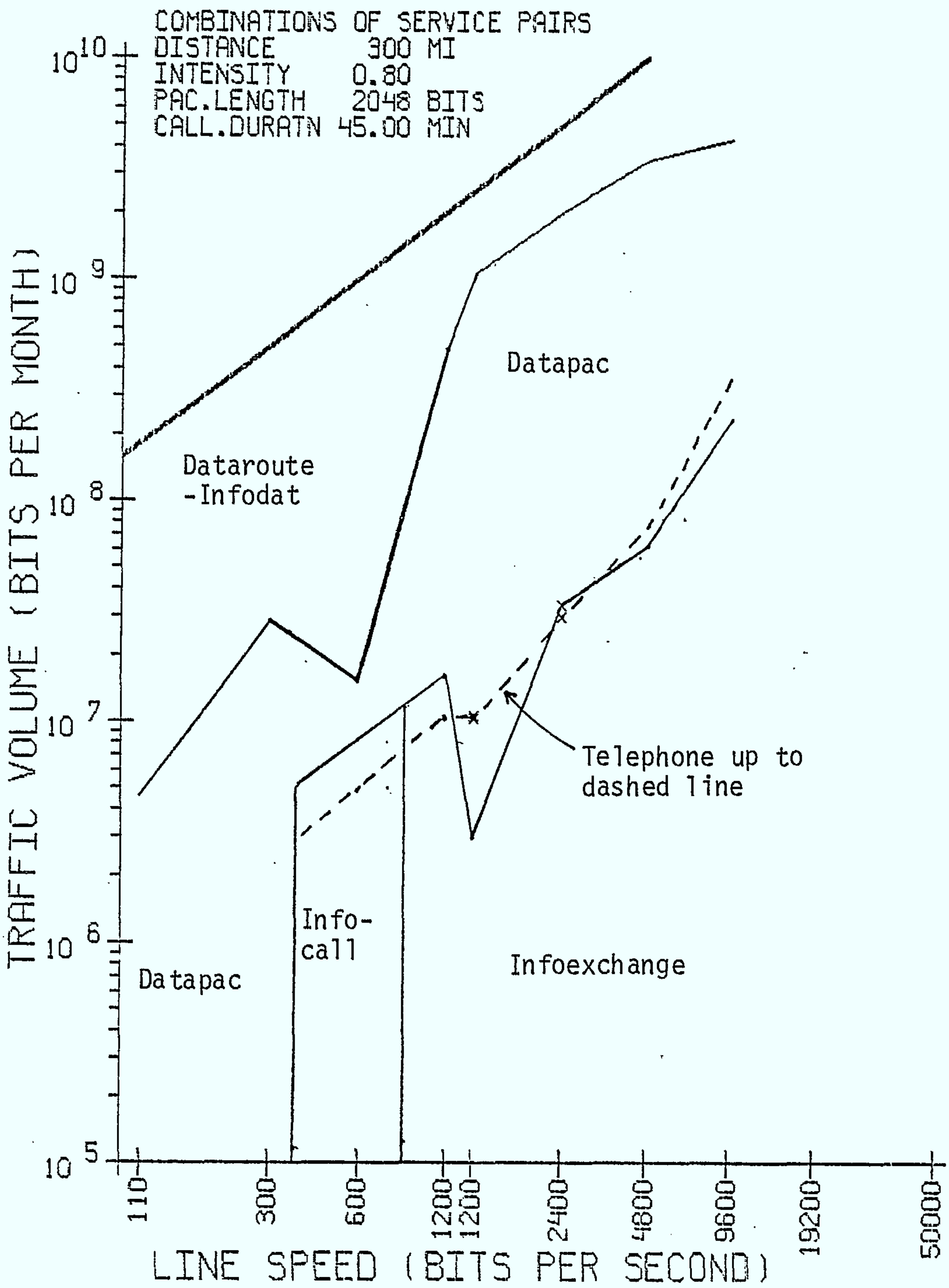


Figure 4.3.4: Most economical service partitions
(Remote Job Entry, Figure 2.5.2(b), 300 miles)

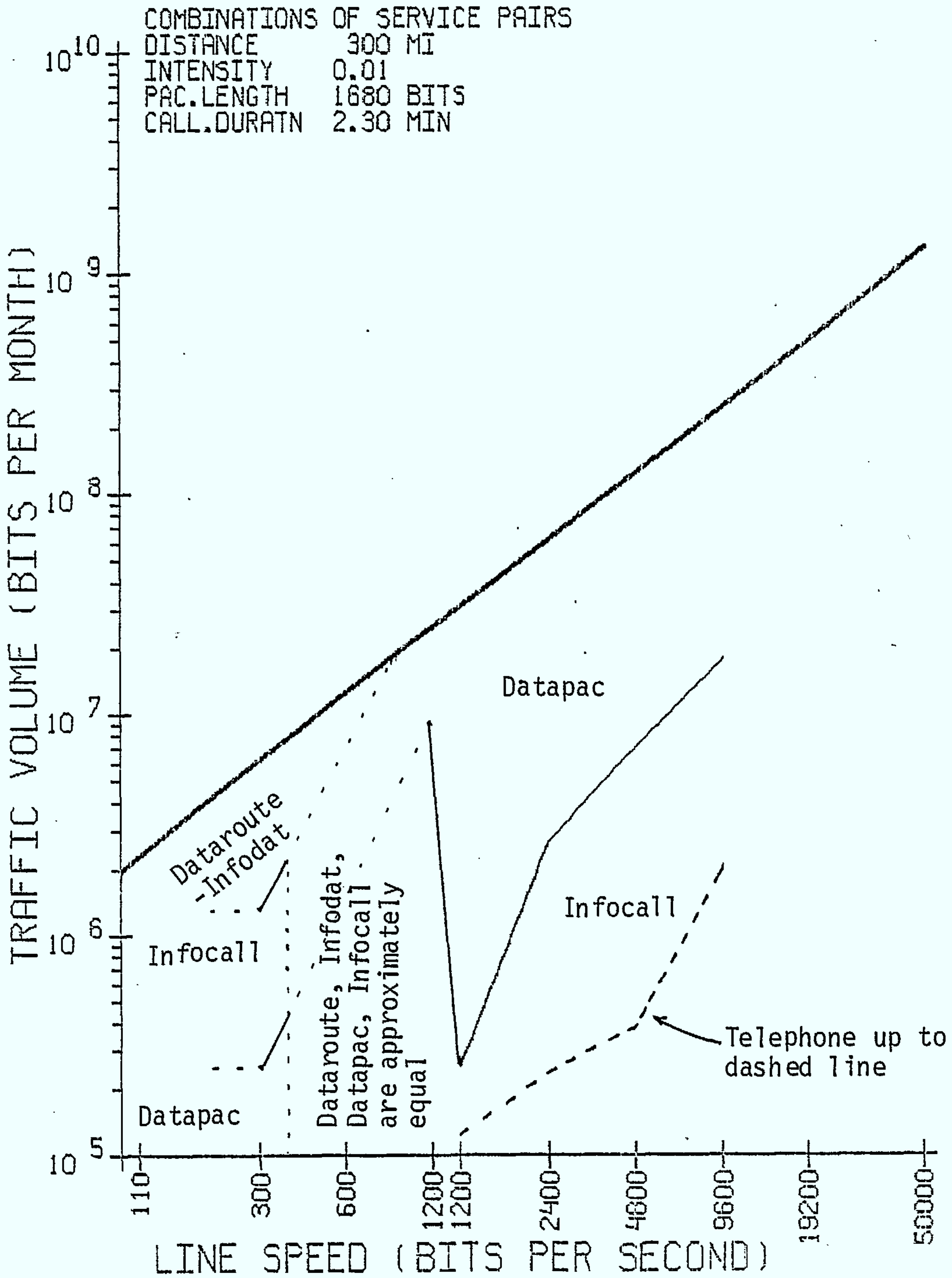


Figure 4.3.5: Most economical service partitions
(COSTPRO, Figure 2.5.2(c), 300 miles)

SECTION 5. EFFECT OF INTERCONNECTIONS

5.1 INTRODUCTION

In this section we consider the effect of a dialed telephone-Infoswitch interconnection, and of a Telex-Datapac interconnection. In each case the apparent advantage is allowing a user to access a more economical digital communications service via an existing widespread local distribution system. Two points are of interest. First, what reduction in costs, relative to available services, would such an interconnection offer a user and second, what impact would such a connection have on the distribution of users between competing services such as Datapac and Infoswitch.

5.2 INFOSWITCH - DIALED TELEPHONE INTERCONNECTION

If access to the Infoswitch network were available through the dial voice telephone network, then Infoexchange and Infocall could offer a service that in many ways would be similar to the Datapac 3101 service which allows "dumb", character mode terminals to access the Datapac network. Such a service is of potential use to many users, especially those supporting time share computing applications with many remote terminals.

This type of interconnection is obviously technically feasible, since it already exists for Datapac, and is not significantly more complex than the widely available dial access ports for computers. Hence it could be quickly provided by the carriers if it were deemed desirable.

To investigate the economic feasibility from the user viewpoint of such an interconnection it is necessary to select an application. It would seem that the most common application for such a service (or for Datapac 3101) would be many slow speed terminals accessing a central computer. This could be either a time sharing system or an enquiry-response system. We will assume that a total of k_1 users at intervals access a central computer capable of accepting k_2 simultaneous users, where $k_2 < k_1$. Further it is reasonable to assume that the terminal speed is 300 bit/s which is the maximum supported over the voice network by Datapac 3101.

The charge per user for such a service would be the access charge for the service, A_{ti}, the network utilization charge, K_iU_i, and the user's share (i.e., $1/k_1$) of the access arrangements at the computer, or

$$\$pm_i = A_{ti} + K_iU_i + (A'_{ci} + X'_{ci})/k_1 \qquad [5.2.1]$$

where A'_{ci} is the total carrier access charge at the computer, and X'_{ci} is the total computer communication hardware and software rental at the computer.

To judge the economic feasibility of such a service it must be compared to its competitor Datapac 3101 which can be described by the equation

$$\$pm_d = A_{td} + K_dU_d + nN + (A'_{cd} + X'_{cd})/k_1 \qquad [5.2.2]$$

where nN represents the charge for setting up n virtual calls and the other symbols have meanings similar to those for the Infoswitch model.

Before proceeding further, it is necessary to postulate a value for the Infoswitch access charge via dialed telephone. Since the facilities required will be very similar to Datapac 3101 it is reasonable to base this charge upon the Datapac 3101 tariff. For public dial access to Datapac 3101 the access charge is listed as

1) a 25¢ per kilopacket surcharge on all packets,

2) a 25% surcharge on all packets for priority service, and

3) a 1.5¢/min (0.9 c dollar/month) connect time charge.

The 25¢ charge is common to all Datapac 3101 access charges and represents a NIM usage charge. The priority service charge is common to any priority system and it is reasonable that users in this class would want priority service. Hence it appears as if TCTS considers an access charge of 0.9 c to be reasonable for the use of the dial telephone facilities and the answer-back modems at the NIM. It is therefore assumed that this will generate sufficient revenue to cover the cost of the answer-back modem at the NIM, the interface to the NIM and any additional load placed on the public dial switching office by telephone access to Datapac. Thus it is reasonable to assume $A_{ti} = m(0.9c)$ as an access charge to Infoswitch over the dial telephone system where m is a small number, greater than one, but probably less than two, to allow for the extra costs of accounting for revenue sharing and for devices to protect the carriers' equipment from each others' equipment malfunctions.

Now, to study the conditions under which Infoswitch with telephone access and Datapac 3101 are competitive we will define a relative cost ratio R as

$$R = \$pm_i/\$pm_d \qquad [5.2.3]$$

and examine its dependency upon the various charging parameters.

Substituting equations [5.2.1] and [5.2.2] into the above, and noting that $K_dU_d = u10^{-5}(1.25U_d + 25)/b$ and $Nn = 0.005n$, yields the result:

$$R = \frac{m(0.9c) + K_iU_i + (A'_{cc} + X'_{cc})/k_1}{0.9c + u10^{-5}(1.25U_d + 25)/b + 0.005n + (A'_{cd} + X'_{cd})/k_1} \qquad [5.2.4]$$

It is useful to re-organize this so that all the access charge terms are grouped. At the same time we can substitute u=2880 cis and s=300 to obtain:

$$\frac{b}{i} = \frac{R(U_d + 20)}{K_iU_i/(10.8c) + x} \qquad [5.2.5]$$

where

$$x = 0.0833(m-R) + \frac{0.005nR}{10.8c} + \frac{(A'_{ci} + X'_{ci}) - R(A'_{cd} + X'_{cd})}{10.8ck_1} \qquad [5.2.6]$$

The term x represents the effect of non-tariff costs (X'_{ci} and X'_{cd}) and number of users (k_1) on the relative costs of Infoswitch-telephone and Datapac 3101. If all the parameters in equation [5.2.5] are held fixed except for x and R, then a reduction in x reduces R while an increase in x increases R. Since a smaller R indicates a more competitive Infoswitch it follows that small values for x are favourable to Infoswitch while large values are favourable to Datapac. It is therefore necessary to estimate the range of values that x may assume.

First it may be noted that ck_1, which is the average connect time per user times the number of users, must be equal to the average connect time per port times the number of ports, k_2. Further, in a well designed system the number of ports k_2 will be chosen so that during the busy period of the working day almost full occupancy will occur. Thus for 4 to 10 hours per day for 20 to 22 days per month one may assume all k_2 ports are in use, while for the balance of the time very few will be active. Hence a reasonable approximation for ck_1 is:

$$100k_2 < ck_1 < 200k_2 \text{ (hour/month)} \qquad [5.2.7]$$

If a value in the above range is substituted into equation [5.2.6] then the quantities A'_{ci}/k_2, X'_{ci}/k_2, A'_{cd}/k_2 and X'_{cd}/k_2 appear. The item A'_{ci}/k_2 is the Infoswitch access charge for a 300 bit/s link, namely \$60/month. The item X'_{ci}/k_2 represents the rental of a low speed communications port on the computer, estimated to be \$50 to \$200. The value A'_{cd}/k_2 represents a Datapac 3000 access charge divided over k_2 virtual channels. Recent studies [7] have shown that a 70 to 90% utilization of a Datapac 3000 service is possible. Hence it is reasonable that a 2400 bit/s service could support twelve 300 bit/s virtual circuits whose average communications intensity was 0.5. This gives a cost per virtual channel of approximately ten dollars. Hence over the range of speeds available a value of \$5 to \$15 is reasonable for A'_{cd}/k_2. The item X'_{cd}/k_2 represents the share of computer port hardware and SNAP software chargeable to each virtual channel. For k_2 in the range 10 to 20 a reasonable estimate for X'_{cd}/k_2 might be \$100 to \$200. These values are summarized in the table below which shows the median value, and the limits most favourable to Infoswitch and Datapac.

		favourable to Infoswitch	median	favourable to Datapac
A'_{ci}/k_2	Infoswitch access charge	-	\$ 60	-
X'_{ci}/k_2	computer access port cost	\$ 50	\$125	\$200
A'_{cd}/k_2	virtual channel access cost	\$ 15	\$ 10	\$ 5
X'_{cd}/k_2	SNAP software	\$200	\$150	\$100
m	telephone access charge factor	1	1.5	2

Table 5.1

Probable access charges

Substituting the median values from this table and $c=150k_2/k_1$ (the median value from equation [5.2.7]) into equation [5.2.6] yields:

$$x = 0.239 - 0.182R + 3\times10^{-6}nRk_1/k_2 \qquad [5.2.8a]$$

It may now be noted that the term $3\times10^{-6}nRk_1/k_2$ is neglible since even with a k_1/k_2 value of 10 (the Nova Scotia study [5] used 4), and an n of 1000 (one call every 10 minutes for an 8 hour day, 21 day month), it is only 15% of the 0.182R term. Hence,

$$x \approx 0.239 - 0.182R \qquad [5.2.8b]$$

is a reasonable approximation for the median access charge term.

If the conditions most favourable to Infoswitch are substituted into [5.2.6] we obtain:

$$x = 0.160 - 0.233R + |0.026 - 0.050R| \qquad [5.2.8c]$$

while the conditions most favourable to Datapac yield:

$$x = (0.347 - 0.156R) + |0.060 - 0.024R| \qquad [5.2.8d]$$

The switch term in the above equations is due to the most favourable loading on the computer access port(s) changing between light load ($ck_1 = 100k_1$) and heavy load ($ck_2 = 200k_1$).

Before considering the specific Infoexchange and Infocall situations it is instructive to first calculate typical Datapac 3101 charges so that we have a background for judging the actual magnitude in dollars implied by various R values.

Substituting the values of the various parameters for Datapac 3101 into equation [5.2.2] yields:

$$\$pm_d = 0.9c + u10^{-5}(1.25U_d + 25)/b + 0.005n + (A'_{cd} + X'_{cd})/k_1 \qquad [5.2.9]$$

Dividing the above equation by the connect hours per month c yields the charge per connect hour,

$$\$/\text{connect-hour} = 0.9 + \frac{A'_{cd}}{ck_1} + \frac{(10.8U_d + 20)}{(b/i)} + \frac{0.005}{(c/n)}$$

[5.2.10]

In the last term of this equation (c/n) is the holding time per call (in hours). Unless the holding time is less than one minute, which is unlikely, this term will be insignificant and may be dropped. Now, substituting the range of values given by Table 5.1 and equation [5.2.7] into the above equation yields the results shown in Figure 5.2.1. From Figure 2.5.2 time sharing and enquiry-response systems have a b/i value in the range 300 to 2000. The exact values for four typical systems are indicated on the figure. Thus, typical Datapac 3101 costs will be \$2.50 to \$4.00 per connect hour for zero distances (i.e. same Datapac serving area) increasing to \$3.00 to \$7.00 at one thousand miles.

5.2.1 INFOEXCHANGE - DIALED TELEPHONE

For Infoexchange the usage function is $K_iU_i = (60c)U_e$ (ignoring both minimum usage charges, i.e., all calls are assumed to be longer than 30 seconds, and large volume reductions). Substituting this into equation [5.2.5] we obtain:

$$\frac{b}{i} = \frac{R(U_d + 20)}{5.555\ U_e + x}$$

[5.2.11]

where x is given by equation [5.2.8b, c or d] as desired. It might be noted that U_d and U_e are purely functions of distance. Hence, the only user characteristic that enters

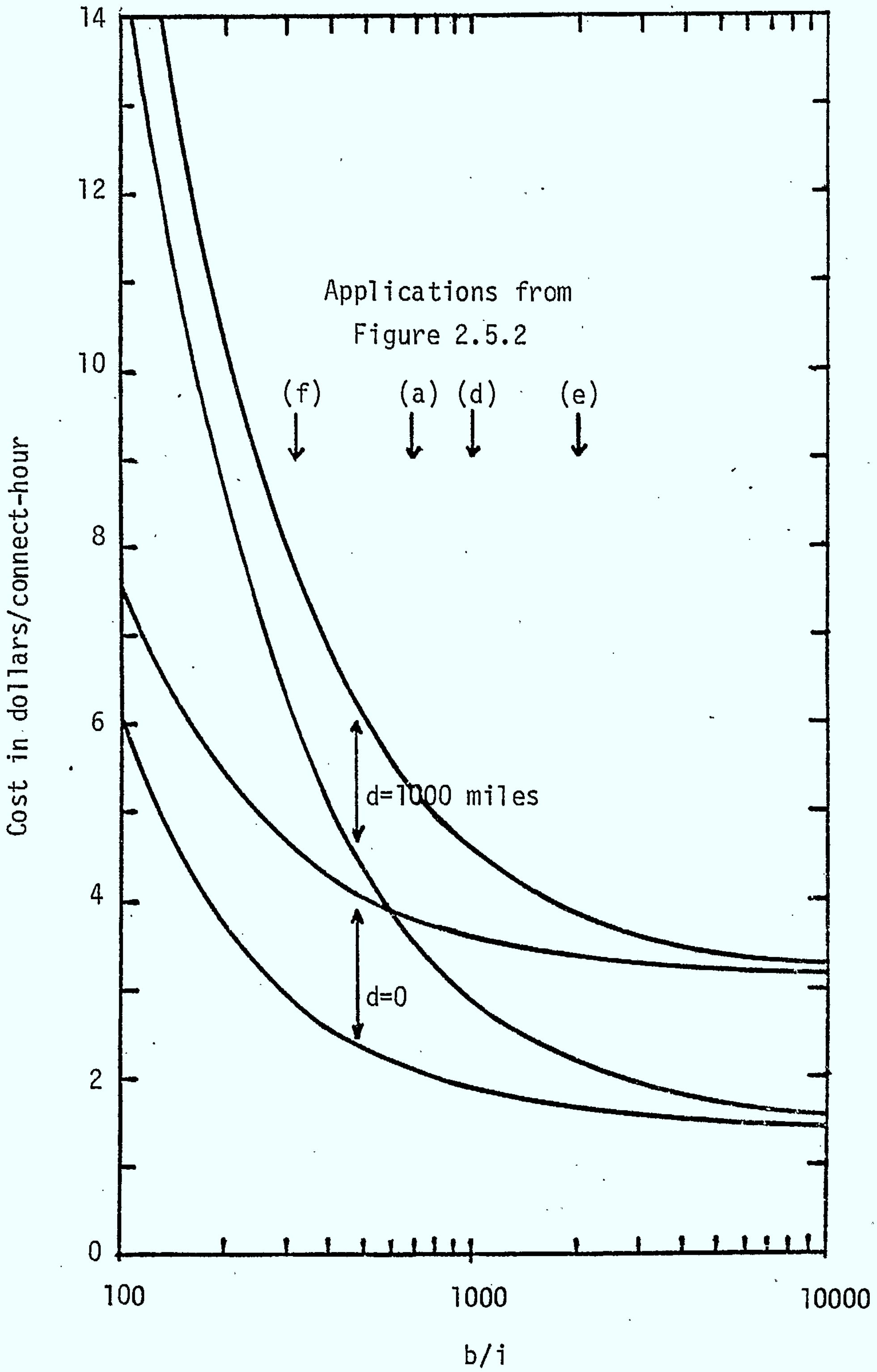


Figure 5.2.1: Dialed Datapac 3101 cost range

the expression is the ratio b/i. Further, if x is sufficiently small, the relative cost ratio R will be directly proportional to b/i. This indicates short messages, high intensity traffic favours Infoswitch while long messages, low intensity traffic favours Datapac 3101. This is not surprising since it is the classical circuit-packet switching division.

To examine the relative cost R more closely it has been plotted as a function of b/i in Figure 5.2.2. The values of x given by equations [5.2.8b, c,d] and distances of 0 and 1000 miles were used. The usage charges for a Datapac Grade 3 D.S.A. was used.

Since probable b/i values lie in the range 300 to 2000 it is obvious that even under the most favourable conditions Infoswitch-telephone will be twice as expensive as Datapac 3101, and that factors of 5 to 8 are not unlikely.

To obtain an estimate of the dollar cost we can proceed as we did for Datapac 3101, substituting for the various parameters in equation [5.2.1], and then dividing by the connect hours per month to obtain the charge per connect hour. This yields:

$$\$/\text{connect-hour} = 0.9m + 60U_e + \frac{A'_{ci} + X'_{ci}}{ck_1} \qquad [5.2.12]$$

Substituting the values from Table 5.1, equation [5.2.7] and $U_e = 0.10$ (local calling) or 0.38 (at 1000 miles) yield values between \$7.50 to \$9.50/hour for local calls and \$23 to \$25/hour for 1000 mile calls. The dominant factor is the

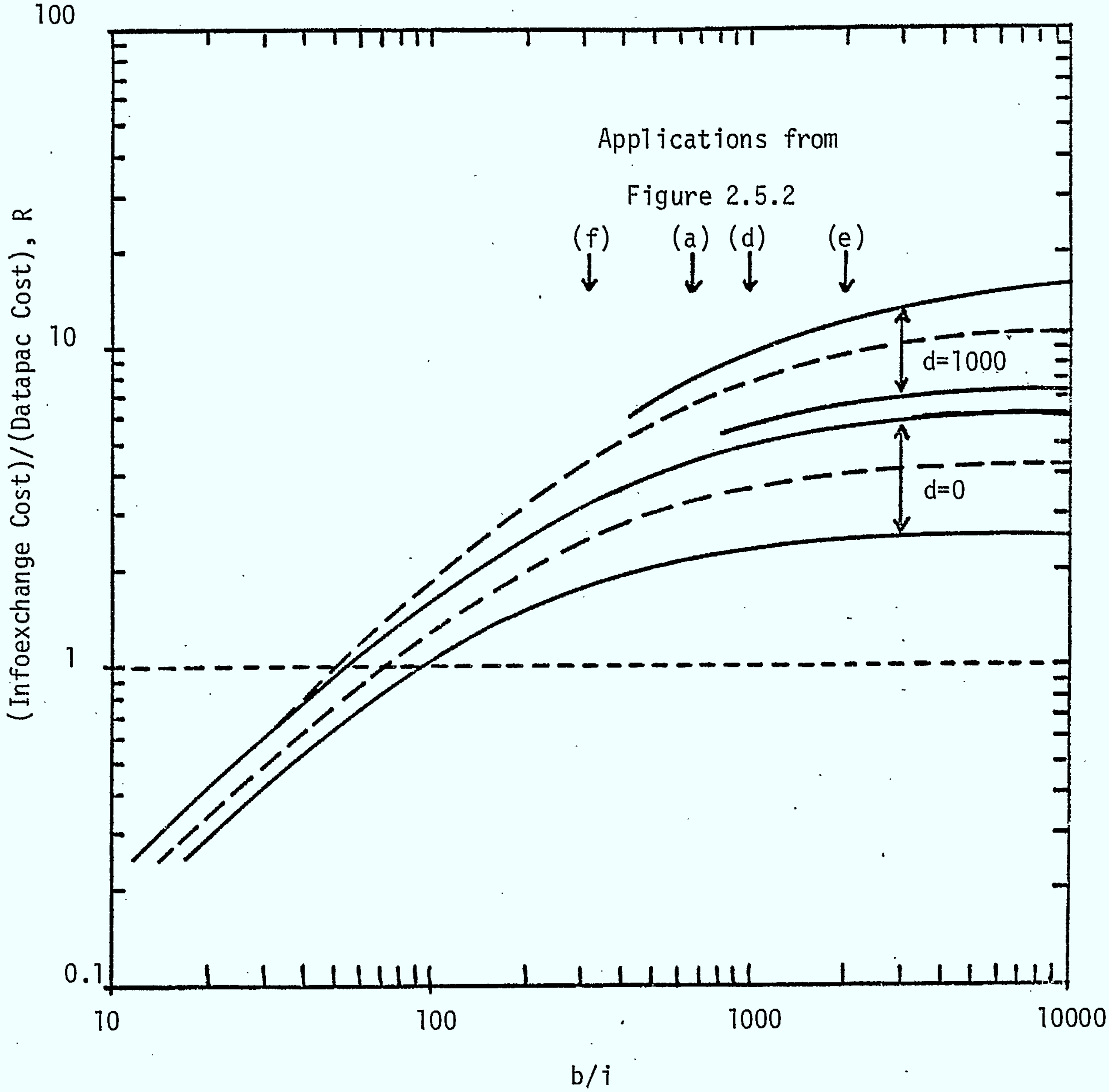


Figure 5.2.2: Relative cost of dialed telephone-Infoexchange and dialed Datapac 3101

utilization charge, and hence the relative costs developed earlier are almost independent of the dialed telephone access charge for the interconnection.

It might be noted that high volume reductions cause the $60U_e$ terms in equation [5.2.12] to reduce towards $40U_e$. However this reduction is not sufficient to alter the conclusions above.

5.2.2 INFOCALL - DIALED TELEPHONE

For Infocall the usage function K_1U_1 is $(u10^{-4}/8)U_c$ (ignoring minimum usage charges). Substituting this into equation [5.2.5], yields:

$$\frac{b}{i} = \frac{R(U_d + 20)}{iU_c + x} \qquad [5.2.13]$$

The only difference between this equation and [5.2.9] for Infoexchange is the replacement of $5.555U_i$ by iU_c.

For local calling the value of U_c is \$0.15. This results in iU_c being less significant than the x term, and R becomes essentially only a function of b/i (as it was for Infoexchange). The result is shown in Figure 5.2.3 where R is plotted as a function of b/i for i values of 0.1 and 1. It is obvious that the variation due to i is less than the variation caused by the non-tariff access charge items. In the range of b/i likely for time sharing or enquiry-response systems R could lie anywhere in the range 0.5 to 2. (The specific ranges for the b and i combinations of the four applications given in Figure 2.5.2 are marked in the figure.) Hence, depending largely on the non-tariff access charges

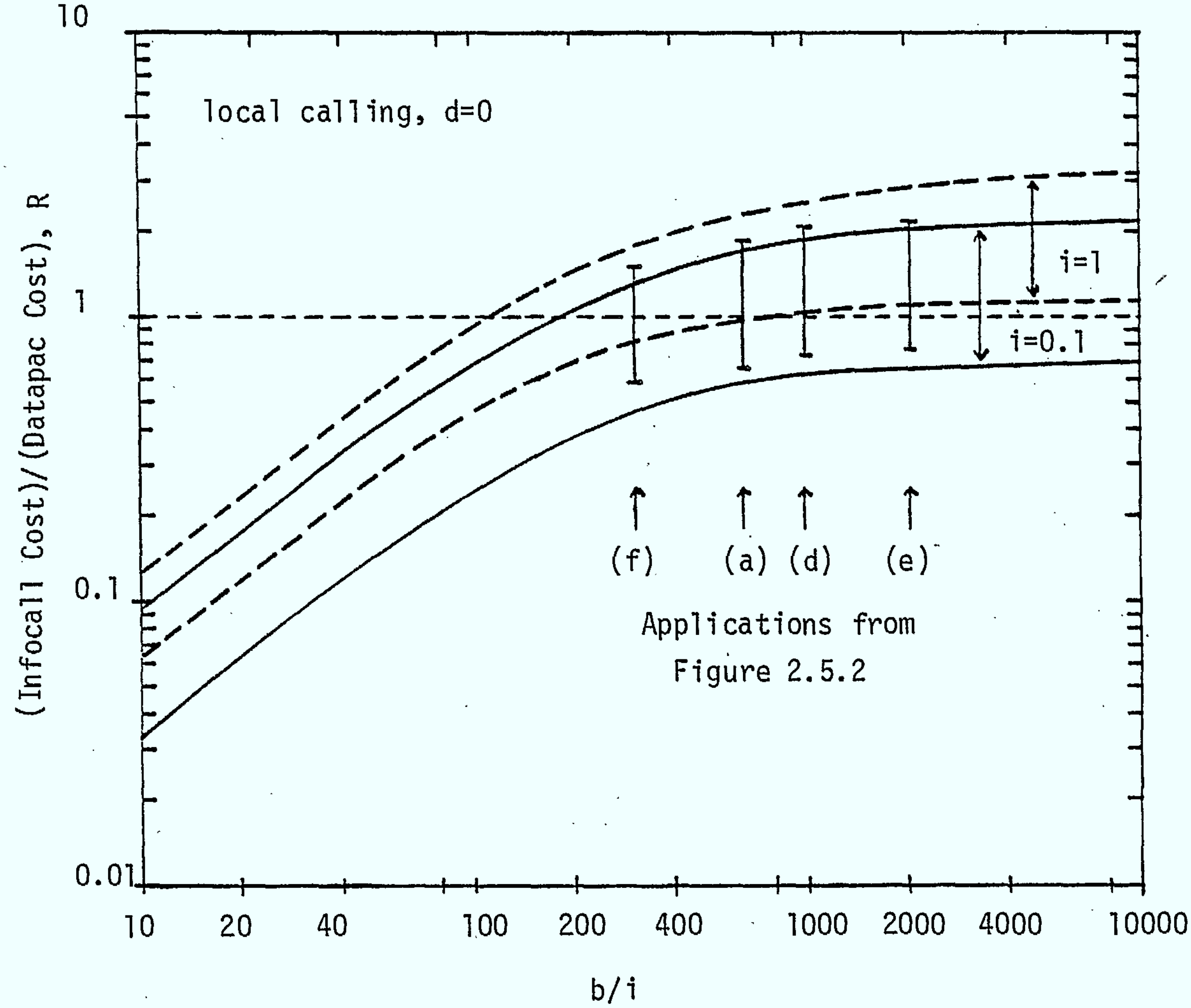


Figure 5.2.3: Relative cost of dialed telephone-Infocall and dialed Datapac 3101, local calls

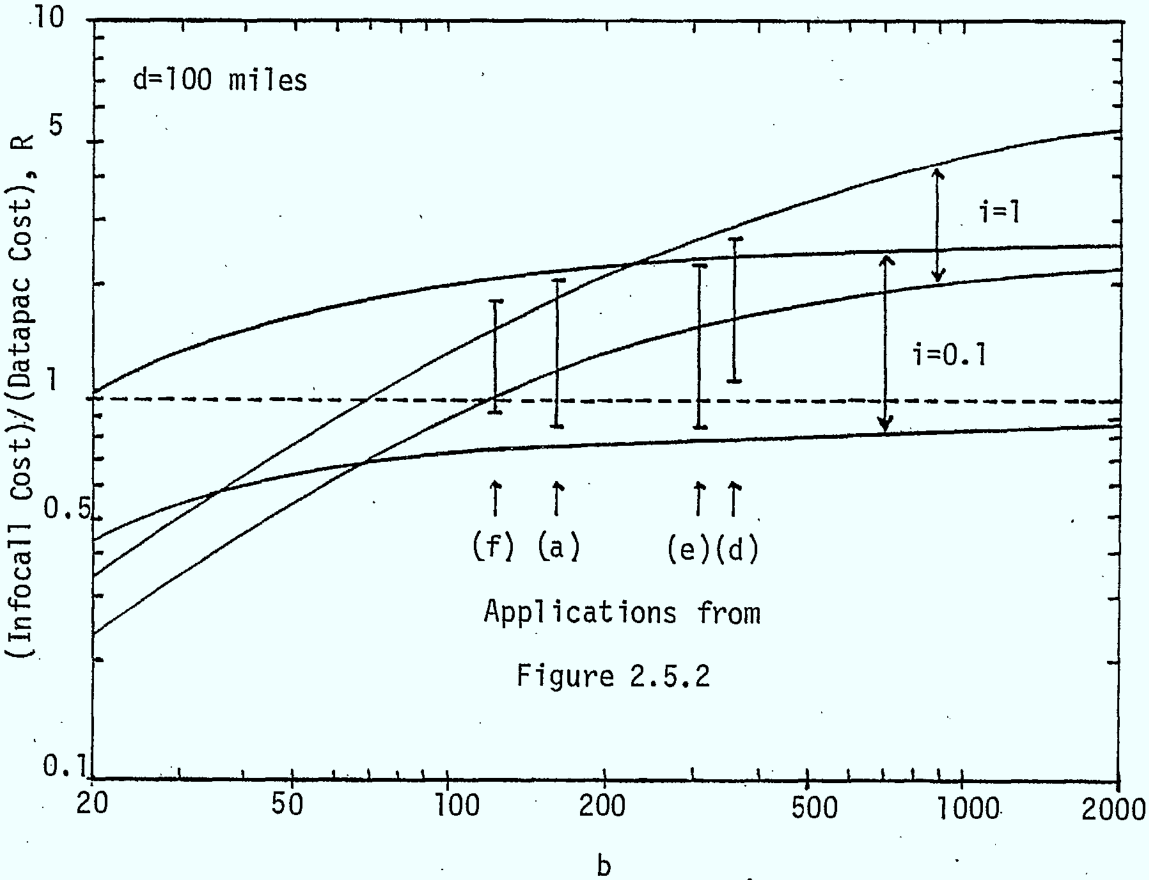
and the interconnect cost, Infocall (local calling) with telephone access is likely to be equally attractive to the user as Datapac 3101 from a cost viewpoint.

For non-local calls U_c starts at \$0.50 and has increased to \$1.00 at a distance of 1000 miles. This larger value for U_c has two effects. First, it increases the value of R, and second, it makes R strongly dependent on both i and b rather than just the ratio b/i as found for local calls. The result is shown in Figure 5.2.4. As before the possible range of R for each of the four typical applications is indicated. The R value could be between 0.8 and 2. Hence, while it is possible that non-local Infocall will be less expensive to the user than Datapac 3101, it is not probable.

To obtain an estimate of the actual cost we can proceed as before, substituting for the various parameters in equation [5.2.1] and dividing by the connect hours per month to obtain the charge per connect hour. This yields:

$$\$/\text{connect-hour} = 0.9m + 10.8\ iU_c + \frac{A'_{ci} + X'_{ci}}{ck_1} \qquad [5.2.14]$$

Substituting the U_c value for local calls yields total costs between \$1.70 to \$5.00 per connect hour. This consists of \$0.90 to \$1.80 for connect charges, \$0.24 to \$0.64 for utilization charges (i between 0.15 to 0.4), and \$0.55 to \$2.60 for computer access. These values confirm our earlier calculation that Infocall (local calls) is comparable with Datapac 3101 in costs to the user. They also indicate that



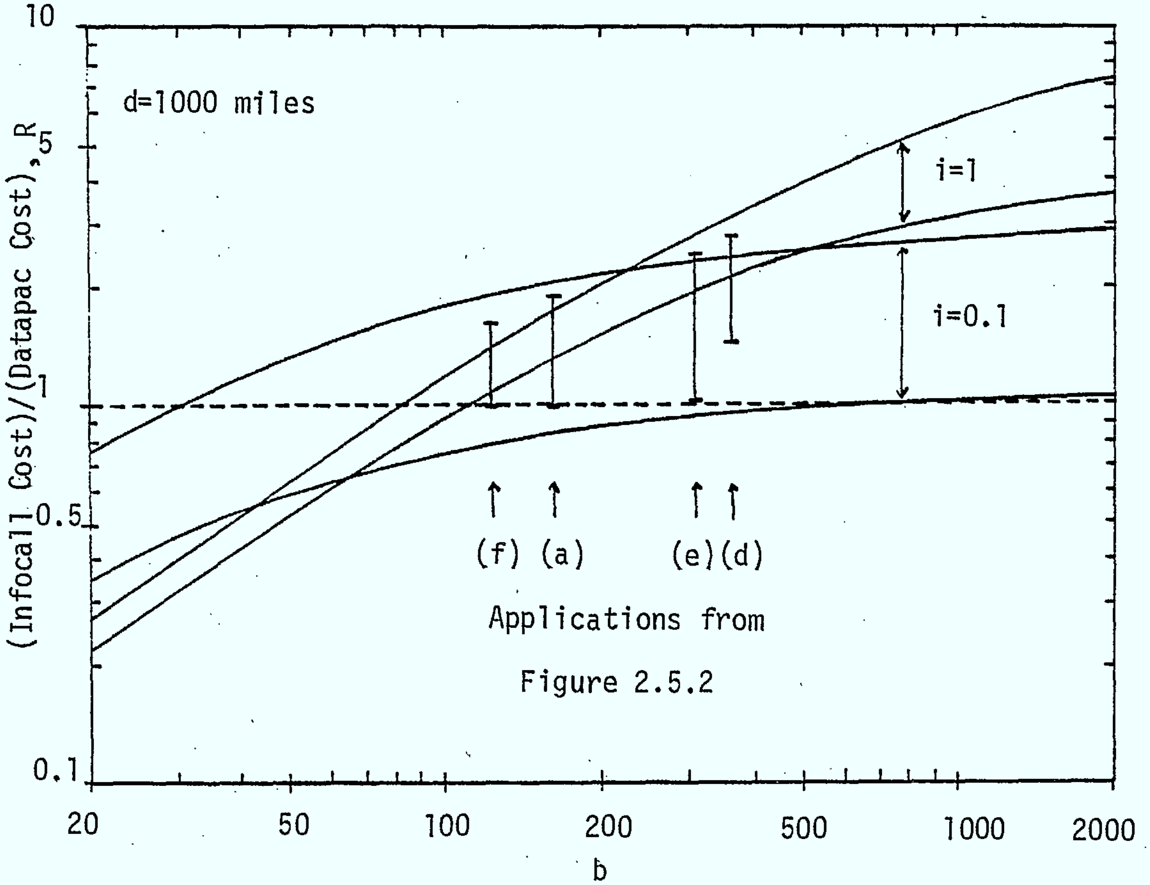


Figure 5.2.4: Relative cost of dialed telephone-Infocall and dialed Datapac 3101

this competitiveness is quite sensitive to the value of the interconnect charge factor m, and the non-tariff computer access charges.

For non-local service the increased utilization charge causes the connect time cost to increase to \$3.00 to \$7.70 at 1000 miles for typical applications. While this appears to overlap the Datapac 3101 range the maximum and minimum for the two services do not occur under the same conditions, and it should be remembered the relative cost ratio varies from 0.8 to 2.0.

(Aside: Since local Infocall is handled as a circuit switched service, not as a packet service, it is effectively identical to Infoexchange in its service. It is therefore interesting to compare the connect charges. The only difference is the utilization charge. From equation [5.2.12] it can be seen that the Infoexchange utilization charge is \$6.00 per connect-hour. From equation [5.2.14] the equivalent Infocall charge is \$1.62i. It is obviously not in a user's interest to use Infoexchange for local calls if Infocall can be used.)

5.3 TELEX - DATAPAC INTERCONNECTION

The Telex network was designed for slow speed message transmission and, since it is a circuit switched system handling bursty traffic, it is possible that a packet switched service could provide more economical long haul service. Hence it is desirable to see what benefit an interconnection of Datapac and Telex would give to the user. There are two possible forms that such an interconnection could take. In the one form Datapac would be used as the long haul service in a fashion transparent to the user. In the second form Telex and Datapac would serve as an inter-worked message network.

A detailed analysis of the first form is not possible. It would require full details of Telex traffic so that the number and locations of the required access ports to Datapac could be estimated. The cost of providing these ports and hence of providing the long haul service could then be evaluated. However some boundary conditions can be established quite easily. Currently Telex rates vary from 14¢/min to 94¢/min according to distance. The local areas which have the 14¢/min rate are quite large, approximately a 100 mile diameter about a major city. Hence, any long haul activities would be between major cities and have the lowest Datapac rates. As will be shown later, these are small compared to Telex, and as an approximation will be ignored. Hence the total charge could be not much more than 14¢/min which is the local area charge, and should at most not exceed a local area charge at each end of the call, namely 28¢/min. Whether this would result in significant savings to the users cannot be stated without knowledge of the distribution of Telex charges between access and usage charges, and knowledge of the geographical distribution of traffic flow.

The second alternative assumes that Telex and Datapac are interconnected with a common address space so any terminal on either network could call any other. Such a mode of operation could be provided by having Datapac switches provide ports to the Telex network that were very similar to Datapac 3101 but also having the ability to orginate calls on the Telex network. Such a service should not cost the user significantly more than the present Datapac 3101 NIM charges. One method of evaluating this configuration is to compare the cost of a Telex-Telex call with an equivalent Datapac-Datapac call.

Before comparing Telex with Datapac, however, it is interesting to compare it with Infoexchange and Infocall. Both these services could be used in their present form to provide a message transmission service between terminals of the same speed, and hence in a sense, are competitors with Telex.

In Section 3.9 the tariff for Telex service was developed. It may be expressed in the form

$$\$pm_t = 107 + 60c\ U_t(d) \qquad [5.3.1]$$

where the \$107 access charge includes a model 33 ASR teletype, and may increase significantly with various terminal options. The similar tariff for Infocall, assuming that a terminal is used exclusively for sending or receiving messages, would be

$$\$pm_c = \$60 + T + \frac{10^{-4}u}{8}\ U_c(d) \qquad [5.3.2]$$

assuming 110 or 300 bit/s operation. The term T represents the monthly terminal charge. A terminal with a capital cost of approximately \$2000 would give a T of \$50, leaving the essential difference in cost between the two services as the difference in the utilization charges.

To compare equation [5.3.2] with the Telex charge we must convert the traffic volume u into an equivalent connection time c. First, recall that u = 3600cis. Secondly, we note that a good typist generates 60 words per minute. This corresponds to 5 character/s or 40 bits/s. Thus, for a good typist the effective communications speed, si, is 40 bit/s. (Note: The minimum charge threshold in asynchronous Infocall is 24 bit/s.) Thus equation [5.3.2] can be reduced to the form

$$\$pm_c = \$60 + T + 60c[0.03U_c(d)] \qquad [5.3.3]$$

The ratio $[0.03U_c(d)]/U_t(d)$ lies between 0.1 at short distances and 0.04 at long distances. Consequently the average utilization charges for an Infocall message service would be less than 10% of those for Telex.

A similar analysis can be carried out for Infoexchange; the results indicate that the Infoexchange utilization charge ranges between 70% at short distances, to 50% at long distances, of those for Telex. Hence while Infoexchange is less expensive than Telex, Infocall is the superior alternative.

Now, we will consider Datapac. Datapac, as currently available, does not offer any service that could be directly used as an alternative to Telex as Infocall could be.

However, if Datapac 3101 services were modified so that a call could be placed to another dedicated Datapac 3101 terminal, then such a Telex-like service would be available. (Indeed, it would be superior since the terminals could operate at different speeds.) Assuming dedicated 110 or 300 bit/s service, Datapac 3101 tariffs yield a cost of

$$\$pm_d = \$60 + T + \frac{10^{-5}}{b}u[(U_d(d) + 25)] + 0.005n \qquad [5.3.4]$$

Making the same substitutions for the traffic volume as earlier yields

$$\$pm_d = \$60 + T + 60c[\frac{0.24}{b}\{10^{-2}U_d(d)+0.25\} + \frac{0.005}{t}] \qquad [5.3.5]$$

where t is the average call duration time in minutes. Comparing the result to equation [5.3.1] for Telex indicates that the only significant difference is the utilization charge. If we assume an average line of 30 characters, i.e. b = 240 bits, and an average call duration of 1/2 minute, i.e. 5 lines of 30 characters at an effective speed of 40 bit/s, then for a Grade 1 to 3 D.S.A, the maximum utilization charge for Datapac is 1.4% of the Telex charge. Most of the Datapac cost is due to the 0.005 n term. Even if the charge per kilopacket were 50 times higher (remote Grade 6 D.S.A.'s), the Datapac utilization charge would still only be 10 to 20% of the Telex value. Datapac 3101 would also be less expensive than a corresponding message service using Infocall.

If an interconnection of the second type were made available, then Datapac-Datapac users would enjoy more economical service than Telex-Telex, and Telex-Datapac, purely on carrier services required, should lie someplace between. Hence it would seem that users would switch to the Datapac service due to (1) lower utilization cost, (2) wider range of speeds available, (3) wide range of terminals available, and (4) the possibility of using the same Datapac 3101 access port for some other application part of the time. How fast this switch would occur is not possible to predict as it depends on whether the access or utilization charge is the dominant feature of the users cost, and on the convenience of changing current user office procedures, including such simple things as new Telex/Datapac numbers on company stationary.

It should be noted that CNCP could provide a similar low cost service to the users by integrating Telex and Infocall.

5.4 EFFECT OF INTERCONNECTION - SUMMARY

The interconnection of Infoswitch and the dialed telephone network would offer the user three services, Infoexchange-dialed telephone, Infocall-dialed telephone, and Infogram-dialed telephone service, all of which would serve the same customer base as dialed access Datapac 3101.

The analysis indicates that due to high Infoexchange usage charges dial telephone-Infoexchange is not competitive with dialed Datapac 3101. Hence while the availability of such service could mean lower costs, and increased convenience, for a user committed to Infoexchange for other reasons, it is unlikely to seriously influence a decision whether to use Datapac or Infoexchange.

Interconnection of Infocall-dialed telephone appears to offer the possibility for lower costs than Datapac 3101 to some users, particularly those who are making only calls to a local host computer. Data presented in Section 6.3 shows that approximately 28% of time-share and enquiry-response users fall in the local call category, and that approximately 67% of enquiry-response users operate in the 110 and 300 bit/s speed range. Hence, one might expect that approximately 20% of the time-sharing and enquiry-response users, who are the logical users of a dial access system, will fall in the region where dialed access-Infoswitch and dialed Datapac 3101 are potentially competitive.

If we assume that the actual non-tariff costs are relatively uniformly distributed across the regions calculated earlier, then we might estimate that for one third of these users Infocall is significantly better, i.e. up to 50%, for another third they are essentially the same cost, and for the balance dialed Datapac 3101 is best. Hence it is unlikely that the presence of a dialed telephone-Infocall interconnection will significantly alter the distribution of users between Infocall and Datapac 3101.

Dialed telephone-Infoswitch interconnection will ultimately allow dial telephone to Infogram service. Since the tariffs for Infogram service are not yet available it is impossible to predict its effect. If the tariff is similar to Infocall then there will be little effect. If it is similar to Datapac then dialed telephone-Infogram would obviously be strongly competitive with Datapac 3101. Hence, one may conclude that for the tariffed services, Infoexchange and Infocall, the presence of dialed access will make little change to the expected usage pattern. Whether dialed access Infogram changes this depends on the (unannounced) tariff.

The interconnection of Telex-Datapac, for long-haul traffic only, would appear to offer substanial usage cost reductions for long distance users. What fraction of the total customer base this represents is not possible to predict. A full interworking interconnection between the two services is seen as leading to Datapac eventually capturing the Telex customer base due to significantly lower utilization costs. Alternatively CNCP could start a program of transferring Telex to Infocall (or Infogram) which would offer the user similar savings as a Datapac interconnection.

SECTION 6. EFFECT OF INTERWORKING

6.1 INTRODUCTION

To consider the question of interworking, and its impact on various user groups, it is necessary to view the optimum application regions somewhat differently than was done in Section 4. In Section 4 the analysis was made for a single user at some specified distance, and there was a discussion of the sensitivity of the boundary between the optimum regions for the various services to the various user sensitive parameters, including distance. In this section we are interested in the boundary location given a group of users with common interests having some geographical distribution. It is assumed that this group of users must use the same communications service because of their common interest, and the question of optimum service for an individual user does not arise provided the average user cost is minimized. Interworking potentially could yield a lower average cost by allowing the individual to select whichever communication service had the lower cost.

It will be assumed that at a given speed the average communications intensity i and average message length b of all users in the group is the same. (This is very likely an unreasonable assumption. However, no data exists that allows a more appropriate model to be constructed.) Now, for a given speed the boundary between the optimum regions for two services exists where the sums of the monthly charges over all users in the group are equal, namely

$$\sum_{j=1}^{m} \$pm_{pj} = \sum_{j=1}^{m} \$pm_{qj} \qquad [6.1.1]$$

where $\$pm_{pj}$ and $\$pm_{qj}$ represent the monthly cost to user j of communication services p and q respectively.

Replacing the total monthly charge by the service and usage components yields

$$\sum_{j=1}^{m} (a_p A_p + K_{pj} U_{pj}) = \sum_{j=1}^{m} (a_q A_q + K_{qj} U_{qj}) \qquad [6.1.2]$$

where it will be noted that the access charge depends only on speed and hence is a constant, independent of j. (This effectively ignores dialed access Datapac 3101 which has an access charge based on connect time; this could be handled by treating that component of access charge as part of the usage function.) We will ignore any nN term on the basis that it is normally small.

In equation [6.1.2] a_p and a_q represent an allowance for the access charge at the computer end of the communications link. For single user point-to-point connections these co-efficients will have the value two, as there are two access charges per link. However, for multidrop services, or for any of the switched services, where a few computer ports may service many terminals, the per terminal share of the access charges at the computer is small and the a_p and a_q co-efficients could approach unity.

It is now necessary to examine K_{pj} and K_{qj} more closely. These terms are either constant (Dataroute, Infodat, analog leased line) or functions of u, i, b and s. It was previously indicated that for a given speed it would be assumed that all users had the same average traffic intensity and average message length. Hence, for a given group of users, these terms are not functions of j but are either functions only of the traffic or are constant, and hence reduce of K_p and K_q respectively. Thus equation [6.1.2] can be reduced to

$$a_p A_p + K_p \frac{1}{m} \sum_{j=1}^{m} U_{pj} = a_q A_q + K_q \frac{1}{m} \sum_{j=1}^{m} U_{pj} \qquad [6.1.3]$$

or

$$a_p A_p + K_p \overline{U}_p = a_q A_q + K_q \overline{U}_q \qquad [6.1.4]$$

where $\overline{U}_p$ and $\overline{U}_q$ represent the average utilization charge over all terminals for service p and service q respectively. Since the utilization charge is a function of distance, these terms require a knowledge of the distance distribution of the terminals for calculation.

It should be emphasized that $\overline{U}_p \neq U_p(\overline{d})$ where $\overline{d}$ is the average distance since usage charges do not vary linearly with distance. For a particular service p it is possible to speak of a representative distance d_p' such that $\overline{U}_p = U_p(d_p')$ However, since the shape of the usage function with distance is not the same for the various services, the representative distance for different services for the same user group can be quite different. Now, assuming that K_p can be written as uF_p (valid for all services except Infodat, Dataroute and leased analog lines) the expression

$$u_{pq} = \frac{a_q A_q - a_p A_p}{F_p - F_q} \qquad [6.1.5]$$

can be developed as the value for the equal cost boundary between two services.

At this point a comment regarding the interpretation of the above equation is in order. Figure 6.1.1 lists the various conditions that can exist.

$F_p - F_q$ \ $a_q A_q - a_p A_p$	-	Ø	+
+	service q is best	service q is best	service q best above boundary, service p best below boundary
Ø	service q is best	identical	service p is best
-	service p best above boundary, service q best below boundary	service p is best	service p is best

Figure 6.1.1: Optimum service based on access and utilization costs.

It should be noted that while $a_q A_q - a_p A_p$ is only a function of the two services and the speed, $F_p - F_q$ is frequently a function of i, b and s and hence its sign may depend on these parameters.

The following sections will consider the characteristics of various user communities that were identified in the Datacom'76 study [1]. (This is the only survey which contains a sampling of actual user data relevent to Canadian communications usage.)

The user communities that it identifies, and for which it contains a significant sample of users, are

- time sharing/enquiry response
- airline reservation terminals
- banking terminals
- remote batch (RJE)
- peripheral-to-peripheral

These user groups are analysed in detail in Sections 6.3 through 6.8. First it is necessary to develop some general equation for evaluating region boundaries.

6.2 USER GROUP PARTITIONS EQUATIONS

To obtain the boundary between communication services for a user group it is necessary to evaluate equation [6.1.4], generally in the form of equation [6.1.5] for the two services in question. For convenience the relevent services, and their K_p values are listed in Figure 6.2.1. (The service numbers correspond to those used in Section 4.2.) Substituting the values from Figure 6.2.1 into equation [6.1.4] leads to the following expressions for the partition boundaries between the various communication services.

service	Name	K_p
1	Dataroute/Infodat	1
2	Infoexchange	u/(48is) (asynchronous) u/(60is) (synchronous)
3	Datapac	10^{-5}u/b
4	Infocall	10^{-4}u/8
5	Telephone	u/(48is) (asynchronous)
6	Analog Leased Line	1

Figure 6.2.1: Usage charge co-efficients for various data communication services

6.2.1 DATAPAC-INFOCALL

The boundary between the Datapac and Infocall regions is given by the traffic volume.

$$u'_{34} = \frac{8 \times 10^4 (a_3 A_3 - a_4 A_4)}{\overline{U}_4 (1 - \frac{80}{b} \frac{10^{-2} \overline{U}_3}{\overline{U}_4})} \qquad [6.2.1]$$

(If $a_3 = a_4 = 2$, then for a single user this equation is identical to Equation [4.2.6].)

Given that $10^{-2}\overline{U}_3/\overline{U}_4$ is usually in the order of unity, and that the average packet length b is normally much equal to 80, the approximate location of the boundary is where the difference in access charges is covered by the (higher) Infocall utilization charges.

Where Datapac or Infocall is being used to service many terminals from a single host computer then we would expect that $a_3 \approx a_4 \simeq 1$. Then if A_4 is equal to A_3 no Infocall region exists. This is the situation for dedicated access Datapac 3101 service at 300 bit/s or less.

6.2.2 DATAPAC-INFOEXCHANGE

The boundary between Datapac and Infoexchange is given by

$$u'_{32} = \frac{60si\,(a_3A_3 - a_2A_2)}{\overline{U}_2\left(1 - \frac{60i}{b}\,\frac{s}{1000}\,\frac{10^{-2}\overline{U}_3}{\overline{U}_2}\right)} \qquad [6.2.2]$$

in the synchronous speed region. Replacing the values of 60 by 48 extends it into the asynchronous region although, as was shown in Sections 4.2 and 4.3, this boundary is not normally of interest there.

We note the appearance of i/b in this equation. Only for a small b/i ratio, i.e. short messages and/or high communications intensity) is the second term in the denominator significant, and as in the Datapac-Infocall case, the boundary is the point where the difference in access charges is covered by the (higher) Infoexchange usage charge.

6.2.3 INFOCALL-INFOEXCHANGE

In Section 4.2 it was shown that this boundary occurred at a particular speed. Substituting into equation [6.1.4], and noting that $A_2 = A_3$, and that for a particular user group it is reasonable with these two services for $a_2 = a_3$, we obtain

$$s'_{24} = \frac{1333}{i}\,\frac{\overline{U}_2}{\overline{U}_4} \qquad [6.2.3]$$

as the boundary (assuming it falls in the synchronous region).

6.2.4 TELEPHONE-DATAPAC

The boundary between telephone and Datapac is given by

$$u'_{35} = \frac{48si\ (a_3A_3 - a_5A_5)}{\bar{U}_5(1 - \frac{48i}{b}\ \frac{s}{1000}\ \frac{10^{-2}\bar{U}_3}{\bar{U}_5}} \qquad [6.2.4]$$

assuming that it occurs in the asynchronous region. Again we note the presence of i/b which indicates the second term in the denominator is normally relatively insignificant.

6.2.5 TELEPHONE-INFOCALL

The boundary between telephone service and Infocall is given by

$$u'_{45} = \frac{48si\ (a_4A_4 - a_5A_5)}{\bar{U}_5(1 - 0.6i\ \frac{s}{1000}\ \frac{\bar{U}_4}{\bar{U}_5})} \qquad [6.2.5]$$

It is probable that the value of a_3 and a_5 would be the same for a given user group.

6.2.6 TELEPHONE-INFOEXCHANGE

The boundary between telephone service and Infoexchange is given by

$$u'_{25} = \frac{60is\ (A_2 - A_5)}{\bar{U}_5 - \bar{U}_2} \qquad [6.2.6]$$

Charges for synchronous speeds have been used as this is normally where this boundary occurs.

6.2.7 DATAPAC-DATAROUTE/INFODAT

The boundary between Datapac and the digital leased line services is given by

$$u'_{13} = b10^5 \frac{(a_1A_1 - a_3A_3) + \bar{U}_1}{\bar{U}_3} \qquad [6.2.7\ a]$$

In the synchronous (Datapac 3000) region $A_1 = A_3$, and for many applications, i.e. dedicated point-to-point service or multidrop type service, $a_1 = a_3$. Hence in these situations

$$u'_{13} = \frac{b10^5\ \bar{U}_1}{\bar{U}_3} \qquad [6.2.7\ b]$$

For asynchronous (Datapac 3101) applications $A_3 > A_1$, and for short distances the boundary can occur at quite low values. In the asynchronous region where the computer probably services many terminals $a_3 \approx 1$ will normally be the case. On the other hand a_1 may also be near unity if it is a multidrop service but could range up to two if the digital leased line connections are on a point to point basis. The net result is that the $(a_1A_1 - a_3A_3)$ can be either positive or negative, and with $a_1 \approx 2$ and $a_3 \approx 1$ to 1.5 could lead to near cancellation of this term, again yielding equation [6.2.7 b] as the boundary.

6.2.8 TELEPHONE-DATAROUTE/INFODAT

The boundary between the telephone system and digital leased lines is only of significance in determining the partitions before Datapac and Infoswitch became available. The boundary is given by

$$u'_{15} = \frac{48is\ [(a_1A_1 - a_5A_5) + \overline{U}_1]}{\overline{U}_5} \qquad [6.2.8]$$

in the asynchronous region.

6.3 TIME SHARING AND ENQUIRY-RESPONSE APPLICATIONS

The Datacom'76 survey contains a sample of approximately 2000 terminals of the time sharing or enquiry-response type.[2] From the survey it is obvious that these terminals are being used to access central computing facilities, and that each central facility is servicing a large number of terminals. The distribution of speeds and communications services is shown in Figure 6.3.1.

communication facility	total	terminal speed 110	300	600	1200	2400	4800
telephone	837	253	547	-	24	-	13
multidrop line (analog)	321	-	-	-	-	282	39
multidrop line (digital)	77	-	-	-	-	77	-
point-point (analog)	152	-	56	6	13	7	70
point-point (digital)	667	-	532	30	-	58	47
	2054	253	1135	36	37	424	169

Figure 6.3.1: Time sharing/enquiry-response communications service distribution

[2]This sample was arrived at by deleting non-Canadian locations, and terminals with missing or obviously incorrect data that could not be estimated or corrected from the context.

It will be noted that 25% of these terminals are 300 bit/s units that access the central computing site via dial telephone links.

By comparing the number of communications lines (and hence computer ports) to the number of terminals one obtains the values shown in Figure 6.3.2.

	analog	digital
average no. of terminals per telephone access port	2.0	---
average no. of terminals per multidrop line	7.0	11.0
average no. of terminals on a point-to-point circuit	1.7	3.1

Figure 6.3.2: Typical concentration figures for time share and enquiry response

The third item in the figure, the number of terminals on a point-to-point circuit, requires further consideration. Intuitively one would assume one terminal per circuit. There are two possible explainations for this anomaly. First, there may have been multidrop circuits reported without qualification as multidrop; secondly, channel deriving may have been utilized to obtain several point-to-point channels from the same circuit. Both reasons are probably valid but there is no method to distinguish them from the available data.

In view of the large number of circuits that are clearly single user point-to-point, plus the large number of telephone users, it was decided that the most reasonable model for this class of users was to assume it consists of point-to-point usage only. Few installations seem to have the distances, or the number of terminals, or the light load that makes line sharing (multidrop or channel deriving) economically attractive.

To analyse the user characteristics further it was necessary to develop the distribution function for the distance between a terminal and the central computer. To do this it was necessary to assume that the distance distribution is independent of traffic and speed distributions. Scatter plots of number of terminals vs. traffic and distance did not exhibit any wide variations that would argue against this assumption. The majority of data is low traffic and/or short distance which makes hypotheses testing difficult. Intuitively one believes that the need to use the computer would be independent of the distance, and while higher communications costs may discourage redundant use, they are not a sufficiently large component of business computer expenses to seriously alter patterns of required usage.

The distance distribution was developed by using the source and destination points in the Datacom'76 survey data and calculating the distance between them. Where a general geographic area was specified the major city in that area was selected. This gives a good model at long and medium distances but the data is seriously distorted at short distances due to the size of the "local areas", i.e., Toronto area includes Kitchener-Waterloo, and Barrie. The significant difficulty with these large sample areas is not the error in the distance, it is the existence or non-existence of special local calling rates for some services. These services are: telephone which has no local call usage charge, Infocall which has a local call rate of 30% of that for short distance non-local calls, and Infodat/Dataroute which does not provide local service.

It was found that overall 48% of the terminals were in the same area as the computer and hence zero distances were obtained. However it was noted that 27% of the digital leased lines, for which local circuits do not exist, were calculated as zero distance but must, in fact, be short links. It was also observed that the distance distribution of the non-local terminals was essentially the same for all three services. Therefore it was assumed that for all three services the same ratio of short links to non-local links exists, as in digital leased lines. This produced the results shown in Figure 6.3.3. The approximate overall distribution is 30% local calling, 20% short distances (say approximately 25 miles) with the remaining 50% distributed exponentially with an average distance in the order of 600 miles.

Using the distances calculated from the Datacom'76 survey, with the above local vs short distance correction, the

	local region		non-local
	local	short	
telephone	488	93	256
digital line	-	198	546
analog line	97	100	276
	585	391	1078

Figure 6.3.3: Distance distribution for time sharing and enquiry-response terminals

average utilization costs for the various services were calculated and are recorded in Figure 6.3.4. The digital leased line charges could be calculated only for the non-zero distance distribution. The analog leased line calculation assumed a minimum distance of 20 miles to allow for local loop charges.

Now, substituting these charges into the equations developed in Section 6.2, the optimum service regions are shown in Figure 6.3.5. Both boundaries between existing services and the new services are indicated.

Since the applications in question have a single computer serving several terminals, the per terminal share of the compiler access charge will be small and it was assumed that all a_p were unity except for leased lines. For leased lines it was assumed that a full access charge would be necessary at both the terminal and computer. (This would not be the case in the line were a multidrop circuit.) In addition, for comparisons using digital leased lines the $\overline{U}_p$ values for non-zero distances were used. Dedicated Datapac

Service	Symbol	Value (all distances)	Value (non-zero distances)	Conditions
Dataroute/ Infodat	$\bar{U}_1$	-	57	$s \leq 300$
		-	114	s=600
		-	225	s=1200
		-	386	s=2400
		-	636	s=4800
Infoexchange	$\bar{U}_2$	.169	.196	$s \leq 1200$
		.220	.250	s=2400
		.340	.390	s=4800
Datapac	$\bar{U}_3$	39.2*	45.0*	(Grade III)
Infocall	$\bar{U}_4$	.531	.683	
Telephone	$\bar{U}_5$	.345	.482	Trans-Canada
Analog Line	$\bar{U}_6$	776	1078	

*not including 25¢ NIM charge for Datapac 3101 service.

Figure 6.3.4: Average utilization charges for time sharing and enquiry-response

3101 charges were used for $s \leq 1200$ bit/s. Values of b = 250, and i = 0.25 were used as being typical for users in this group.

From Figure 6.3.5 it will be noted that most of the potential Datapac region was originally in the digital leased line area. Infocall only has a small area falling largely into what was a dial telephone region before the introduction of the new services. Infoexchange does not appear at all. The boundary between Infocall and Infoswitch is near 2400 bit/s. However, in the region where Infoswitch would be expected, dial telephone is less expensive by $20 to $40 per month. The Infoswitch-Datapac boundary is very close to the telephone-Datapac boundary. If we refer to

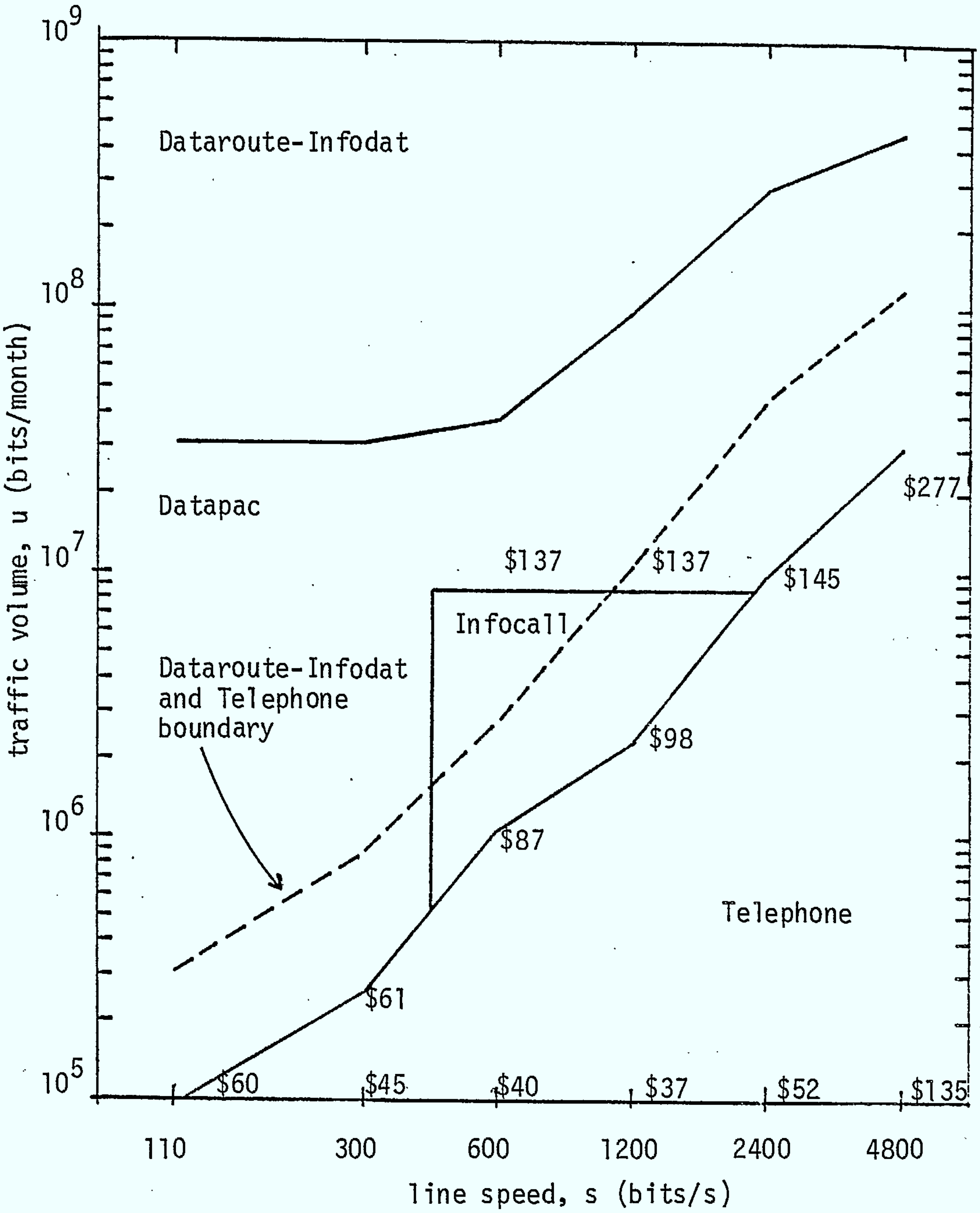


Figure 6.3.5: Optimum service regions, Datacom'76
Time share and enquiry-response applications,
(b=250, i=0.25)

equation [6.2.6] and Figure 6.3.4 we note that the difference $\bar{U}_5 - \bar{U}_3$ is small, especially at high speeds. Hence the lower access cost favours the dial telephone system. From quality of service, reliability and convenience viewpoint Infoswitch should be better, so Infoswitch may be chosen rather than telephone due to these non-tariff factors.

The monthly costs are marked on the figure at the boundary lines between the regions. Between these boundaries, costs vary linearly with u. In Figure 6.3.6 the boundaries from Figure 6.3.5 have been reproduced, and the "average" locations of the time sharing and enquiry-response terminals have been added. These "average" locations were obtained by sorting the terminals in a given speed group by traffic volume, then dividing the sorted list into ten approximately equal size groups and finding the average traffic volume for each group. If the averages of adjacent groups were very close these groups were lumped. The resulting numbers of terminals at that average traffic and speed are plotted in Figure 6.3.6.

It can be seen that while the terminals orginally were scattered across the digital leased line-dial telephone boundary the bulk of them now fall into the Datapac region. The exceptions are primarily at the high speed end. However, many of these terminals were on multidrop systems, and were probably operated at that speed for polling reasons, rather than user requirements. Based on their

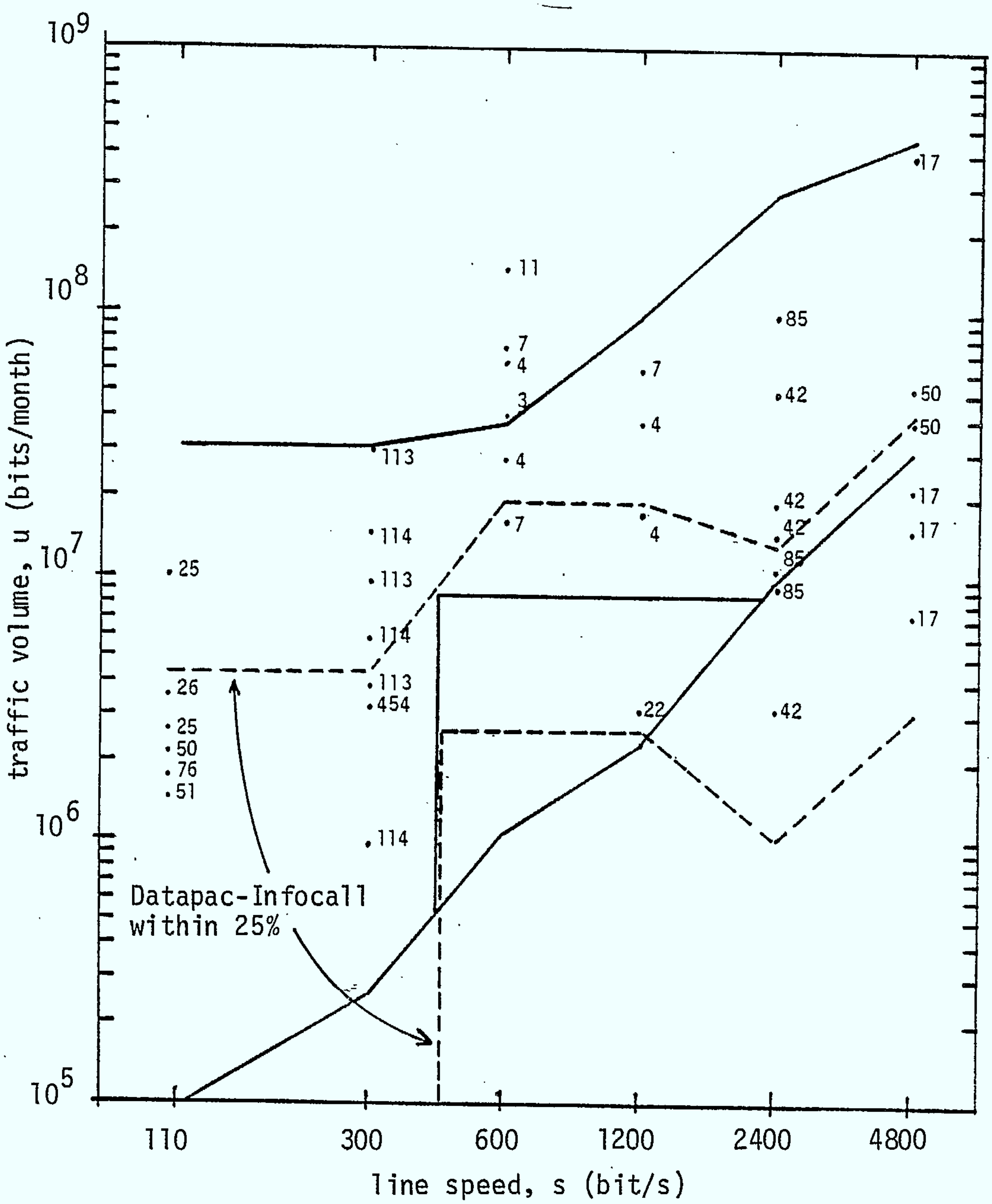


Figure 6.3.6: Optimum service regions, Datacom'76
Time share and enquiry-response application,
showing numbers of terminals

traffic volume they could be operated at a lower speed quite satisfactorily. Hence, some of the high speed applications may "migrate" to lower speeds given the cost advantages.

It will be noted that the Infocall region has few terminals. It might pick up some by the "migration" discussed above, but it appears that overall Datapac is the least expensive alternative for most time sharing and enquiry-response use. In Section 7.3.2 an analysis of GTA traffic indicates a very similar pattern for interactive terminal applications. To illustrate this further a region has been marked in Figure 6.3.6 where Datapac and Infocall/Infoexchange are within 25% of each other in cost. It will be noted that this allows Datapac to cover every terminal, while Infocall/Infoexchange still only covers part of the area. This indicates that some applications will be strongly biased to Datapac while the balance could go either way. Unless interworking is available to allow a free choice in the latter region the tendency will be for these latter terminals to also be Datapac, ultimately leading to this whole applications area being Datapac. It might be noted that the boundaries are relatively insensitive to the b and i values. Reducing b to 150 bits moves the Datapac-Infocall boundary up by a factor of almost two, but only makes about a 20% change in Datapac-Infoexchange boundaries. Doubling i moves the Datapac-Infoexchange a boundary up by a factor of two. These changes do not significantly alter the fraction of the terminals in the Datapac region. to illustrate the cost advantage that Datapac has, for the group as a whole, the average access and usage charges, by speed, are shown in Figure 6.3.7. At higher speeds the differences become very significant.

speed	average traffic	Datapac	Infocall	Infoexch.	Telephone
110	2.9×10^6	60+7 =67	60+17 =79	60+371 =431	35+758 =793
300	8.0×10^6	60+21 =81	60+53 =113	60+376 =436	35+767 =802
600	2.5×10^7	115+192 =307	80+495 =575	80+1751 =1831	35+3575 =3610
1200	1.9×10^7	115+50 =165	80+128 =208	80+227 =307	35+462 =497
2400	3.2×10^7	130+50 =180	100+213 =313	100+196 =296	52+308 =360
4800	7.2×10^7	230+114 =344	175+481 =656	175+390 =515	126+397 =473

Figure 6.3.7: Monthly communications cost for average time share-enquiry response terminal

6.4 AIR LINE RESERVATION TERMINALS

The Datacom'76 survey contains a usable sample of approximately 3000 airline reservation terminals. The overwhelming majority of these units are currently connected to their host computers via multidrop lines, primarily at 2400 bit/s, as shown in Figure 6.4.1.

If it is assumed that all terminals operate at 2400 bit/s and that the distance distribution from the Datacom'76

speed (bit/s)	telephone	analog multidrop	digital multidrop	total
1200	-	166	-	166
2400	20	634	2289	2943
4800	-	157	54	211
total	20	957	2393	3320

Figure 6.4.1: Speed and communications service type distribution for airline reservation terminals.

survey applies then the average monthly utilization charge, if all circuits were digital leased lines, would be in the order of $800 per circuit. The equivalent cost if all the circuits were analog leased lines would be slightly more than twice this, namely $1800.

It was observed in the survey data that each analog multidrop circuit has an average of 7.1 terminals, while each digital multidrop circuit has an average of 61 terminals. The above information, along with access charges, was used to calculate the average monthly communications cost per terminal. The results are summarized in Figure 6.4.2. The access charge for the analog line is the modem cost as given by Equation [3.7.1] and, as was indicated earlier, is subject to considerable variations due to differences between modems. The average access charge, per terminal, at the computer will be small, given the number of terminals per circuit, and has been ignored, i.e. all a_p = 1. (The large difference between the number of terminals per circuit for the analog and digital multidrop services is not unreasonable; the digital system is full duplex, and hence does not have any modem turn around delay, thus allowing it to support more terminals.)

service	average circuit cost	average terminals per circuit	utilization cost per terminal	access charge	total cost per terminal
analog multidrop circuit	$1800	7.1	246	27	273
digital multidrop circuit	$ 800	61	13	130	143

Figure 6.4.2: Average monthly communication cost for an airline reservation terminal

If these terminals were serviced by Datapac or Infoswitch the average utilization charges given in Figure 6.4.3 would apply. A speed of 2400 bit/s is assumed.

Service	Utilization Charge	Access Charge
Datapac (Grade 3)	59 cent/kilopac	$130
Infoexchange	0.35 dollar/minute	$100
Infocall	0.75 dollar/10^4 characters	$100

Figure 6.4.3: Average utilization and access charges for air line reservation terminals

Substituting the Infoexchange and Infocall values into equation [6.2.3] indicates, provided $i < 0.25$ which is almost certainly the case, that Infocall is less expensive than

Infoexchange. Now, substituting the values for Datapac and Infocall into equation [6.2.1] yields

$$u'_{34} = \frac{8 \times 10^4 (A_3 - A_4)}{0.75(1 - 63/b)} \qquad [6.4.1]$$

as the value of traffic volume for which Datapac and Infocall have equal cost. Hence, by noting that b will be much greater than 63 bits, and substituting for the access charges, we find that the boundary is at 3×10^6 bit/month. When this is compared to the average usage, as calculated from the Datacom'76 survey data, of 19×10^6 bit/month with a standard deviation of 5×10^6 bit/month it is obvious that this application is more suitable for Datapac than Infocall. The average monthly communications cost per terminal, at 19×10^6 bit/month, would be \$278 for Infocall and \$141 for Datapac (assuming b = 1000 bits).

The estimated Datapac cost may be compared with the digital leased line cost of \$143 as given in Figure 6.4.2. There would appear to be no economic incentive for the users to switch from a digital multidrop system to Datapac.

Datapac would seem to be much more attractive for those users currently on analog leased lines, but this raises the question - why aren't they already on digital leased lines which would yield the same apparent saving. There appear to be four possible answers: (1) digital leased line service is not available (very unlikely), (2) users are not aware of the possible lower cost, (3) the cost reduction is not considered significant or (4) there are cost/benefits that are not possible to reconstruct from the survey data. Whatever the reason is it will probably also apply to a conversion to Datapac. Hence these users may be summarized by stating that they are potential candidates for exclusively Datapac service, since its costs is approximately 50% of equivalent Infocall service. However, due to little reduction in cost it is unlikely there will be a rapid change away from existing service unless the cost of current services rise drastically, or some other benefit is provided by switching to Datapac.

6.5 BANKING TERMINALS

The Datacom'76 survey contains a useable sample of nearly 10000 banking terminals. These are used primarily for deposit accounting although some are used for other banking functions part of the time. A few (2%) are used exclusively for other banking functions.

The distribution of the terminals over speed and communications service is shown in Figure 6.5.1. It will be noted that 600 and 2400 bit/s are the most common speeds, and that analog leased line is the most common service. Most communications circuits are short, 87% under 200 miles. While the survey reports the leased lines as either "multidrop" or "single user", it is obvious from the number of terminals per circuit that the so called "single user" are either multidrop or use concentrators. We have assumed they are multidrop.

	speed					
	600	1200	2400	4800	9600	total
telephone	-	-	63	-	-	63
digital leased line	-	5	-	60	67	132
analog leased line	4160	1037	4209	63	-	9469
total	4160	1042	4272	123	67	9664

Figure 6.5.1: Type and speed of banking terminal communications circuits

In Figure 6.5.2 is shown the utilization charges per terminal for the various communications services. Since a large number of terminals were available in each speed range, the values for each speed were calculated independently, as well as the overall average.

Dataroute/Infodat is not included in Figure 6.5.2 since approximately 66% of the terminals involved were in the same region as the computer and consequently were calculated as zero distances. Since almost all the services are currently analog lines there was no data available to correct these "zero" distances as was done in Section 6.3. Hence Infodat/Dataroute calculations would be meaningless. For analog lines the minimum distance was taken as 20 miles to allow for local loops. The average analog line cost per terminal was obtained by calculating the average circuit cost and dividing by the average number of terminals per multidrop circuit.

The large percentage of "zero" distances biased all the utilization charges low. To estimate the bias the overall figures were re-calculated after replacing all "zero" distances by 50 miles. The result is shown in the last column of Figure 6.5.2. The change in Infocall and

	symbol	600	1200	2400	4800	9600	overall	overall $d \geq 50$
Number of terminals	-	4160	1042	4272	123	67	9664	9664
Number of leased circuits	-	390	71	1424	10	4	1899	-
Infoexchange	$\overline{U}_2$	.159	.106	.154	.580	.367	.137 ($s \leq 1200$)	.143 ($s \leq 1200$)
Datapac (Grade 3)	$\overline{U}_3$	36.4*	24.4*	27.2	69.4	33.2	31.4*	33.7*
Infocall	$\overline{U}_4$	.425	.194	.267	.805	.551	.336	.567
Telephone (Trans-Canada)	$\overline{U}_5$	.302	.044	.123	.673	.427	.201	.323
Analog Line	$\overline{U}_6$	67.2	15.9	110.6	165.2	38.1	81.7	106.

*Does not include 25¢/kilopacket NIM charge for Datapac 3101 service

Figure 6.5.2: Banking terminal utilization charges for various communications services

telephone is about 60% and leased analog lines 20%, with the other changes being neglible.

It is not significant to draw a partition diagram using the data from Figure 6.5.2. Examination of equation [6.2.1] for the boundary between Datapac and Infocall illustrates the problem. For the $\overline{U}_p$ calculated above the denominator term $(80/b)(10^{-2}\overline{U}_3/\overline{U}_4)$ becomes very significant, unity assuming that a typical banking packet would be 100 to 200 bits. Hence, given the large uncertainity in $\overline{U}_4$ the calculation of most partitions is essentially meaningless.

Some comments can be made with respect to the Infocall-Infoexchange boundary. Substituting $\overline{U}_p$ values from Figure 6.5.2 into equation [6.2.3] yields speed values between 300/i and 600/i for the boundary. Hence it is almost certain that the 600 bit/s terminals should be on Infocall and, provided the communications intensity does not exceed 0.1 to 0.2, it is highly likely that the 2400 bit/s terminals are also best on Infocall.

In order to compare the remaining services it is necessary to calculate the monthly charges for some typical load. Examination of the reported traffic for these terminals gives a mean value of 5.4×10^6 bit/month; 98% of the values lie between 0.8×10^6 and 14.2×10^6 bits/month.

It is also necessary to make some assumptions about access charges. For Datapac at 600 bit/s we will use the dedicated Datapac 3101 service, and at 2400 bit/s Datapac 3000 at each terminal. The latter makes the assumption that it is possible for the terminals to support X.25. It will also be assumed that the Datapac 3000 service at the computer is shared over sufficient terminals that it may be neglected. For Infocall the normal access charges will be used. It will also be assumed that the host computer ports are shared over sufficient terminals that their costs may be neglected. In order for this sharing to be achieved it is necessary for a new call setup at the start of each transaction. This may be unrealistic, and will not be necessary when the Infocall Concentration option becomes available. For analog lines the access charges were taken as the modem charges given by equation [3.7.1].

The access and usage charges may now be calculated for the two most common speeds. The overall utilization charges from Figure 6.5.2 are used, yielding the results shown in Figure 6.5.3.

It can be seen that Infocall, Datapac and leased analog lines are all very close in cost, and that small variations in traffic, message length, distance or costs at the host computer could move any one of the services to the preferred position. Hence it is probable that the users will stay with the existing analog service until increasing tariffs, or reliability considerations, cause a switch to the new digital services. When such a switch does occur it is impossible to say, from the existing data, which carrier will be in the most advantageous position.

Service	Speed	Access	Usage	Total
Datapac	600	$115	$301/b	$118*
Infocall	600	$ 80	$23 to $ 35	$103 to $115
Analog Leased Line	600	$ 10	$82 to $106	$ 92 to $116
Datapac	2400	$130	$180/b	$132*
Infocall	2400	$100	$23 to $ 35	$123 to $135
Analog Leased Line	2400	$ 27	$82 to $106	$107 to $133

*assuming b = 100

Figure 6.5.3: Monthly communications costs for typical banking terminal

6.6 TAPE-TO-TAPE TERMINALS

The Datacom'76 survey contains a sample of 404 tape-to-tape terminals, all but four of which utilize the dial telephone network. The speed distribution of the terminals is given in Figure 6.6.1.

speed	600	1200	1800	2400	50000
number of terminals	266	124	4	9	1

Figure 6.6.1: Speed distribution for tape-to-tape terminals

As with the banking terminals, in approximately 66% of the cases the two units were in the same region and a distance of zero was calculated. Consequently the average utilization charges were calculated twice, first with the distances as calculated (with a 20 mile minimum for analog lines), and then again with the zero distances replaced by 50 miles. The results are shown in Figure 6.6.2.

		distances as calculated	minimum distance=50
Dataroute/ Infodat	$\overline{U}_1$		
s=600		-	66
s=1200		-	133
s=2400		-	229
Infoexchange	$\overline{U}_2$		
s≤1200		.146	.152
s=2400		.190	.198
Datapac Grade 3	$\overline{U}_3$	33.5*	35.8*
Infocall	$\overline{U}_4$	.357	.589
Telephone Trans-Canada	$\overline{U}_5$	.207	.330
Analog line	$\overline{U}_6$	598	718

*Does not include 25¢/kilopacket NIM charge for Datapac 3101 Tape-to-Tape terminal

Figure 6.6.2: Utilization charges for the various communications services

Using these utilization charges the partition boundaries may be calculated. The significant boundaries are shown in Figure 6.6.3. To produce the boundaries assumptions regarding communications intensity, packet length and access charges are necessary.

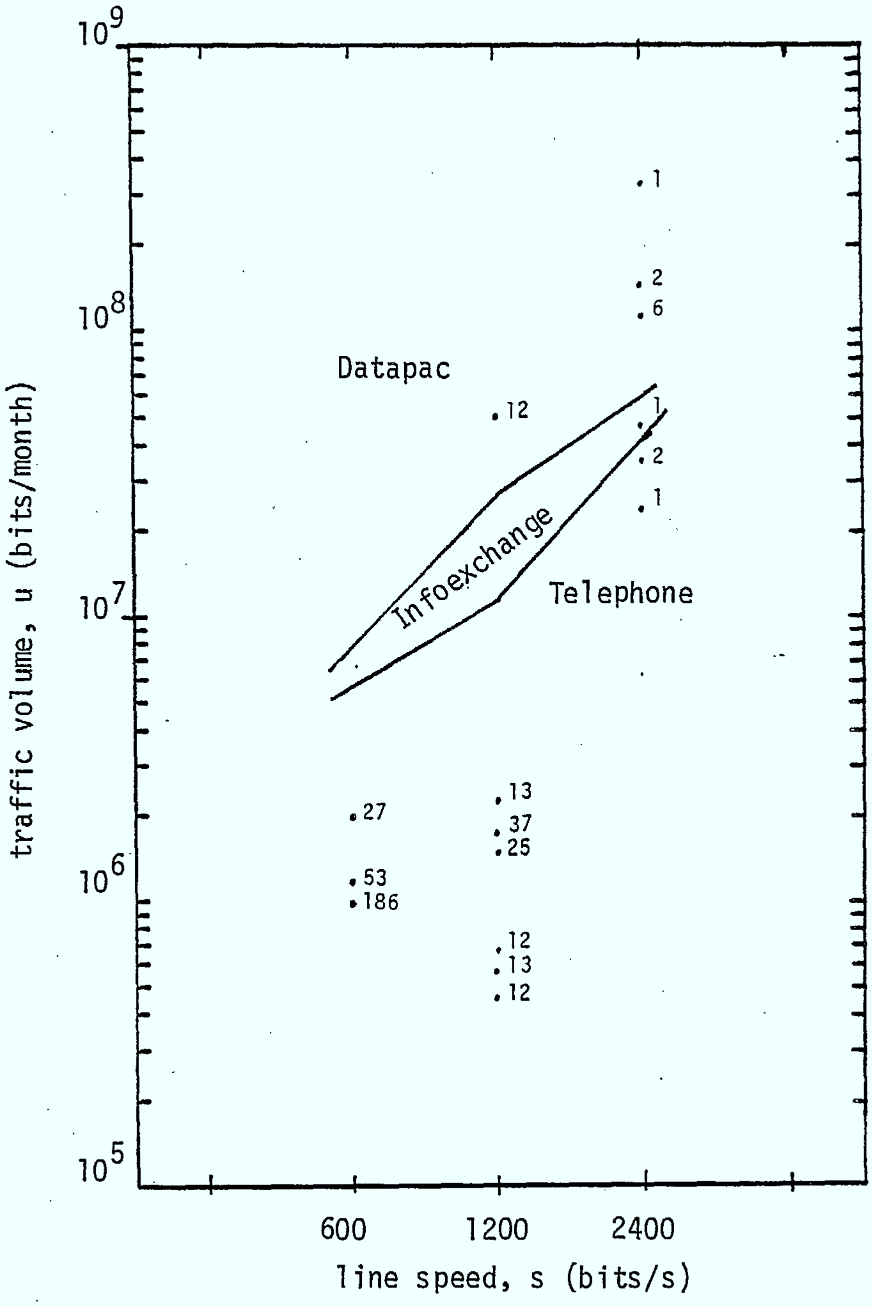


Figure 6.6.3: Optimum service regions, Datacom'76 tape-to-tape application, showing numbers of terminals, (b=300, i=0.8)

Since the units are tape-to-tape, they should operate at a high communications intensity. Consequently we have assume 0.8. As the information being transferred is orders, claims, or other business records the packets will be of a moderate length; we have assumed 300 bits, approximately 37 characters. The survey data shows that one central site serves several remote units, hence we have assumed the access charge at the central site can be ignored, i.e. all $a_p=1$. The utilization figures for a minimum distance of 50 miles were used. Reasonable changes to any of these assumptions will move the boundary by at most a factor of two in traffic volume.

Figure 6.6.3 also shows the "average" location of the user terminals. These locations were obtained by the technique discussed in Section 6.3. It can be seen that for the large majority of users neither of the new communications services is superior to the dial telephone network, although Infoexchange is better than Datapac. To illustrate this further, the average cost of a terminal at each speed and service was computed. This is recorded in Figure 6.6.4. The values are shown as a sum of access charges and usage charges.

On a purely economic basis this application would remain a telephone user until the telephone rates increased by at least 50%. Infoexchange then becomes the preferred service. Of course the differences in cost are small enough that service selection may equally well be made on the basis

speed	600	1200	2400
Average traffic	1.1×10^6	6.1×10^6	1.1×10^8
Datapac	115 + 2 = 117	115 + 12 = 127	130 + 133 = 263
Infoexchange	80 + 8 = 88	80 + 20 = 100	100 + 193 = 293
Telephone	35 + 16 = 51	35 + 44 = 79	52 + 321 = 373

Figure 6.6.4: Average communication charges for tape-to-tape terminal for various services

of convenience or quality of service. Which service is then preferred is not possible to predict.

6.7 REMOTE JOB ENTRY (REMOTE BATCH) TERMINALS

The Datacom'76 survey contains a sample of 770 remote job entry terminals. The communications facilities are either dial telephone, or single user analog or digial leased lines, at speeds from 1200 to 50000 bit/s as shown in Figure 6.7.1. It will be noted that approximately half the terminals are accessed at 2000 or 2400 bit/s via the dial telephone network.

service	1200	2000 2400	4800	7200	19200 9600	50000	total
telephone	8	312	34	-	-	-	354
analog leased line	9	63	90	19	10	6	207
digital leased line	-	129	45	30	4	1	209
total	17	504	179	49	14	7	770

Figure 6.7.1: Speed and communications service distribution for remote job entry terminals

When the distance distribution was developed it was found that 50% of the terminals were in the same area as the computer. This was corrected by the same technique as in Section 6.3, namely, by using the same proportion of short distance to non-local for all services as was obtained for digital leased lines. The results are shown in Figure 6.7.2. The overall distribution is approximately 37% local calling, 13% short distances (say approximately 25 miles) with the remaining 50% distributed exponentially with an average distance in the order of 650 miles. The similarity to the distribution for time sharing and enquiry-response terminals is noted.

	local area		non-local
	local	short	
telephone	178	34	129
digital line	-	39	151
analog line	93	23	88
	271	96	368*

*The total does not agree with Figure 6.7.1 due to missing destinations in the survey data.

Figure 6.7.2: Distance distribution for remote job entry terminals

Using the distances from the survey, with the abovelocal distance correction, yields the average utilization costs shown in Figure 6.7.3. As usual the leased digital line values are calculated using only the non-zero distances, and the minimum distance for analog leased lines is taken as 20 miles to allow for local loops.

Using the above charges the optimum service regions were calculated using the equations in Section 6.2. In making the calculations several assumptions were necessary. First, it was assumed that two access charges were appropriate, i.e., all $a_p = 2$, since the service is essentially of a dedicated nature. Secondly, it was assumed that the communications intensity i was 0.8. Well designed RJE

Service	Symbol	value	conditions
Dataroute/ Infodat	$\overline{U}_1$	296	s=1200
		509	s=2400
		840	s=4800
		1066	s=9600
		2124	s=19200
		5808	s=50000
Infoexchange	$\overline{U}_2$	.183	s=1200
		.238	s=2400
		.366	s=4800
		.458	s=9600
Datapac (Grade III)	$\overline{U}_3$	42.4	
Infocall	$\overline{U}_4$	.535	Trans-Canada
Telephone	$\overline{U}_5$	.363	
Analog Line	$\overline{U}_6$	942	

Figure 6.7.3: Average utilization charges for remote job entry terminals

systems, with continuous traffic at either or both ends, should achieve this value. Thirdly, the packet length was assumed to be 2000 bits, which is almost the maximum Datapac size. This parameter is usually user controlled and it is logical that it would be set at the most economical size.

The results of the calculations are shown in Figure 6.7.4. Also shown in the figure are the "average" terminal locations, computed by the same method as used in the previous sections. It will be noted that almost all the terminals fall in the Datapac region. Infoexchange is the most economical of the Infoswitch services, but it is more expensive than dialed telephone. The boundary between Datapac and both Infoexchange and dialed telephone is shown

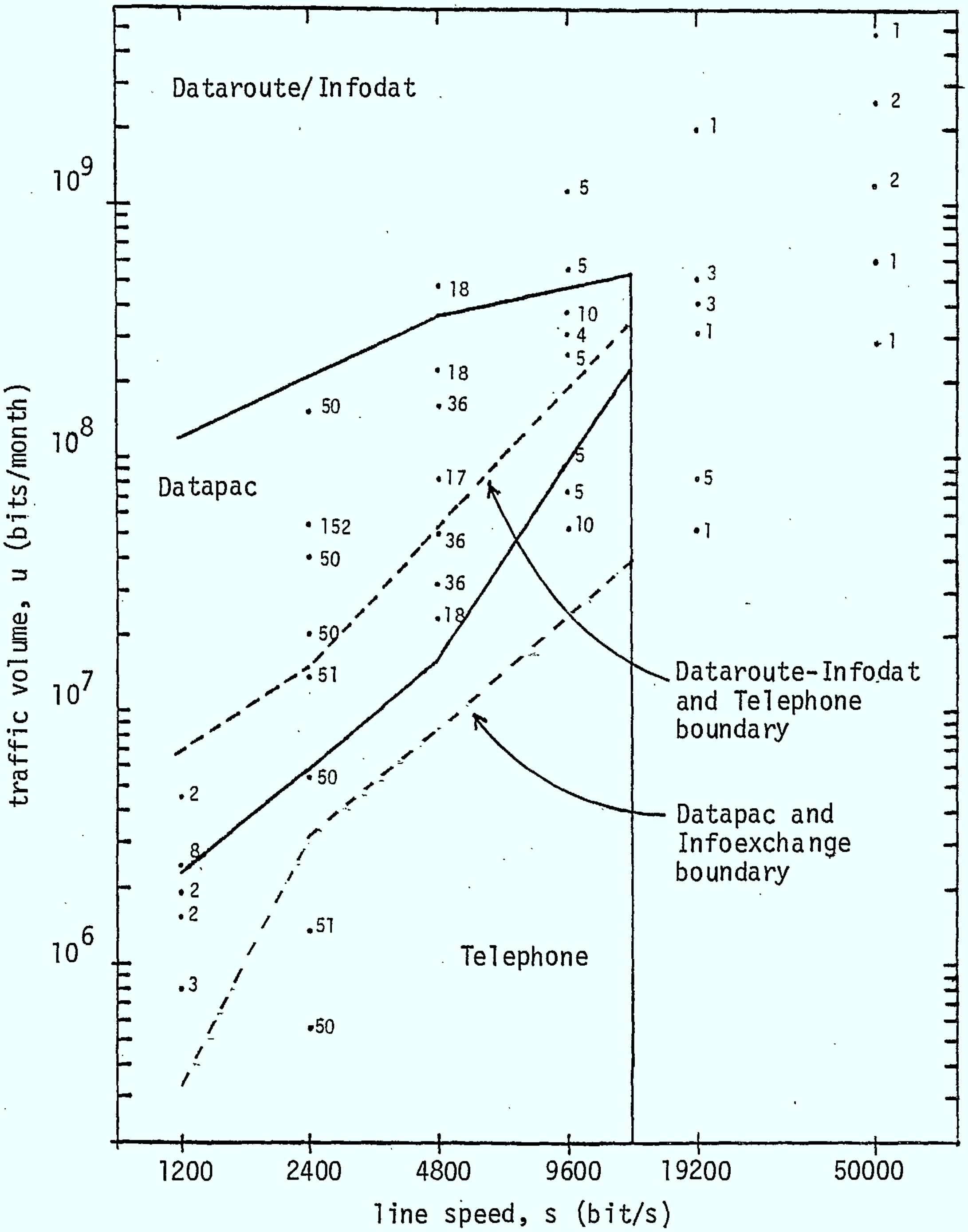


Figure 6.7.4: Optimum service regions, Datacom'76 RJE applications, showing numbers of terminals, (b=2000, i=0.8)

in the figure. They occur at approximately the same traffic values. As it was not expected that the terminals would fall almost completely in the Datapac region, the basic assumptions were examined to see what effect changing them would have. Using only a single access charge lowers the boundaries by a factor of two, and hence favors Datapac. Reducing the intensity i also favors Datapac. Reducing b favors Infoswitch, but even dropping it to 1000 bits makes only a small change in the boundary. Hence it appears that Datapac is better suited to remote job entry applications than is any other communications service. To illustrate this further the average cost figures for all the terminals at each speed are given in Figure 6.7.5. The values are given as the sum of access charge plus utilization charge so the dominant factors may be observed. The results in Section 7.3.3 from the analysis of GTA remote job entry traffic are very similar.

6.8 SUMMARY

In this section we will review the more significant results of Sections 6.3 through 6.7 with respect to interworking, and then use the average cost figures developed in those sections to estimate the effect of Datapac-Infoswitch interworking on the data communications service scene. We are interested in three points (1), the fraction of the data communications market that would be effected by interworking, (2) the possible effects on the carriers' revenues,

Line speed	1200	2400	4800	9600
Dataroute/ Infodat	2(105) + 296 = 506	2(130) + 509 = 769	2(230) + 840 = 1300	2(417) + 1066 = 1900
Datapac	2(105) + 5 = 215	2(130) + 84 = 344	2(230) + 276 = 736	2(417) + 700 = 1534
Infoexchange	2(100) + 70 = 270	2(100) + 810 = 1010	2(175) + 2060 = 2410	2(320) + 3260 = 3900

Figure 6.7.5: Average monthly cost of the various communications services for remote job entry terminals

and (3) an estimate of a reasonable tariff for such a service.

For time share and enquiry-response users, Datapac is on the average approximately 20% less expensive than Infoswitch in the asynchronous speed region, and 50% less expensive in the synchronous speed region. Further, Datapac is within 25% of Infoswitch in those areas where Infoswitch is less expensive; however, the converse is not true. Since Datapac is clearly best for many applications, and competitive for the balance, there will be a tendency for the members of this user community to adopt Datapac because it is most economical overall. Interworking would eliminate this tendency, and would make this area more competitive.

The air line reservation terminals are currently on analog and digital leased lines. Conversion to Datapac would reduce costs for the analog lines systems but would make little change for digital. Hence this area will probably remain leased line unless there is a significant increase in leased line rates. The Infocall costs would be twice those of Datapac and, consequently, the presence/absence of interworking will have little effect on user actions.

The on-line banking terminals are currently using analog leased lines. Either Datapac or Infocall costs would be approximately the same as current leased line costs. Consequently Datapac and Infocall are both contenders for the data communications service for this application, especially if there is an increase in leased analog line rates. Without interworking, one carrier may capture a major fraction of this market, especially if "compatability" questions are raised due to Electronic Funds Transfer considerations. Interworking would eliminate this "compatability" requirement and leave the area open for competition. Given the very similar costs, and the high importance of non-cost considerations such as reliability, convenience, etc., of the data communications to this user group, it is impossible to predict how the market will be split between the carriers.

The tape-to-tape terminals represent a relatively small use of data communications. Unless telephone rates increase by 50% these terminals are best serviced by the dial telephone system. Infoexchange is then best by about 15% relative to Datapac. Given the characteristics of the application, i.e. sending data from branch offices to a central site, interworking would appear to be of little significance to this user group.

For remote job entry (remote batch), Datapac is most economical, typically by a factor of two or more. Hence the presence/absence of interworking will have little effect. Most users will select Datapac unless unknown non-tariff factors enter the evaluation.

The above conclusions are summarized in Figure 6.8.1.

User group	Without interworking	With interworking
time share enquiry-response	strongly biased toward Datapac	competitive with bias toward Datapac
air line reservation	Datapac	Datapac
on-line banking	competitive but "compatability" problem	competitive
Tape-to-Tape	competitive with bias to Info-exchange	competitive with bias to Info-exchange
RJE	Datapac	Datapac

Figure 6.8.1: Summary of the most economical service (Datapac or Infoswitch) for various user groups

	Dataroute /Infodat	Analog line	Datapac	Infocall	Infoexch.	Telephone
Time share Enquiry-Response	-	-	130	200	430	730
Air Line Reservations	140	270	140	280	-	-
On Line Banking	-	110	120	-	120	-
Tape-to Tape	-	-	120	-	100	70
RJE	960	-	510	-	1510	-

Figure 6.8.2: Average communications costs for various user groups and communications services

We now wish to estimate a reasonable service charge for interworking. To begin, the overall weighted averages for each of the significant communications services for each user group are shown in Figure 6.8.2. For the applications where interworking seems desirable, either to give lower user costs or to preserve competition, namely, time share, enquiry-response and on-line banking, the typical cost of the more economical service is less than \$150 per terminal. Of this, \$60 to \$100 represents the access charge. Hence in potential interworking applications the monthly usage charge is in the order of \$50. We now note that for time share and enquiry-response applications the Datapac 3101 NIM charge of 25¢/kilopacket represents about 40% of this charge. Hence, if an interworking charge of 25¢/kilopacket were used, it would represent \$20/month to a typical user. This would increase the monthly cost to the average user by 10 to 20% which is approximately equivalent to the difference in cost of the two services in regions where it appears interworking may benefit the user. If the charge for interworking exceeds this value the economic benefit of interworking to the user becomes questionable. It might be noted that a zero charge for interworking is a reasonable scenerio, in as much as the proposed tariffs for the Datapac-Tymnet and Datapac-Telenet interconnections appear to have little, or no, interworking charge.

To estimate the overall impact of interworking on carrier revenues, consider Figure 6.8.3. This contains estimates of the number of terminals in the various user groups. These numbers are based on the Datacom'76 survey [1] and data supplied by Bell Canada [4]. The first column of data in the figure gives the percentage distribution of the terminals in the Datacom'76 survey. About 5% of the approximately 20000 terminals in the survey were ignored, since they were used for unreported or small applications. The third column of data is a similar estimate based on the Bell Canada data. The Bell Canada data estimates 90000 terminals were in use in 1976. The most significant variation between the two reports is that the Bell Canada data lists approximately one third of the total terminals as point-of-sale, while the Datacom'76 survey reports less than 1% as point-of-sale. (Due to the small Datacom'76 sample, it was impossible to produce partition diagrams for this application.) The breakdown given in Figure 6.8.3 ignores the point-of-sale applications. Due to the lack of detail in the Bell Canada survey some difficulty was encountered in matching the Bell Canada catagories to the Datacom'76 categories. Consequently the air line and on line banking values for the Bell Canada data are estimates.

Using these terminal distributions, plus the most economical average cost for each terminal from Figure 6.8.2, the fractions of carrier revenues that may be expected from each user category were calculated. These values are recorded as the second and fourth columns of data in Figure 6.8.3. (It should be noted these revenue estimates do not include any allowance for point-of-sale activity which, according to Bell Canada data, accounts for one-third of the terminals).

	Based on Datacom'76 Survey		Based on 1976 terminal distribution supplied by Bell Canada	
Application Area	Percent of Terminals	Percent of Carrier Revenue	Percent of Terminals	Percent of Carrier Revenue
Time share & Enquiry-Response	21%	19%	57%	50%
Air line Reservation	20%	19%	13%	12%
On-line Banking	52%	43%	20%	20%
Tape-to-Tape	2%	1%	-	-
RJE	5%	18%	5%	18%
	100%	100%	100%	100%

Figure 6.8.3: Distribution of terminals and carrier revenue by application group

Comparing these percentages against the most economical services for various user groups as indicated in Figure 6.8.1, indicates that 30 to 37% of revenues (RJE and air line reservation terminals) are candidates for Datapac service. This will not be realized immediately but will grow as individual users migrate to the most economical service. It is not possible to predict the growth rate as it depends on many non-tariff factors. Increases in telephone or leased line tariffs could accelerate the transfer. service.

The balance of the revenue is open for competition between Datapac and Infoswitch, with a strong bias towards Datapac for the time sharing and enquiry-response group which is the group most likely to achieve major savings by conversion from existing services. In our opinion the presence of interworking would reduce the probability of one carrier capturing the major share of these areas.

While the above estimates ignored several data communications activities, most notably point-of-sale due to the unavailability of sufficient data, the general trend is obvious. For several major applications, Datapac is economically superior to existing services and to Infoswitch. There is no major application where Infoswitch is economically superior. Thus the competitiveness of Infoswitch seems to rest largely on the (unannounced) tariff for Infogram. Only if it is lower than the Infocall and Infoexchange tariffs will there be general competition between the two services.

SECTION 7. CLOSED USER GROUPS

7.1 INTRODUCTION

This section reports the results of the study of three closed user groups: Electronic Funds Transfer Systems (EFTS), systems identified by the Government Telecommunications Agency and COSTPRO. The objective was to find which data communications systems are most economical for their operations.

Due to the greatly differing nature of the user groups, general analysis is not possible and each group is considered separately in the following sections. It will be shown that EFTS is currently insufficienty defined to yield numerical values but probably both Datapac and Infocall will be suitable. It is shown that the systems identified by the GTA are essentially similar to those in the public use sector and, hence, the conclusions of Section 6 apply. It appears that Datapac is the superior service for COSTPRO but some of the supplied data on COSTPRO terminals and traffic seems high.

7.2 ELECTRONIC FUNDS TRANSFER SYSTEMS

Considerable literature is available concerning EFTS. However, this information is largely concerned with the economic and social impact of electronic funds transfer. Nothing seems to have been written about the communications aspect other than various projections of terminal counts or total expenditures. Without reasonable estimates of traffic characteristics (per terminal) it is impossible to state which of the current and proposed data communications services would be most economical, or to give any estimate of the cost of the communications service required.

The only data that was included in the Datacom'76 survey that might be representative of future EFTS traffic was the bank terminal traffic (Section 6.5) and some terminals listed as "order or claims processing" which we included in the time-sharing and enquiry-response group (Section 6.3). It is noted that in the former group Datapac and Infocall were competitive, and in the latter group while Datapac has an advantage, Infocall is not out of the question. Hence, it may be conjectured that Datapac and Infocall will be competitive for electronics funds transfer traffic, and that costs will be similar to those in these two application areas, namely, \$100 to \$150 per terminal. Further projections are not possible without data on source, destination, and traffic characteristics per terminal.

7.3 GOVERNMENT TELECOMMUNICATIONS AGENCY DATA

7.3.1 INTRODUCTION

It was desired to analyse the data communication requirements of the government departments to find the most economical data communications service for the various applications. To this end the Government Telecommunications Agency supplied data in the form of a survey of the data communication activity in several departments [8]. The survey is somewhat narrative in form, but in general indicates the location of terminals and computers, the terminal type, the application and an estimate of the connect time per day.

From the survey data a database was constructed containing approximately 450 entries. Since many sites have more than one terminal, the terminal count is approximately 900. However, for many of the entries one, or more, significant items, e.g., speed, was missing or ambiguous. If all such entries are deleted the number of entries is reduced by 60%, and the terminal count by 70%. This does not leave enough items for a reasonable sample, and hence, wherever possible the missing or ambiguous items were estimated from the context, sometimes by comparison with similar activities reported elsewhere in the survey. (Estimates were not made unless we were satisfied they were reasonable.) This increased the sample size to 687 terminals, about 80% of the original survey.

It might be noted here that of the user parameters discussed in Section 2, the GTA survey reported connection time c, speed s and distance d. Datacom'76 [1] reported traffic volume u, speed and distance. Either of these two sets is equally satisfactory; however it is recommended that in future surveys an attempt should be made to also obtain estimates of the traffic intensity i and the average packet length b. The number of calls n, or holding time t, would complete the set of user parameters but are usually less significant in tariff evaluation than the other parameters.

Given the nature of the data, and the small number of terminals that would be involved, it was not considered feasible to attempt a detailed study of the data on a department by department, or application by application, basis. Biases in the data for a few terminals would lead to highly questionable results. Instead the data was split into two groups, interactive and remote job entry. The interactive application included all teletype and CRT terminals activity. These two groupings correspond with the general user groupings discussed in Section 6.3 and 6.7. The results obtained for each group will be discussed in the next two sections.

7.3.2 INTERACTIVE TERMINAL APPLICATIONS

A total of 585 teletype and CRT terminals were considered to be of an interactive nature, either time sharing, data entry, text processing, enquiry-response, or similar activities. The distribution of speeds and average connection time is shown in Figure 7.3.1. It will be noted that

speed	110 to 150	300	1200	2000 and 2400	4800 and 7200
number of terminals	83	470	10	18	4
average connection time(hr/day)	3.6	5.4	2.5	2.1	3.1

Figure 7.3.1: Interactive terminal speed and usage distributions (GTA)

activity is strongly concentrated at 300 bit/s.

Of these terminals, 319 have a "zero" distance from the host computer; the remaining 266 are distributed approximately exponentially with distance with an average distance in the order of 700 miles. Since most of the locations were quite well defined it was not necessary to correct this "zero" distance as in Section 6; most of the "zero" distances were Ottawa-Ottawa, Ottawa-Hull, and Ottawa-Shirley Bay. Using the distance distribution to calculate average utilization charges yielded the values in Figure 7.3.2. As usual the Dataroute/Infodat values are based only on the 266 non-zero distances.

Dataroute /Infodat	U_1	86	$s \leq 300$
		173	s=600
		338	s=1200
		578	s=2400
		950	s=4800
Infoexchange	U_2	.336	s=4800
Datapac	U_3	38.8*	Grade 3
Infocall	U_4	.441	
Telephone	U_5	.306	(Trans-Canada)

*does not include NIM charge

Figure 7.3.2: Utilization charges for GTA identified interactive terminals

Using the above usage charges, the optimum service partitions shown in Figure 7.3.3 can be calculated using the method developed in Section 6. The "average" terminal locations are also indicated. This figure may be compared with Figure 6.3.6 and the strong resemblence noted. While an Infocall region exists, the terminals are not there.

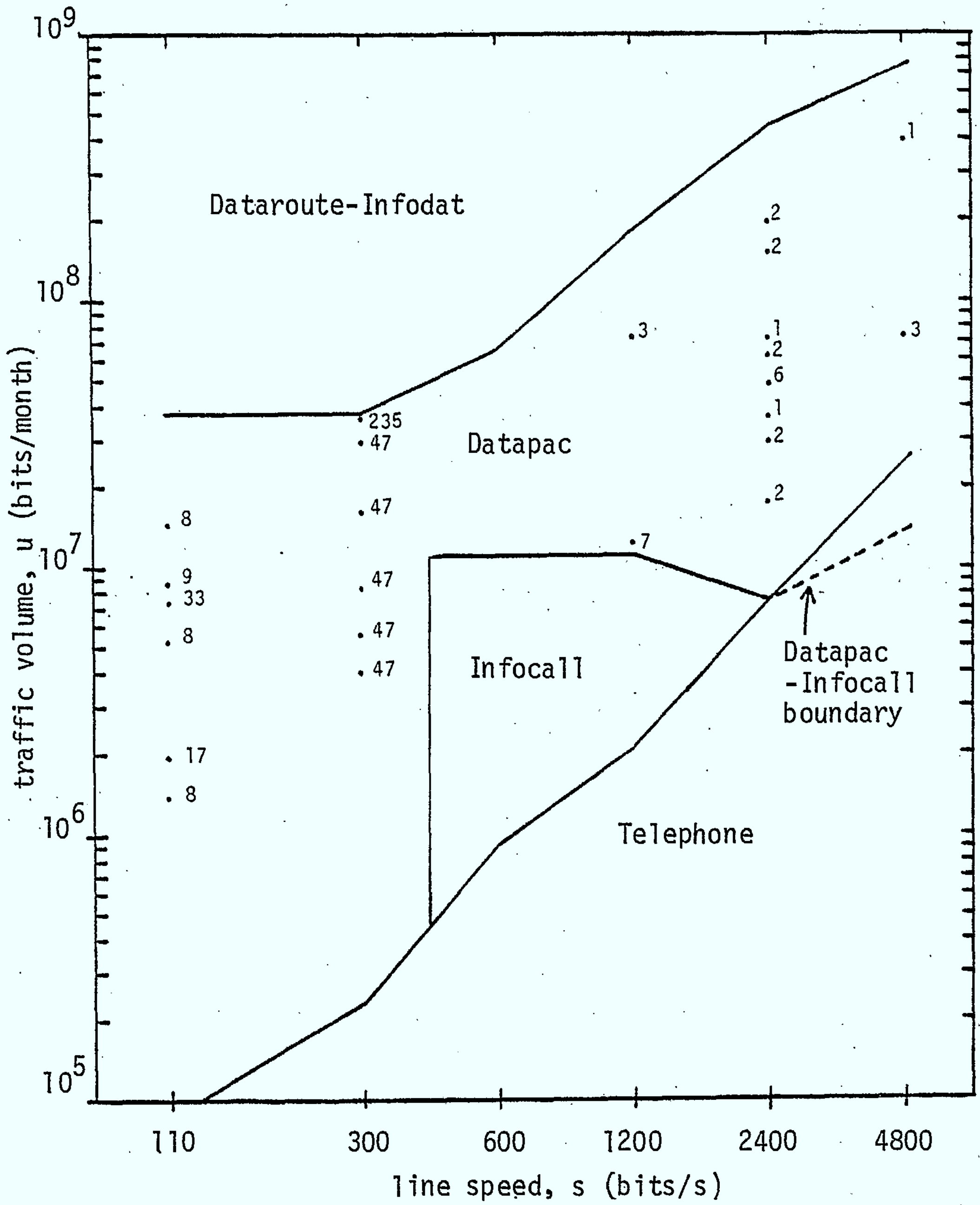


Figure 7.3.3: Optimum service regions, Government interactive terminal applications, showing numbers of terminals, (b=250, i=0.2)

To produce the partitions it was necessary to assume values for i and b. The values selected were i=0.2 and b=250 which represent median values, for this type of application, as listed in Figure 2.5.2. Reasonable variations do not affect the form of the results.

All the sample points fall in the Datapac region except a large cluster of terminals at 300 bit/s that are almost on the boundary with digital leased lines. (This boundary should be interpreted carefully since $\overline{U}_1$ is based only on non-zero distances.) Figure 7.3.1 indicates that the average connect time for the 300 bit/s terminals was 5.4 hours/day. If this represents a valid reporting of the production time, and i=0.2 is a reasonable estimate then leased lines should be considered. However, if this time represents unused connection time, then a much lower i is appropriate, and the terminals will move to the Datapac region. Of course if the connection is via a local telephone call, then that is already the most economical service.

7.3.3 RJE APPLICATIONS

A total of 112 RJE applications were obtained from the survey data. The distribution of terminal speeds and average connection time is shown in Figure 7.3.4.

Of these 112 terminals, 34 are located at a "zero" distance from the host computer; the balance are distributed approximately exponentially with distance with an average in the order of 600 miles. As with the interactive application

speed	600	1200	2000 and 2400	4800	9600	19200
number of terminals	3	32	55	14	7	1
average connection time (hr/day)	6.0	3.3	2.8	5.0	2.9	20

Figure 7.3.4: RJE terminal speed and usage distribution (GTA)

most of the "zero" distances were located in the Ottawa area. Using the distance distribution to calculate the average utilization charges yields the values in Figure 7.3.5. As usual the digital leased line values are based only on the non-zero distances.

Dataroute/ Infodat	U_1	159	s=600
		317	s=1200
		546	s=2400
		900	s=4800
		1143	s=9600
		2280	s=19200
Infoexchange	U_2	.198	
Datapac	U_3	45.6*	Grade 3
Infocall	U_4	.581	
Telephone	U_5	.450	

*does not include NIM charge at s=600

Figure 7.3.5: Utilization charges for GTA identified RJE terminals

Using the above usage charges, the optimum service partitions shown in Figure 7.3.6 can be calculated. Also shown in the figure are the "average" terminal locations with respect to traffic volume and speed. It was assumed that

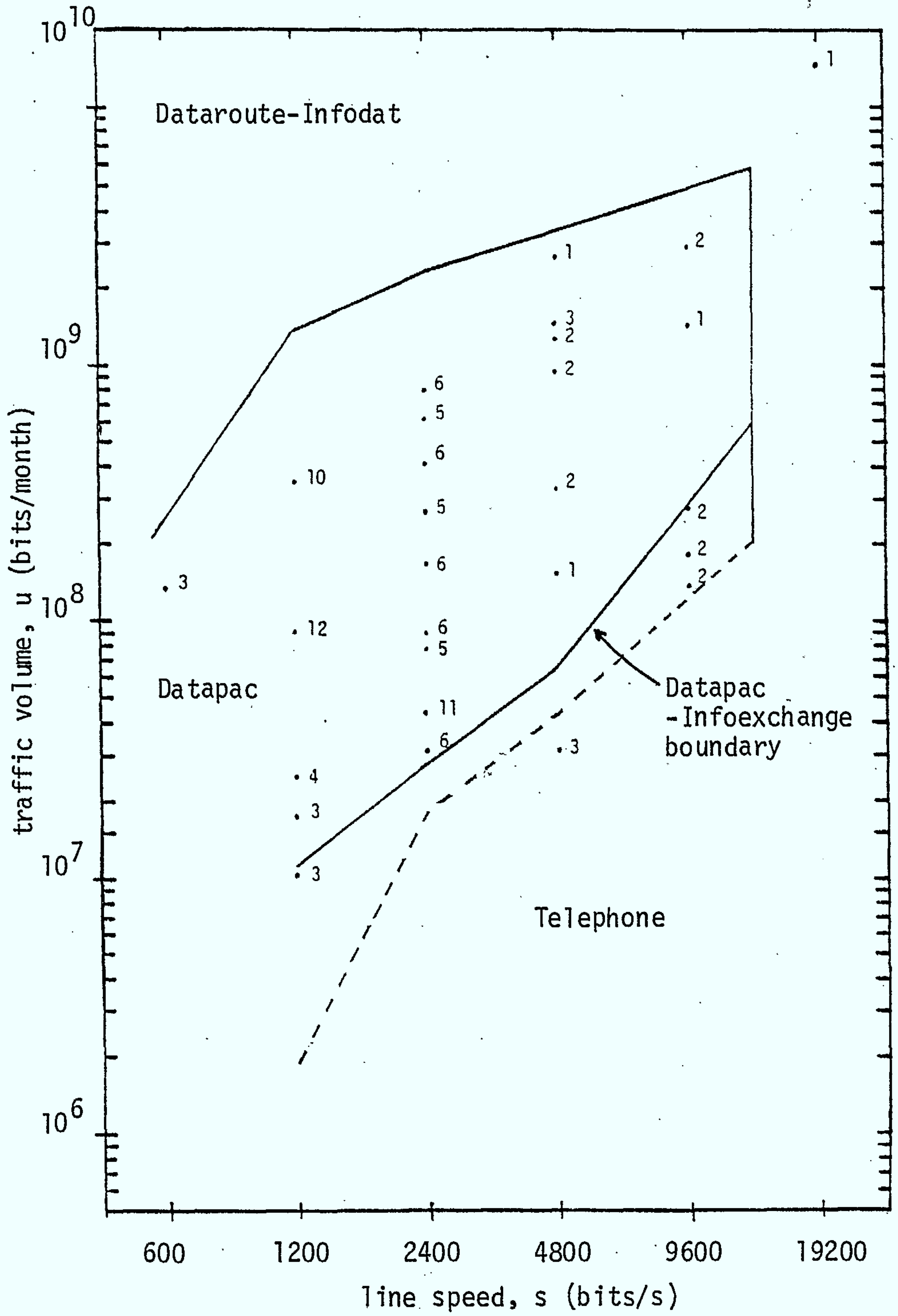


Figure 7.3.6: Optimum service regions, Government RJE applications, showing numbers of terminals, (b=2000, i=0.5)

the packet length b was 2000 bits, and that the communications intensity i was 0.5. This value is lower than the value of 0.8 used in Section 6.7, but since many of the terminals appeared to be connected for a long period of time, using a smaller value seems more reasonable. Further reducing i could move partitions by a factor of two but this does not affect the form of the result.

It can be seen that Datapac is the more economical service.

In conclusion, we may note that for both interactive terminal traffic and RJE traffic the partition diagrams are essentially the same as those for general users as developed in Section 6, and hence all comments in that section are relevant to government data communications activities.

7.4 COSTPRO

COSTPRO (Canadian Organisation for the Simplification of Trade Procedures) is involved extensively in the investigation of using data networks for the handling of trade documents associated with the movement of goods. Several studies have been undertaken in the past. These include the development of a special purpose intelligent terminal and modelling of trade-related data traffic, etc. This section deals with the evaluation of costs for handling such trade related traffic. Given the tariffs for various packet-switched public data networks, and the total traffic we can evaluate expected costs of using such networks. That is the objective of this section.

The modelling of trade related traffic [9] considered the document flow associated with the movement of goods in both the domestic and international environments. A detailed study of this nature would require the shipment volume for each city in the TRADEX network. For our initial study such statistics were not available. However we had adequate details for one location viz. Toronto. These statistics gave information regarding goods movement in the four modes of transportation, namely, road, rail, air and water. We have used the traffic model for this one city and together with GNP figures for Toronto and other regions (or provinces) produced traffic source-destination volume matrices for all the regions of the TRADEX network. First consider the various messages which arise in the movement of goods.

As identified by COSTPRO, there are several types of data messages associated with a shipment. These include long messages for customs, consignee, etc., short carrier messages, enquiry and response messages into various data bases, etc. The TRADEX network can be conceptually viewed as three stages of interactions as shown in Figure 7.4.1. Each stage has its own data base or library. Data traffic associated with a particular shipment can be present at all levels. This traffic in terms of messages have been identified earlier. We observe that since a public network is envisaged for use in handling this traffic, it will not matter how the various messages are distributed over the

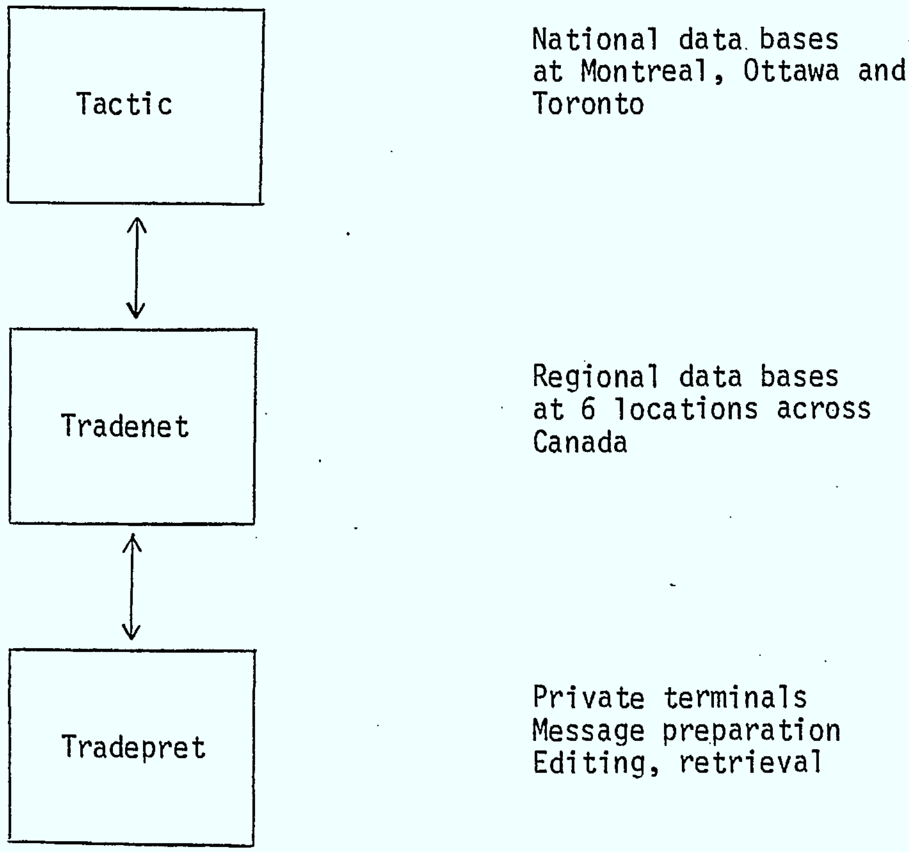

Tactic
National data bases
at Montreal, Ottawa and
Toronto
Tradenet
Regional data bases
at 6 locations across
Canada
Tradepret
Private terminals
Message preparation
Editing, retrieval

Figure 7.4.1

three stages. As such we shall deal with the total expected volume and its distribution by region rather than by the three stages. Consider now the various messages associated with the movement of a shipment.

i) Long Messages: These messages of 800 and 600-character size, occur between the shipper, consignee, insurance company, customs, etc. With reference to Figure 7.4.1, these would be at the Tradepret level. The long messages are initiated at a terminal in a region and their destination would also be some terminal in the system.

ii) Short Messages: These are between the shipping company and the regional data bases. These short messages concern carrier identification, updates, scheduling requests, archiving requests, etc. The short messages are at the Tradenet level and will make use of the various regional data bases.

iii) Enquires: Associated with each shipment there will be enquiries regarding tariffs, import duties, taxes, customs formalities, goods code number, etc. These are short messages each with a response. These occur between various terminals and the databases at the federal level, i.e., at TACTIC, COSTPRO has identified these database (libraries) locations as Toronto, Ottawa, Montreal with possible expansion in the future. In our studies we have used the preliminary locations only.

The messages described above are identified by Type Number and are illustrated in Figure 7.4.2.

Given the volume of shipments in each mode and the message generation as outlined in Figure 7.4.2, a traffic volume study can be carried out. Such a study was undertaken for COSTPRO in 1976 and the results are reported in [9]. The table of Figure 7.4.3 gives the results in a summary form for Toronto and has formed the basis for our present study.

7.4.1 DATA TRAFFIC PROJECTIONS FOR OTHER REGIONS

Given the 'goods movement' activity of the other provinces we can obtain the message traffic for each province similar to that shown in Figure 7.4.3 for Toronto. However such information is not readily available. In consultation with COSTPRO staff [10] it was agreed that a reasonable method for estimating the message traffic for the six regions of the TRADEX network would be to extrapolate the Toronto figures using GNP figures. The following table gives GNP figures for various provinces grouped together into various regions - each region corresponding to a particular database in Tradenet.

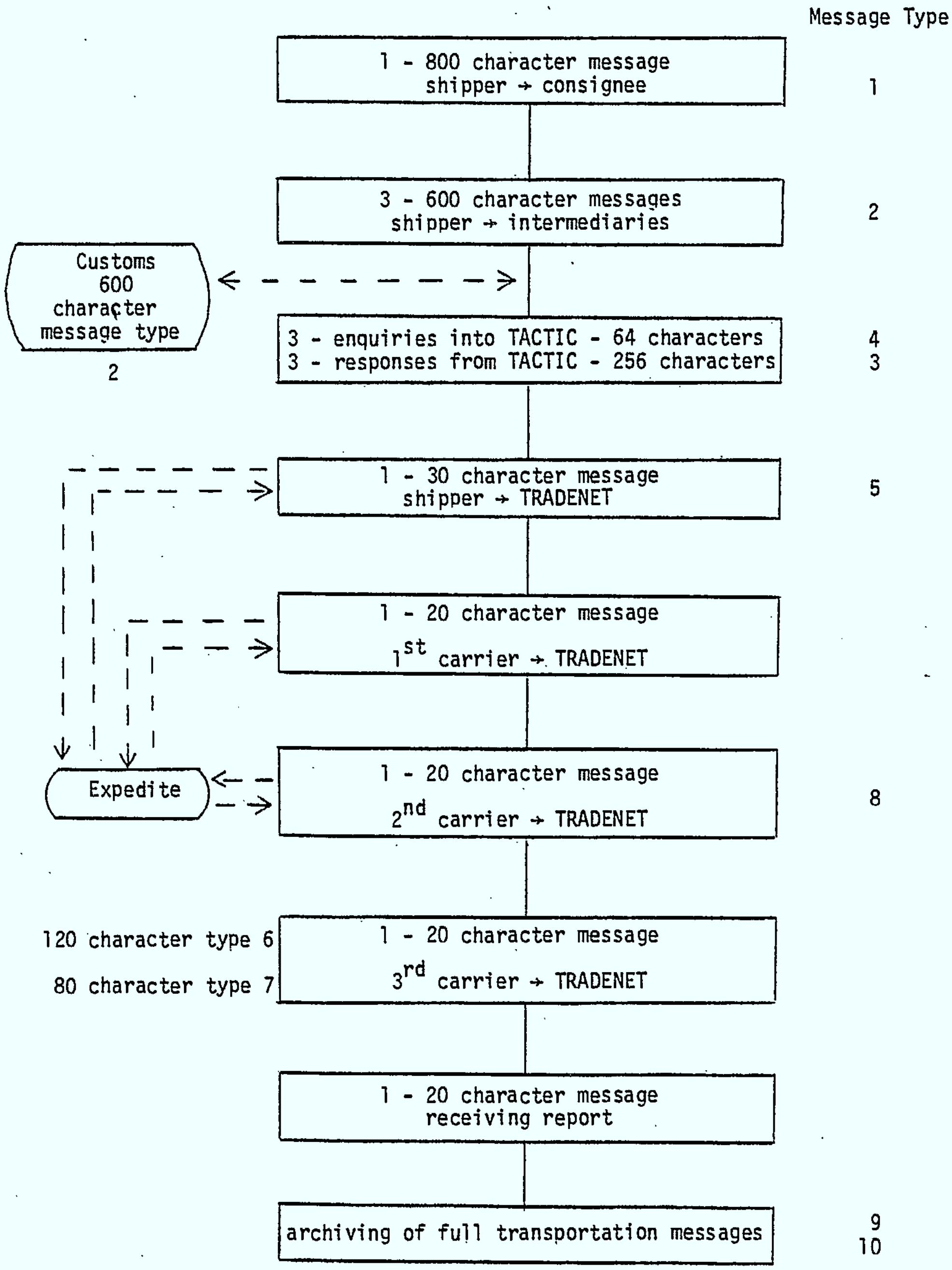


Figure 7.4.2: Messages Per Shipment

		G.N.P.	
Region 1	British Columbia	11.00	%
Region 2	Alberta	9.63	%
Region 3	Sask. Manitoba, N.W. Territories	8.06	%
Region 4	Ontario	38.83	%
Region 5	Quebec	25.84	%
Region 6	N.B, N.S, N.F, P.E.I.	6.64	%

In terms of GNP figures, Toronto represents 29% while Montreal represents 18% of the Canadian GNP total. Thus the message traffic of Figure 7.4.3 represents 29% of the total traffic. This relation to GNP can now be used to find the total traffic for other regions. We note that the 'water mode' traffic is of the order of 1% of the total. Hence, although it does not occur for some of the regions, its inclusion will not cause any significant errors, in the traffic analysis. The expected message traffic calculated using GNP figures, is shown in Figure 7.4.4. Here the provinces are identified by regions of the TRADEX network.

7.4.2 TERMINALS AND THEIR DISTRIBUTION

The terminals in such a network will generally be associated with the trading companies, shipping agencies, transport companies, customs, banks, etc.

The concentration of these terminals will depend on the size of the companies. The projections by COSTPRO are based on a random sample of 7915 companies in all the provinces. If this sample is used and if we assume that as stipulated by COSTPRO, 80% of the companies will use the network by

Message Type and Type Length in Characters	Number of Messages/Month by Each Mode: Road	Rail	Air	Water	Total Number for Each Type	Total as % of all Network Traffic
1 Shipper → Consignee 800	1,485,939	793,327	105,145	13,901	2,398,312	9.97 %
2 Shipper → Intermediaries 600	4,545,663	2,526,902	352,865	49,427	7,474,858	31.1 %
3 TACTIC Responses 256	2,476,566	1,322,214	175,242	23,109	3,997,191	16.62 %
6 Expedite 120	-	161,115	35,048	2,317	198,480	.8 %
7 Expedite 80	165,104	-	-	-	165,104	.69 %
4 TACTIC Enquiries 64	2,476,566	1,322,214	175,242	23,169	3,997,191	16.62 %
5 Shipper → TRADENET 30	825,522	440,738	58,414	7,723	1,332,397	
8 Transport Messages & Receiving Reports 20	1,651,044	1,246,315	234,656	19,307	3,151,322	13.1 %
9 Archive 120	-	440,738	58,414	7,723	506,875	2.1 %
10 Archive 80	825,522	-	-	-	825,522	.34 %
				TOTAL NUMBER OF MESSAGES	24,047,252	

Figure 7.4.3: Message Activity per Month for all Modes for Toronto

Message Type	Message Details	Region 1 British Columbia	Region 2 Alberta	Region 3 Sask. Manitoba, N.W.T.	Region 4 Ontario	Region 5 Quebec	Region 6 N.B., N.S., NFLD, P.E.I.
1	800 characters shipper → consignee	909,705	796,405	668,565	3,211,257	2,136,979	549,131
2	600 characters shipper → intermediaries	2,835,291	2,482,168	2,077,495	10,008,577	6,660,356	1,711,485
3	256 characters Tactic Responses	1,516,176	1,327,343	1,110,943	5,352,100	3,561,635	915,219
4	64 characters Tactic Enquiries	1,516,176	1,327,343	1,110,943	5,352,100	3,561,635	915,219
5	30 characters Transport Messages	505,392	442,448	370,315	1,784,034	1,187,212	305,073
6	120 characters Expedite	75,286	65,909	55,164	265,758	178,853	45,445
7	80 characters Expedite	62,626	54,826	45,888	221,089	147,113	37,803
8	20 characters Transport	1,195,329	1,046,456	875,850	4,219,512	2,807,937	721,544
9	120 characters Archive	192,263	168,318	140,876	678,688	451,643	116,057
10	80 characters Archive	313,129	274,130	229,438	1,105,346	735,569	189,017

Figure 7.4.4: Messages for Six Regions (Messages/Month)

1984, we obtain a terminal count of 129847 terminals (Figure 7.4.5). This is almost twice as many as the number arrived at by other estimates. We have discussed this aspect with COSTPRO staff [10]. It has been suggested that the higher number is more likely to be correct. We feel that if this were the case then the revenue from access charges (e.g. DATAPAC) will be of the order of $13 M per month. This is excessive. Furthermore, given the traffic volume, an extremely low intensity is achieved. In view of these considerations, we feel that the terminal projections are inaccurate. We recommend that a more detailed study of this aspect be undertaken by COSTPRO or DOC to obtain a more accurate estimate of the number of terminals. In our tariff calculations, therefore, we have used a modified approach. This is outlined in the next section. We have also considered the possible distribution of traffic based on some COSTPRO statistics. These deal with the number of testing days. These calculations are based on census values provided by Statistics Canada. The percentage terminal and/or traffic distribution among the various cities is shown in Figure 7.4.6.

For tariff calculations, since the terminal distribution is not well defined, and since the traffic for most locations is small, we have assumed that as a first approximation we can assume that for any one region all traffic is concentrated into one city. It should be pointed out that once accurate figures for terminal distributions are known,

	Company Size →	3	4	5	6	7	8	9	10	11	12		
	Terminal → Concentration	1	1	2	4	8	12	16	16	16	16		
Region	Provinces ↓	Number → of Terminals										Total	80 % Total
2	Alberta	3230	1820	1540	2360	2960	1680	80	-	160	80	13910	11128
1	British Columbia	4180	2340	1820	2800	4400	2400	112	48	128	-	18228	14583
3	Manitoba	1720	1330	1420	1920	2720	1800	-	48	64	-	11022	8818
3	Saskatchewan	1440	850	700	1000	960	360	32	16	48	-	5406	4325
3	N.W.T. & Yukon	500	160	140	-	160	-	-	-	16	-	976	781
4	Ontario	11710	5760	5000	7720	12080	8040	240	96	336	128	51110	40888
5	Quebec	7800	4940	4720	6640	9280	6600	256	16	272	48	40572	32458
6	New Brunswick	1310	970	880	1200	1920	720	32	-	64	32	7128	5702
6	Nova Scotia	1540	1060	920	1520	1440	840	16	-	192	-	7528	6023
6	Prince Edward Island	490	340	300	280	-	-	-	-	-	-	1410	1128
6	Newfoundland	1040	1040	1360	560	560	360	32	32	32	-	5016	4013
												162526	129847

1984 Projection

Figure 7.4.5: Terminal Projections: 1984 Projection

	% Terminal Distribution % Traffic Distribution
Region 1	
Kamloop	10
Prince George	10
Vancouver	70
Victoria	10
Region 2	
Calgary	50
Edmonton	50
Region 3	
Regina	37
Saskatoon	13
Winnipeg	50
N.W.T.	-
Region 4	
Brantford	1
Cornwall	1
Guelph	1
Hamilton	3
Kingston	1
K-W	2
London	3
Oshawa	1
Ottawa	3
Peterborough	1
St. Catherines	1
Sarnia	1
Sault Ste. Marie	1
Sudbury	1
Thunderbay	1
Toronto	75
Windsor	3
Region 5	
Chicoutimi	1.5
Drummondville	1.5
Hull	1.5
Montreal	75
Quebec	7
Rimonski	1.5
Rouyn-Noranda	1.5
St. Jean	1.5
St. Jerome	1.5
Sept. Iles	1.5
Sherbrooke	1.5
Sorel	1.5
Trois-Rivieres	1.5
Valleyfield	1.5
Region 6	
St. John	20
Halifax	20
Sydney	20
St. John's	20
Charlottetown	20

Figure 7.4.6: Distribution of Traffic and Terminals Within the Six Regions

the model can be easily modified to perform a more detailed evaluation. Thus for our calculations, the source-destination traffic matrix will consist of six regions as sources and as destinations.

7.4.3 SOURCE-DESTINATION OF MESSAGES

Since no details are available, we have made the following assumptions in our calculations of source-destination traffic distributions.

a) All TACTIC traffic regardless of origin will go to the three data bases or originate from them. These three data bases are at Toronto, Ottawa, and Montreal. We shall assume that this traffic is uniformly distributed. We note that TACTIC will eventually have more locations. However given the volume of traffic to and from TACTIC this should not have a very significant effect on tariff projections. All TACTIC traffic is to be at 9600 bits/sec. This will affect the access charges in DATAPAC. This aspect is considered in tariff calculations.

b) All carrier messages, i.e., transportation messages, will be directed to the regional data bases in the region of the shipping company and also to other regions according to the trade volume.

c) All long messages concern the terminals, with the terminal at the consignee or customer, acting as destination. We have stipulated that regions trade with each other according to their respective GNP figures. This will apply to carrier messages also. Thus for all provinces 38.83% of the total goods movement is to Ontario. Consider now tariff evaluations for one specific case, i.e., DATAPAC.

7.4.4 COSTPRO TRAFFIC AS VIEWED BY DATAPAC

Datapac packets can be any size up to a maximum of 256 characters. The tariffs are to be levied in two parts.

1) Terminal access charge. This access charge will depend on the speed required.
2) Transmission charges in $/kilopackets per month. No speed constraint is imposed in this part of the tariff.

In what follows, we shall first evaluate the transmission charges. We note that calculation of the first part is trivial once the number of terminals is known. The message volume matrix can now be modified such that the volume is now in kilopackets/month for each message type. This table is shown in Figure 7.4.7. It should be noted that long message traffic are all maximum size packets and account for almost 70% total packet traffic.

From Figures 7.4.10 and 7.4.11 we note that for DATAPAC to handle the COSTPRO traffic, the transmission cost would be $96844 per month. To this must be added the 'access' charges. These will depend on the speed used by the terminals. If only 1% of the terminal projection is used then we would have 1300 terminals. Even at the lowest bit rate of 300 bits/sec., the access charge would be $136,500 per month. This charge will increase as the terminal count and speed requirements increase with the effect that the 'access' charges will tend to dominate in the revenue projections.

The total number of packets to be handled by DATAPAC is 159.37×10^6 packets/month. This corresponds to a volume of 251.5 packets/sec. Consider now the use of Infocall service to handle this traffic.

Message Type	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	% of Total Packets
1	3.64	3.19	2.68	12.85	8.55	2.20	20.78
2	8.51	7.45	6.23	30.03	19.98	5.14	48.53
3	1.52	1.33	1.11	5.35	3.56	0.92	8.65
4	1.52	1.33	1.11	5.35	3.56	0.92	8.65
5	0.51	0.44	0.37	1.78	1.19	0.31	2.89
6	0.075	0.066	0.055	0.27	0.18	0.045	0.43
7	0.063	0.055	0.046	0.22	0.15	0.037	0.37
8	1.20	1.05	0.88	4.22	2.81	0.72	6.83
9	0.19	0.17	0.14	0.68	0.45	0.12	1.10
10	0.31	0.27	0.23	1.11	0.74	0.19	1.79

Total Number of Packets = 159.37 X 10^6 packets/month

NOTE: Maximum Packet Size 256 characters

Minimum Packet Size 20 characters

Figure 7.4.7: Packets Corresponding to DATAPAC (X 10^6 packets/month)

Destination/ Source	1	2	3	4	5	6
1	1.6	1.4	1.17	5.63	3.75	0.99
2	1.4	1.22	1.02	4.93	3.28	0.87
3	1.17	1.02	0.86	4.13	2.75	0.73
4	5.63	4.93	4.12	19.87	13.22	3.50
6	0.96	8.44	0.71	3.40	2.26	0.60

NOTE: All messages except type no. 3 and 4 are accounted in the above matrix.

Figure 7.4.8: Source/Destination Volume Matrix ($X10^3$ k8/month)

To/From Region	Ottawa	Montreal	Toronto
1	1.02	1.02	1.02
2	.88	.88	.88
3	.74	.37	.37
4	3.56	3.56	3.56
5	2.38	2.38	2.38
6	0.62	0.62	0.62

Figure 7.4.9: TACTIC Traffic accounting for Messages Type 3 and 4 ($X10^6$ packets/month)

Transmission Charges

	1	2	3	4	5	6
1	304	742	866	5236	3563	1030
2	742	232	551	4388	2985	870
3	866	551	198	3469	2420	708
4	5236	4380	3461	2981	5288	2450
5	3563	2985	2420	5288	1319	1351
6	1030	8440	689	2380	1311	138

Total Revenue: $84420

Figure 7.4.10: Transmission Charges using DATAPAC for Traffic of Figure 7.4.8

Tactic $ Revenue

	Ottawa	Toronto	Montreal
1	969	949	969
2	792	783	819
3	3229	3118	3266
4	1146	534	1424
5	595	952	357
6	391	434	360

Total Revenue: $12424

Figure 7.4.11: Transmission Charges using DATAPAC for TACTIC messages from Figure 7.4.9

7.4.5 COSTPRO TRAFFIC IN TERMS OF OTHER SERVICES

Infocall type services have based their tariff rates in terms of message characters to be transmitted per month. This can be easily calculated since message volume is known (Figure 7.4.4). Thus Figures 7.4.12, 7.4.13, and 7.4.14, give the volumes by characters/month. In particular Figure 7.4.4 deals with source/destination matrix of traffic for Tradenet. Given this together with the Infocall tariffs we can easily evaluate the revenue. Infocall tariffs are subject to a certain minimum rate. We have assumed that COSTPRO traffic is such that the actual rate will apply, in which case these tariffs are then specified for 10000 characters. The total costs are now $2.3 M/month for transmission alone (Figures 7.4.15 and 7.4.16). We observe that this is much higher than for DATAPAC. It would therefore appear that COSTPRO is better suited to DATAPAC service than for Infocall.

Message Type	Regions 1	2	3	4	5	6
1	728.1	637.0	535.0	2569.0	1710.0	435.0
2	1701.2	1489.3	1246.5	6005.0	3996.2	1026.9
3	338.0	339.8	284.4	1370.1	911.8	23430.0
4	97	84.9	71.1	342.5	227.9	58.6
5	15.2	13.3	11.1	53.5	35.6	9.2
6	9.0	7.9	6.6	31.9	21.5	5.5
7	5.0	4.4	3.7	17.7	11.8	3.0
8	23.9	20.9	17.5	84.4	56.2	14.4
9	23.1	20.2	16.9	81.4	54.2	13.9
10	25.1	21.9	18.4	88.4	58.8	15.1

TOTAL: 23003.8 X 10^6 characters/month

Figure 7.4.12: Source/Destination Traffic Volume Matrix For All Messages Excluding TACTIC Type Messages ($X10^6$) Characters/Month.

To/From	Regions 1	2	3	4	5	6
1	278.4	243.7	204.0	982.6	653.9	173.1
2	243.5	213.2	178.5	859.7	572.1	151.4
3	204.1	178.7	149.5	720.5	479.5	126.9
4	982.4	860.1	719.9	3468.2	2307.9	610.9
5	657.8	572.4	479.1	2308.1	1536.0	406.5
6	167.9	147.0	123.0	592.9	384.5	1044.0

TOTAL: 23003.8 X 10^6 characters/month

Figure 7.4.13: Source/Destination traffic volume matrix for all messages excluding TACTIC type messages (X 10^6) characters/month.

To/From Region	Ottawa	Toronto	Montreal
1	161.7	161.7	161.7
2	141.6	141.6	141.6
3	118.5	118.5	118.5
4	570.9	570.9	570.9
5	379.9	379.9	379.9
6	22.6	22.6	22.6

Figure 7.4.14: TACTIC Traffic X 10^6 characters/month

	1	2	3	4	5	6
1	4176	17059	20400	117888	78468	20772
2	17040	3198	12496	103164	68652	18168
3	20110	21444	2243	79255	57540	15228
4	117888	103212	79189	52023	161553	73308
5	78936	68688	57484	161567	23040	28455
6	20148	17640	14760	71148	46140	1566

Total Cost = $2.017 M/month

Figure 7.4.15: Transmission Costs with Infocall services ($/month) for Traffic of Figure 7.4.13

To/From Region	Ottawa	Toronto	Montreal
1	19404	19404	19404
2	16992	16992	16992
3	14220	14220	14220
4	28545	8564	9963
5	18995	26593	5699
6	2034	2260	1582

Total Cost = $286083/month

Figure 7.4.16: Transmission Costs for TACTIC Messages ($/month)

SECTION 8. REFERENCES

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APPENDIX

TABLE OF GEOGRAPHICAL DISTANCES

The following pages contain the geographical distance, in miles, between all cities served by Dataroute, Infodat, Datapac and Infoswitch. The following abbreviations are used to identify the cities:

bar	Barrie	nby	North Bay
bmp	Brampton	oak	Oakville
bdn	Brandon	osh	Oshawa
btf	Brantford	ott	Ottawa
cal	Calgary	pet	Peterborough
ctn	Charlottetown	pge	Prince George
clk	Clarkson	que	Quebec
cor	Cornwall	rdr	Red Deer
edm	Edmonton	reg	Regina
fre	Fredricton	stc	St. Catherines
gal	Galt	sth	Ste. Hyacinthe
gra	Granby	stj	St. John
gue	Guelph	sts	St. John's
hal	Halifax	sar	Sarnia
ham	Hamilton	sas	Saskatoon
jon	Jonquiere	ssm	Sault Saint Marie
kam	Kamloops	shb	Sherbrooke
kel	Kelowna	sud	Sudbury
kng	Kingston	syd	Sydney
kit	Kitchener	ter	Terrace
let	Lethbridge	tby	Thunderbay
lon	London	tim	Timmins
mht	Medicine Hat	tor	Toronto
mct	Moncton	trs	Trois Rivieres
mon	Montreal	van	Vancouver
mjw	Moose Jaw	vic	Victoria
nel	Nelson	wds	Windsor
ngf	Niagara Falls	wnp	Winnipeg
nor	Noranda	woo	Woodstock

	bar	bmp	bon	btf	cal	ctn	clk	cor	edm
bar	0.								
bmp	50.	0.							
bon	1026.	1041.	0.						
btf	92.	46.	1040.	0.					
cal	1646.	1600.	626.	1664.	0.				
ctn	811.	830.	1700.	806.	2301.	0.			
clk	61.	14.	1053.	42.	1678.	826.	0.		
cor	240.	205.	1217.	304.	1840.	506.	263.	0.	
edm	1038.	1602.	632.	1665.	175.	2245.	1675.	1814.	0.
fre	642.	600.	1551.	697.	2159.	169.	657.	396.	2111.
gal	78.	35.	1029.	16.	1653.	863.	37.	299.	1653.
gra	347.	306.	1296.	405.	1916.	464.	304.	101.	1883.
gue	65.	26.	1025.	29.	1655.	856.	32.	291.	1648.
hal	790.	802.	1723.	834.	2333.	112.	797.	545.	2285.
ham	80.	30.	1053.	22.	1677.	843.	22.	282.	1677.
jon	487.	522.	1292.	566.	1893.	408.	524.	286.	1840.
kam	1919.	1938.	899.	1934.	274.	2571.	1950.	2113.	352.
kal	1884.	1902.	867.	1897.	251.	2550.	1914.	2084.	361.
kng	157.	167.	1163.	203.	1789.	664.	163.	103.	1773.
kit	77.	39.	1019.	24.	1643.	869.	44.	305.	1643.
let	1589.	1606.	574.	1601.	108.	2268.	1618.	1790.	267.
lon	125.	88.	1005.	50.	1627.	915.	89.	352.	1632.
mht	1493.	1511.	476.	1507.	165.	2168.	1523.	1693.	270.
mct	732.	750.	1630.	787.	2235.	79.	747.	486.	2183.
mon	308.	330.	1255.	369.	1875.	504.	328.	66.	1844.
mjw	1270.	1290.	250.	1288.	375.	1941.	1302.	1466.	402.
nel	1788.	1805.	773.	1799.	178.	2464.	1817.	1990.	325.
ngf	95.	53.	1092.	61.	1717.	810.	40.	253.	1714.
nor	208.	317.	950.	358.	1564.	756.	328.	301.	1528.
nby	133.	182.	972.	223.	1596.	778.	193.	245.	1574.
oak	66.	17.	1052.	37.	1678.	831.	6.	268.	1675.
osh	53.	48.	1072.	88.	1698.	782.	47.	217.	1690.
ott	206.	233.	1163.	275.	1786.	607.	233.	54.	1761.
pet	67.	84.	1082.	126.	1708.	749.	84.	183.	1696.
pge	2017.	2041.	1007.	2043.	414.	2613.	2054.	2193.	380.
que	441.	408.	1327.	509.	1938.	386.	468.	209.	1895.
rar	1640.	1662.	623.	1602.	85.	2273.	1675.	1826.	90.
reg	1232.	1252.	212.	1253.	414.	1902.	1264.	1427.	432.
stc	88.	44.	1081.	51.	1706.	817.	30.	258.	1704.
sth	339.	361.	1279.	409.	1898.	473.	359.	96.	1865.
stj	669.	684.	1596.	718.	2207.	150.	679.	423.	2162.
sjs	1304.	1326.	2122.	1364.	2692.	500.	1323.	1061.	2614.
sar	168.	140.	958.	107.	1578.	970.	144.	406.	1587.
sas	1339.	1303.	330.	1364.	328.	1974.	1375.	1523.	302.
ssm	269.	296.	753.	307.	1379.	1007.	310.	473.	1368.
shb	386.	405.	1332.	442.	1950.	425.	402.	140.	1916.
sud	159.	204.	900.	235.	1524.	850.	217.	318.	1505.
syd	951.	909.	1832.	1005.	2427.	140.	965.	705.	2366.
ter	2252.	2277.	1245.	2285.	650.	2830.	2290.	2424.	615.
tby	532.	558.	494.	565.	1119.	1224.	571.	723.	1105.
tim	293.	340.	843.	373.	1459.	863.	353.	392.	1425.
tor	54.	19.	1058.	57.	1684.	812.	15.	249.	1679.
trs	370.	397.	1279.	438.	1894.	449.	397.	139.	1856.
van	2050.	2067.	1034.	2062.	418.	2718.	2079.	2251.	509.
vic	2070.	2086.	1058.	2079.	452.	2749.	2097.	2274.	557.
wds	222.	190.	960.	151.	1570.	1017.	191.	454.	1591.
wnp	901.	924.	125.	925.	747.	1576.	936.	1094.	740.
woo	103.	62.	1019.	24.	1643.	889.	63.	326.	1645.
	bar	bmp	bon	btf	cal	ctn	clk	cor	edm

	fre	gal	gra	gus	hal	ham	jon	kam	kel
fre	0.								
gal	694.	0.							
gra	295.	400.	0.						
gue	686.	13.	392.	0.					
hal	174.	833.	448.	828.	0.				
ham	674.	25.	382.	29.	812.	0.			
jon	274.	557.	219.	546.	446.	546.	0.		
kam	2431.	1924.	2189.	1921.	2605.	1949.	2164.	0.	
kel	2408.	1888.	2161.	1885.	2581.	1912.	2142.	66.	0.
kng	494.	199.	202.	192.	636.	180.	382.	2062.	2030.
kit	700.	10.	406.	14.	840.	35.	560.	1914.	1878.
lat	2122.	1591.	1870.	1588.	2294.	1616.	1859.	338.	297.
lon	746.	53.	453.	63.	884.	72.	609.	1897.	1859.
mht	2023.	1497.	1772.	1494.	2195.	1522.	1760.	428.	391.
mct	90.	783.	385.	770.	115.	764.	342.	2506.	2484.
mon	335.	364.	42.	356.	489.	347.	228.	2149.	2121.
mjw	1795.	1277.	1544.	1273.	1967.	1301.	1533.	649.	617.
nel	2319.	1790.	2069.	1787.	2492.	1814.	2050.	158.	102.
ngf	642.	66.	352.	67.	776.	41.	525.	1988.	1952.
nor	501.	343.	357.	330.	773.	348.	356.	1837.	1812.
nby	613.	208.	331.	195.	775.	213.	410.	1869.	1839.
oak	662.	32.	369.	29.	801.	16.	530.	1949.	1913.
osh	612.	82.	318.	74.	754.	67.	478.	1970.	1936.
oct	438.	268.	145.	258.	592.	254.	295.	2059.	2030.
pat	579.	119.	284.	109.	724.	105.	440.	1981.	1947.
pge	2483.	2032.	2261.	2027.	2657.	2056.	2211.	246.	311.
que	225.	503.	121.	494.	396.	487.	110.	2210.	2186.
rdr	2135.	1651.	1899.	1647.	2308.	1675.	1866.	302.	296.
reg	1756.	1240.	1505.	1236.	1929.	1264.	1494.	687.	656.
stc	648.	55.	358.	57.	784.	31.	528.	1978.	1941.
sth	364.	395.	[illegible]	386.	460.	378.	208.	2172.	2144.
stj	50.	716.	324.	709.	127.	695.	328.	2480.	2456.
sjs	667.	1360.	960.	1352.	558.	1341.	856.	2955.	2942.
sar	801.	108.	507.	115.	941.	129.	655.	1647.	1809.
sas	1834.	1353.	1595.	1348.	2007.	1376.	1566.	598.	578.
ssm	843.	293.	562.	286.	1007.	314.	624.	1652.	1619.
shb	256.	438.	[illegible]	431.	408.	420.	209.	2224.	2197.
sud	685.	219.	405.	207.	849.	231.	474.	1797.	1767.
syd	309.	1002.	604.	995.	195.	982.	540.	2696.	2677.
tar	2704.	2208.	2489.	2203.	2877.	2292.	2431.	436.	500.
tby	1068.	552.	804.	540.	1238.	575.	821.	1392.	1361.
tim	709.	357.	458.	345.	880.	368.	461.	1732.	1706.
tor	643.	51.	350.	44.	784.	36.	510.	1955.	1920.
trs	283.	432.	66.	423.	448.	417.	155.	2167.	2141.
van	2576.	2052.	2329.	2050.	2749.	2077.	2310.	157.	168.
vic	2505.	2070.	2354.	2067.	2778.	2094.	2341.	206.	202.
was	848.	155.	555.	164.	984.	173.	709.	1843.	1303.
wnp	1426.	913.	1172.	909.	1598.	937.	1168.	1020.	990.
woo	72.	27.	427.	38.	858.	46.	584.	1913.	1876.
	fre	gal	gra	gus	hal	ham	jon	kam	kel

	kng	kit	let	lon	mht	mct	mon	mjw	nel
kng	0.								
kit	206.	0.							
let	1735.	1581.	0.						
lon	252.	50.	1563.	0.					
mht	1638.	1487.	99.	1470.	0.				
mct	584.	789.	2200.	836.	2100.	0.			
mon	169.	369.	1829.	417.	1731.	424.	0.		
mjw	1413.	1267.	327.	1252.	228.	1873.	1503.	0.	
nel	1935.	1780.	200.	1761.	298.	2397.	2028.	525.	0.
ngf	150.	75.	1655.	110.	1561.	731.	319.	1340.	1854.
nor	302.	339.	1523.	379.	1424.	683.	319.	1196.	1721.
nby	204.	204.	1546.	246.	1448.	701.	289.	1222.	1745.
osk	167.	40.	1617.	84.	1522.	752.	333.	1301.	1816.
osh	119.	87.	1640.	135.	1545.	702.	282.	1322.	1839.
ott	91.	272.	1737.	321.	1639.	528.	104.	1412.	1936.
pet	90.	123.	1652.	172.	1556.	669.	247.	1332.	1851.
pge	2152.	2022.	513.	2010.	578.	2552.	2222.	767.	385.
que	312.	507.	1898.	556.	1799.	310.	144.	1572.	2097.
rdr	1780.	1641.	182.	1628.	204.	2203.	1859.	379.	245.
reg	1375.	1230.	366.	1215.	267.	1834.	1465.	39.	564.
stc	156.	65.	1645.	101.	1551.	738.	324.	1330.	1844.
sth	199.	400.	1853.	448.	1755.	394.	31.	1527.	2052.
stj	517.	722.	2168.	768.	2069.	84.	365.	1841.	2366.
sjs	1161.	1365.	2672.	1413.	2574.	578.	997.	2351.	2363.
sar	307.	161.	1512.	58.	1420.	891.	470.	1204.	1710.
sas	1477.	1343.	317.	1331.	226.	1908.	1555.	129.	498.
ssm	411.	283.	1324.	287.	1227.	930.	520.	1003.	1523.
shb	240.	444.	1906.	491.	1807.	346.	81.	1580.	2105.
sud	268.	212.	1473.	243.	1376.	773.	363.	1149.	1673.
syd	803.	1008.	2397.	1054.	2297.	219.	644.	2070.	2592.
tar	2385.	2258.	744.	2248.	814.	2771.	2451.	1006.	592.
tby	671.	542.	1067.	538.	970.	1151.	763.	744.	1267.
tim	373.	350.	1416.	380.	1317.	791.	419.	1090.	1615.
tor	149.	57.	1624.	104.	1529.	733.	314.	1307.	1823.
trs	241.	436.	1852.	485.	1753.	371.	75.	1525.	2050.
van	2197.	2042.	462.	2023.	558.	2652.	2288.	785.	263.
vic	2218.	2060.	484.	2039.	583.	2682.	2313.	811.	285.
wds	354.	151.	1507.	102.	1416.	937.	519.	1203.	1703.
wnp	1642.	903.	698.	892.	600.	1506.	1131.	372.	897.
woo	225.	26.	1579.	26.	1485.	809.	391.	1267.	1773.
	kng	kit	let	lon	mht	mct	mon	mjw	nel

	ngf	nor	nby	oak	osh	ott	pat	pge	que
ngf	0.								
nor	356.	0.							
nby	223.	135.	0.						
oak	39.	333.	198.	0.					
osh	56.	300.	170.	52.	0.				
ott	231.	251.	191.	239.	187.	0.			
pat	91.	275.	150.	90.	38.	149.	0.		
pge	2094.	1905.	1953.	2054.	2070.	2139.	2076.	0.	
que	461.	377.	393.	473.	421.	235.	384.	2269.	0.
rdr	1714.	1545.	1583.	1675.	1693.	1772.	1701.	388.	1915.
rsg	1303.	1157.	1183.	1264.	1284.	1374.	1294.	801.	1533.
stc	16.	351.	218.	29.	54.	234.	91.	2083.	466.
sth	349.	338.	316.	364.	313.	134.	278.	2243.	116.
stj	661.	646.	649.	684.	636.	468.	604.	2534.	270.
sjs	1309.	1212.	1258.	1328.	1278.	1098.	1244.	2964.	867.
sar	168.	399.	272.	140.	188.	371.	223.	1965.	607.
sas	1415.	1242.	1280.	1375.	1392.	1469.	1399.	679.	1613.
ssm	349.	276.	232.	310.	322.	421.	329.	1748.	621.
shb	389.	389.	369.	407.	357.	184.	323.	2293.	102.
suo	253.	152.	74.	220.	208.	265.	200.	1884.	464.
syo	948.	892.	918.	970.	921.	747.	888.	2731.	525.
ter	2330.	2132.	2185.	2290.	2305.	2370.	2310.	239.	2492.
tby	611.	408.	478.	572.	585.	669.	592.	1485.	843.
tim	387.	107.	173.	356.	338.	339.	322.	1803.	484.
tor	41.	318.	184.	20.	32.	218.	69.	2058.	453.
trs	390.	330.	330.	402.	350.	165.	314.	2232.	71.
van	2117.	1980.	2006.	2078.	2102.	2197.	2114.	321.	2354.
vic	2134.	2007.	2030.	2096.	2121.	2221.	2134.	381.	2382.
wcs	208.	454.	328.	186.	237.	423.	273.	1967.	658.
wnp	975.	826.	849.	936.	954.	1040.	962.	1119.	1202.
woo	85.	363.	229.	58.	109.	295.	146.	2024.	530.
	ngf	nor	nby	oak	osh	ott	pat	pge	que

rcr	0.								
reg	414.	0.							
stc	1704.	1293.	0.						
sth	1881.	1488.	354.	0.					
stj	2184.	1802.	668.	335.	0.				
sjs	2653.	2313.	1315.	900.	653.	0.			
sar	1381.	1167.	159.	501.	823.	1467.	0.		
sas	303.	145.	1404.	1578.	1882.	2365.	1286.	0.	
ssm	1372.	965.	340.	548.	881.	1479.	263.	1072.	0.
shb	1932.	1541.	393.	53.	284.	921.	545.	1629.	501.
sud	1513.	1111.	246.	391.	722.	1326.	253.	1210.	158.
syc	2397.	2032.	956.	613.	289.	365.	1109.	2099.	1146.
tar	627.	1446.	2319.	2471.	2756.	3165.	2202.	916.	1983.
tby	1109.	705.	601.	788.	1111.	1671.	501.	807.	263.
tim	1441.	1051.	380.	[illegible]	753.	1315.	384.	1137.	195.
tor	1680.	1270.	34.	344.	666.	1309.	158.	1380.	312.
trs	1374.	1486.	395.	53.	322.	936.	535.	1571.	506.
van	456.	824.	2136.	2312.	2524.	3103.	1972.	745.	1786.
vic	498.	856.	2124.	2337.	2652.	3144.	1987.	779.	1807.
wds	1581.	1167.	200.	550.	868.	1514.	55.	1290.	298.
wnp	739.	334.	965.	1155.	1472.	2005.	847.	440.	633.
wod	1642.	1236.	76.	422.	741.	1386.	83.	1345.	292.
	rcr	reg	stc	sth	stj	sjs	sar	sas	ssm

shb	0.								
sud	443.	0.							
syc	565.	939.	0.						
tar	2521.	2117.	2945.	0.					
tby	941.	456.	1359.	1726.	0.				
tim	492.	138.	999.	2032.	361.	0.			
tor	338.	212.	951.	2294.	575.	346.	0.		
trs	72.	402.	589.	2458.	790.	436.	382.	0.	
van	2364.	1934.	2845.	431.	1528.	1874.	2086.	2319.	0.
vic	2390.	1957.	2876.	477.	1551.	1900.	2104.	2336.	65.
wds	593.	307.	1155.	2205.	519.	435.	206.	587.	1965.
wnp	1208.	777.	1707.	1356.	372.	719.	941.	1154.	1157.
wod	465.	233.	1028.	2261.	547.	370.	77.	459.	2340.
	shb	sud	syc	tar	tby	tim	tor	trs	van

vic	0.			
wds	1978.	0.		
wnp	1132.	853.	0.	
wod	2057.	129.	905.	0.
	vic	wds	wnp	wod