1. INTRODUCTION

International telecommunication traffic flows, especially those in telephony, are influenced by the effect of difference in local standard times between the two places of calling and called parties. For the purposes of network planning and circuit operation, it is necessary to know quantitatively the nature of traffic flows influenced by the time difference. There have not been, however, any time distribution patterns available for use for such purposes.

This paper proposes a set of traffic distribution patterns for each hour of a day on the circuits connecting stations located in different time zones. The distributions are derived by postulating a function \( f(t) \), which represents the degree of convenience to each party in making a telephone call, and which is a function of the local time \( t \). The time distribution of traffic between two stations is then proposed to be convolution of two convenience functions. Using these distribution patterns, the nature of the traffic flows influenced by the time difference will be clarified.

In the latter part of this paper, discussions are made concerning network efficiency and network planning. When we consider circuit efficiency in the international network which involves many locations of different time zones, the fact that busy traffic hours of various routes do not coincide must be taken into account. It is proposed that efficiency is expressed by the average efficiency over sufficiently long period, so that the effects of time difference are fully reflected to the observed efficiency.

Network is composed of stations and circuit groups connecting them. In order to express the whole network, we usually make summation of the products of number of circuit groups by their length. Likewise, a new unit to express traffic volume can be introduced which is defined by the product of traffic duration of a call (in Erlang) by the length to its destination. This volume is called as traffic work \( w(t) \), which is also considered to be a function of time. A new measure to express network efficiency is then defined and proposed.

Using the newly defined measure of network efficiency, it becomes possible that performance of network and routing rules are quantitatively evaluated. Examples to have applied this measure to some cases such as comparison of demand assignment satellite systems, large detour routing in the global network model, and others are shown in this paper.

2. TIME DIFFERENCE

2.1 MATHEMATICAL EXPRESSION OF TRAFFIC FLOW INFLUENCED BY TIME DIFFERENCE

Telephone traffic occurs when a man wishes to call someone and starts dialling, but a pair of parties have to be on the line in order that a telephone call is established. It is therefore considered that a telephone call is made at the time which is convenient for both of the calling and called parties. Degree of convenience for making a telephone call is considered to be a periodical function of time \( t \), whose cycle being 24 hours. We express the degree of convenience in the form of \( f(t) \), when time difference does not exist between both parties, where \( t \) is local standard time. We will call \( f(t) \) as basic pattern. The graphic shape of
f(t) will be determined by the mode of human activities, and will resemble or fairly coincide to the hourly traffic distribution of national (or local) telephone network.

Let us consider the hourly traffic distribution when Τ hours of time difference exist between the originating and the called locations. It can be assumed that the hourly traffic distribution \( F_{R}(t) \) is expressed by convolution of convenience functions of two locations Τ hours apart:

\[
F_{R}(t) = k \{ f(t) \cdot f(t + \tau) \}^{n}
\]

(1)

When there is no time difference (Τ = 0), \( F_{R}(t) \) should be f(t) itself by definition. Therefore the value of n in the above equations is determined as n = 1/2. The sign of \( \tau \) is positive when the time difference at the destination is gaining, and negative when the time of destination is behind the reference time.

The distribution of equation (1) represents the sum of outgoing and incoming traffic. It is known that the traffic flow is directional when there exists time difference. In Tokyo-Oakland circuits, for example, the incoming traffic to Japan is greater than the outgoing traffic from Japan in the morning, but the direction of superior traffic flow changes in the evening.

In order to express directional hourly traffic distribution, we need to extend the concept of convenience function f(t), and define convenience function for the caller \( f_{c}(t) \) and convenience function for the called \( f_{d}(t) \). Then the directional traffic distribution of east-bound and west-bound telephone calls, in case of Τ hour difference, are similarly expressed as follows:

\[
\begin{align*}
F_{R, east}(t) &= k \{ f_{c}(t) \cdot f_{d}(t + \tau) \}^{1/2} \\
&= k \left[ \int_{24 \text{ hours}} \{ f_{c}(t) \cdot f_{d}(t + \tau) \}^{1/2} \right. \\
&\left. \cdot dt \right]^{1/2}
\end{align*}
\]

(2)

\[
\begin{align*}
F_{R, west}(t) &= k \{ f_{d}(t) \cdot f_{c}(t + \tau) \}^{1/2} \\
&= k \left[ \int_{24 \text{ hours}} \{ f_{d}(t) \cdot f_{c}(t + \tau) \}^{1/2} \right. \\
&\left. \cdot dt \right]^{1/2}
\end{align*}
\]

(3)

where \( t \) is the local standard time of west station in case of positive \( \tau \).

It is a nature of telephony that a caller makes a call considering the convenience of the called person, and therefore convenience function of the called person \( f_{d}(t) \) contributes much more than the convenience of the caller \( f_{c}(t) \) to the directional distribution \( F_{R} \). We can write as follows:

\[
f_{d}(t) = k_{1} \{ f(t) \}^{p} \cdot f_{0}(t) = k_{2} \{ f(t) \}^{q}
\]

(4)

where \( k_{1} \) and \( k_{2} \) are normalizing coefficients to satisfy the following relations:

\[
\int_{24 \text{ hours}} f_{d}(t) \cdot dt = 1, \quad \int_{24 \text{ hours}} f_{0}(t) \cdot dt = 1
\]

2.2 HOURLY DISTRIBUTION PATTERN

For easiness of calculation and also considering the actual application, we will choose a steps-like function in Fig. 1 as the basic pattern f(t). Calculation was made by equation (1) to get the hourly distribution \( F_{R}(t) (\tau = 1 \sim 12) \). The results showed that the midnight part of traffic volume in the calculated distribution was considerably larger than that of the measured distribution on the actual international circuits. There are very little traffic from one to six o’clock in the morning on the commercial circuits. It was observed that convenience function at the midnight time affects too much to the output when product of convenience functions are calculated.

A slight modification of the equation (1) will improve the defects. By putting:

\[
\begin{align*}
f(t) &= f(t) - \Delta F \\
\Delta F &= 0.004 (\text{the value of distribution from 1 to 6 o’clock in Fig. 1})
\end{align*}
\]

and if equation (1) is modified as follows:

\[
\begin{align*}
F_{R}(t) &= k' \{ f'(t) \cdot f'(t + \tau) \}^{1/2} + \Delta F \\
k' &= (1 - 24 \Delta F) / \left[ \int_{24 \text{ hours}} \{ f'(t) \cdot f'(t + \tau) \}^{1/2} \right. \\
&\left. \cdot dt \right]
\end{align*}
\]

(5)

then, correlation of convenience functions at the midnight band is effectively suppressed, and the calculated distributions have become to fit the actual data.

The shape of basic pattern f(t) as shown in Fig. 1, however, is a provisional one which is simply assumed from the hourly distribution in a local telephone network. We have to obtain a proper shape of basic pattern f(t) by some means. Changing the shape of the steps-like function f(t) little by little, fitness of calculated distributions to the measured distributions on Tokyo-Oakland and Tokyo-Vancouver circuits (1) was checked, and as its result the graphic shape of function f(t) which showed the best fitness was determined as the basic function.

The steps-like function shown in Fig. 1 is actually the function thus obtained. Fig. 2 and Fig. 3 show that the calculated distributions agrees fairly well with the measured distributions on the commercial circuits.
2.3 NATURE OF TRAFFIC FLOWS INFLUENCED BY TIME DIFFERENCE

We are able to clarify the inherent nature of telephone traffic flows influenced by the effect of time difference by utilizing the calculated bothway traffic distributions (Annex 1) and the directional traffic distributions which are obtainable from the modified equations (2) and (3). The effect of time difference on the telephone traffic is summarized as follows:

(1) Peak factor:
In comparison with the case of no time difference, existence of time difference makes the suitable time band (STB, suitable time in a day for making a telephone call) shorter, and peak factor higher. Within 7 hours of time difference, the larger the difference, the higher becomes peak factor.

(2) Two suitable time band
At 8 hours or more time difference, two suitable time bands appear in a day.

(3) West- and east-bound traffic
All the west-bound traffic distributions have their only peak in the afternoon (referred to the clock at the east side station) regardless whether the time difference is large or small. On the other hand, though the east-bound traffic distributions for the time difference of less than 8 hours have their only peak in the afternoon (referred to the clock of the east side station), a second peak appears in the morning when the difference is 8 hours, and the second peak becomes larger according as the time difference becomes larger, finally exceeding the peak in the afternoon.

(4) Compound time zone
On the circuits to the compound-time-zone area (such as the United States which have 4 time zones), time difference smoothing effects are observed, that is, the suitable time band becomes longer compared with the case on the single time-zone circuits.

3. NETWORK EFFICIENCY

It is considered that the telecommunication services consist of two conflicting factors, efficient utilization of communication facilities and maintenance of high grade of service. In the telephone network, the both factors are represented by circuit efficiency and loss probability respectively. In order to evaluate the international network, discussions are made here for both factors, and also a proposal is made to combine the two factors.

3.1 CIRCUIT EFFICIENCY WHEN TIME DIFFERENCE IS CONSIDERED

In most cases circuit efficiency is expressed by

\[ \eta = \frac{a}{n} \]  

where, \( a \) is carried traffic in Erlang and \( n \) is number of circuits.

In the international network, however, the busiest hours of one part do not coincide with those of the other part. The expression of equation (6) is insufficient, since it is possible to route more than two kinds of traffic flows with different peak hours on to one circuit group. To fully express the efficiency in such cases, it is necessary that average circuit efficiency is taken over sufficiently long observation period \( T \). The equation (6) is then extended as follows:

\[ \overline{\eta} = \frac{1}{T} \int_0^T \eta(t) \, dt = \frac{1}{T} \int_0^T \frac{a(t)}{n} \, dt \]  

where \( a(t) \) is traffic in Erlang as a time function. When a global network is considered, the observation period \( T \) should be 24 hours.

3.2 TRAFFIC WORK

In most of the studies on traffic theory which have been dealt hitherto, traffic volume has been taken as the volume to occupy "circuits" and not as the volume to occupy "circuit length". When we consider the services offered by the network, it will be necessary to take account of circuit length and number of switching connections, in addition to the time during which circuits are occupied. That is to say, a measuring unit of traffic volume is necessary that takes account of the work (service) which the network offers to the customers.

Let us introduce a new unit to express the traffic volume. Traffic work \( V_{ij} \) between Stations \( i \) and \( j \) is defined by the following equations:

\[ V_{ij} = c_{ij} \cdot a_{ij} \cdot C_{ij} = a(1, s) \]  

where \( a_{ij} \) is traffic volume in Erlang between Stations \( i \) and \( j \), and \( c_{ij} \) is a cost coefficient determined by the transmission cost \( 1 \) and switching cost \( s \) when a call is connected between Stations \( i \) and \( j \).

In the case of trans-oceanic submarine cable circuits, for example, cost coefficient is determined by circuit length, and in the case of satellite circuits the coefficient will become a constant regardless of the surface length of the two stations. If the switching cost is dominant to the transmission cost, the traffic work is written as

\[ (\text{Traffic work}) = (\text{Traffic Erlang}) \times (\text{Number of Links}) \]

The traffic work \( V_{ij} \) has two meanings: (1) the work which a call requests the network to perform (Demand), and (2) the work done by the network for a call (Carried traffic). As for the demand traffic in meaning (1), there can be a few definitions to specify the cost coefficient:

(1) hypothetical great circle distance to connect the originating and the terminating stations;
(2) the shortest route among the existing routes to connect the call; and
(3) the average route distance of all the existing routes to connect the call.

Coefficient (1) is determined independent of the actual shape of network and considered to be proper for purely theoretical network study, and coefficients (2) and (3) are proper for actual evaluation of the existing network. The coefficient (2) is simpler and convenient for calculation, and therefore adopted in this paper.

3.3 NETWORK EFFICIENCY

Network efficiency can be induced by extending circuit efficiency to the all branches which compose the network. In the definition of average circuit efficiency of equation (7), we have to replace the traffic volume \( a(t) \) by the traffic work \( V(t) \) in advance. The network efficiency is then defined as the ratio of the average total traffic volume carried in the network concerned during the observation time \( T \) to the summation of all the component circuits of the network concerned where component circuits are weighted by the cost coefficient.

The network efficiency \( \overline{E} \) will read:

\[ \overline{E} = \frac{\sum_i \sum_j T \int_0^T V_{ij}(t) \, dt}{T \sum C_{pq} n_{pq}} \]  

where

- \( V_{ij}(t) \): Demand traffic work which is being carried in the network at time \( t \). The origin of the call is Station \( i \) and its destination is Station \( j \) or vice versa.
- \( C_{pq} \): Cost coefficient between the neighboring and directly connected stations \( p \) and \( q \).
- \( n_{pq} \): Number of the circuits connecting the neighboring stations \( p \) and \( q \).

3.4 AVERAGE BLOCKING PROBABILITY

The loss probability usually used for direct circuits between 2 stations is the following Erlang B formula:
As for the blocking probability of the whole network, we can consider (1) average loss probability per link, (2) overall loss probability for the permissible maximum tandem links to connect a call, and (3) average network blocking probability defined by the following equation (3): 

\[ B = \frac{\sum_{ij} a_{ij} \cdot b_{ij}}{\sum_{ij} a_{ij}} \]  

(11)

where,

\[ a_{ij} : \text{demand traffic in Erlang between stations } i \text{ and } j \]
\[ b_{ij} : \text{loss probability on the circuits between stations } i \text{ and } j \]
when \[ a_{ij} \] is offered.

In order to express the nature of whole network, the blocking probability of equation (11) is superior to the others.

As mentioned in the previous discussions, the blocking probability of equation (11) is to be extended to represent the average value during the observation time \( T \), and also to replace traffic volume (in Erlang) \( a_{ij} \) by the traffic work \( v_{ij} \). It will become as follows:

\[ B = \frac{\sum_{ij} \frac{v_{ij}(t) \cdot b_{ij}(t) \, dt}{T}}{\sum_{ij} \frac{v_{ij}(t) \cdot b_{ij}(t) \, dt}{T}} \]  

(12)

3.5 EVALUATION OF NETWORK PERFORMANCE

There can be considered two ways of network evaluation, analytical evaluation and synthetic evaluation. If we take the analytical approach, changing the traffic conditions or the routing rules, we will evaluate the performance of network by its average blocking probability. If we make approaches from synthetic point of view, changing the traffic conditions or the grade of services, the network will be evaluated by its efficiency (or equivalently by the required number of circuits, total circuit length, or overall cost of the facilities). In both cases, either blocking probability or efficiency is the measure of evaluation and the other is a parameter to be changed. Therefore, if we measure that involves both of them is obtained, any network can be evaluated by this measure. Here is proposed such a new measure to evaluate overall network performance that takes account of balance of efficiency and service grade. This measure will be called as performance efficiency \( P \).

To include loss probability \( B \) into the performance efficiency \( P \), we will use the form of call success probability \( 1-B \), and for efficiency \( E \), it will be proper to use the form \( E \) as it is. As for the method to combine them, there can be considered a few forms such as

(1) \[ E^2 + k(1-B)^2 \]
(2) \[ E^2 + rxE(1-B) + k(1-B)^2 \]
(3) \[ E^2(1-B) \] As the second one (2) is intermediate means between (1) and (3), we will compare the methods (1) and (3).

The method (1) is usually adopted to combine mutually independent values, but \( E \) and \( 1-B \) actually make influence to each other. In addition, \( P \) must tend to zero according as either \( E \) or \( 1-B \) tends to zero, since the performance efficiency is to show the degree of overall balance of efficiency and grade of services.

Thus the form (3) is chosen, and we obtain the following performance efficiency:

\[ P = E^2(1-B) \]  

(13)

As \( E \) and \( B \) in the performance efficiency, \( E \) of equation (9) and \( B \) of equation (12) should be used respectively. Concerning the \( I \) and \( J \) in the equation (13), though the simplest values \( I=J=1 \) are usable in purely theoretical studies, it is necessary to decide proper values from the viewpoints of circuit engineering. Generally, we will not be lost if proper value of \( J \) is sought with \( I \) fixed to be \( I=1 \).

3.6 EXAMPLE

In a very simple network of Fig. 4, suppose that the traffic demand shown by equations (14) and (15) occurs between each station.

\[ R(T_1) = \begin{bmatrix} (1) & 30 & 0 & 10 \\ (2) & 30 & 40 & 10 \\ (3) & 10 & 40 & 20 \\ (4) & 0 & 10 & 20 \end{bmatrix} \]  

(14)

\[ R(T_2) = \begin{bmatrix} (1) & 20 & 0 & 10 \\ (2) & 20 & 0 & 10 \\ (3) & 10 & 0 & 20 \\ (4) & 30 & 10 & 20 \end{bmatrix} \]  

(15)

Let us consider the following questions. "Determine the circuit capacity of each branch of the network so as to perform most efficient operation and also to maintain a certain grade of services."

![Fig. 4 Simple Network](image)

Table 1 is the result of calculation when loss probability per link is set to be 0.01. The table shows that the total required circuit length in the large detour routing method is 401, while that in the shortest path method is 441. Since the same traffic load is offered to the network, the large detour method is about 10% superior in efficiency to the shortest path method. As for the average blocking probability, however, the table shows that the large detour method is a little inferior.

Changing the link blocking probability, calculation was made similarly and the performance efficiency of equation (13) was obtained as shown in Fig. 5. 1 of equation (13) is fixed to \( I=1 \) and \( J \) is changed from 0 to 3. \( T_1 \) in the figure denotes the performance efficiency \( E(1-B) \). The upmost curves for the heavy

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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1, 2)</td>
<td>1</td>
<td>50</td>
<td>64</td>
<td>64</td>
<td>45</td>
<td>58</td>
</tr>
<tr>
<td>(2, 3)</td>
<td>2</td>
<td>50</td>
<td>64</td>
<td>128</td>
<td>35</td>
<td>47</td>
</tr>
<tr>
<td>(3, 4)</td>
<td>3</td>
<td>20</td>
<td>30</td>
<td>90</td>
<td>35</td>
<td>47</td>
</tr>
<tr>
<td>(4, 1)</td>
<td>3</td>
<td>40</td>
<td>53</td>
<td>159</td>
<td>25</td>
<td>36</td>
</tr>
<tr>
<td>Total</td>
<td>160</td>
<td>211</td>
<td>441</td>
<td>140</td>
<td>188</td>
<td>401</td>
</tr>
<tr>
<td>( E )</td>
<td>0.538</td>
<td></td>
<td>0.592</td>
<td></td>
<td>0.592</td>
<td></td>
</tr>
<tr>
<td>( B )</td>
<td>0.0081</td>
<td></td>
<td>0.0099</td>
<td></td>
<td>0.0099</td>
<td></td>
</tr>
</tbody>
</table>
Performance Efficiency

![Graph showing Performance Efficiency vs. Link Blocking Probability](image)

**Fig. 5 Performance Efficiency**

**4. NETWORK PLANNING**

In planning the construction of submarine cables or satellite systems, it is necessary to have the knowledge on traffic flows influenced by the time difference. Also in operating the international circuits, we have to know the nature of the time difference traffic. The effect of time difference on the circuit operation and system design is studied here by assuming some network models.

4.1 LINEAR CIRCUITS

On the linear circuits which are connected in tandem, the traffic flows observed at the east-end station show low peak factor, while those observed at the west-end station have a peak in the morning (as referred to the local time of west-end station).

As an example, let us suppose linear circuits with 7 stations which are placed on the line in such a manner that the distance from a station to its neighboring stations is 2 hours of time difference as shown in Fig. 6. If the traffic demand between any two stations during a day is all the same amount, the expected hourly distribution on the east-end section (6, 7) will become as shown in Fig. 7 and that on the west-end section (1, 2) will become as shown in Fig. 8. The peak of traffic distribution on the west-end station occurs because every eastern station is waiting the sunrise and business hours of the west station and calls to Station 1 concentrate from 9 to 12 o'clock in the morning (referred to the clock of Station 1).

4.2 CIRCLE NETWORK

The effect of time difference typically appears on the circle network surrounding the earth in the east-west direction. It is therefore necessary and interesting to investigate the nature of circle network. As mentioned in the previous section 3.6, there are two ways of routing in such a circle network: (1) shortest path routing which always route calls on to the nearest path (or direction) to their destination, and (2) detour routing method by which calls are permitted to select the lightly loaded direction from time to time.

Finally, we are now able to answer the above-mentioned question as follows: "The large detour routing method is recommended. Required number of circuits on each section is as shown in Table 1. In this case, average blocking probability and network efficiency are both within proper extent which maintains optimum network performance efficiency."
In the case of shortest path routing, the amount of traffic on each circuit section is easily calculated, for the direction of each call is uniquely determined. In the case of large detour routing, the traffic volume to flow on each section can be obtained by means of linear program by taking account of the minimum value of cut-sets.\(^5\)

The following is a brief explanation of the linear programming method to seek the maximum traffic flow on each section. On the model network of Fig. 9, let us suppose that the traffic demands at time \(t_K\) \((K \geq 1, 2, \ldots, m)\) between any two stations are given by the following matrix.

\[
M(t_K) = \begin{pmatrix}
  (1) & K_{v1} & K_{v1} & \cdots & K_{v1n} \\
  (2) & K_{v2} & K_{v2} & \cdots & K_{v2n} \\
  \vdots & \vdots & \vdots & \ddots & \vdots \\
  (m) & K_{vn} & K_{vn} & \cdots & (n)
\end{pmatrix}
\]

where,

\[
K_{vj} = x_{ij}\ \text{and} \ x_{ij} = \text{vi}^jF_{T}\ (t_K)
\]

\(\text{vi}^j\) : total traffic demand between Stations i and j. During a day

\(t, t_j\) : standard time and local time respectively

\(T = t_j - t_i\)

We will further denote the required number of circuits on section \((q, q+1)\) as \(Z_q\) and its length as \(C_q\). For all the times \(t_K\) \((K = 1, 2, \ldots, m)\), in order that the circle network can handle the traffic demand \(M(t_K)\), the following relation must be satisfied between the required number of circuits and the cut-sets to cross the section \((p-1, p)\) and section \((q, q+1)\).

\[
Z_{p-1} + Z_q \geq \sum_{h=1}^{n} K_{vh}h
\]

where,

\(p, q = 1, 2, \ldots, n\) \((p < q)\)

\(h = p, p+1, \ldots, q-1, q\)

\(\sum\) : denotes total summation for all \(h\) and \(i\) except \(i=h\).

As these inequalities contain \(n\) variables \(Z_i\) \((i=1, 2, 3, \ldots, n)\) and number of inequalities is \(1/2n (n+1)\), we can not solve them algebraically. Using inequalities \((17)\) as limiting conditions, however, we can solve \(Z_i\) by the linear programming method to minimize the total circuit length \(C\) of equation \((18)\). Though \(Z_i\) has been treated as the number of circuits on section \((i, i+1)\) in the above explanation, it should be considered as the maximum amount of traffic on the section concerned for all \(K\) of \(t_K\).

\[
C = \sum_{i=1}^{n} C_i \cdot Z_i
\]

4.3 OPERATIONAL FEATURES OF CIRCLE NETWORK

Taking some simple models as examples, the operational features of circle network was examined. In the first model with 24 stations \((n = 24\) in Fig. 9) which are placed with equal interval, the time difference between the neighboring stations is an hour.

Supposing 30 Erlang traffic between any two stations, calculation was made to obtain the required number of circuits of each section, and network efficiency \(E\) defined by equation \((9)\). Table 2 shows its result.

### Table 2 Required Number of Circuits

<table>
<thead>
<tr>
<th>Routing Method</th>
<th>Max. Erlang per Sect.</th>
<th>Link Blocking Prob. 1%</th>
<th>Link Blocking Prob. 0.1%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Circuits</td>
<td>Net Eff</td>
<td>No. of Circuits</td>
</tr>
<tr>
<td>Shortest Path</td>
<td>170 E</td>
<td>190 Ch</td>
<td>44.4%</td>
</tr>
<tr>
<td>Detour</td>
<td>105 E</td>
<td>122 Ch</td>
<td>67.8%</td>
</tr>
</tbody>
</table>

As the number of tandem connection is not limited in this model,
Table 5 shows the calculated total hourly traffic distributions at each station. The underlined figures are the maximum traffic at each station. We see in this table that the traffic peak of each station ranges from time 3 to time 12, though most of the station peaks concentrate between time 9 and time 12, and that the peak of the grand total traffic 3359.7 Erl is 9.2% of the total traffic 3640 Erl. offered to the system in a day.

Required number of satellite channels to carry the traffic given by Table 4 is calculated for 3 typical operation modes, and the result is shown in Table 6. The circuit gaining effect derived from TASI like system is also calculated as shown in Table 7.

Table 6  Comparison of Operation Modes

<table>
<thead>
<tr>
<th>Operation Modes</th>
<th>Fixed Assign.</th>
<th>Time Preassign.</th>
<th>Variable Destin.</th>
<th>Fully Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required No. of Ch.</td>
<td>5472 Ch</td>
<td>4588 Ch</td>
<td>4074 Ch</td>
<td>3554 Ch</td>
</tr>
<tr>
<td>Percent No. of Ch.</td>
<td>100%</td>
<td>84%</td>
<td>75%</td>
<td>65%</td>
</tr>
<tr>
<td>Ckt. Efficiency of eq. (9)</td>
<td>27.7%</td>
<td>33.1%</td>
<td>37.2%</td>
<td>42.7%</td>
</tr>
</tbody>
</table>

Table 7  Effect of TASI-like System

<table>
<thead>
<tr>
<th>Operation Modes</th>
<th>Fixed Assign.</th>
<th>Time Preassignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required No. of Channel</td>
<td>4078 Ch</td>
<td>3530 Ch</td>
</tr>
<tr>
<td>Required No. of Channel</td>
<td>75%</td>
<td>65%</td>
</tr>
<tr>
<td>Ckt. Efficiency of eq. (9)</td>
<td>37.2%</td>
<td>43.0%</td>
</tr>
</tbody>
</table>

It can be concluded from the above calculation that: (1) Circuit economization is remarkable in the fully variable mode, (2) Circuit economization effect is not so remarkable in the case of time pre-assignment mode, (3) TASI-like system contributes a great deal to the circuit economy, and that (4) Circuit efficiency of the time pre-assignment system with TASI is comparable to that of the fully variable system.

5. CONCLUSION

For the purposes of international circuit operation and network planning, it is necessary to have the knowledge on the traffic flows influenced by the time difference. In this paper, concerning the telephone traffic, a theoretical equation to express the hourly traffic distributions has been introduced and empirically modified so as to agree with the measured distributions on the actual international circuits. The proposed set of distribution patterns is very useful when we need to know the nature of time differenced traffic quantitatively.

Discussions were made in the latter part of this paper on the efficiency and performance of the network between whose stations time differences exist. New definitions of traffic volume and network efficiency are proposed there. Though these proposed measures to evaluate network characteristics are applicable to the practical circuit engineering and were actually applied to some model networks, the author feels that a little more studies to refine the new measures are required further, especially on the average network blocking probability $B$ and the value $J$ in the performance efficiency $E(1-B/J)$.

Some useful characteristics of time differenced traffic in the network were clarified by the simple model studies. Lastly, as an example of application, the result of studies made on the comparison of various operation modes of multiple access satellite system was briefly explained.

The author wishes that many traffic engineers feel interest in the discussions and proposals made in this paper, and also wishes that the annexed hourly traffic distribution patterns are utilized by the traffic engineering people for circuit planning purposes until such time that more accurate distribution patterns become available.

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REFERENCES


ANNEX 1.

HOURLY TRAFFIC DISTRIBUTION PATTERNS