(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 258 654 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication of patent specification: **21.04.93**

(51) Int. Cl.[5]: **H04Q 3/66**, H04Q 3/00, H04Q 3/545

(21) Application number: **87111172.0**

(22) Date of filing: **03.08.87**

(54) **Adaptive, tariff dependent traffic routing and automatic network management system for multiservice telecommunication networks.**

(30) Priority: **27.08.86 US 900756**

(43) Date of publication of application:
09.03.88 Bulletin 88/10

(45) Publication of the grant of the patent:
21.04.93 Bulletin 93/16

(84) Designated Contracting States:
BE CH DE FR GB GR LI

(56) References cited:

PROCEEDINGS OF THE ELEVENTH INTERNATIONAL TELETRAFFIC CONGRESS, Kyoto, 4th-11th September 1985, part 2, pages 615-621, IAC; E. SZYBICKI: "Adaptive, tariff dependent traffic routing and network management in multi-service telecommunications networks"

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EP 0 258 654 B1

Description

This invention relates to a computer based, adaptive traffic routing and network management system according to the preamble of claim 1.

This system serves for the control of traffic routing in telecommunication networks, where communications between nodes (exchanges) of the network are established over inter-node transmission facilities (trunks).

The principal function of the invention is to route traffic in the network such, that the revenue is maximized. The routing mechanism of the invention, therefore, uses the distance- and service differentiated tariffs applied in the network as control parameters. The invention, therefore, specifically applies to:

1) intercity telephone networks, where different tariffs are applied for communications, depending on the distance between the nodes and sometimes depending also on the hour of the day:

2) integrated services networks (ISN), where in addition different tariffs may apply to different types of services.

However, the invention makes use of a general purpose routing algorithm, so that it can also be used in flat rate networks, such as:

3) metropolitan telephone networks,

4) private (PABX) networks,

5) data communications networks,

6) security and military communication networks.

Any type of nodes can be used, however, the network must accommodate at least 5 nodes of the so called Stored Program Control type to benefit from the invention. In other words, at least 5 nodes of the network must use computer control.

Fig. 1 shows an example of a telephone network, where nodes 1 through 5 are telephone exchanges of the Stored Program Control type (computer control) and nodes 6, 7 and 8 are exchanges using marker control (mechanical relay control). Any type of transmission facilities between the nodes can be used. Each such facility can accommodate several channels, or trunks, which constitute a trunk group. The trunks can be of one-way type (to be used in one direction), or of two-way type, which can be used in both directions.

PRIOR ART

A system as defined in the preamble of claim 1 is known from the Applicant's article in the PROCEEDINGS OF THE ELEVENTH INTERNATIONAL TELETRAFFIC CONGRESS, 4th-11th september, 1985, pages 615-621 : "Adaptive, tariff dependent traffic routing and network management in multi-service telecommunications networks".

The matter discussed in this article proposes a system for the control of traffic routing and network management in multi-exchange (multi-node) telecommunication networks with the following characteristics :

- Routing of traffic is based on distant sensitive tariffs, that is on tariffs applied between the different nodes (cities) of the network. This is clearly shown in the article by the symbol "C_{ij}" which denotes the tariff used between nodes i and j. As can be seen in the Article, only tariffs, dependent on the distances between the nodes are used in the condition for finding a path through the network.
- The control applies to a single service type, for instance the telephone traffic; different service types cannot be discriminated.
- If any other type of service is also switched by the network (for instance TELEFAX) it is treated in the same way as the telephone traffic.
- Network management is performed without regard to differences in requirements of the various service types.

A typical example of a network for which the proposed system would be applicable are the present intercity telephone networks, where different tariffs are being applied for communication between the exchanges (nodes) of the network, depending on the distances between cities.

The Article discusses therefore the management of network on a global basis, disregarding the management of a large number of service types individually.

Moreover, the matter discussed does not consider the actual network status.

The presently used conventional telecommunication networks use both the hierarchical and non-hierarchical design. In both cases the network is dimensioned such, that for a given node-to-node communication traffic intensity, the amount of network equipment is determined so that the probability of network congestion does not exceed a given predetermined figure.

The set up of the necessary connection for a communication between an originating node and a destination node is made in a fixed and predetermined manner. The direct trunks between the nodes are used as a first choice for the connection. Should all the direct trunks be occupied, the connection can be set up as overflow over other nodes using two, or more trunks in tandem. The traffic routing scheme in the case of hierarchical design can be briefly characterized as:

* sequential and hierarchical hunting for a free path between the call originating node and the destination node;
* step-by-step set up of connections;
* each node makes indvidual routing decisions.

In such a network design, overflow calls may enter the network even if from the distant tandem node no further path to the destination exists due to overload, or equipment out-of-service. This sort of unsuccessful connections produce an extra and ineffective traffic load in the network, which in extreme overload situations can lead to serious operational network disturbances. In those situations network managers perform network management by rerouting of traffic. This is done by changing traffic routing tables in the different nodes. At present this procedure is executed on a more or less manual basis. Since it is time consuming the interventions may be too late and hence they may be inadequate, have no effect, or may even worsen the situation.

Due to the particular way of routing overflow traffic, the different trunk groups carry both the direct traffic to the destination and overflow traffic to another destination node. The prior art of traffic routing in telecommunications networks disregards the fact that the different traffic parcels are subject to different tariffs, which is the case for instance in the intercity networks.

BACKGROUND OF THE INVENTION

In present telephone networks, alternative routing is used to handle traffic between a call originating exchange node and the destination exchange node. The direct trunks between these nodes are used as a first choice for the establishment of the connection. Should all the direct trunks be occupied, the overflow is routed over one, or more other nodes in tandem. Thus a trunk group between two nodes may handle direct traffic to a destination and some portion of overflow traffic to another destination.

Existing traffic routing systems in telephone networks, route traffic without regard to applied tariffs. However, in the case of intercity networks different tariffs are applied for calls to different cities, depending on the distance. Since an overflow connection occupies two, or more trunks in series, it blocks in this way paths for the direct traffic in several trunk groups. It may occur that a low revenue overflow connection has blocked paths for the more profitable direct traffic parcels. This may be especially true during overload situations when the percentage of overflow connections is increased.

The situation may be even more accentuated in the future integrated services networks (ISN), where the tariffs will depend not only on the intercity distances, but also on the type of service provided. Since the present traffic routing systems disregard tariffs, they do not result in maximum revenues.

Another deficiency of present routing systems is that each node routes traffic without regard to the actual out-of-service and overload status in the entire network. Thus, calls may enter the network even if no free path to the destination exists, relevant equipment is overloaded, or out-of-service. These calls must be released, but have occupied the network for some time without being successful, blocking in this way paths for calls, which could get through. This phenomenon contributes to non-effective traffic, loading the network and resulting in drop of revenues. As mentioned earlier, the presently practiced network management on manual, or semi-automatic basis is too slow for the relatively quick traffic variations. Late interventions may be inadequate, have no effect, or even worsen the situation. The objective of the invention is to eliminate these defficiencies and to provide a traffic control mechanism, which results in maximum revenue traffic routing.

SUMMARY OF THE INVENTION

The object of the present invention consists in an extension of the known system and its possibilities of applications.

According to the invention this object is achieved by means of characteristics described in the characterizing parts of claim 1.

In this way the new system permits to route traffic in telecommunication networks with regard to applied distance- and service sensitive tariffs, such that the total revenue from handling traffic by the network is maximized and such, that the revenues are automatically protected in case of overload in the network. In routing the traffic, the system automatically performs also the following functions:

1) by-pass of overloaded and out-of-service network equipment.
2) Blocking of calls at origin to overloaded, out-of-service, or hard-to-reach destinations.
3) Blocking of calls at origin to restricted destinations.

Based on tariff differences, the system can for instance control discount traffic on a 24 hours-a-day basis.

Apart from the automatic network management functions, the system had facilities for on-demand interventions, which can quickly be activated over computer console. These are for instance:

4) Reservation of path between two nodes for a given point of time.
5) Definition of restricted destinations.
6) Blocking of given nodes, or trunk groups for certain type of services.
7) Definition of network scanning interval.
8) Modification of network definition.

The on-demand interventions are executed by means of a special System Management & Intervention Language (SMIL), which due to modular design can easily be extended to accommodate other on-demand interventions as needed.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic of a network using the stored program control (SPC) exchange nodes features of the present invention.

Figure 2 is a schematic of an intercity telephone network according to the present invention consisting of five PSC exchange nodes and the transmission connections between them (trunk groups).

Figures 3a-d is a schematic showing various feasible tandem paths existing between an originating node and a destination node.

Figure 4 is a flow chart illustrating the possible paths which a call may take utilizing the present invention.

Figure 5 is a schematic showing the general design of a computer-based simulator and the relationship between the real network and the configuration in the computer-based simulator.

Figure 6 is a chart showing the statistical results obtained when using the hierarchical routing techniques of the prior art.

Figure 7 is a chart showing the statistical rates obtained using the adaptive, tariff dependent routing method of the present invention.

Figure 8 is a schematic of an intercity network configuration using the prior art fixed hierarchical routing method.

Figure 9 is a graph showing the results of a study demonstrating the difference in the number of choices tried in a node, both in the case of the prior art fixed-hierarchical routing and in the case of the adaptive, tariff dependent traffic routing of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

For reasons of convenience, where necessary the invention will be abbreviated by AR-NEM system.

Although the invention can be used in different network applications, here it will be described only for networks where distance- and service differentiated tariffs are applied, (see also FIELD OF INVENTION). Two examples of such network applications are for instance intercity telephone networks and integrated services networks (ISN). The invention can operate in the mixed digital and analog switch and transmission environment, but requires a certain number (c:a 5) of switch nodes in the network to be of the Stored Program Control (SPC) type for beneficial operation.

The SPC nodes are controlled by a computer, while the non-SPC nodes are assumed to be controlled by any type of relay marker equipment. First, the invention will be described for networks accommodating only SPC nodes. Then it will be explained how calls originating in non-SPC nodes can benefit from the AR-NEM system.

Figure 2 shows an example of an intercity telephone network consisting of 5 SPC exchange nodes and transmission connections between them (trunk groups). In contrast to present intercity networks, here the exchanges do not need to be organized in hierarchy levels. Any of the exchange nodes can originate calls, receive calls and can be used as tandem for transit connections. Fig. 2 shows one of several possible realizations of the invention. It is built up of equipment available on the market. It consists of:

* a computer for programs and fast access data,
* a disk memory for data bases,

* a tape station for storing statistics and back-up programs,
* a screen and console terminal for system operation,
* a printer for printing operational reports.

All this equipment is duplicated for reliability reasons. Display of network sectors can be done on terminal screen, although a wall screen can be used optionally. The computer is connected to the SPC nodes of the network over two-way data communication links. The computer programs stored in the computer, perform the specific control function of the adaptive, tariff dependent traffic routing and automatic network management as defined in the invention. The equipment constitutes the operational aids.

The invention (AR-NEM System) performs the control of traffic routing in the network based on the following parameters:

a) distance and service dependent tariffs; these are stored in the computer's memory;
b) definition of restricted destinations;
c) service dependent network access;
d) the actual traffic load and out-of-service indicators for the SPC nodes and interconnecting trunk groups;
the indicators are obtained through periodic scanning of the network by the AR-NEM computer; the scanning interval depends somewhat on the actual network application; normally, the scanning interval is in the range of 3 - 20 sec.

For the functional description of the invention, the following symbol definitions are used:

m =	total number of SPC transit nodes in the network;
i =	the number of an originating node;
j =	the number of a destination node;
N_{ij} =	number of channels in service in the trunk group between nodes i and j;
D_i =	the identity (number) of data link connecting the AR-NEM system computer and node i;
$y_{ij}(k)$ =	call intensity for calls of service type k, originating in node i and destined to node j;
$h_i(k)$ =	average holding time for successful connections of service k, originating in node i;
$h(k)$ =	average holding time for the whole network, servie k;
$c_{ij}(k)$ =	tariff; charging unit for calls of service k, per time unit of connection between nodes i and j;
p_{ij} =	traffic indicator for trunk group i - j; it gives the actual number of occupied trunks in the trunk group between nodes i and j;
$N_{ij} - p_{ij}$ =	number of free trunks in trunk group i - j ; $N_{ij} - p_{ij} > 0$; trunk group between nodes i and j can be used for service; $N_{ij} - p_{ij} = 0$; trunk group between nodes i and j cannot be used for service;
$q_{ij}(k)$ =	network access for service k; $q_{ij}(l) = N_{ij}$; $p_{ij} < q_{ij}(k)$; service k is allowed to use trunk group i - j; $p_{ij} \geqq q_{ij}(k)$; service k is not allowed to use trunk group i - j;

The switching elements in the nodes that are required for the set up of connections are:

* receivers,
* senders,
* connecting network,
* Central Processing Unit (CPU).

All the elements must be available for the successful set up of a connection. If any of the above elements is out-of service, no connection can take place. Similarly, if any of the elements is overloaded, the call will be rejected, or must wait to be switched. Should the delay exceed a certain limit, the waiting call will be nevertheless rejected due to time-out. Thus, a composite traffic and out-of-service indicator is used for the nodes, as follows:

$$\begin{cases} r_{ix} = 1 & \text{if a receiver of type x in node i can be used for service;} \\ r_{ix} = 0 & \text{if no receiver of type x in node i is available for service;} \end{cases}$$

$$\begin{cases} s_{ix} = 1 & \text{if a sender of type x in node i can be used for service;} \\ s_{ix} = 0 & \text{if no sender of type x in node i is available for service;} \end{cases}$$

$$\begin{cases} f_{i} = 1 & \text{if the connecting network of node i can be used for service;} \\ f_{i} = 0 & \text{if the connecting network of node i cannot be used for service;} \end{cases}$$

$$\begin{cases} v_{i} = 1 & \text{if the central processing unit of node i can be used for service;} \\ v_{i} = 0 & \text{if the central processing unit of node i cannot be used for service.} \end{cases}$$

In modern SPC telephone exchanges, means exist for proper assignment of indicator values. The composite traffic and out-of-service indicator is then defined as:

$$R_{ix} = r_{ix} \cdot s_{ix} \cdot f_i \cdot v_i$$

If the resulting value of the composite indicator

$$\begin{cases} R_{ix} = 1 & \text{the node i can be used for service associated with the receiver and sender of type x;} \\ R_{ix} = 0 & \text{the node i cannot be used for service associated with the receiver and sender of type x.} \end{cases}$$

The values of the indicators (R_{ix}) can be set automatically, or manually by the operator of the node. In the case of automatic setting, the tresholds depend on the type of switch used in the different nodes.

The memory of the computer accommodates definitions of network, network access for each service, service- and distance dependent tariffs and restricted destinations. The network is defined by the following parameters:

* number of trunks N_{ij}, between nodes i and j;

$i = 1, 2, ---- m;$
$j = 1, 2, ---- m; \quad i \neq j;$

* trunk type for each trunk group i - j; one-way, or two-way.

In the case of two-way trunks, the same trunk type and number of trunks will appear for trunk group i-j as for trunk group j-i.

The service dependent network access is defined as:

$q_{ij}(k)$; $q_{ij}(k) \leqq N_{ij}$
$i = 1, 2, ---- m$;
$j = 1, 2, ---- m$; $i \neq j$;
$k = 1, 2, ---- K$;

The tariff information is stored in form of charging units for calls of service k per time unit of connection between node i and j:

$c_{ij}(k)$;
$i = 1, 2, ---- m$;
$j = 1, 2, ---- m$; $i \neq j$;
$k = 1, 2, ---- K$;

where K is the total number of services in the network. As a rule, for the same service, $c_{ij}(k) = c_{ji}(k)$. The computer data files accommodate also information on restricted areas. These are service dependent and are defined as nodes, which do not accept service k calls. These calls will be rejected at the originating node; they will not be allowed to enter the network.

By periodic scanning of the network, the computer collects from each node the traffic and out-of-service parameters:

R_{ix}; $y_{ij}(k)$; $h_i(k)$;

and

p_{ij};   or $N_{ij} - p_{ij}$;

These data, once collected are stored in the computer's memory.

The transfer of information from the SPC nodes to the computer is made over data links. Thus from node 1 the parameters:

p_{1j}; R_{1x}; $y_{1j}(k)$; $h_1(k)$;
$j = 2, 3, --- m$;
$k = 1, 2, --- K$;

are transferred to the computer over data link D_1. From node 2 the parameters:

p_{2j}; R_{2x}; $y_{2j}(k)$; $h_2(k)$;
$j = 1, 3, --- m$;
$k = 1, 2, --- K$;

are transferred to the computer over data link D_2, a.s.o. until the required data has been transferred to the computer from all the SPC nodes. In the practical realization of the system a certain flexibility exists. For instance, only the parameter p_{ij} needs to be transferred at each scanning. The parameters R_{ix} can be transferred only when a change occurs, not necessarily at each scanning of the nodes. Similarly, measurements of the parameters $y_{ij}(k)$ and $h_i(k)$ are performed in the different nodes over a longer period of time and with lower frequency than the network scanning. The average holding time for the entire network, h(k) is calculated in the system's computer.

The scanning of the nodes can be performed in a sequential fashion. Should a data link be out-of-service, it will be indicated to the computer, so that it does not wait for transfer of information from the corresponding node. In that case, the system will not receive any new data, but can still operate based on previous data, until the data link connection has been reestablished. In normal cases, this is a temporary situation.

Once the data has been transferred from the nodes to the computer, the system has a global view of the actual situation in the network, in terms of:

* actual traffic load in the different trunk groups and nodes;
* out-of-service situation in the different trunk groups and nodes;
* actual offered traffic originating in each node, destined to any other node for each type of service;
* actual holding time for each type of service.

Based on this global network view and on the data stored in the system's computer, such as:

* network definition,
* network access parameters,
* restricted area definitions,
* service and distance dependent tariffs,

the system determined traffic routing instructions for each SPC node and each type of service, destined to any other node. At the same time the system performs automatic network management interventions, such that:

1) Calls to restricted destinations are blocked at the originating exchange.
2) Calls to overloaded and/or out-of-service destination exchanges are blocked at the originating exchange.
3) Calls, which do not have a free path to the desired destination are blocked at the originating exchange.
4) Overloaded and/or out-of-service transit exchanges are automatically by-passed.
5) Congested and/or out-of-service trunk groups are automatically by-passed.
6) Optimum traffic routing:
    * maximizing revenues in tariff differentiated multi-service networks;
    * maximizing traffic throughput in flat rate networks;
    * service protecting in grade-of-service differentiated multi-service networks.

In situations described in items 1) through 3) the calls never enter the network and consequently do not contribute to the noneffective traffic load in the network. As a result, the incident of network overload will be reduced. In multi-service networks, the AR-NEM system may issue different routing instructions for the different services. In the case of tariff differentiated networks this is the consequence of different tariffs applied to the different services. In flat rate networks, this is the consequence of different network access assigned to the different services. Once determined in the AR-NEM computer, the routing instructions are transferred to the different SPC exchanges and are used for routing traffic until modified after next scanning interval or later. The transfer takes place over the respective data links. In the SPC nodes, the discrimination between the services can be done either by subscriber category or by means of dedicated service codes.

In addition to the automatic network management, the system has features for on-demand network management interventions. These can be executed over the AR-NEM computer console (terminal) by means of a special System Management and Intervention Language (SMIL). For example, the following interventions can be performed:

1) Modification of network definition.
2) Modification of restricted areas.
3) Modification of service dependent network access and tariffs.
4) Modification of network scanning interval.
5) Blocking of given exchanges and trunk groups for traffic.
6) Reservation of path between two given exchanges.
7) Blocking of network for low priority services. Reservation of network capacity for certain type of services.

For example, by defining two different tariffs, one for discount service and one for regular service, the AR-NEM system will automatically perform routing and management of the discount traffic on a 24 hours a day basis and such that the revenues are maximized.

The network access parameters $q_{ij}(k)$ are used for the two functions:

1) to control routing of different services in flat rate network applications,
2) as an instrument for the on-demand network management.

The principle is the same in both cases. A service k may use a trunk group i-j for connection if the actual number of occupied trunks p_{ij} in the group is lower than the service related network access $q_{ij}(k)$. Since the probability of network congestion depends on network access, these can be determined such that the probability of blocking in a trunk group i-j, for the different services k, satisfy given predetermined figures ϵ_k, e.g.:

Blocking for service k: $E_{ij}(k) \leq \epsilon_k$
i = 1, 2, ---- m;
j = 1, 2, ---- m; i ≠ j;
k = 1, 2, ---- K;

In this way a grade-of-service differentiated routing is achieved.

Provided that the values for ϵ_k are given, the network access in a trunk group for the different services can be determined. For instance, for three services this can be done in the following way:

Set $q_{ij}(1)$ = N = network access for service 1;
$q_{ij}(2)$ = M = network access for service 2;
$q_{ij}(3)$ = L = network access for service 3;
A = traffic offered, service 1;
a = traffic offered, service 2;
b = traffic offered, service 3;

E = probability of trunk group blocking for service 1;
E′ = ditto for service 2;
E″ = ditto for service 3;

The blocking probabilities can be expressed by means of recursive formulas as a function of network access.

For service 1:

$$\begin{cases} E_{r,M,L} = \dfrac{A \cdot E_{r-1,M,L}}{r + A \cdot E_{r-1,M,L}} & r = M+1, --- N \\ E_{s,s,L} = \dfrac{(A+a) \cdot E_{s-1,s-1,L}}{s + (A+a) \cdot E_{s-1,s-1,L}} & s = L+1, --- M \end{cases}$$

For service 2:

$$\begin{cases} E'_{r,M,L} = \dfrac{r \cdot E'_{r-1,M,L}}{r + A \cdot E_{r-1,M,L}} + E_{r,M,L} \\ E'_{s,s,L} = \dfrac{(A+a) \cdot E'_{s-1,s-1,L}}{s + (A+a) \cdot E_{s-1,s-1,L}} \end{cases}$$

For service 3:

$$\begin{cases} E''_{r,M,L} = \dfrac{r \cdot E''_{r-1,M,L}}{r + A \cdot E_{r-1,M,L}} + E_{r,M,L} \\ E''_{s,s,L} = \dfrac{s \cdot E''_{s-1,s-1,L}}{s + (A+a) \cdot E_{s-1,s-1,L}} + E_{s,s,L} \end{cases}$$

$$E''_{L,L,L} = E'_{L,L,L} = E_{L,L,L} = \frac{(A+a+b)^L}{L!} \Big/ \sum_{\mu=0}^{L} \frac{(A+a+b)^\mu}{\mu!}$$

The network access parameters M, N, L can be determined such that:

$$E_{N,M,L} \leq \mathcal{E}_1 \qquad E'_{N,M,L} \leq \mathcal{E}_2 \qquad E''_{N,M,L} \leq \mathcal{E}_3$$

During the network operations, the network access parameters can be maintained constant or can be modified on-line, depending on operational objectives.

Different services may have different or the same network access, e.g.:

$q_{ij}(1) = q_{ij}(2) = \text{---} = q_{ij}(K);$

This feature can be used for the on-demand network management functions. For instance, using the AR-NEM computer console, the parameters can be set as:

$q_{ij}(1) = N_{ij}; \quad q_{ij}(2) = \text{----} = q_{ij}(K) = 0;$

Using these parameters, the network will only handle service of type 1 calls, until the parameters are changed again. Thus in emergency situations, the network can be assigned to handle only certain type of service of services.

In intercity networks, the tariffs depend also on distances between the different nodes. In order to explain the principle of routing traffic, such that the revenues are maximized, the case of network providing only one type of service will be considered first. Then, extension will be made to multi-service networks.

The general principle for routing traffic according to this invention is as follows:

1) Calls originating in a SPC node i, destined to a node j are routed over the direct trunks between nodes i and j as a first choice.

2) Should all the direct trunks between nodes i and j be occupied, out-of-service or non-existing, the calls are routed over any other SPC node, which can be reached from node i and which can reach node j; in this case, the path is built up of two trunk groups used in series (tandem); this alternative is used as a second choice;

3) Should also all the two-link paths between nodes i and j be occupied or non-existent, any combination of three-link path can be used for the establishment of the connection; in this case 3 trunk groups are used in series and two SPC nodes are used in tandem between the originating node i and the destination j; this alternative is used as a third choice.

In principle, paths utilizing more than two tandem nodes can also be used. However, using paths with more than 3 links in series does not result in substantial increase of the network's capacity, but would complicate the system.

The direct path between the originating node i and the destination j, does not require any intervention from the AR-NEM system. The originating node can perform the necessary test of free direct trunks itself. The role of the AR-NEM system is to find suitable tandem paths between each SPC node and each other node (destination) to be used in case the direct trunks to the desired destination are occupied.

The selection of nodes as candidates for tandem connections is made according to a special algorithm, as follows:

a) A two-link path is candidate for tandem connection if the expected revenue from the connection is greater than the estimated loss of revenues from directly handled traffic in the two affected trunk groups, due to occupied trunks by the tandem connection.

b) A three-link path is candidate for tandem connection if the expected revenue from the connection is greater than the estimated loss of revenues from directly handled traffic in the three affected trunk groups, due to occupied trunks by the tandem connection.

The condition for allowing a two-link tandem connection to be set up, can be deduced in the following way:

The expected revenue from a tandem connection of service type 1, between node i and j is:

$h(1) \cdot c_{ij}(1)$;

If the tandem connection is not established, the expected revenue from traffic handled over direct trunks in group i-t, during the period of $\overline{h}(1)$ time units is estimated to be:

$h(1) \cdot y_{it}(1) \cdot [1 - B(N_{it};p_{it})] \cdot c_{it}(1) \cdot h(1)$;

and if the tandem connection is established, the corresponding revenue is estimated to be:

$h(1) \cdot y_{it}(1) \cdot [1 - B(N_{it} - 1;p_{it})] \cdot c_{it}(1) \cdot h(1)$;

Consequently, the expected loss of revenues from the directly handled traffic in trunk group i-t, due to an established tandem connection is estimated to be:

$h(1) \cdot y_{it}(1) \cdot c_{it}(1) \cdot [B(N_{it}-1;p_{it}) - B(N_{it};p_{it})] \cdot h(1)$;

where

$B(N_{it};p_{it})$ = conditional probability of all N_{it} trunks being busy, given p_{it} trunks have been observed to be occupied at the moment of network scanning.
This function is also dependent of the parameters h(1) and $y_{it}(1)$.
It can be obtained either by using theoretical formulas, or by means of statistics. In the first case, experience shows that also simple approximations give satisfactory performance. For instance, Erlang's loss formula has been used as an approximation with satisfactory results. In that case (see page 26),

$B(N_{it};p_{it}) = E(N_{it};A_{it}(1))$;
$A_{it}(1) = h(1) \cdot y_{it}(1)$;

However, when scanning the network, the number of occupied trunks in each trunk group p_{it} is transferred from the different nodes to the AR-NEM computer. This applies also to the state $p_{it} - N_{it}$. Statistics can therefore be used to approximate the function $B(N_{it};p_{it})$.

In a similar way the expected loss of revenue for trunk group t-j can be obtained. Consequently, it is profitable to allow a tandem connection between nodes i and j to be set up if

$$c_{ij}(1) > c_{it}(1) \cdot A_{it}(1) \cdot \left[B(N_{it} - 1;p_{it}) - B(N_{it};p_{it})\right] + c_{tj}(1) \cdot A_{tj}(1) \cdot \left[B(N_{tj} - 1;p_{tj}) - B(N_{tj};p_{tj})\right] ;$$

else, at this point of time (until next scanning) it is more profitable to use the trunks in groups i-t and t-j for handling direct traffic, or use them for tandem connections between other nodes.

The resulting algorithm used for the search of tandem path between nodes i and j is as follows:

1) A node t can be used as tandem for a two-link connection between an originating node i and a destination node j if the following conditions are all satisfied at the same time:
$R_{tx} = 1$; node t is available for service;
$N_{it} - p_{it} > 0$; trunk group i-t can be used for service;
$N_{tj} - p_{tj} > 0$; trunk group t-j can be used for service;

$$c_{ij}(1) > c_{it}(1) \cdot A_{it}(1) \cdot \left[B(N_{it} - 1;p_{it}) - B(N_{it};p_{it})\right] + c_{tj}(1) \cdot A_{tj}(1) \cdot \left[B(N_{tj} - 1;p_{tj}) - B(N_{tj};p_{tj})\right] ;$$

2) Nodes t and u can be used as tandems for a three-link connection between an originating node i and a destination node j if the following conditions are all satisfied at the same time:

$R_{tx} = 1$; $R_{ux} = 1$;

$N_{it} - p_{it} > 0$; $N_{tu} - p_{tu} > 0$; $N_{uj} - p_{uj} > 0$;

$$c_{ij}(1) > c_{it}(1)\cdot A_{it}(1)\cdot\left[B(N_{it}-1;p_{it}) - B(N_{it};p_{it})\right] + c_{tu}(1)\cdot A_{tu}(1)\left[B(N_{tu}-1;p_{tu}) - B(N_{tu};p_{tu})\right] + c_{uj}(1)\cdot A_{uj}(1)\cdot\left[B(N_{uj}-1;p_{uj}) - B(N_{uj};p_{uj})\right];$$

Should any of the traffic and/or out-of-service indicators not satisfy the conditions, the corresponding network element will be excluded from the path search and automatically by-passed when routing a call through the network. Similarly, if $c_{ij}(1)$ does not satisfy the inequality condition, it implies that it is not profitable at this moment to route a tandem connection from node i to node j over the nodes t, or t and u.

3) The path search between nodes i and j is performed only if the destination node j is in service, e.g.: $R_{jx} = 1$; Should this condition not be satisfied, calls destined to this node will not be allowed to enter the network, but will be rejected at the originating node i.

4) In multi-service networks, when performing the path search, the network access $q_{ij}(k)$ assigned to the different services is taken into account.

5) Similarly, the on-demand network management interventions are respected during the path search. Thus calls to restricted areas or to blocked destinations will be rejected at the originating node.

For practical realization of the invention, computer programs have been developed for the evaluation of the algorithm. The programs are stored in the AR-NEM computer, which performs path search for each SPC node to any other node, based on the network data and according to the algorithm's conditions. Once the path search is completed, routing instructions are sent to the different SPC nodes.

A feasible path, if existing is defined in terms of node identities. For instance, a two-link path is defined by the tandem node t and a three-link path is defined by the node identities t and u. Although, in principle a tandem connection can be set up over more than three links, for practical reasons the number of links that can be used for tandem connections is here limited to three. The routing instructions are then valid until next scanning is performed and a new set of tandem identities is transferred to the SPC nodes. During the path search process, several cases may occur, such as:

1) no feasible tandem path exists between nodes i and j;

2) only one feasible tandem path exists between nodes i and j;

3) several feasible tandem paths exist between nodes i and j.

In the first case, the tandem identity is replaced by a special code (-1). If also all the direct trunks to the desired destination are occupied, the code indicates network congestion. Calls to node j in that case will be rejected by the originating node i, without being allowed to enter the network.

If several feasible tandem paths exist between nodes i and j, the AR-NEM system will select two paths at random, I and II, to be tried in that order. Should the principal path I be snatched away, the second path (II) can be used automatically. Some possible situations that can occur are shown in Fig. 3a through 3d. The type of information, in terms of tandem identities, defining the tandem paths depends on the actual situation in the network. Each node, however, will receive two identities, e.g. t_1 and t_2. Should only one path exist, t_2 will be replaced by (1-). Should there not be any feasible tandem path between nodes i and j, both t_1 and t_2 will be replaced by (1-). The arrangement in the nodes to accommodate the information and how it should be utilized for call routing depends on the type of switch used in the nodes. The arrangement includes also the limitation for any tandem connection to use more than three links. Although the arrangement has been developed for some type of switch, it cannot be generally covered in this document, as it must be adapted to each particular network application.

The actual procedure for routing a call through the network is shown in Fig. 4. It applies to the case as shown in Fig. 3a, but can be generally adapted to all the other cases and to more than one service.

The described algorithm is valid for the case when the originating node is of SPC type. This restriction does not apply to the destination node, which can be of any type. For calls originating in non-SPC nodes an addition must be made. Non-SPC nodes, as a rule have marker control of mechanical type. Consequently, these cannot communicate with the AR-NEM system computer and cannot receive routing instructions from the system. Calls originating in non-SPC nodes can still use the direct trunks to the destination as a first choice. A tandem connection, however can be set up over the SPC-node network. In order to benefit from the adaptive, tariff dependent traffic routing a call originating in a non-SPC node must connect first to one of the SPC-nodes.

So far the function of the system was described assuming only one type of service in the network. In order to describe the system for more than one service it is necessary to define the relationship between the different service types. Here, it assumed that the service types differ in tariffs such that:

$c_{ij}(1) > c_{ij}(2) > ---- > c_{ij}(K)$;

The principle of the invention is to route traffic in a network such, that maximum revenues are achieved from the network operations. It is then obvious that the high tariff service will be handled with somewhat higher priority than the low tariff services. However, it must be underlined, that the network must be designed such, that at the engineering traffic level the assigned grade-of-service must be satisfied for all the services as required. Due to traffic variations, low tariff services will be handled by network facilities when and where the intensity of high tariff traffic is rather low and vice versa, the high tariff traffic will be protected during periods of network overload. In this way maximum possible revenues will be achieved.

The algorithm for routing traffic in multi-service networks is similar to that for one-service networks. The only difference is in the condition for setting up the connection. For multi-service networks this condition is as follows:

1) A call of service k, originating in node i and destined to node j is allowed to use a direct trunk between these nodes if

$$c_{ij}(k) > \left[B(N_{ij}-1;p_{ij}) - B(N_{ij};p_{ij})\right] \cdot \sum_{\mu=1}^{k-1} c_{ij}(\mu) \cdot A_{ij}(\mu) \quad ;$$

2) A call of service k, originating in node i and destined to node j can be set up as a two-link tandem connection over node t, if

$$c_{ij}(k) > \left[B(N_{it}-1;p_{it}) - B(N_{it};p_{it})\right] \cdot \sum_{\mu=1}^{k} c_{it}(\mu) \cdot A_{it}(\mu) \; + \; + \left[B(N_{tj}-1;p_{tj}) - B(N_{tj};p_{tj})\right] \cdot \sum_{\mu=1}^{k} c_{tj}(\mu) \cdot A_{tj}(\mu) \quad ;$$

3) A call of service k, originating in node i and destined to node j can be set up as a three-link tandem connection over nodes t and u, if

$$c_{ij}(k) > \left[B(N_{it}-1;p_{it}) - B(N_{it};p_{it})\right] \cdot \sum_{\mu=1}^{k} c_{it}(\mu) \cdot A_{it}(\mu) \; + \; + \left[B(N_{tu}-1;p_{tu}) - B(N_{tu};p_{tu})\right] \cdot \sum_{\mu=1}^{k} c_{tu}(\mu) \cdot A_{tu}(\mu) \; + \; + \left[B(N_{uj}-1;p_{uj}) - B(N_{uj};p_{uj})\right] \cdot \sum_{\mu=1}^{k} c_{uj}(\mu) \cdot A_{uj}(\mu) \quad ;$$

where $A_{ij}(k) = y_{ij}(k) \cdot h(k)$;

Note that services of higher tariff than $c_{ij}(k)$ satisfy also these conditions.

The traffic routing algorithm can also be used in flat rate networks, such as the metropolitan telephone networks. In those networks the same tariff is used for all calls, independently of service type, or the distance between the originating node and the destination. Thus, the tariff can be set to be:

$c_{ij}(k) = 1$;

for all i, j and k values. In those cases the condition is as follows:

1) A call originating in node i and destined to node j is using a direct trunk be trunk between these nodes as a first choice. Should all the direct trunks be occupied, or not available for service, then:

2) a two-link tandem connection can be used, if:

$$1 > \left[B(N_{it}-1;p_{it}) - B(N_{it};p_{it})\right] \cdot A_{it} + \left[B(N_{tj}-1;p_{tj}) - B(N_{tj};p_{tj})\right] \cdot A_{tj};$$

3) and a three-link tandem connection can be used, if:

$$1 > \left[B(N_{it}-1;p_{it}) - B(N_{it};p_{it})\right] \cdot A_{it} + \left[B(N_{tu}-1;p_{tu}) - B(N_{tu};p_{tu})\right] \cdot A_{tu} + \left[B(N_{uj}-1;p_{uj}) - B(N_{uj};p_{uj})\right] \cdot A_{uj};$$

where

A_{ij} = total traffic offered from node i to node j.

In the case of flat rate networks, the traffic handled by the network is automatically maximized. The tandem connections will be allowed if it is expected that these will result in increased traffic handled. Tandem connections will not be allowed if it is estimated that these would prevent the trunks from handling direct traffic resulting in higher total handled traffic. This will be mostly the case when the network is overloaded. Thus, the invention (AR-NEM system) protects automatically the network against undesirable effects of overload.

In all the cases the tandem nodes must satisfy the conditions:

$t \neq i$; $t \neq j$;
$u \neq i$; $u \neq j$; $u \neq t$;

The tandem identities once stored in the nodes are valid until next set of feasible tandem identities has been determined and sent to the different nodes. This feature provides an automatic back-up system. In case all the data links are out-of-service, or the AR-NEM system computer is out-of-service the network will still operate based on the tandem identities stored in the nodes. These data will be used until faulty devices have been repaired and put in operation again. At that moment the network will automatically return to normal AR-NEM operations. During the period of complete system failure, the network will route traffic depending on the last network situation observed. In the best case, the routing scheme will correspond to that shown in Fig. 3a.

As an example, feasible two-link paths will be determined between node 1 and 2 in the 5-node network as shown in Fig. 2. It is assumed to be an intercity network, providing only one service. The following assumed data apply:

* all nodes in service;
* average holding time, h(1) = 200 seconds;

* for simplicity reasons, the function B(N;p) will be approximated by Erlang's Loss Formula, e.g.:

$$B(N;p) \approx E(N;A) = \frac{\frac{A^N}{N!}}{\sum_{v=0}^{N} \frac{A^v}{v!}}$$

TABLE 1. N_{ij}, Number of trunks in operation.

FROM NODE i	TO NODE j 1	2	3	4	5
1	—	10	15	10	20
2	12	—	10	12	15
3	16	12	—	15	12
4	10	12	10	—	0
5	18	12	15	0	—

TABLE 2. p_{ij}, Number of occupied trunks.

FROM NODE i	TO NODE j 1	2	3	4	5
1	—	10	10	7	16
2	10	—	6	10	11
3	13	8	—	15	6
4	7	9	8	—	0
5	15	8	15	0	—

TABLE 3. $A_{ij}(1)$, The actual traffics in erlangs.

FROM NODE i	TO NODE j 1	2	3	4	5
1	—	7.0	10.0	8.0	15.0
2	11.0	—	7.0	11.0	11.0
3	13.0	8.0	—	15.0	6.0
4	7.0	10.0	8.0	—	0.0
5	16.0	7.0	15.0	0.0	—

TABLE 4. $c_{ij}(1)$, Tariffs.

FROM NODE i	TO NODE j 1	2	3	4	5
1	—	2	3	4	2
2	2	—	2	3	3
3	3	2	—	2	4
4	4	3	2	—	2
5	2	3	4	2	—

The possible two-link paths between nodes 1 and 2, as shown in Fig. 2, are:

(i - t - j): 1 - 3 - 2
1 - 4 - 2
1 - 5 - 2

Further from Tables 1 and 2 it can be seen that:

$N_{13}-p_{13} > 0$;
$N_{14}-p_{14} > 0$;
$N_{15}-p_{15} > 0$;
$N_{32}-p_{32} > 0$;
$N_{42}-p_{42} > 0$;
$N_{52}-p_{52} > 0$;

Feasible two-link tandem paths are those for which:

$$c_{ij}(1) > F_t = c_{it}(1) \cdot A_{it}(1) \cdot \left[E(N_{it}-1;A_{it}(1)) - E(N_{it};A_{it}(1))\right] + $$
$$+ \; c_{tj}(1) \cdot A_{tj}(1) \cdot \left[E(N_{tj}-1;A_{tj}(1)) - E(N_{tj};A_{tj}(1))\right] \; ;$$

where $E(N_{yz};A_{yz}(1))$ can be obtained from Erlang's table.

For $i=1$ and $j=2$, $c_{12}(1)=2$. Then for $t=3$, $c_{13}(1)=3$ and $c_{32}(1)=2$, the value of F can be calculated according to the above formula:

$$F_3 = 3\cdot 10.0\cdot\left(E(14;10.0) - E(15;10.0)\right) + $$
$$+ 2\cdot 8.0\cdot\left(E(11;8.0) - E(12;8.0)\right) = $$
$$= 30\cdot(0.0568 - 0.0365) + 16\cdot(0.0813 - 0.0515) = \underline{1.086}$$

Similarly, for $t=4$, $c_{14}(1)=4$ and $c_{42}(1)=3$ ...... $F_4 = \underline{2.920}$

For $t=5$, $c_{15}(1)=2$ and $c_{52}(1)=3$ .... $F_5 = \underline{0.981}$

For nodes 3 and 5, $c_{12}(1)>F_3$ and $c_{12}(1)>F_5$ respectively. Hence, these nodes can be used as candidates for feasible two-link tandem paths. For node $t=4$, $c_{12}(1)<F_4$. In this case, therefore, it is more profitable to use the trunk groups 1-4 and 4-2 for direct traffic.

For the purpose of system testing and network performance testing, the AR-NEM software has been used to create a computer-based emulator. Additional software modules have been developed in order to generate traffic and perform traffic measurements, as well as print statistics. Fig. 5 shows the general design of the emulator and the relationship between the real network configuration and the computer-based emulator. Since the emulator is using the real AR-NEM programs, running the emulator, the statistics will reflect the AR-NEM system performance and the network performance as they would do in real life. Several system and network studies have been performed using the emulator, as regards normal load, overload as well as different out-of-service situations, such as:

* a node is out-of-service,
* one, or several trunk groups are out-of-service,
* the AR-NEM computer is out-of-service.

The results of the studies have been presented, as mentioned earlier, at the 11:th International Teletraffic Congress, in Kyoto, september 4-11, 1985 in the paper "Adaptive, Tariff Dependent Traffic Routing and Network Management in Multi-Service Networks". Using the network emulator, networks using present routing techniques can also be studied. Figures 6 and 7 show extracts from results. Fig. 7 shows the results of network performance when traffic routing is performed under the command of the AR-NEM system and Fig. 6 shows the results when the fixed-hierarchical traffic routing is used. The results apply in both cases to the same network and the same traffic conditions. It is a 16-node intercity network, handling two types of services. The results demonstrate the following:

* as can be seen in Fig. 6, the present art, fixed-hierarchical routing does not take into account the service and distance differentiated tariffs; the node-to-node congestion is the same for the two services, or 0.057, which is the same as the average for the entire network;
* in Fig. 7 it can be seen that the adaptive, tariff dependent routing provides much better grade-of-service; the average congestion for the entire network, in this case is only 0.011 as compared to 0.057 above; the high tariff service 1, experiences somewhat lower congestion opr 0.005, than the low tariff service 2, which experiences a congestion of 0.017;
* similarly, it can be seen that the adaptive, tariff dependent routing results in higher revenues than the present art, fixed-hierarchical routing; in addition to the better grade-of-service, the total revenues in the first case are 183 227.2 units while in the second case the total revenues are 177 682.2 units;
* as could be expected, the increase of revenues is mainly coming from the high tariff service 1, from 119 595.6 to 123 878.2, while the revenues for the low tariff service 2, increase only from 58 086.6 to 59 349.0 units; this effect, clearly demonstrates the efficiency of the adaptive, tariff dependent traffic routing mechanism.

For other results, see the paper referenced above.

The capacity requirement for the AR-NEM system computer depends on the number of nodes in the network, but not on the traffic load in the network. Therefore, the AR-NEM system is practically insensitive to network traffic overload. However, the incident of path snatching increases with increasing network load and with increasing length of scanning interval. The scanning interval, therefore, should be kept on a low level.

In the present art, fixed-hierarchical networks, when searching for a free trunk in the originating node, several trunk groups may be tested before a free trunk is found. Especially in the intercity networks, the number of choices tried can be in the range of five, see Fig. 8. It is time consumming for the control systems (CPU:s) of the SPC nodes. In the case of adaptive, tariff dependent routing, the situation is different. The computer of the AR-NEM system provides the SPC nodes with information on trunk groups where free trunks can be found. Consequently, the SPC nodes do not need to test all the choices, but at the most two trunk groups as defined for the two alternative tandem paths I and II by the respective tandems t_1 and t_2. The search for a free trunk is in this case much less time consumming and hence, the invention is deloading the CPU:s of the different SPC nodes. Fig. 9 shows results of a study demonstrating the difference in the umber of choices tried in a node, in the case of fixed-hierarchical routing and in the case of the adaptive, tariff dependent traffic routing.

Claims

1. A computer based, adaptive traffic routing and network management system for telecommunication networks, comprising

a plurality of nodes

a plurality of transmission trunks connecting the nodes and

wherein the plurality of nodes are Stored Program Control (SPC), nodes;

means for determining a tariff, in communication with the nodes, for communication between nodes depending on distance between the nodes,

means for providing the nodes with instructions for routing connections within the network of nodes such that revenues are maximized and such that trunks and nodes which are not available for service are automatically bypassed, said means comprise a computer having a data base, the tariff information being stored in the data base;

and wherein for connections originating in each SPC node i to each other destination node j, the direct trunks will be indicated to be used as a first choice and two other alternative paths I and II will be indicated, each of them comprising a two-link path over a tandem node t to be used as a second choice and a three-link path over tandem nodes t and u to be used as a third choice,

characterized in that

said system comprises means for handling a plurality of different service types in the same network, such as public telephone traffic, emergency traffic, computer data traffic, TELEFAX traffic, etc., and also in different network types such as metropolitan networks, intercity networks, private networks, computer networks, military and security networks, mobile telecommunication networks, etc.;

said system providing means for determining tariff for each service type for communication of the different service types between the nodes, depending on service type provided and on destination;

means for providing the nodes with instructions for routing each of the different service types in the same network to each destination such that revenue from handling the ensemble of service types is maximized and such that service management objectives for each service type and for each pair of nodes are satisfied;

said routing instructions being determined for each service type and for each pair of nodes utilizing the actually economic network paths being part of service related network access and depending on tariffs applied for each service type to each destination and on traffic intensity for each service type between each pair of nodes;

said routing instructions being determined taking into account the actual global network status and such that out-of-service trunk groups and nodes which cannot be used to handle a particular service type are automatically bypassed;

said routing instructions being determined such that during network overload the high tariff service types are automatically preferenced and such that service and network management interventions are respected,

and wherein the routing instructions are sent to the nodes in terms of indicators for using direct trunks and tandem nodes t and u for each service type and for each SPC node i to each other destination j and wherein the routing instructions are revised and sent to the nodes with a frequency as required for optimum utilization of each network type;

said network access being assigned to each trunk group, for each service type and for each pair of nodes in accordance with service management objectives, service requirements and restrictions applied to each service type and to each node;

said data base accommodating information relating to overall network status in terms of

- node-to-node call intensities for each service type between each pair of nodes, and
- holding times for each service type in each node, and
- actual number of occupied trunks in each trunk group, and

- actual traffic load in each SPC node, relating to Central Processing Unit (CPU) and to switching unit, and
- availability of trunk groups and nodes for each type of service,

wherein the information stored in the data base, in communication with the nodes is automatically and frequently up-dated and accomodating information relating to

- tariffs for each service type and for each node to each destination, and
- network access for each service type and for each pair of nodes, and
- service and network management interventions, wherein the tariffs, network access and interventions

for each service type can be manually modified.

2. The system defined in Claim 1 wherein said data base is accommodating also information relating to,

- offered call intensities for each service type and for each node to each other node,
- actual out-of-service status of trunk groups and nodes, and
- network access for each service type.

3. The system defined in claims 1 and 2, wherein for calls of each service type said direct trunks and said alternative paths will be indicated.

4. The system defined in claim 3 wherein the indicators for paths in terms of direct trunks and/or identities of tandem nodes t and u respectively, are determined for each type of service originating in an SPC node i to any destination node j according to the following algorithm:

a) calls of service type k with the related tariff $c_{ij}(k)$, where:

$c_{ij}(1) > c_{ij}(2) > ---- > c_{ij}(K);$

will be indicated to use direct trunks between node i and j as a first choice, if

* the destination node j is available for service, ($R_{jx} = 1$) and
* the trunk group between node i and j has at least one trunk available for service, ($N_{ij}-p_{ij} > 0$) and
* the actual traffic and occupancy status for the trunk group between nodes i and j is such that the expected revenue from a connection of service k is greater than the estimated loss of revenue due to this connection, from services of higher tariffs, which mathematically can be expressed as:

$$c_{ij}(k) > \left[B(N_{ij}-1;p_{ij}) - B(N_{ij};p_{ij})\right] \cdot \sum_{\mu=1}^{k-1} c_{ij}(\mu) \cdot A_{ij}(\mu);$$

b) node t as a feasible tandem for a two-link path is determined, if

* the destination node j is available for service, ($R_{jx} = 1$) and such, for which
* the tandem node t is available for service, ($R_{tx} = 1$) and
* trunk groups between nodes i and t as well as between nodes t and j, each have at least one trunk available for service, ($N_{it}-p_{it} > 0$ and $N_{tj}-p_{tj} > 0$) and
* the expected revenue from the service k tandem connection is greater than the estimated loss of revenues, due to this connection from traffic that could be handled over direct trunks in the two trunk groups i-t and t-j, which mathematically can be expressed as:

$$c_{ij}(k) > \left[B(N_{it}-1;p_{it}) - B(N_{it};p_{it})\right] \cdot \sum_{\mu=1}^{k} c_{it}(\mu)\cdot A_{it}(\mu) + $$
$$+ \left[B(N_{tj}-1;p_{tj}) - B(N_{tj};p_{tj})\right] \cdot \sum_{\mu=1}^{k} c_{tj}(\mu)\cdot A_{tj}(\mu) \; ;$$

c) nodes t and u as feasible tandems for a three-link tandem path are determined, if

- * the destination node j is available for service, (R_{jx} = 1) and such, for which
- * the tandem nodes t and u are available for service, (R_{tx} = 1 and R_{ux} = 1) and
- * the trunk groups between nodes i and t, between nodes t and u and between nodes u and j each have at least one trunk available for service, (N_{it}-p_{it}>0, N_{tu}-p_{tu}>0 and N_{uj}-P_{uj}>0) and
- * the expected revenue from the service k tandem connection is greater than the estimated loss of revenues, due to the tandem connection from traffic that could be handled over direct trunks in the three trunk groups i-t, t-u and u-j, which can be expressed mathematically as:

$$c_{ij}(k) > \left[B(N_{it}-1;p_{it}) - B(N_{it};p_{it})\right] \cdot \sum_{\mu=1}^{k} c_{it}(\mu)\cdot A_{it}(\mu) + $$
$$+ \left[B(N_{tu}-1;p_{tu}) - B(N_{tu};p_{tu})\right] \cdot \sum_{\mu=1}^{k} c_{tu}(\mu)\cdot A_{tu}(\mu) + $$
$$+ \left[B(N_{uj}-1;p_{uj}) - B(N_{uj};p_{uj})\right] \cdot \sum_{\mu=1}^{k} c_{uj}(\mu)\cdot A_{uj}(\mu) \; ;$$

where:

i =	number of an originating node; i = 1, 2,---m;
j =	number of a terminating node; j = 1,2---m;j ≠ i;
m =	total number of Stored Program Control nodes in the network which can be used as tandems;
k =	number of a service type; k = 1,2,---K;
K =	total number of services;
$c_{ij}(k)$ =	tariff per time unit of communication between nodes i and j for service type k;
R_{jx} =	availability indicator for node j; R_{jx} = 1 indicates that node j is available for service associated with receiver and sender x;
N_{ij} =	total number of trunks in operation in trunk group between nodes i and j;
P_{ij} =	the actual number of occupied trunks in trunk group between nodes i and j;
$A_{ij}(k)$ =	traffic of service type k, offered from node i to node j; $A_{ij}(k) = y_{ij}(k).h_i(k)$;
$y_{ij}(k)$ =	call intensity of service type k, offered in node i to node j;
B(N;p) =	conditional probability of all N trunks busy, given p trunks have been observed to be occupied at the moment of network scanning; can be approximately calculated from:

$$B(N;p) \approx \frac{\frac{A^N}{N!}}{\sum_{v=0}^{N} \frac{A^v}{v!}};$$

A =	total traffic offered to N trunks;
t =	identity (number) of tandem node 1;
t =	1,2,---m; $t \neq 1$; $t \neq j$;
u =	identity (number) of tandem node 2;
u =	1, 2,---m; $u \neq i$; $u \neq j$; $u \neq t$;
$h_i(k)$ =	average holding time for service type k, originating in node i.

5. The system defined in claim 4 wherein the algorithm is applied to only one type of service, e.g.:

$c_{ij}(1) > 0$ and $c_{ij}(2) = c_{ij}(3) = ---- = c_{ij}(K) = 0$;
$A_{ij}(1) > 0$ and $A_{ij}(2) = A_{ij}(3) = ---- = A_{ij}(K) = 0$;

in which case the system is directly applicable to present intercity telephone networks and if setting the tariff for a communication equal to unity, e.g.:

$c_{ij}(1) = 1$;

the system is directly applicable to flat rate networks, such as the present metropolitan telephone networks.

6. The system defined in claim 4 wherein the two alternative paths I and II, if existing are selected at random and where alternative I is used as a principal tandem path and alternative II is used only in case path I is found to be snatched away.

7. The system defined in claim 6 wherein the use of a trunk group as a part of the feasible path between nodes i and j depends on network access parameter $q_{ij}(k)$ assigned to each trunk group ij, for each service type k, such that

- a trunk in group ij can be used for a connection of service type k only if the number of occupied trunks p_{ij} observed in the group at the last network scanning, is lower than the corresponding network access parameter $q_{ij}(k)$, and where
- the assigned network access parameters $q_{ij}(k)$ can be maintained constant or be modified during the network operations according to operational objectives, and where
- the tariffs can be disregarded, in which case the system can be used for service dependent, grade-of-service differentiated routing of traffic.

8. The system defined in claim 7 wherein the routing instructions in terms of tandem node identities are transferred to the SPC nodes over data links provided between the nodes and the system's computer and wherein these data links are also serving for transfer of data from the SPC nodes to the computer in terms of indicators for:

- node-to-node offered call intensities, $y_{ij}(k)$;
- trunk group availabilities, P_{ij} or $N_{ij} - p_{ij}$;
- average holding times, $h_i(k)$;
- node availabilities, R_{ix};

9. The system defined in claim 8 wherein the service dependent network access parameters $q_{ij}(k)$ are also used for the on-demand management of traffic and network resources, such as:

- * blocking of network resources for certain type of service by setting the corresponding network access parameter $q_{ij}(k) = 0$, and/or
- * reserving network resources for certain type of service by setting the corresponding network access parameter $q_{ij}(k) = N_{ij}$ = a total trunk group capacity,

and where also the other on-demand interventions, such as:

- * modification of network definition,
- * modification of restricted areas,
- * modification of tariffs and/or network acess parameters,
- * modification of network scanning interval,
- * blocking of given nodes and trunk groups for traffic,

can be performed over the system's computer by means of a special System Management and Intervention Language, (SMIL).

10. The system defined in claim 9 wherein the last routing instructions stored in the SPC nodes for each service type serve as a back-up for routing the different service types in case all communication means between the SPC nodes and the AR-NEM system computer are out-of-service.

Patentansprüche

1. Ein auf Computerbasis beruhendes, adaptives Verkehrsleitweglenkungs- und Netzmanagementsystem für Fernmeldenetze, welche

- eine Mehrzahl von Knoten
- eine Mehrzahl von Verbindungsleitungen zwischen den Knoten umfassen und in welchen die Mehrzahl der Knoten vom Stored Program Control (SPC) Typ sind;

Mittel für die Bestimmung eines Tarifs, in Verbindung mit den Knoten, für Verbindungen zwischen den Knoten in Funktion der Distanz zwischen den Knoten;

Mittel für die Ausrüstung der Knoten mit Instruktionen für die Verkehrsleitweglenkung innerhalb des Knotennetzes derart, dass die Einnahmen maximalisiert werden und dass die Verbindungsleitungen und Knoten, welche für den Betrieb nicht benützbar sind, automatisch umgangen werden; diese Mittel umfassen einen Computer mit Datenbank, wobei die Tarifinformation in der Datenbank gespeichert ist;

und in welchem für Verbindungen ausgehend von jedem SPC-Knoten i zu jedem anderen Zielknoten j in erster Wahl die direkten Verbindungsleitungen angegeben werden und zwei andere, alternative Wege I und II bestimmt werden, wobei jeder dieser Wege einen zweigliedrigen (Zweilink) Weg über einen Tandemknoten t als zweite Wahl und einen dreigliedrigen (Dreilink) Weg über die Tandemknoten t und u als dritte Wahl umfasst,

gekennzeichnet dadurch, dass

besagtes System Mittel umfasst für die Behandlung einer Mehrzahl verschiedener Dienstleistungsarten in ein und demselben Netz, wie öffentlicher Telefonverkehr, Notfallverkehr, Computerdatenverkehr, Telefaxverkehr, usw., und dies ebenfalls in verschiedenen Netztypen, wie Stadtnetze, Fernverkehrsnetze, Privatnetze, Computer-Netze, Militär- und Sicherheitsnetze, mobile Fernmeldenetze, usw.;

besagtes System Mittel umfasst für die Festlegung der Tarife jeder Dienstart für den Verkehr der verschiedenen Dienstarten zwischen den Knoten, in Abhängigkeit von Dienstart und Bestimmungsort;

Mittel vorgesehen sind, für die Ausrüstung der Knoten mit Instruktionen für die Leitweglenkung der verschiedenen Dienstarten in ein und demselben Netz an jeden Bestimmungsort derart, dass die Einnahmen aus der Gesamtheit der Dienstarten maximalisiert werden und derart, dass die Dienstmanagementobjektive für jede Dienstart und für jedes Knotenpaar erfüllt werden;

besagte Leitweglenkungsinstruktionen für jede Dienstart und jedes Knotenpaar bestimmt werdenunter Benützung der jeweiligen wirtschaftlichsten Wege als Bestandteil des Netzzuganges des bezüglichen Dienstes und in Abhängigkeit der Tarife jeder Dienstart nach jedem Bestimmungsort und der Verkehrsintensität jeder Dienstart zwischen jedem Knotenpaar;

besagte Leitweglenkungsinstruktionen bestimmt werden unter Berücksichtigung des jeweiligen globalen Netzzustandes und derart, dass die Leitungsbündel und Knoten, welche für gewisse Dienste nicht benützt werden können, automatisch umgangen werden;

besagte Leitweglenkungsinstruktionen derart festgelegt werden, dass während Netzüberlastung die hochtarifierten Dienstarten automatisch Priorität erhalten und derart, dass die Managementinterventionen betreffend Dienste und Netz befolgt werden;

und wobei die Leitweglenkinstruktionen an die Knoten in Form von Indikatoren gegeben werden für die Benützung der direkten Leitungen und Tandemknoten t und u für jede Dienstart und für jeden SPC-

Knoten i nach jedem anderen Bestimmungsort j und wobei die Leitweglenkungsinstruktionen revidiert und mit einer für die optimale Benützung jedes Netztyps benötigten Frequenz an die Knoten gesandt werden;

besagter Netzzugang jedem Leitungsbündel für jede Dienstart und für jedes Knotenpaar zugewiesen wird in Uebereinstimmung mit den Dienstmanagementobjektiven, den Dienstanforderungen und den für jede Dienstart und jeden Knoten geltenden Einschränkungen;

besagte Datenbank Informationen enthält betreffend den globalen Zustand des Netzes in Form von

- Knoten-zu-Knoten Anrufsintensitäten für jede Dienstart, und
- Belegungsdauern für jede Dienstart in jedem Knoten, und
- momentaner Zustand der gleichzeitig belegten Leitungen in jedem Leitungsbündel, und
- momentane Verkehrsbelastung der Zentralen Processor Einheit (CPU) und die Koppelanordnungen in jedem SPC-Knoten, und
- Verfügbarkeit von Leitungsbündel und Knoten für jede Dienstart,

wobei die in der Datenbank gespeicherte Information, in Verbindung mit den Knoten, automatisch und häufig erneuert wird, und

welche Information enthält betreffend

- Tarife für jede Dienstart und für jeden Knoten zu jedem Bestimmungsort, und
- Netzzugang für jede Dienstart und für jedes Knotenpaar, und
- Interventionen bezüglich der Dienste und den Netzbtrieb, in welcher die Tarife, der Netzzugang und die Interventionen für jede Dienstart manuell verändert werden können.

2. System nach Anspruch 1, in welchem die besagte Datenbank ebenfalls Information erhält betreffend

- angebotene Anrufsintensität für jede Dienstart und von jedem Knoten zu jedem anderen Knoten, und
- momentaner Ausserbetriebszustand von Leitungsbündeln und Knoten, und
- Netzzugang für jede Dienstart.

3. System nach den Ansprüchen 1 und 2, in welchem für Anrufe jeder Dienstart die besagten direkten Leitungen und die besagten alternativen Wege angezeigt sein werden.

4. System nach Anspruch 3, in welchem die Wegindikatoren in Form von direkten Leitungen und/oder Tandemknotenidentitäten t beziehungsweise u, für jede in einem SPC-Ausgangsknoten i angebotene Dienstart zu jedem Bestimmungsknoten j gemäss dem folgenden Algorithmus bestimmt werden:

a) die Anrufe der Dienstart k mit dem entsprechenden Tarif $c_{ij}(k)$, wo:

$c_{ij}(1)>c_{ij}(2)>$ ---------- $> c_{ij}(K)$;

werden angewiesen, direkte Leitungen zwischen Knoten i und j als erste Wahl zu benützen, wenn

* der Knoten des Bestimmungsortes j für den Dienst verfügbar ist, ($R_{jx}=1$), und
* das Leitungsbündel zwischen Knoten i und j mindestens eine Leitung für den Dienst verfügbar hat $(N_{ij} - p_{ij})>0$, und
* der momentane Verkehrs- und Belegungszustand des Leitungsbündels zwischen den Knoten i und j so ist, dass die erwartete Einnahme aus einer Verbindung des Dienstes k grösser ist als der geschätzte Einnahmenverlust wegen dieser Verbindung, von Diensten mit höheren Tarifen, was mathematisch wie folgt ausgedrückt werden kann:

$$c_{ij}(k) > \left[B(N_{ij} - 1;p_{ij}) - B(N_{ij};p_{ij})\right] \cdot \sum_{\mu=1}^{k-1} c_{ij}(\mu) \cdot A_{ij}(\mu);$$

b) Knoten t als möglicher Transitknoten für einen zweigliedrigen Weg ist bestimmt, wenn

* der Zielknoten j für den Dienst verfügbar ist, ($R_{jx}=1$) und für welchen
* der Transitknoten t für den Dienst verfügbar ist, ($R_{tx}=1$) und
* die Leitungsbündel zwischen Knoten i und t, sowie zwischen t und j, jedes mindestens eine Leitung für den Dienst verfügbar haben, $N_{it} - p_{it} > 0$ et $N_{tj} - p_{tj} > 0$, und

* die erwartete Einnahme von der Dienst k Verbindung über den Transitknoten grösser ist als der geschätzte Einnahmenverlust wegen dieser Verbindung von Verkehr, welcher über die direkten Leitungen in den zwei Leitungbündeln i - t und t - j abgewickelt werden könnte, was mathematisch wie folgt ausgedrückt werden kann:

$$c_{ij}(k) > \left[B(N_{it}-1;p_{it}) - B(N_{it};p_{it})\right] \cdot \sum_{\mu=1}^{k} c_{it}(\mu) \cdot A_{it}(\mu) + \\ + \left[B(N_{tj}-1;p_{tj}) - B(N_{tj};p_{tj})\right] \cdot \sum_{\mu=1}^{k} c_{tj}(\mu) \cdot A_{tj}(\mu) ;$$

c) Knoten t und u als mögliche Transitknoten für einen dreigliedrigen Weg sind bestimmt, wenn

* der Zielknoten j für den Dienst verfügbar ist ($R_{jx} = 1$) und für welchen
* die Transitknoten t und u für den Dienst verfügbar sind, ($R_{tx} = 1$) und ($R_{ux} = 1$) und
* jedes Leitungsbündel zwischen den Knoten i und t, zwischen den Knoten t und u und zwischen den Knoten u und j wenigstens eine freie Leitung zur Verfügung hat, $N_{it} - p_{it} > 0$; $N_{tu} - p_{tu} > 0$ und $N_{uj} - P_{uj} > 0$, und
* die erwartete Einnahme von der Dienst k Verbindung über die Transitknoten grösser ist als der geschätzte Einnahmenverlust wegen dieser Transitverbindung von Verkehr, welcher mittelst der direkten Leitungen in den drei Leitungsbündeln i - t, t - u und u - j abgewickelt werden könnte, was mathematisch wie folgt ausgedrückt werden kann:

$$c_{ij}(k) > \left[B(N_{it}-1;p_{it}) - B(N_{it};p_{it})\right] \cdot \sum_{\mu=1}^{k} c_{it}(\mu) \cdot A_{it}(\mu) + \\ + \left[B(N_{tu}-1;p_{tu}) - B(N_{tu};p_{tu})\right] \cdot \sum_{\mu=1}^{k} c_{tu}(\mu) \cdot A_{tu}(\mu) + \\ + \left[B(N_{uj}-1;p_{uj}) - B(N_{uj};p_{uj})\right] \cdot \sum_{\mu=1}^{k} c_{uj}(\mu) \cdot A_{uj}(\mu);$$

wo:

i =	Nummer eines Ausgangknotens;
j =	Nummer eines Zielknotens;
m =	totale Anzahl SPC-Knoten im Netz, welche als Transitknoten verwendet werden können;
k =	Nummer einer Dienstart;
K =	totale Anzahl der Dienste;
$c_{ij}(k)$ =	Tarif pro Zeiteinheit einer Verbindung zwischen Knoten i und j für Dienstart k;
R_{jx} =	Verfügurbarkeitindikator für Knoten j; $R_{jx} = 1$ bedeutet, dass Knoten j verfügbar ist zum Dienst mit Empfänger und Sender x;
N_{ij} =	totale Anzahl von in Betrieb befintlichen Leitungen im Leitungsbündel zwischen Knoten i und j;
p_{ij} =	momentane Anzahl der belegten Leitungen im Leitungsbündel zwischen Knoten i und j;
$A_{ij}(k)$ =	von Knoten i nach Knoten j angebotener Verkehr der Dienstart k; $A_{ij} = y_{ij}(k) \cdot h_i(k)$;
$y_{ij}(k)$ =	im Knoten i in Richtung Knoten j angebotene Anrufsintensität der Dienstart k;
B(N;p) =	bedingte Wahrscheinlichkeit, dass alle N Leitungen belegt sind, angenomen dass im Moment der Netzsondierung p Leitungen als besetzt beobachtet worden sind; dies kann annäherungsweise mit der folgenden Formel berechnet werden:

$$B(N;p) \approx \frac{\frac{A^N}{N!}}{\sum_{v=0}^{N} \frac{A^v}{v!}}$$

A =	totaler, an N Leitungen angebotener Verkehr;
t =	Identität (Nummer) des Transitknotens 1; t = 1, 2, ------- m; $t \neq i$; $t \neq j$;
u =	Identität (Nummer) des Transitknotens 2;
	u = 1, 2, ------ m; $u \neq 1$; $u \neq j$; $u \neq t$;
$h_i(k)$ =	mittlere Belegungsdauer für Dienstart k, ausgehend vom Knoten i.

5. System nach Anspruch 4, in welchem der Algorithmus nur auf eine einzige Dienstart angewendet wird, z.B.:

$c_{ij}(1) > 0$ und $c_{ij}(2) = c_{ij}(3) =$ ------ $c_{ij}(K) = 0$;
$A_{ij}(1) > 0$ und $A_{ij}(2) = A_{ij}(3) =$ ------ $A_{ij}(K) = 0$;

in welchem Falle das System direkt auf die gegenwärtigen Fernverkehrsnetze angewendet werden kann, und, wenn der Tarif für eine Verbindung gleich eins gesetzt wird, z.B.:

$c_{ij}(1) = 1$;

das System direkt auf Einheitstarifnetze, wie die gegenwärtigen Ortsnetze, angewendet werden kann.

6. System nach Anspruch 4, in weichem die zwei alternativen Wege I und II -wenn existierend- aufs Geratewohl gewählt werden und in welchem Alternative I als Haupttransitweg benützt wird und Alternative II nur benützt wird, falls Weg I schon als weggeschnappt befunden wird.

7. System nach Anspruch 6, in welchem die Benutzung eines Leitungsbündels als Teil des möglichen Weges zwischen Knoten i und j vom Netzzugangsparameter $q_{ij}(k)$ abhängt, welcher für jede Dinstart k, jeder Leitungsgruppe ij zugeordnet ist, derart, dass

* eine Leitung des Bündels ij für eine Verbindung der Dienstart k nur dann benützt werden kann, wenn die Anzahl der belegten Leitungen p_{ij} aufgrund der letzten Netzbeobachtung kleiner ist als der entsprechende Netzzugangsparameter $q_{ij}(k)$, und in welchem
* die zugewiesenen Netzzugangsparameter $q_{ij}(k)$ während dem Netzbetrieb konstant gehalten oder verändert werden können in Uebereinstimmung mit den Netzmanagementobjektiven, und in velchem
* die Tarife unbeachtet gelassen werden können, in welchem Falle das System für die Verkehrsleitweglenkung in Abhängigkeit des jeder Dienstart zugeordneten Ausnutzungsgrades (grade-of-service) benützt werden kann.

8. System nach Anspruch 7, in welchem die Verkehrsleitweglenkungsinstruktionen ausgedrückt als Transitknotenidentitäten an die SPC-Knoten über die Datenvermittlungsleitungen geleitet werden, welche zwischen den Knoten und dem Computer des Systems installiert sind und in welchem diese Datenvermittlungsleitungen ebenfalls dienen für die Vermittlung von Daten von den SPC-Knoten zum Computer in Form von Indikatoren für:

* angebotene Knoten-zu-Knoten Anrufsintensitäten, y_{ij} (k);
* Verfügbarkeit der Leitungsbündel, p_{ij} oder N_{ij}- p_{ij};
* mittlere Belegungsdauer, $h_i(k)$;
* Verfügbarkeit der Knoten, R_{ix};

9. System nach Anspruch 8, in welchem die von der Dienstart abhängigen Netzzugangsparameter $q_{ij}(k)$ ebenfalls für das bedarfsmässige (on-demand) Management der Verkehrs- und Netzeinrichtungen benützt werden, wie z.B.:

* Blockierung von Netzeinrichtungen für eine gewisse Dienstart, indem der entsprechende Netzzugangsparameter $q_{ij}(k) = 0$ gesetzt wird, und/oder
* Reservation von Netzeinrichtungen für eine gewisse Dienstart, indem der entsprechende Netzzugangsparameter $q_{ij}(k) = N_{ij}$ = totale Kapazität des Leitungsbündels gesetzt wird,

und in welchem auch andere "on-demand" Interventionen, wie z.B.:
* Aenderung der Netzdefinition,
* Aenderung der Zonenbeschränkungen,
* Aenderung der Tarife und/oder Netzzugangsparameter,
* Aenderung des Netzsondierungsintervals,
* Blockierung von Knoten und Leitungsbündel für Verkehr,

durch den Computer des Systems vorgenommen werden können mittelst einer besonderen Sprache für das Management des Systems und die Interventionen (SMIL).

10. System nach Anspruch 9, in welchem die zuletzt in den SPC-Knoten für jede Dienstart gespeicherten Leitweglenkungsinstruktionen als Reserve für die Leitweglenkung der verschiedenen Dienstarten dienen für den Fall, dass alle Datenverbindungsleitungen zwischen den SPC-Knoten und dem Computer des AR-NEM Systems ausser Betrieb sind.

Revendications

1. Un système d'acheminement adaptif de trafic et de gestion de réseaux de télécommunication, à base d'un ordinateur, comprenant

une pluralité de noeuds,

une pluralité de circuits de transmission interconnectant les noeuds et

dans lesquels la plupart des noeuds sont du type contrôle par programme enregistré (Stored Program Control = SPC), SPC noeuds;

des moyens pour déterminer un tarif, en communication avec les noeuds, pour communications entre les noeuds, en fonction de la distance entre les noeuds,

des moyens de munir les noeuds avec des instructions pour l'acheminement des connexions dans le réseau de noeuds de telle façon que les revenus sont maximalisés et de telle façon que les circuits et les noeuds qui sont hors-service sont automatiquement contournés, ces moyens comprenant un ordinateur avec une base de données, l'information concernant les tarifs étant emmagasinée dans la base de données;

et dans lesquels pour les connexions en provenance de chaque noeud SPC i à chaque autre noeud de destination j, les circuits directs seront désignés à être utilisés comme premier choix et deux autres chemins alternatifs I et II seront indiqués, chacun d'eux comprenant un chemin de deux circuits en série par un noeud de transit (tandem) t pour être utilisé comme second choix et un chemin de trois circuits en série par les noeuds de transit t et u pour être utilisé comme troisième choix,

caractérisé en ce que

ledit système comprend des moyens pour gérer une pluralité de différents types de services dans le même réseau, tels que trafic de téléphone public, trafic d'urgence, trafic de données entre ordinateurs, trafic de téléfax, etc., et aussi dans différents types de réseaux tels que réseaux urbains, réseaux interurbains, réseaux privés, réseaux d'ordinateurs, réseaux militaires et de sécurité, réseaux de télécommunication mobiles, etc.;

ledit système est muni de moyens pour déterminer les tarifs de chaque type de service pour les communications des différents types de service entre les noeuds, en fonction du type de service et de la destination;

comporte des moyens de munir les noeuds d'instructions pour l'acheminement des différents types de service dans le même réseau à chaque destination de telle manière que le revenu provenant de l'ensemble des services est maximalisé et de telle manière que les objectifs de gestion de chaque type de service et chaque paire de noeuds sont satisfaits;

lesdites instructions d'acheminement sont déterminées pour chaque type de service et pour chaque paire de noeuds utilisant les chemins les plus économiques du réseau et font partie de l'accès au réseau en fonction de chaque type de service et des tarifs de chaque type de service à chaque destination et en fonction de l'intensité de trafic de chaque type de service entre chaque paire de noeuds;

lesdites instructions d'acheminement sont déterminées en tenant compte de l'état actuel et global du réseau et de telle manière que les circuits de transmission hors-service et les noeuds nondisponibles pour un certain type de service sont automatiquement évités;

lesdites instructions d'acheminement sont déterminées de telle manière que pendant la période de surcharge du réseau les types de service à tarifs élevés sont automatiquement privilégiés et que les interventions en ce qui concerne la gestion des services et du réseau sont respectées,

et dans lequel les instructions d'acheminement sont communiquées aux noeuds en termes d'indicateurs pour l'utilisation de circuits directs et noeuds de transit t et u pour chaque type de service et pour chaque noeud SPC i à chaque destination j et dans lequel les instructions d'acheminement sont revues et transmises aux noeuds avec une fréquence nécessaire pour l'utilisation optimale de chaque type de réseau;

ledit accès au réseau est attribué à chaque groupe de circuits pour chaque type de service et pour chaque paire de noeuds conformément aux objectifs de gestion des services, aux exigences des services et aux restrictions appliquées à chaque type de service et à chaque noeud;

ladite base des données comporte l'information relative à l'état global du réseau en termes

- de l'intensité des appels pour chaque type de service entre chaque paire de noeuds, et
- de la durée de connexion pour chaque type de service dans chaque noeud et
- du nombre effectif de circuits occupés dans chaque groupe de circuits, et
- de la charge effective de trafic dans chaque noeud SPC, relative à l'Unité Centrale de Processeur (CPU) et au réseau de connexion, et
- de la disponibilité des groupes de circuits et des noeuds pour chaque type de service,

dans lequel l'information emmagasinée dans la base de données, en communication avec les noeuds, est automatiquement et fréquemment renouvelée, et

comprend l'information relative

- aux tarifs pour chaque type de service et pour chaque noeud à chaque destination, et
- à l'accès au réseau pour chaque type de service et pour chaque paire de noeuds, et
- aux interventions de gestion des services et du réseau,

dans lequel les tarifs, l'accès au réseau et les interventions pour chaque type de service peuvent être modifiés manuellement.

2. Le système défini en Revendication 1 dans lequel ladite base de données contient également l'information relative à

- l'intensité des appels offerts pour chaque type de service et de chaque noeud à chaque autre noeud,
- l'état effectif de hors-service des groupes de circuits et des noeuds, et
- l'accès au réseau pour chaque type de service.

3. Le système défini selon Revendications 1 et 2, dans lequel lesdits circuits directs et lesdits chemins alternatifs seront indiqués pour les appels de chaque type de service.

4. Le système défini selon Revendication 3 dans lequel les indicateurs de chemins en termes de circuits directs et/ou respectivement d'identités des noeuds de transit t et u, pour chaque type de service en provenance d'un noeud SPC i à un noeud quelconque de destination j sont déterminés selon l'algorithme suivant:

a) les appels d'un type de service k avec le tarif correspondant $c_{ij}(k)$, où:

$$c_{ij}(1) > c_{ij}(2) > \text{---------} > c_{ij}(K);$$

seront indiqués d'utiliser les circuits directs entre les noeuds i et j comme premier choix, si

- * le noeud de destination j est disponible au service, ($R_{jx} = 1$), et
- * le groupe de circuits entre les noeuds i et j a au moins un circuit disponible au service, ($N_{ij} - p_{ij}) > 0$, et
- * l'état effectif de trafic et d'occupation du groupe de circuits entre les noeuds i et j est tel que le revenu attendu provenant d'une connexion du type de service k est supérieur à l'estimation du revenu perdu à cause de cette connexion, provenant de services à tarifs plus élevés, ce qui peut être formulé comme suit:

$$c_{ij}(k) > \left[B(N_{ij}-1;p_{ij}) - B(N_{ij};p_{ij})\right] \cdot \sum_{\mu=1}^{k-1} c_{ij}(\mu) \cdot A_{ij}(\mu) \;;$$

b) le noeud t comme noeud de transit faisable pour un chemin à deux chaînons est déterminé, si

* le noeud de destination j est disponible au service, ($R_{jx} = 1$) et pour lequel
* le noeud de transit t est disponible au service, ($R_{tx} = 1$) et
* les groupes de circuits entre les noeuds i et t comme entre les noeuds t et j, chacun a au moins un circuit disponible au service, $N_{it} - p_{it} > 0$ et $N_{tj} - p_{tj} > 0$, et
* le revenu attendu provenant du service k acheminé sur le noeud de transit est supérieur à la perte estimée à cause de cette connexion, provenant de trafic direct qui pourrait être traité par les deux groupes de circuits i - t et t - j, ce qui peut être exprimé comme suit:

$$c_{ij}(k) > \left[B(N_{it}-1;p_{it}) - B(N_{it};p_{it})\right] \cdot \sum_{\mu=1}^{k} c_{it}(\mu) \cdot A_{it}(\mu) \; + \; + \left[B(N_{tj}-1;p_{tj}) - B(N_{tj};p_{tj})\right] \cdot \sum_{\mu=1}^{k} c_{tj}(\mu) \cdot A_{tj}(\mu) \;;$$

c) les noeuds t et u comme noeuds de transit faisables pour un chemin sur trois chaînons sont déterminés, si

* le noeud de destination j est disponible au service, ($R_{jx} = 1$) et pour lequel
* les noeuds de transit t et u sont disponibles au service, ($R_{tx} = 1$ et $R_{ux} = 1$) et
* chaque groupe de circuits entre les noeuds i et t, entre les noeuds t et u et entre les noeuds u et j a au moins un circuit disponible au service, ($N_{it} - p_{it} > 0$, $N_{tu} - p_{tu} > 0$ et $N_{uj} - p_{uj} > 0$) et
* le revenu attendu provenant du service k acheminé sur les noeuds de transit est supérieur à la perte de revenu estimée à cause de cette connexion, provenant du trafic qui pourrait être traité sur les circuits directs par les groupes de circuits i - t, t - u et u - j, ce qui peut être formulé comme suit:

$$c_{ij}(k) > \left[B(N_{it}-1;p_{it}) - B(N_{it};p_{it})\right] \cdot \sum_{\mu=1}^{k} c_{it}(\mu) \cdot A_{it}(\mu) \; + \; + \left[B(N_{tu}-1;p_{tu}) - B(N_{tu};p_{tu})\right] \cdot \sum_{\mu=1}^{k} c_{tu}(\mu) \cdot A_{tu}(\mu) \; + \; + \left[B(N_{uj}-1;p_{uj}) - B(N_{uj};p_{uj})\right] \cdot \sum_{\mu=1}^{k} c_{uj}(\mu) \cdot A_{uj}(\mu) \;;$$

où:

i =	numéro d'un noeud de départ
j =	numéro d'un noeud d'arrivée
m =	nombre total de noeuds SPC dans le réseau qui peuvent être utilisés pour le trafic de transit;
k =	numéro d'un type de service
K =	nombre total de services
$c_{ij}(k)$ =	tarif par unité de temps de communication entre les noeuds i et j pour le service du type k;
R_{jx} =	indicateur de disponibilité au service pour le noeud j;

R_{jx} = 1, noeud j est disponible pour le service associé avec le récepteur et l'émetteur de type x;

N_{ij} = nombre total de circuits opérationnels du groupe de circuits entre les noeuds i et j;

p_{ij} = nombre effectif de circuits occupés du groupe de circuits entre noeuds i et j;

$A_{ij}(k)$ = trafic du type de service k offert du noeud i au noeud j; $A_{ij}(k) = y_{ij}(k) \cdot h_i(k)$;

$y_{ij}(k)$ = intensité des appels du type de service k offerte du noeud i au noeud j;

B(N;p) = probabilité conditionnelle de la totalité des N circuits occupés étant admis que p circuits ont été observés comme occupés au moment du dernier sondage du réseau; peut être calculée approximativement de façon suivante:

$$B(N;p) \approx \frac{\frac{A^N}{N!}}{\sum_{v=0}^{N} \frac{A^v}{v!}}$$

A = trafic total offert à N circuits;

t = identité (numéro) du noeud de transit 1;
$t = 1, 2, \text{-----} m; \quad t \neq i; \quad t \neq j;$

u = identité (numero) du noeud de transit 2;
$u = 1, 2, \text{-----} m; \quad u \neq i; \quad u \neq j;$

$h_i(k)$ = durée moyenne de communication pour le type de service k en provenance du noeud i;

5. Le système défini selon revendication 4 dans lequel l'algorithme est appliqué à un seul type de service, par exemple:

$c_{ij}(1)>0$ et $c_{ij}(2) = c_{ij}(3) = \text{-----} c_{ij}(K) = 0;$
$A_{ij}(1)>0$ et $A_{ij}(2) = A_{ij}(3) = \text{-----} A_{ij}(K) = 0;$

dans ce cas le système est directement applicable aux réseaux de téléphone interurbains existants et, si le tarif pour une communication est égal à 1, par exemple:

$c_{ij}(1) = 1;$

le système est directement applicable aux réseaux à tarif unitaire, tels que les réseaux téléphoniques urbains existants.

6. Le système défini selon revendication 4 dans lequel les deux chemins alternatifs I et II, s'ils existent, sont sélectionnés de façon aléatoire et dans lequel l'alternative I est utilisée comme le chemin de transit principal et l'alternative II est utilisée seulement lorsque le chemin I est déjà pris.

7. Le système defini selon revendication 6 dans lequel l'utilisation d'un groupe de circuits comme partie d'un chemin faisable entre les noeuds i et j dépend du paramètre d'accès au réseau $q_{ij}(k)$ attribué à chaque groupe de circuits ij, pour chaque type de service k, de telle manière que

* un groupe de circuits ij peut être utilisé pour une connexion du type de service k seulement si le nombre de circuits occupés p_{ij} observé dans le groupe des circuits lors du dernier sondage du réseau, est inférieur au paramètre d'accès au réseau $q_{ij}(k)$ correspondant, et où
* les paramètres d'accès au réseau attribués $q_{ij}(k)$ peuvent être maintenus constants ou peuvent être modifiés pendant les opérations de gestion du réseau selon des objectifs opérationnels, et où
* les tarifs peuvent être négligés, dans quel cas le système peut être utilisé pour acheminement de trafic selon le grade-de-service dépendant de et attribué à chaque type de service.

8. Le système défini selon revendication 7 dans lequel les instructions d'acheminement de trafic en termes d'identités de noeuds de transit sont transferées aux noeuds SPC par les circuits de transmission de données installés entre les noeuds et l'ordinateur du système, et dans lequel ceux-ci sont utilisés pour le transfert de données des noeuds SPC à l'ordinateur du système en termes d'indicateurs pour:

* l'intensité d'appels offerte entre les noeuds, $y_{ij}(k)$;
* les disponibilités des groupes de circuits, p_{ij} ou N_{ij} - p_{ij} ;
* les durées moyennes de connexion, $h_i(k)$;
* les disponibilités des noeuds, R_{ix}.

9. Le système defini selon revendication 8 dans lequel les paramètres d'accès au réseau dépendant du type de service $q_{ij}(k)$ sont également utilisés pour la gestion sur demande du trafic et des ressources du réseau, tels que

* le blocage de ressources du réseau pour un certain type de service en mettant le paramètre correspondant qui commande l'accès au réseau $q_{ij}(k) = 0$, et/ou
* la réservation de ressources du réseau pour un certain type de service en mettant le paramètre correspondant qui commande l'accèe au réseau $q_{ij}(k)$ = N_{ij} = capacité totale d'un groupe de circuits,

et où également les autres interventions sur demande, telles que:

* la modification de la définition du réseau,
* la modification de zones restreintes,
* la modification de tarifs et/ou de paramètres d'accès au réseau,
* la modification de l'intervalle de sondage du réseau,
* le blocage de noeuds et groupes de circuits pour le trafic,

peuvent être exécutées par l'ordinateur du système en utilisant un langage spécial de gestion du système et des interventions (SMIL).

10. Le système défini selon revendication 9 dans lequel les dernières instructions emmagasinées dans les noeuds SPC pour chaque type de service servent de réserve pour l'acheminement des différents types de service au cas où tous les moyens de communication entre les noeuds SPC et l'ordinateur du système AR-NEM sont hors-service.

FIG. 1

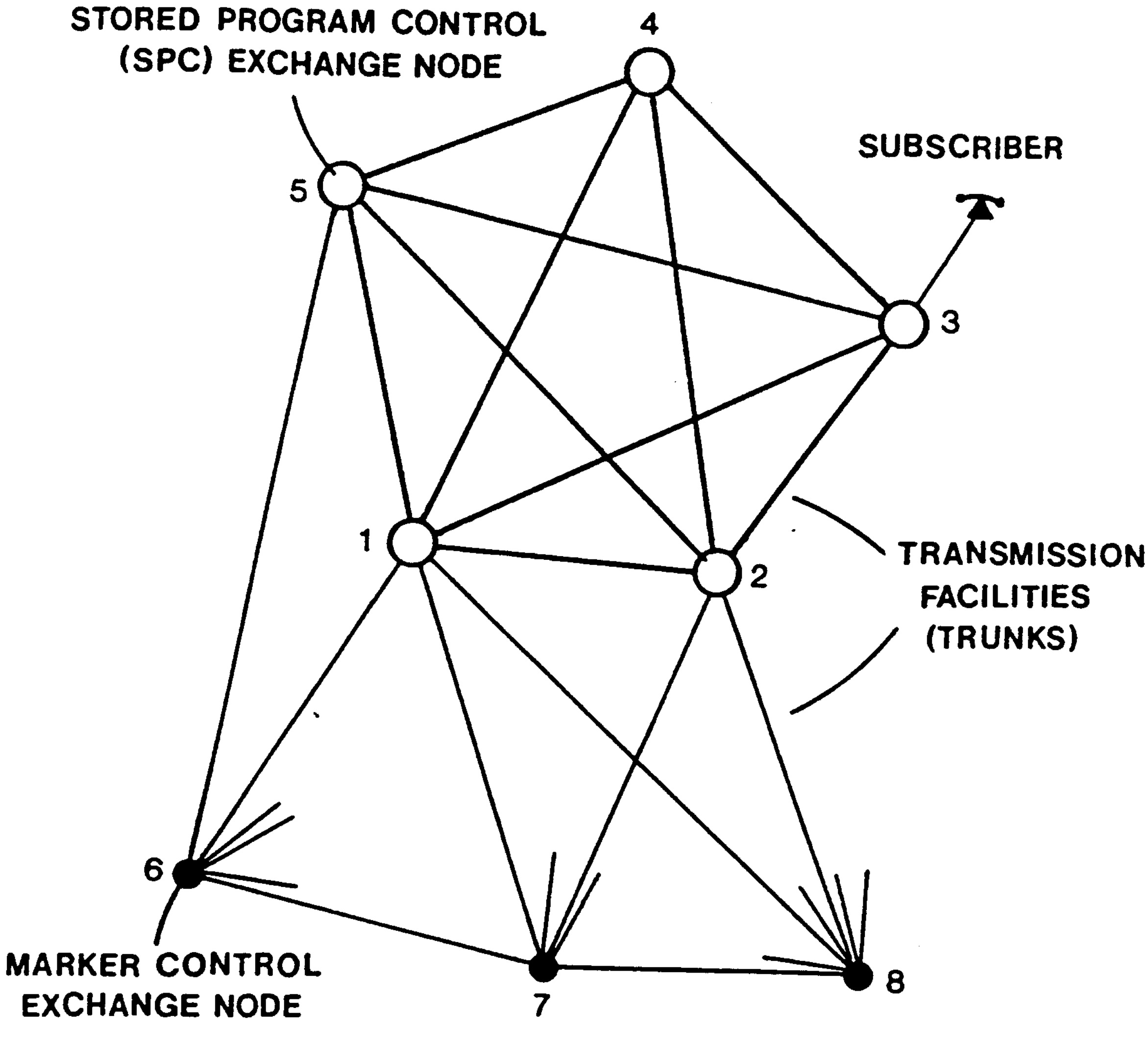

STORED PROGRAM CONTROL
(SPC) EXCHANGE NODE
4
SUBSCRIBER
5
3
1
2
TRANSMISSION
FACILITIES
(TRUNKS)
6
MARKER CONTROL
EXCHANGE NODE
7
8

FIG.2

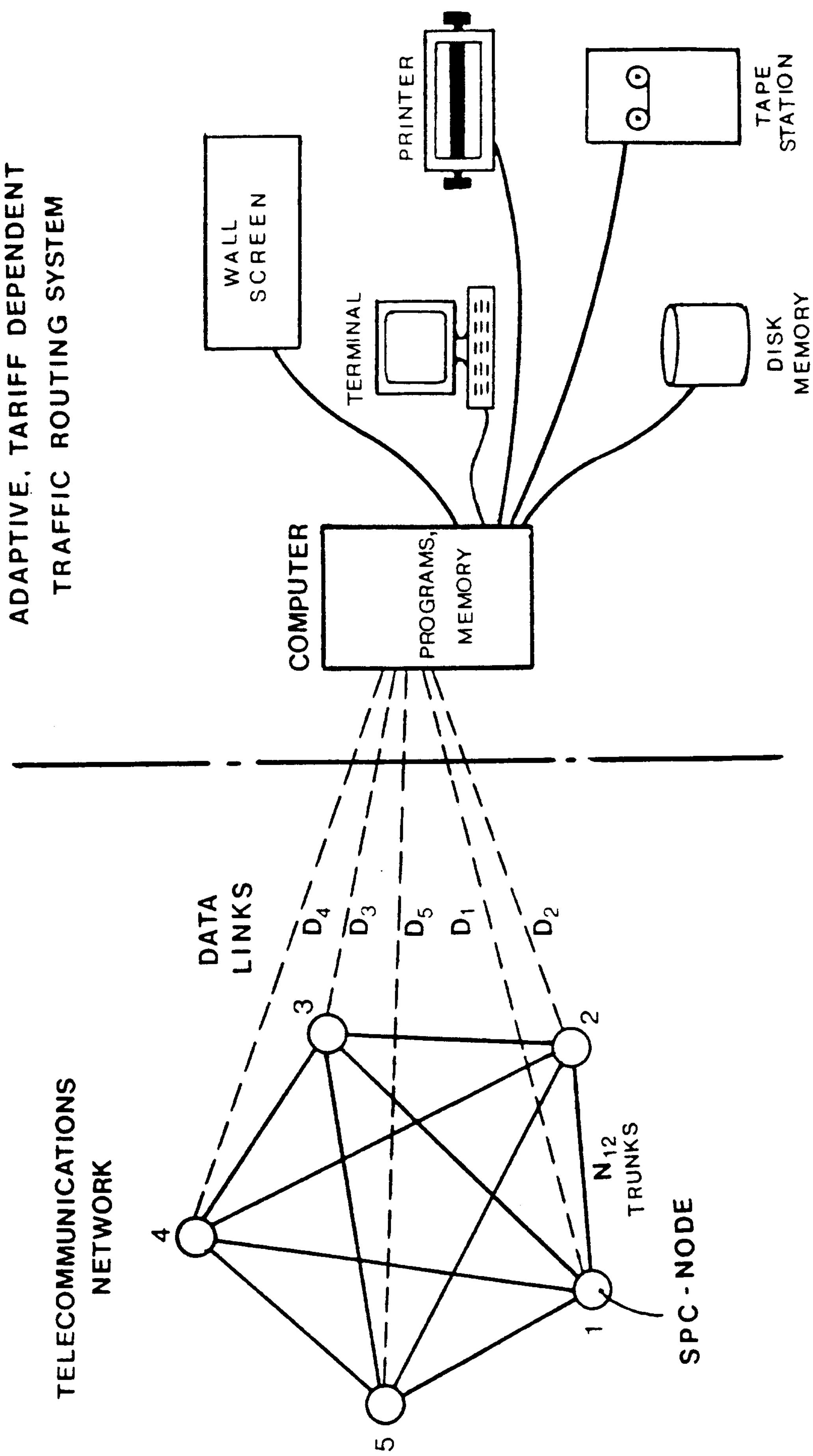

ADAPTIVE, TARIFF DEPENDENT
TRAFFIC ROUTING SYSTEM
WALL SCREEN
PRINTER
TAPE STATION
TERMINAL
DISK MEMORY
COMPUTER
PROGRAMS, MEMORY
DATA LINKS
D4
D3
D5
D1
D2
TELECOMMUNICATIONS NETWORK
1
2
3
4
5
N12 TRUNKS
SPC-NODE

FIG. 3

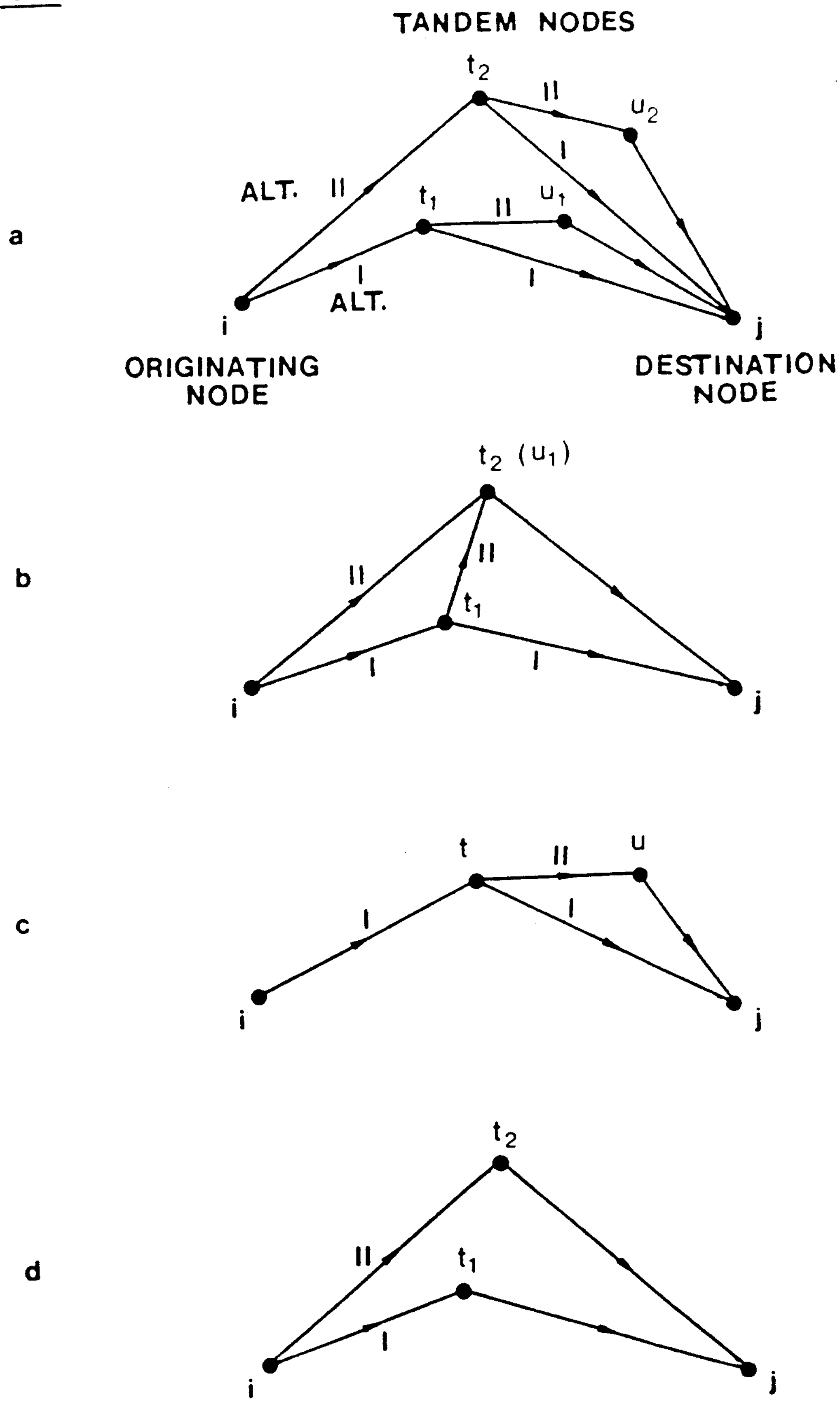

TANDEM NODES
a
t_2
II
u_2
I
ALT.
II
t_1
II
u_1
I
ALT.
I
i
j
ORIGINATING NODE
DESTINATION NODE
b
t_2 (u_1)
II
II
t_1
I
I
i
j
c
t
II
u
I
I
i
j
d
t_2
II
t_1
I
i
j

FIG. 4

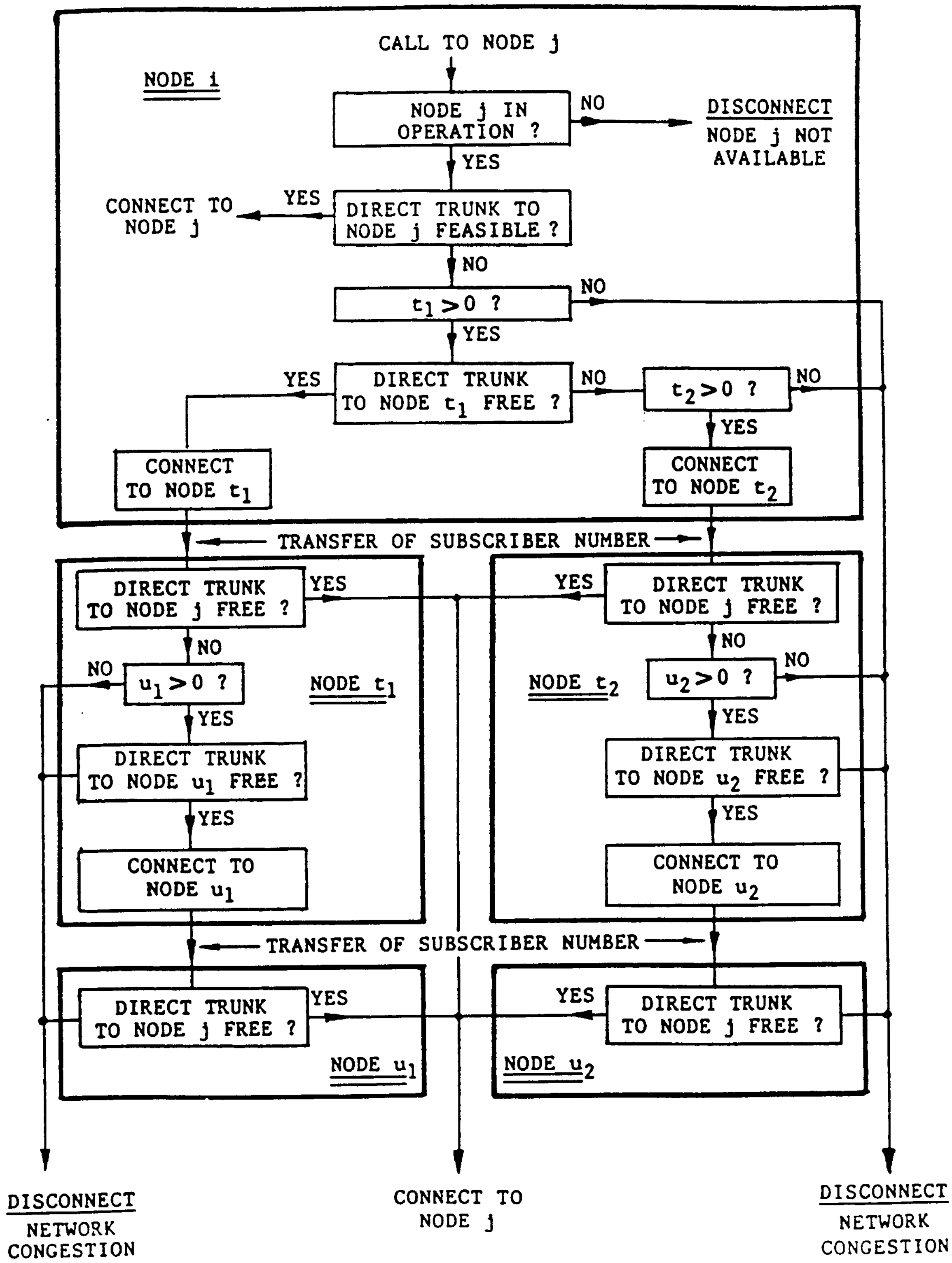
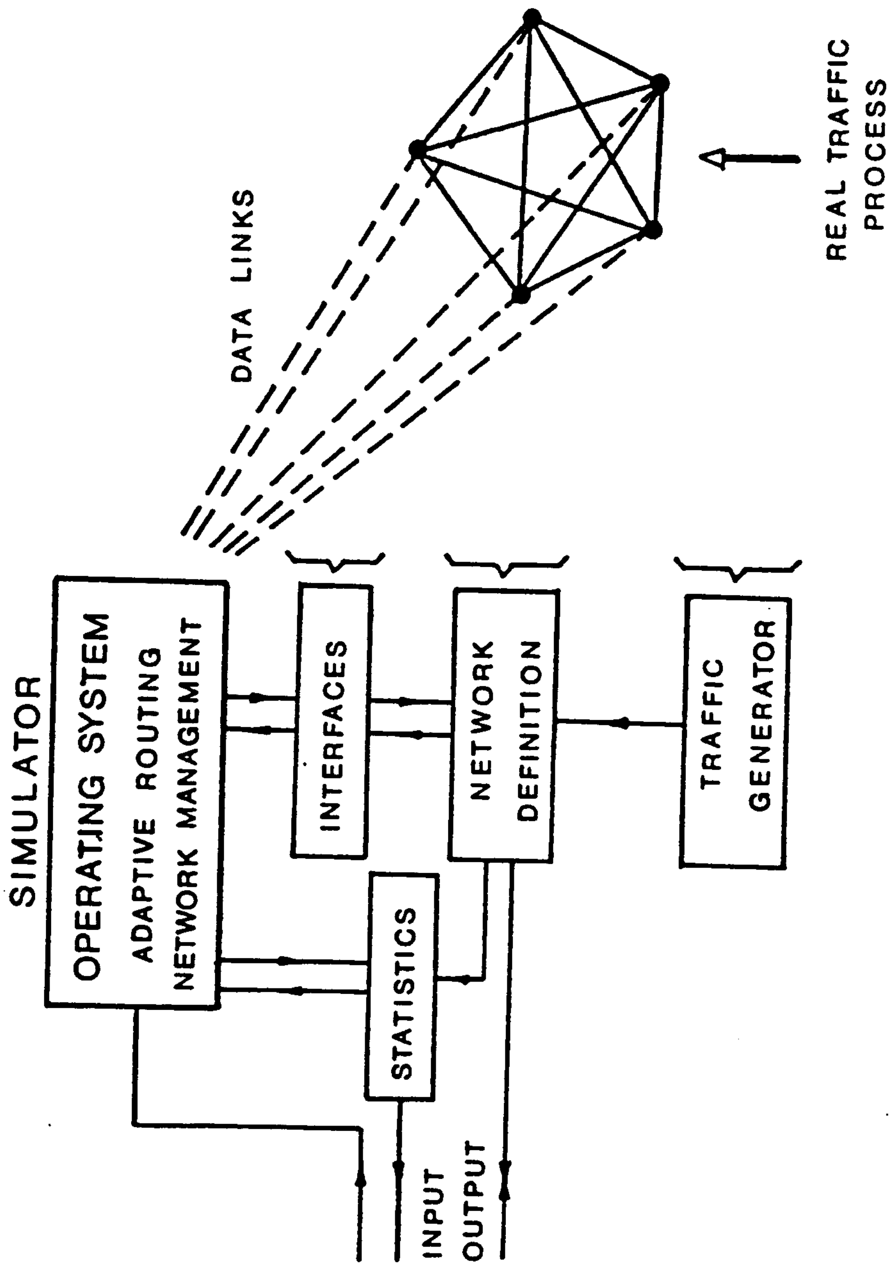

CALL TO NODE j
NODE i
NODE j IN OPERATION ?
NO
DISCONNECT
NODE j NOT AVAILABLE
YES
CONNECT TO NODE j
DIRECT TRUNK TO NODE j FEASIBLE ?
$t_1 > 0$?
DIRECT TRUNK TO NODE t_1 FREE ?
$t_2 > 0$?
CONNECT TO NODE t_1
CONNECT TO NODE t_2
TRANSFER OF SUBSCRIBER NUMBER
DIRECT TRUNK TO NODE j FREE ?
$u_1 > 0$?
NODE t_1
NODE t_2
$u_2 > 0$?
DIRECT TRUNK TO NODE u_1 FREE ?
DIRECT TRUNK TO NODE u_2 FREE ?
CONNECT TO NODE u_1
CONNECT TO NODE u_2
NODE u_1
NODE u_2
DISCONNECT
NETWORK CONGESTION
CONNECT TO NODE j
DISCONNECT
NETWORK CONGESTION

FIG. 5

STUDY TOOL

COMPUTER-BASED SIMULATOR



LINK	HANDLED CALLS	HANDLED TRAFFIC	TRA OFF	TOT TRNKS	HOLD TIME	HTI	TLOAD	LSO
1	13726	1323.5						
2	2012	204.5						
3	1297	120.4						
4	17	1.4						
5	0	0.0						
6	0	0.0						
TOTAL	17052	1650.1	1745.9	2675	209.02	0.6169	0.7848	0

SERVICE	TOT CALLS	HANDL CALLS	MINTS SRVD	REV $	TOT CONG
1	9148	8624	29889.6	119595.6	0.057
2	8935	8428	29514.3	58086.6	0.057
TOTAL	18083	17052	59403.9	177682.2	0.057

FIG. 6

PRESENT ART, FIXED-HIERARCHICAL ROUTING

LINK	HANDLED CALLS	HANDLED TRAFFIC	TRA OFF	TOT TRNKS	HOLD TIME	HTT	TLOAD	LSO
1	14040	1356.3						
2	2442	241.0						
3	1406	129.3						
4	0	0.0						
5	0	0.0						
6	0	0.0						
TOTAL	17888	1726.8	1745.9	2671	208.51	0.6465	0.8334	0

SERVICE	TOT CALLS	HANDL CALLS	MINTS SRVD	REV $	TOT CONG
1	9148	9101	31555.8	123878.2	0.005
2	8935	8787	30607.7	59349.0	0.017
TOTAL	18083	17888	62163.4	183227.2	0.011

10 seconds scanning interval

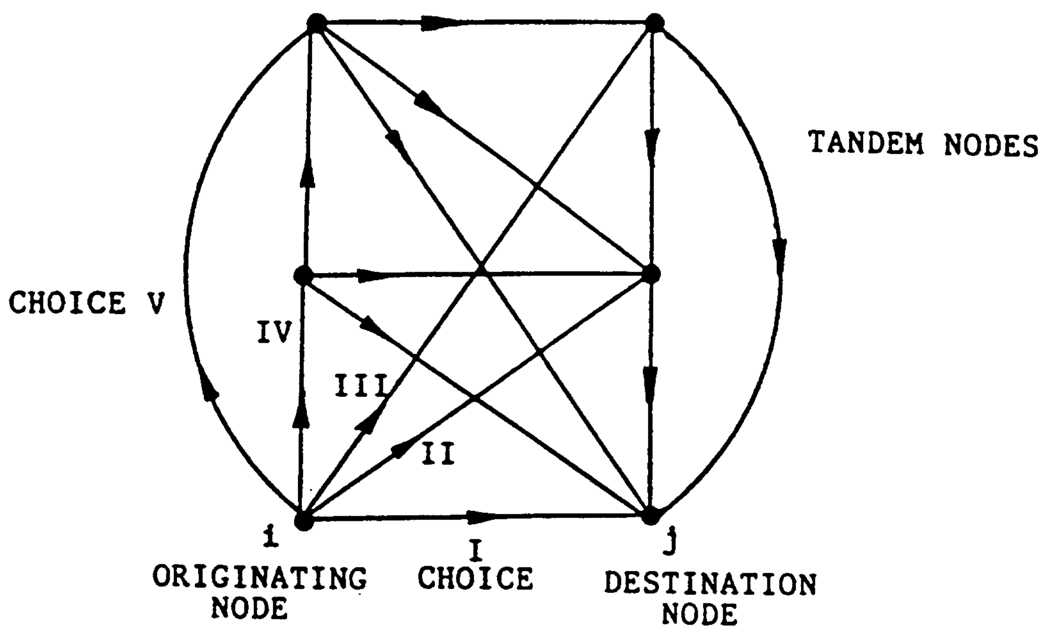
FIG. 7

ADAPTIVE, TARIFF DEPENDENT ROUTING
(THE INVENTION)

FIG. 8

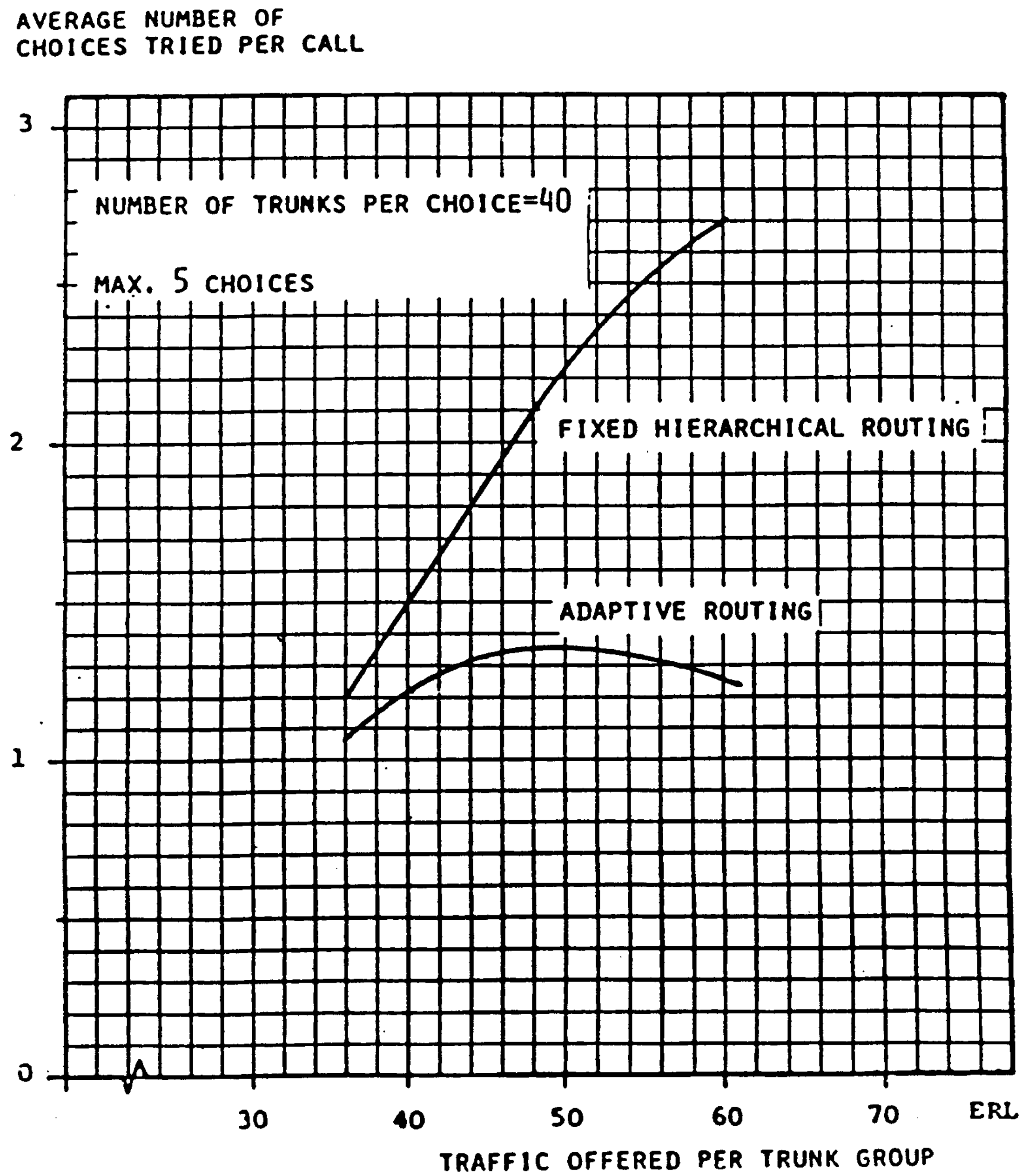
PRESENT ART

FIXED-HIERARCHICAL ROUTING



INTERCITY NETWORK CONFIGURATION

FIG. 9


AVERAGE NUMBER OF
CHOICES TRIED PER CALL
3
2
1
0
NUMBER OF TRUNKS PER CHOICE=40
MAX. 5 CHOICES
FIXED HIERARCHICAL ROUTING
ADAPTIVE ROUTING
30
40
50
60
70
ERL
TRAFFIC OFFERED PER TRUNK GROUP