Network Stucture and Design

Mr. Moumoulidis, OTE

UNION INTERNATIONALE DES TELECOMMUNICATIONS
INTERNATIONAL TELECOMMUNICATION UNION
UNION INTERNACIONAL DE TELECOMUNICACIONES

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1. INTRODUCTION

Planning becomes more efficient, if we have a complete knowledge of the structure of the network we are studying. This enables planners

- to collect reliable data for the network involved;
- to outline practical scenarios;
- to determine the transmission and switching systems to be employed;
- to judge the applicability of the results achieved of the network investigated.

The purpose of this text is to give a brief description of the following networks which forms the three major types of network:

- Metropolitan areas networks
- Rural areas networks
- National (Long distance) and international networks

An insight of the structure of local networks (subscriber's and junction network) will be provided, since this represents a substantial proportion of the investment cost. The text will conclude with a general description of the so-called hierarchical and non- hierarchical networks. Especially the latter is a consequence of the advent of SPC technology and particularly the digital technology in switching. Digital SPC switching systems allow a non-hierarchical network, namely routing of traffic is not necessarily carried by specific predetermined centres. This new possibility increases the efficiency of the digital switching systems and provides economy against conventional hierarchical network.

2. NETWORK STRUCTURE

2.1 Local networks

Local networks are divided into three subtypes, according to the size of the area and the amount of urban development.

a) Rural networks

The main characteristics of the type of network is the wide subscriber dispersion around a small or medium-size town. There are limited alternatives for exchange locations. Subscriber lines are much longer than those of urban and metropolitan areas and therefore, special transmission equipment is required for providing telephone service. Such equipment is:

- EDM and TDM multiplexers
- Line concentrators (conventional or electronic type)
- Open wire lines
- Radio relay links

b) Urban networks

These networks are characterized by the fact that several main local exchanges are necessary to which subscribers are directly connected. Planning studies are necessary to find the optimum locations, area and capacity of local exchanges.

c) Large metropolitan networks

These networks are characterized by the high concentration of subscribers in the network area. A large number of local exchanges are required to provide connections to subscribers. Planning studies are necessary to optimise the network.

2.2 Medium and long distance networks

Medium and long distance networks connect different local areas. This type of network is usually hierarchical with one, two or three levels depending on the number of these areas and the total traffic carried in the network.

2.3 International network

This network comprises international transit centres and transmission links to other countries.

3. LOCAL NETWORK STRUCTURE & DESIGN

3.1 General

The local switching systems, outside plant for junctions and subscriber circuits makes up the local network. In Figure 1 a local network of a small metropolitan area is shown. Some useful terms are given below for local networks:

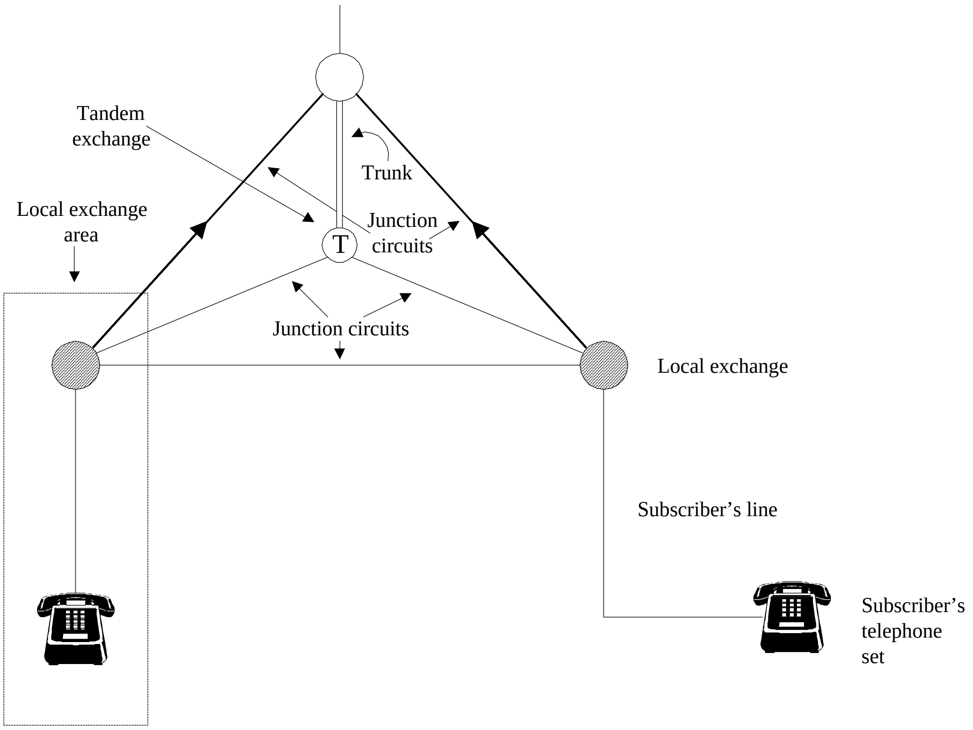

Fig. 1
Local network with two local exchanges

- Local exchanges.
  These are the exchanges to which subscribers are connected.

- Subscriber’s line.
  The circuit connecting the subscribers telephone set to the local exchange.

- Local exchange area.
  The area of local exchange and subscriber’s network.

- Direct junction circuit.
  The circuits between two local exchanges.

- Primary centre.
  The centre to which local exchanges are connected and via which trunk (long distance) connectors are carried out.

- Trunk junction circuits.
  The junction network between local exchanges and their primary centre, which can participate in long-distance (including international) connections.

- Tandem exchange.
  The exchange via which the traffic of other exchanges is served.

3.2 Subscriber’s line networks

This network connects subscriber to local exchanges. In fig. 2 a simplified subscriber’s line network is shown.

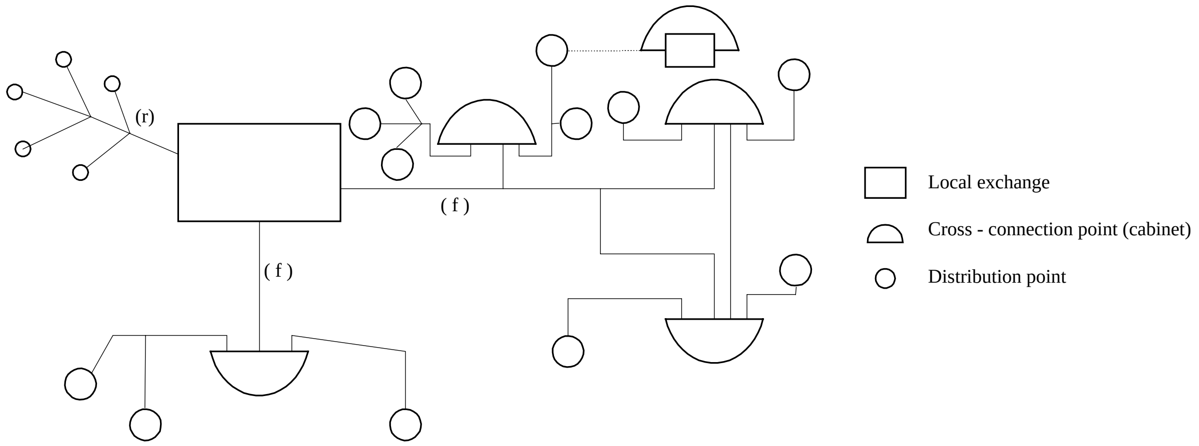

Fig. 2
Subscriber’s line network

The network shown in the above figure consists of:

- Main distribution frame (MDF)
  The connection frame in a telephone exchange on which the local cable pairs and exchange multiple terminate. It is arranged so that any cable pair can be cross-connected to any exchange multiple number.

- Cross-connection point (CCP)
  This is the equipment which enables, by use of jumpers wires or equivalent, an incoming pair to be connected to any of the outgoing pairs.

- Distribution point (DP)
  The last point in the exchange area cable network from which pairs are distributed to individual subscribers.

- Main cable
  Cable, usually of large pairs, connecting the exchange to a cross-connection point.

- Distribution cable
  Cable serving a distribution point or cable between two cross-connection points

- Link cable
  Cable containing link pairs to give flexibility and relief between two cross- connection points.

- Subscriber’s service line.
  The part of the subscriber’s line between the distribution point and the telephone set, regardless of the material or method used.

We can distinguish two kinds of local networks :

- Rigid networks
  In a rigid network all conductors are electrically prolonged from one cable section to another by joints - i.e the conductors are firmly jointed together and all pairs are thus taken through from the MDF to DP (the part of the network characterized by (r) in figure 2)

- Flexible networks
  In flexible network the subscribers line network is divided into separate sections (main cable and distribution cable sections) by the cross-connection point where the connections may or may not be made systematically in advance.

3.3 Junction and Trunk network

As defined in the previous paragraph junction and trunk networks are needed to serve traffic between local exchanges and local exchanges and primary exchanges. For the junction network we can make the following distinctions:

- Star network

A number of exchanges are said to form a pure star network when the only possible connection between them is through a single tandem or transit exchange to which all others are connected (see fig.3)

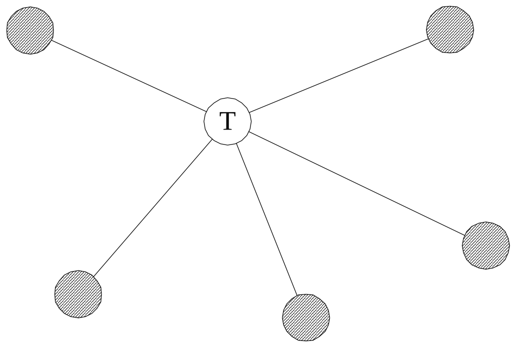

Fig. 3
Star network

A double star network consists of a set of star-connected exchanges of which the tandem exchanges are connected in star to a major centre (super tandem) (see fig 4)

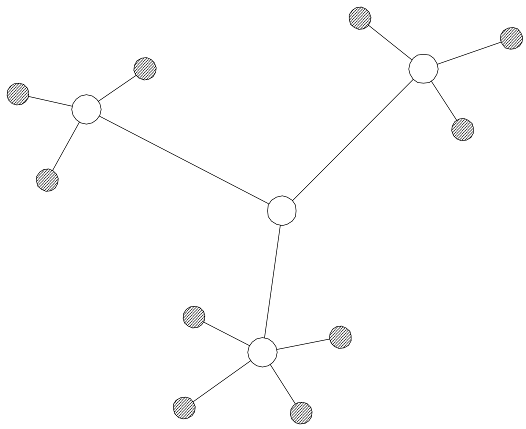

Fig. 4
A double star network

- Mesh network

The opposite of a star network is a full mesh network in which each exchange is connected to all others, and the only connection between exchanges is a direct connection. Figure 5 shows a full mesh network.

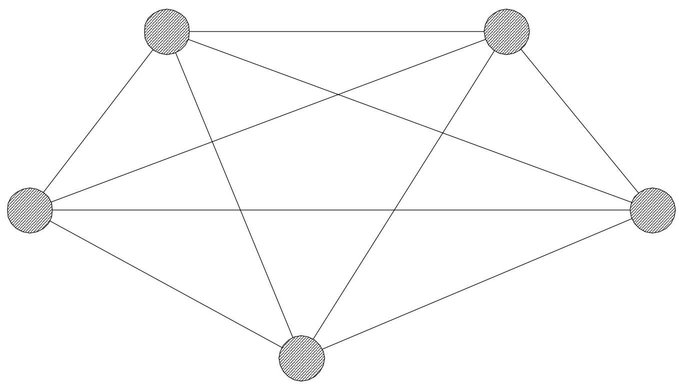

Fig. 5
A full mesh network

- Star and mesh network

The junction and trunk network is subject to optimisation which leads to a compromise between the two forms, (the star form and the mesh form) having some of the characteristics of each. For instance, a set of major exchanges may be connected in mesh but each as a switching point giving access to minor exchanges in star formation around it. (see fig.6)

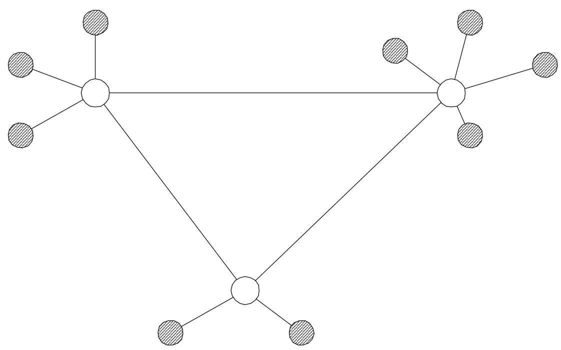

Fig. 6
A compromise of star and mesh network

3.4 Local networks design

Local networks design includes :

- the location of new exchanges
- the location of remote subscriber units (RSU)
- size of subscriber's networks
- size of junction circuits between local exchanges and types of routes
- determination of tandem centres

For the investigation of local networks it is necessary to know not only the expected number of lines in a town or district but also their distribution over the area, if possible, to the extent of a separate forecast for each building block. From this data the exchange locations, the RSU locations, and the number of working lines in each locations at the planning dates are determined. Traffic figures and distribution enter the determination of exchange locations in the form of estimates of junction requirements. However, cost of the junction network is not a major factor in the placement of exchanges.

From the exchange location results, an accurate estimate of traffic martix is made. From this traffic matrix the size of junction network and types of routes are determined as well as the number and location of tandem centres. As regards planning periods, a twenty-year fundamental plan sounds reasonable. The intermediate plans., should be elaborated for 10-years and 5-years periods. The intermediate plans form an economic step between the existing and the future desired network. In general, this simplifies many problems because a number of alternatives can be ruled out at a first examination, although, sometimes new problems arise through incompatibilities between present-day and future proposed equipments.

4. LONG-DISTANCE NETWORKS

Large values of traffic and low cost of circuits favour a mesh connections between exchanges. This is the rule in local networks where there are areas with large exchanges and with short distances between them. Unlike the long distance network, traffics values are rather small and the circuit cost is very high. As a result of this argument the intercity network is more like a star types network than a mesh one

4.1 Nomenclature

There is much confusion in terms applying to long distance systems. The term "long distance" is used for the American term "Toll" and English "Trunk". The term "junction" is used for a short distance connection between exchanges.

- Primary centres
  Centres to which local exchanges are connected and via which long distance connections are established

- Secondary centres
  Centres to which primary centres are connected in order that long-distance connections might be established.

- Tertiary centres

- Quaternary centres

- Quirary centres
  These centres can be defined in an analogous way to secondary centres.

- Trunk circuits.
  These are circuits interconnecting the primary, secondary, tertiary centres etc.

4.2 Trunk transmission systems

Trunk transmission systems mostly fall into two types;

- Frequency Division Multiplex systems using transmission media Radio relay links and Caxial cables and sometimes symmetrical cables

- Time division multiplex, especially pulse code modulation using transmission media:
  Radio relay links
  Coaxial cables
  Fibber optics cables

5. HIERARCHICAL AND NON HIERARCHICAL NETWORKS

5.1 Hierarchical networks

5.1.1 Types of routing

5.1.1.1 Direct routing

Direct route is a low loss route which caries all the traffic from one exchange to another. This is the simplest and commonest route. Figure-7 shows a direct route.

Fig.7
Direct route

5.1.1.2 Tandem routing

As the number of separate switching centres increases in an network (Metropolitan ar long-distance network) the number of different trunk routes between them increases. Above about ten centres the number of trunk routes becomes very large and routes tend to contain too few circuits to make the network economic. This argument leads to the concept of concentrating the traffic to certain routes connecting the switching centres to a specific centre the role of which is to route the whole traffic. It is understandable that the role of this switch centre from the point-of-view of handling the traffic is different than the rest ones. Figure-8 shows the configuration of a such a network. This kind of network is called a "star network"

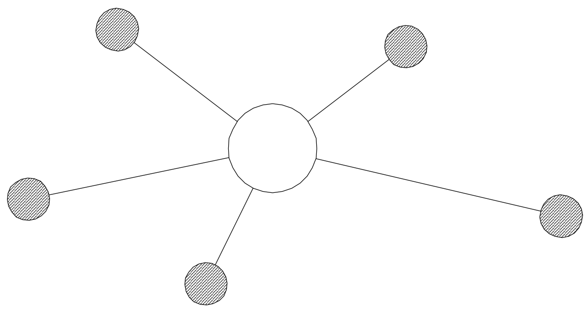

Fig. 8

This consideration introduces the concept of hierarchical network namely the switching systems are classified in hierarchical levels; those which can route traffic to various destinations and those which cannot. The former systems are transit (tandem) centres, the latter are terminals. The routes through transit switching systems are called "tandem routes". Schematically a tandem route is illustrated in fig.9

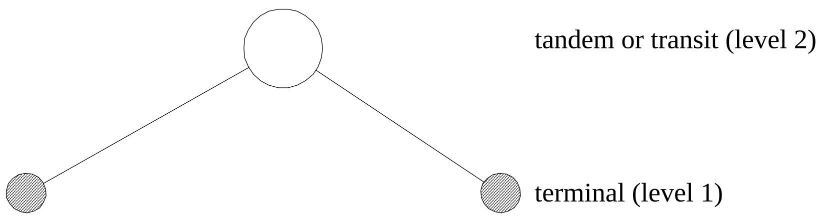

Fig. 9
A tandem route

When the number of exchanges is large/it is economical to adopt several tandems each one serving a specific group of terminal centres.

The traffic between the tandem centres may be served on direct routes. The resultant network is of double star network and is shown in fig-6. Schematically the routes are illustrated in fig-10

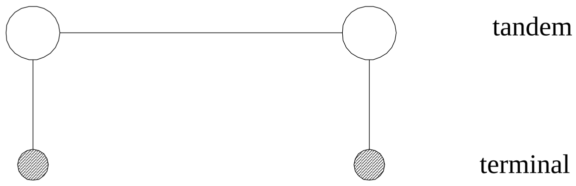

Fig. 10
Tandem route with two transit switching centres

It is worthwhile pointing out that in the above route the tandem centres are of the same level in the hierarchy. So this network is characterized by two level switching centres. When the number of tandem centres becomes high the adoption of third level tandem makes the network economical. Here we speak about hierarchy with three levels of centres. In figure 11 a tandem route with three level tandems is shown.

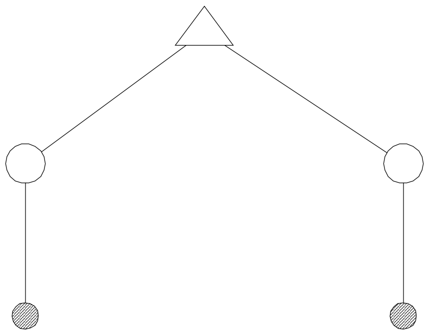

Fig. 11

5.1.1.3 <u>Alternative routing</u>

In most of the cases it is more economical to establish a direct route between two centres for the major part of the traffic. The remainder (usually not more than 30%) of the traffic, when all the direct circuits are busy, can be routed via tandem centre. This kind of routing is called "alternative routing" and can be establish only when the switching systems can provide alternative routing facility.

It is worthwhile pointing out that alternative routing is subject to optimization, subsequently it is the routing which play a significant role in network planning. The size of the direct route which in this case is called "High Usage" route is determined only on economic factors. Schematically the route is shown in fig.12.

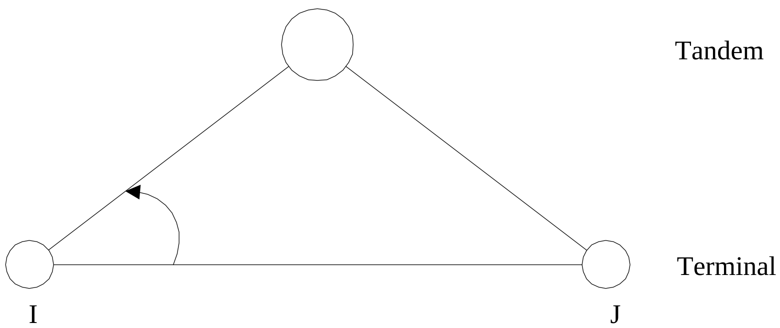

Fig. 12
Alternative routing

The arrow means alternative routing between the exchanges I and J and is pointing to the route on which traffic overflows.

5.1.2 Hierarchical routing plan

As regards the routing of traffic for a particular pair of exchanges, it is necessary to provide all kinds of possible routes. When the number of switching centres gets large it is impractical to elaborate a plan that describes the routes for each particular pair. To be able to cope with all the difficulties, it is much easier to elaborate a plan describes the routes according to the hierarchical level of the centres. In figure-13 there is a hierarchical routing plan.

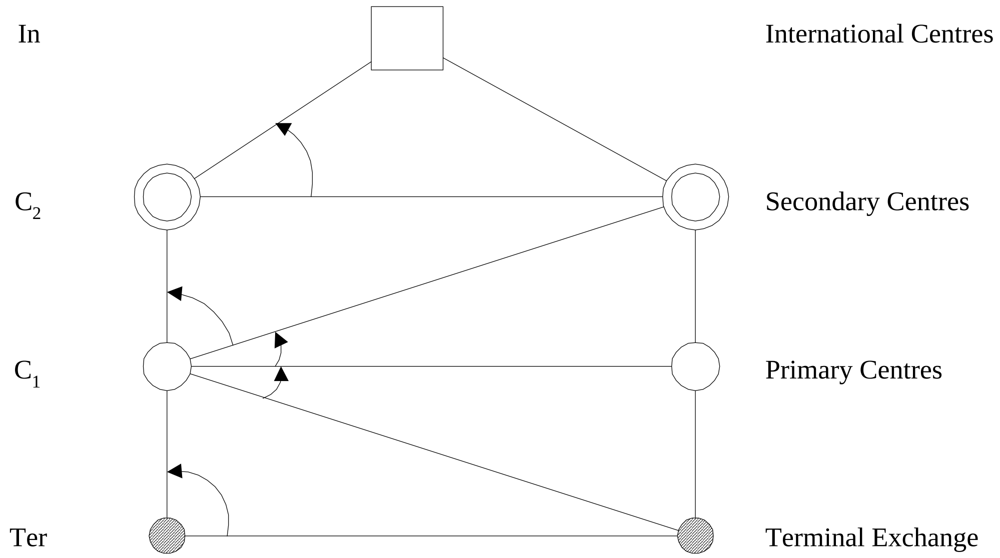

Fig. 13
Hierarchical routing plan

The above example concerns a "long-distance" network with a hierarchy of four levels.

5.2 Non - hierarchical network

5.2.1 Introduction

For this type of network a lot of terms can be found. The terms "intelligent routing" networks or "Advanced traffic routing" networks are also used.

The fixed hierarchical traffic routing which is currently used in trunk networks has been in operation for about some decades. Its design was dictated by the technology of the time and characterized by analogue cross-bar switching with wired logic common control. Although in general the fixed hierarchical routing provides quite satisfactory service, the traffic efficiency can be improved. Since especially the long distance networks are quite expensive, even a small increase in their efficiency would result in considerable savings for the telephone administrations.

The following main reasons provide the low efficiencies of fixed hierarchical routing:

- In case all direct trunks to the desired destination are busy, the overflow traffic is handled over a limited number of dedicated tandem trunks in other parts of the network cannot be used.
- an overflow call is set up to the tandem office without the knowledge of whether further connection is possible or not.
- small trunk routes are inefficient

The advent of stored program control (SPC) in the switching and digital technology in the switching and transmission has created suitable conditions for the introduction of a more intelligent traffic routing and network management system in trunk networks than in the case of presently used in hierarchical networks. The intelligence of SPC can be used to route traffic based on the knowledge of the actual state in the trunks and in the SPC nodes.

The success of a connection in network does not only depend on accessibility to a free trunk path. To a great extent the success also depends on the availability of the switching systems in different nodes used for the establishment of the connection. Especially during peak traffic periods this situation could create severe network blockage, if uncontrolled. In an intelligent traffic routing path selection is based on two conditions:

- the availability of the free trunks and
- the availability of the switching equipment in the various nodded needed to set up the connection.

5.2.2 Principles of non-hierarchical routing network.

The switching systems in a non-hierarchical network can be divided into two categories, namely:

- digital systems forming the so-called Trunk Network Switch and performing the tandem switching function, under certain conditions analogue stored program control systems, can also be considered in this category.

- analogue systems with wired logic control.

Fig.17 shows the configuration of the non-hierarchical routing

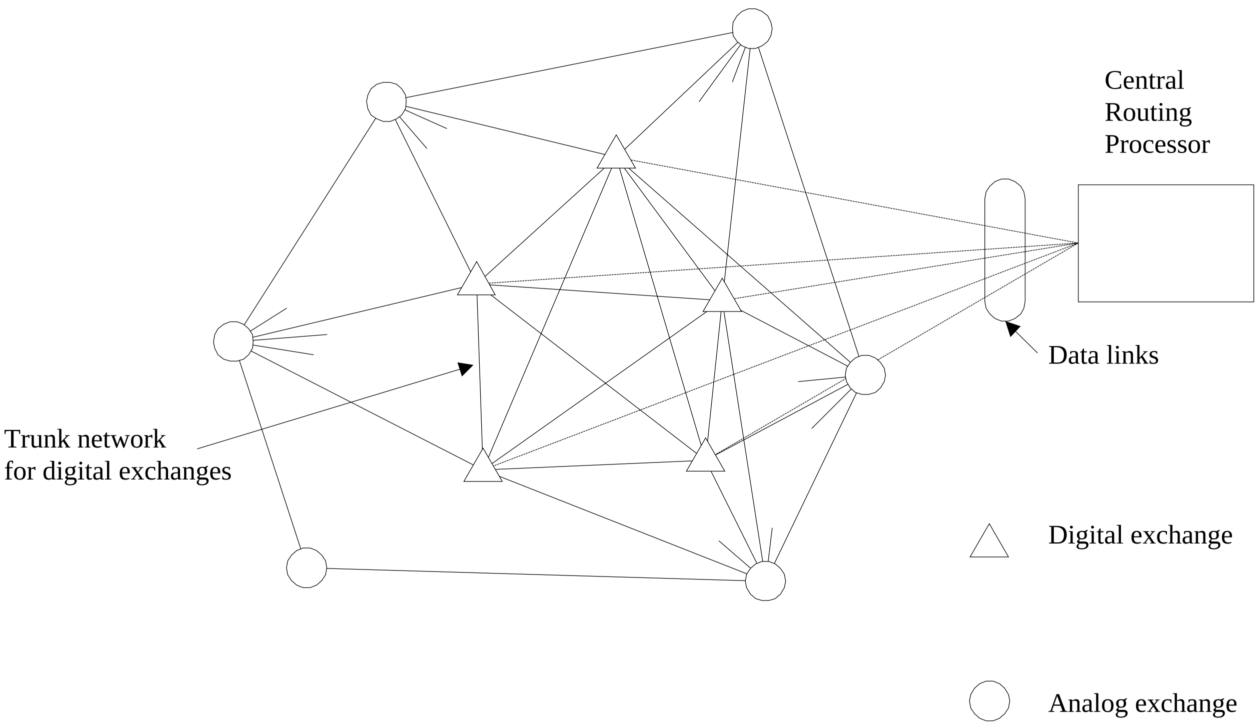

Fig. 14
A non-hierarchical network

The operation of the non-hierarchical network is the following:

- direct routes to the desired destination are always taken as first choice.

- if a call originating on a digital system finds all the direct trunks busy, any other digital system can be used as tandems. Which one of the tandems should be used to switch the call is determined by the conditional path selection over the digital trunk network.

- the path search is performed by the central routing processor in given time intervals (say every 2 seconds), and independently of whether there is a call to be switched or not, the central routing processor collects data from the digital switching systems on the actual busy-idle states in the different trunks groups, calculates, the suitable alternative path for each pair of offices and sends back this information to the digital offices.

- an overflow call originating on an analogue system will first have to be switched to one of the digital systems in order to take advantage of the non-hierarchical systems; the connection is set up by random selection of a trunk out of all free trunks leading to the digital systems from there, the call is treated like an ordinary call originating at the digital system.