Digitalisation Principles and Strategies

Comparison Analogue / Digital Networks

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DIGITALISATION PRINCIPLES AND STRATEGIES. COMPARISON ANALOGUE/DIGITAL NETWORKS

Contents

1. INTRODUCTION

Digitalisation of a telecommunications network is to introduce digital transmission and switching components into the network. The reasons are mainly economical, but there are also other reasons such as improved and extended services to the subscribers, improved transmission quality, improved operation and maintenance facilities, etc.

The best economy and performance is achieved if both transmission and switching are digital and integrated (no A/D conversions needed). However, since the existing telephone sets are analogue and costs of replacing them with digital sets are substantial, the subscriber lines will be kept analogue to start with while the rest of the network is digitalized. This leads to the Integrated Digital Network, IDN, which is the first goal of the digitalisation process (see Figure 1).

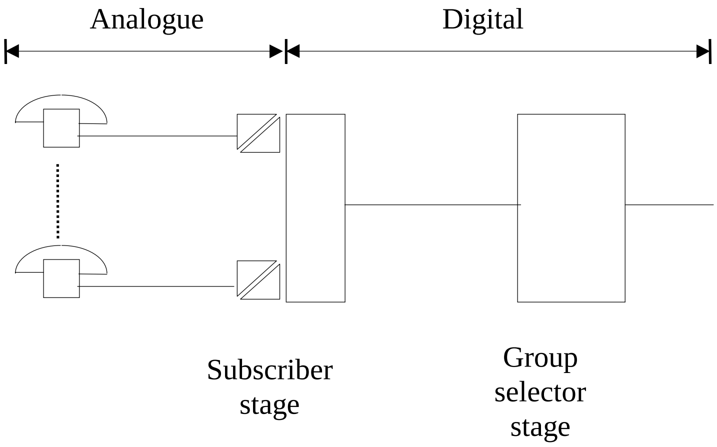

Figure 1: First goal IDN

The final digitalisation of the subscriber lines opens up the future possibilities of connecting a wide variety of digital equipment at the subscriber's premises, such as data terminals, telefax, teletex, etc. We then have an Integrated Services Digital Network, ISDN, where telephone services, data services, etc., are switched by one integrated telecommunications network (see Figure 2).

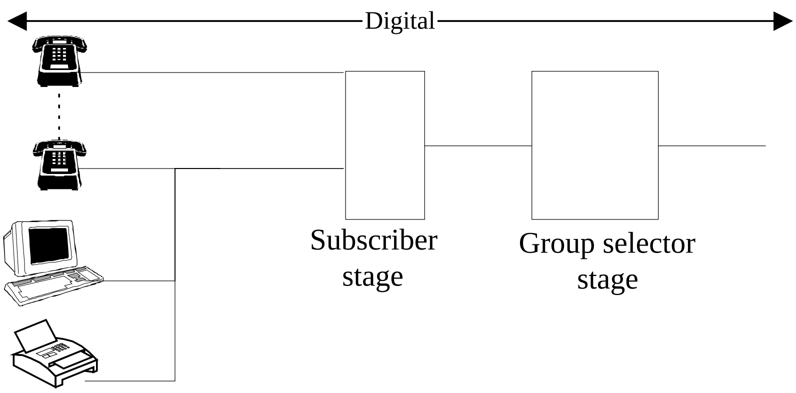

Figure 2: Ultimate goal ISDN

Since the existing analogue telephone network is still in many countries by far the most important network of various types that exists today (telephone, telex, data, etc.), the development towards IDN/ISDN will start from this network. The following study of digitalisation principles and strategies is therefore based on this fact. The study goes up to the transition into IDN because the further transition into an ISDN still remains to be discussed and formalised in some respects. The study ends with a comparison between the characteristics of the analogue telephone network and a digital network.

2. DIGITALISATION PRINCIPLES

2.1 GENERAL

A typical analogue telephone network is shown in Figure 3. We will study the digitalisation of various parts of this network.

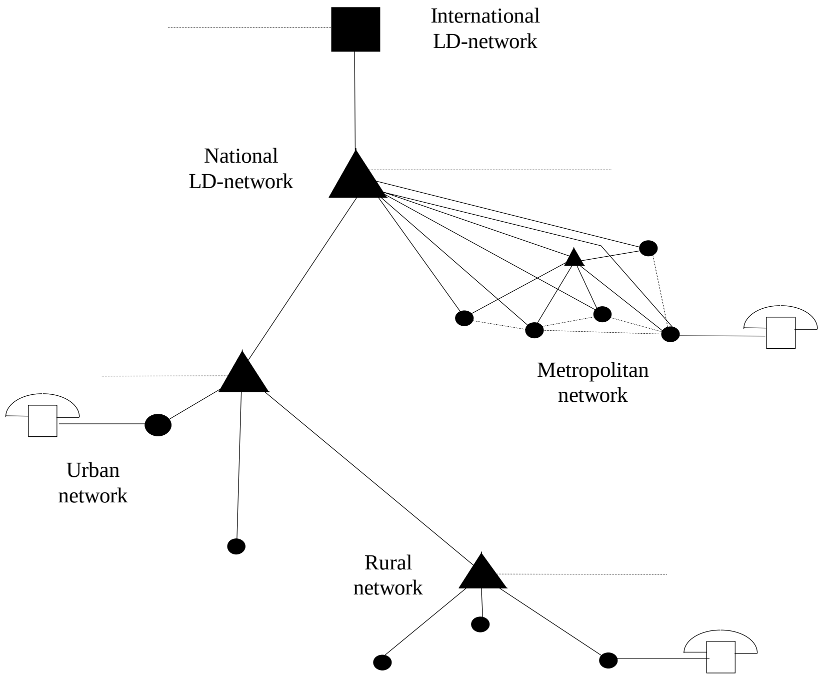

Figure 3: Structure of analogue network

2.2 DIGITALISATION OF SUBSCRIBER LINE NETWORKS

Subscriber line networks and local exchanges form parts of metropolitan networks, urban networks and rural networks. The digitalisation principles are very much the same in all cases, so let us study the digitalisation of the subscriber line network and a local exchange in a city area (see Figure 4). Two thousand (2,000) subscribers are connected to the subscriber switch SS. The 2-wire group switch GS has routes to 10 other exchanges, each route with 30 2-wire junction lines. SS and GS are connected with 300 2-wire connections.

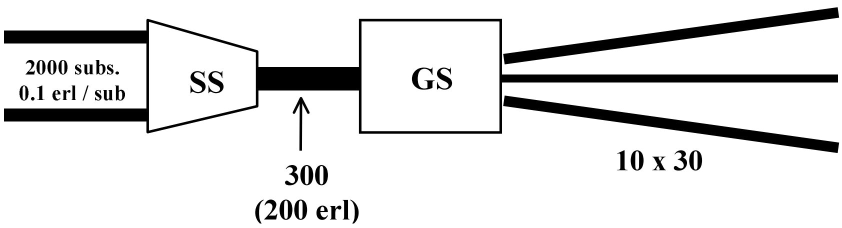

Figure 4: Local exchange

Figure 5 shows that the 2,000 subscribers are connected with a 2,000 pair primary cable from the exchange to a cable distribution cabinet (simplified to one cabinet only), from where 10 secondary cables with 200 pairs each lead further towards the subscribers.

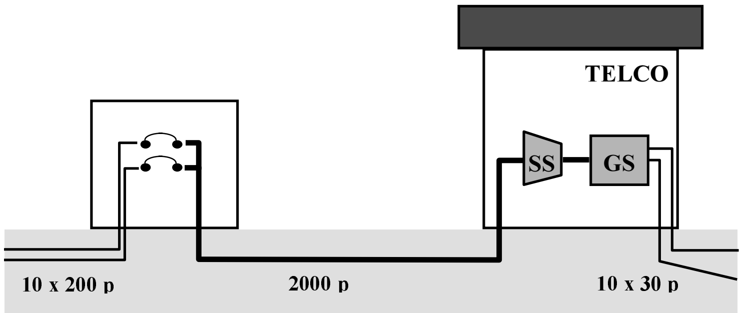

Figure 5: Connection of subscribers

A dramatic reduction in primary cable is achieved by introducing PCM and a remote subscriber switch (see Figure 6). Twenty (20) pairs for 10 30 channel PCM-systems (2 pairs for each system, 1 pair per transmission direction) give approximately 300 speech channels between the remote SS and GS, which is actually more than enough for the offered traffic 200 erlangs. The number of pairs are reduced from 2 000 to 20, which is a factor of 100.

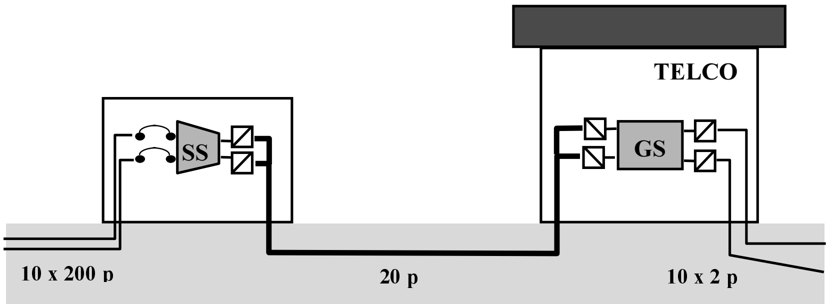

Figure 6: Introduction of digital transmission

In Figure 6, we also have introduced a 30 channel PCM system on each junction route, resulting in a reduction in junction cables from 30 pairs to 2 pairs per route, which is a factor of 15. The pair gain factor is less than for the primary cable because a junction pair carries more traffic originally than a subscriber pair (0.7-0.8 erlang compared to 0.05-0.15 erlang). There is more about digitalisation of the junction network in section 2.3.

As can be seen, the pair gain by introducing PCM is substantial. It is, of course, to a certain degree counterbalanced by the cost of the PCM-equipment.

By introducing digital switches as shown in Figure 7, A/D converters are only needed on the subscriber lines which are still analogue since the telephone sets are analogue. We have the characteristic structure of an Integrated Digital Network, IDN.

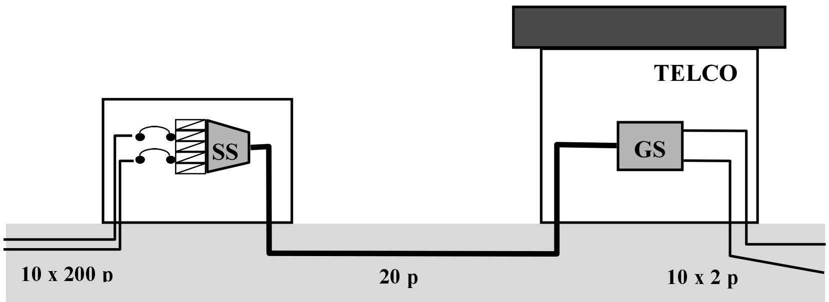

Figure 7: Introduction of digital switching

2.3 DIGITALISATION OF JUNCTION NETWORKS

Junction lines are connections between local exchanges and connections between a local exchange and a tandem or transit exchange.

Consider a 2-wire junction route between 2 local exchanges (see Figure 8). The route consists of 300 junctions or 300 pairs. The cost of the route is distance dependent, as shown, and is the sum of the fix cost of the group switch and a varying cable cost depending on distance.

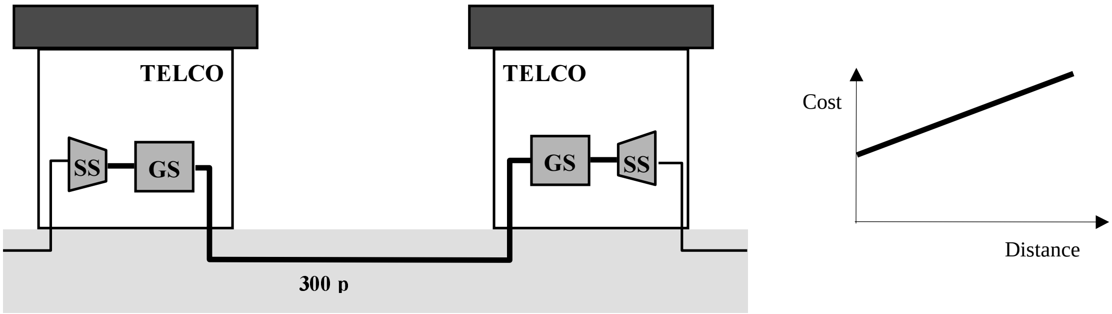

Figure 8: Junction route

In Figure 9, we have introduced PCM on the route. Ten (10) systems of 30 channels PCM still give 300 connections, but only 20 pairs. The costs of the PCM terminals will increase the fix cost while the cable cost is reduced and the route is economical above a certain distance.

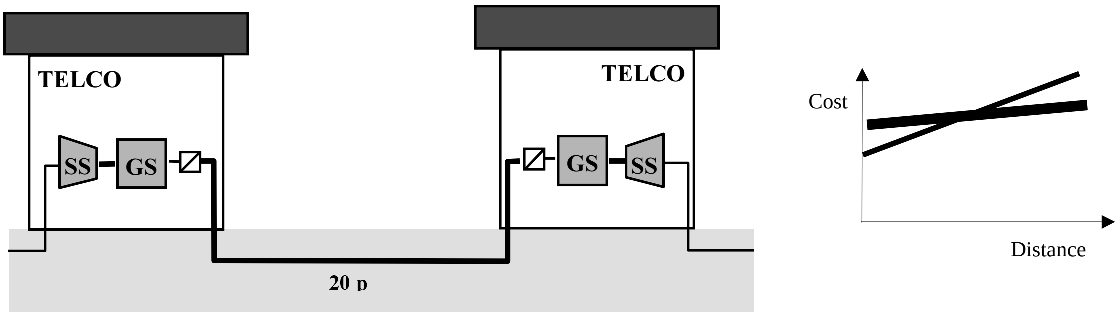

Figure 9: PCM on the Route

As in the case with the subscriber line network, the best economy is achieved when the exchanges are digitalized and the PCM terminals integrated into the exchange (see Figure 10). The method is cost effective from 0 km.

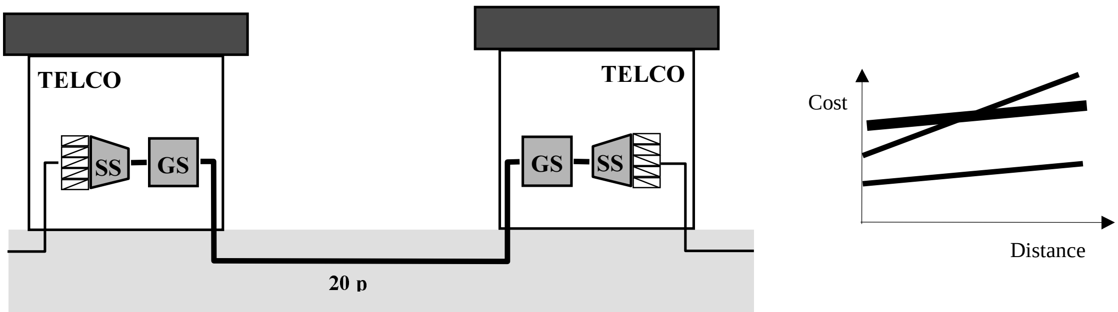

Figure 10: PCM on the route and digital exchanges

2.4 DIGITALISATION OF TRUNK NETWORKS

Trunks are connections between transit exchanges in the long distance network. Today, these connections are sometimes established by highly efficient FDM systems, and the savings would be minor by introducing digital transmission systems. However, the economy in digital long distance transmission is improving fast, especially in fibre optical systems.

While retaining analogue transmission in the long distance network, digital transit exchanges could still be introduced with good economy, particularly if the co-operating local exchanges and/or junction lines are digital.

3. DIGITALISATION STRATEGIES

3.1 GENERAL

Although it is proved that digitalisation is economical, it is not possible to digitalize the whole network in one step because the initial investments and resources needed would be enormous. Digitalisation will have to be a stepwise, evolutionary process. It is therefore important that each Administration makes up its own digitalisation strategy as to where, when and how the various steps of digitalisation have to be taken.

There are three different strategies:

- Overlay strategy,
- Island strategy,
- Pragmatic strategy.

The overlay strategy is to create a fairly thin digital network spread over a wide geographical area, overlaid the existing analogue network (see Figure 11).

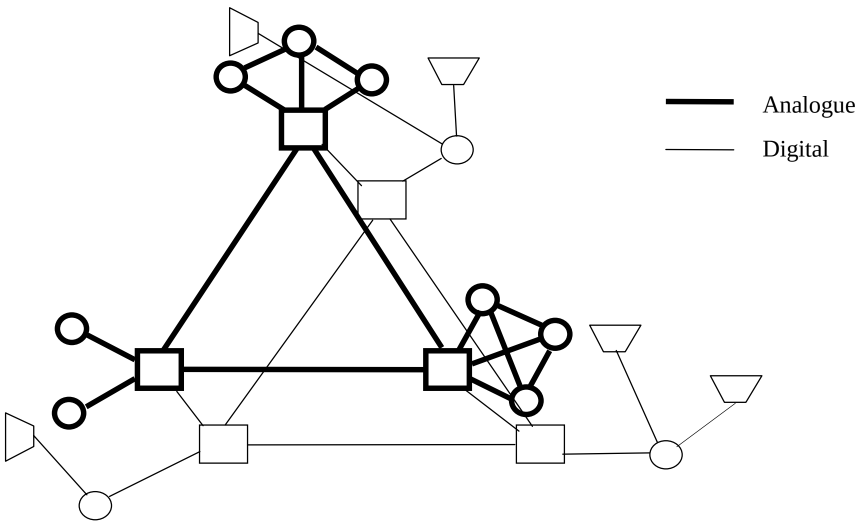

Figure 11: Overlay strategy

The island strategy is to begin the digitalisation by providing complete digital capabilities within certain limited geographical areas, called digital islands (see Figure 12).

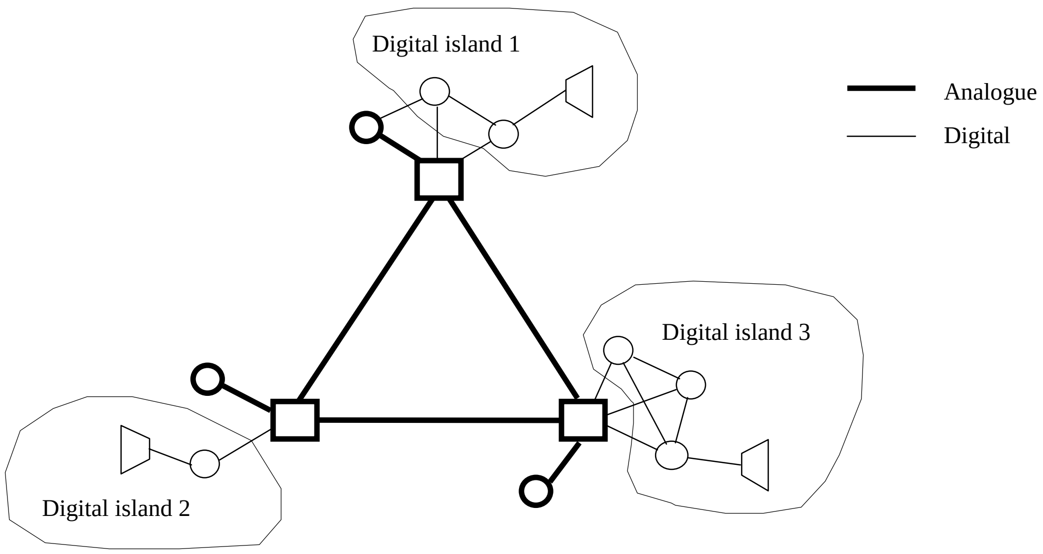

Figure 12: Island strategy

The overlay strategy and the island strategy are the two principal strategies. The pragmatic strategy is a practical compromise between the two (see Figure 13).

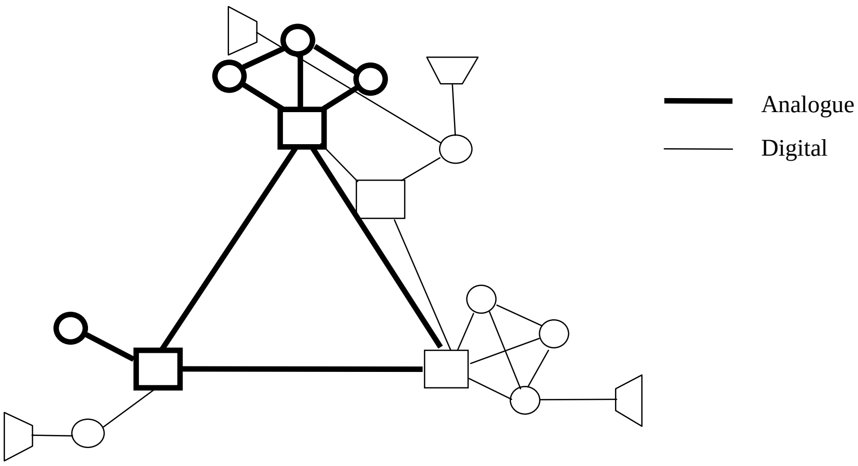

Figure13: Pragmatic strategy

A few guidelines in the choice of strategy is found in the following brief description of the various strategies.

3.2 OVERLAY STRATEGY

The characteristics of the overlay strategy are:

1. Rapid provision for digital services on a nation-wide basis.
2. High initial investment costs, compared to the low initial capacity provided. This is because certain digital long distance switching and transmission facilities are needed initially.
3. Additional operation and maintenance staff and equipment on a nation-wide basis, meaning increased operation and maintenance costs.
4. Limited alternative routing in the initial stage, due to the thin network.
5. Different treatment and services provided to subscribers with access to the overlay network compared to other subscribers in the same geographical area.

The early provision of end-to-end digital services makes the overlay strategy most suitable in countries with a high and urgent demand for new and enhanced telephone services and where the existing analogue network has a relatively long projected useful life. The overlay strategy is also applicable to create a separate, dedicated network for non-voice services in countries where such a network does not exist today but where the demand is pressing.

The overlay strategy could also be dictated by an Administration's policy to meet the growth of subscribers and traffic by digitalisation. This could, for instance, be achieved by connecting new subscribers to remote subscriber switches of a few new digital exchanges rather than extending existing analogue exchanges. The digital exchanges could then be interconnected in a nation-wide overlay network.

New and improved services imply new revenues which have to be traded off against the high initial investment costs and the additional nation-wide operation and maintenance costs which penalise the overlay strategy. The limited alternative routing possibilities in the initial stage should also be considered and the routes engineered accordingly. Finally, the different treatment and services provided to subscribers with access to the overlay network, compared to other subscribers in the same geographical area, may cause same polity explanatory problems to an Administration and should be carefully thought of before a decision is taken to adapt the overlay strategy.

The demand for new and enhanced telephone services and/or improved non-voice services eminates to a large extent from the business sector, which normally contributes to the major part of an Administration's income. Business activities are mainly concentrated to metropolitan and city areas. Combined with the fact that digitalisation savings are largest in the subscriber and junction network, the start of digitalisation process becomes very attractive in such areas. Also, if the same strategy is set by an Administration's policy to meet growth by digitalisation, the city and metropolitan areas seem the most suitable starting points because these areas generally show the highest growth rates.

3.3 ISLAND STRATEGY

The characteristics of the island strategy are:

1. Provision of complete digital services within certain limited geographical areas by replacing existing analogue switching and transmission equipment. Nation-wide service is not necessarily an immediate goal.
2. Full advantage of integrated digital switching and transmission for the island area from the start. Digital equipment can be concentrated to areas where it is mostly needed and can be most effectively utilised. Availability of digital long distance switching and transmission capabilities are not needed initially. Waiting for economy to be achieved in digital long haul facilities is therefore possible.
3. Additional operation and maintenance staff and equipment only needed for the digital island and not on a nation-wide basis.
4. Alternative routing possibilities not affected, neither within a digital island nor between digital islands.
5. Same treatment and services provided to subscribers within the digital island.

The island strategy is best suited to countries with growth localised to areas with a relatively large amount of old exchanges which are at the end of their economical lifetime, have reached their maximum switching capacity or cannot be extended unless the building are extended. These exchanges are replaced with exchanges of larger switching capacity and/or smaller size. Dismantled old exchanges in relative good condition could be reconditioned and reused in other places where they can still serve during many years. Others, which are practically worn out and expensive to maintain at an acceptable level, are scrapped.

A candidate for a digital island is also often characterised by already existing digital transmission to a relatively large extent. By introducing digital switching, the economy of integrated digital switching and transmission is achieved within the digital island.

The island strategy may also be advantageous, when large geographic distances separate growth areas and the present cost of digital long distance interconnection is high.

City and metropolitan areas also seem to be the best starting points for the island strategy because these areas normally have the highest growth rate. These areas also often show the highest percentage of existing digital transmission.

3.4 PRAGMATIC STRATEGY

As seen from the previous text, the digitalisation strategy to be adopted will vary from country to country depending on the demand of the present network, the policy of the Administration, the geographical shape of the country, etc. However, in the end, there is the trade-off economy versus services provided which dictates the strategy. In most cases, neither the pure overlay strategy nor the pure island strategy shows a satisfactory trade-off. Instead, a compromise will have to be used, the pragmatic strategy.

A pragmatic strategy aims at a best possible trade-off economy versus services by:

1. Optimising the usefulness of existing equipment.
2. Optimising the effectiveness of new investment.

The pragmatic strategy implies that as a network evolves towards its target configuration and nature, parts of it may become modernised (digitalized) by overlay applications and other parts be updated by digital islands. To the extent that imbedded elements can play a meaningful role in the evolution towards IDN and ISDN, they are retained (sometimes modernised).

A controlling characteristic of pragmatic strategies is a tendency to follow the natural driving forces for network evolution such as growth in demand, the desire to provide a capability for new services and the need to modernise the telecommunications plants, all appropriately weighted through the overall economics. This means there are at least as many distinct pragmatic strategies as there are countries which are candidates for IDN/ISDN evolution.

In general, pragmatic strategies suggest a more detailed technical and economical analysis of numerous potential combinations of island and/or overlay flavoured strategies as applied to all segments of the network to achieve an optimal solution. Various computerised network forecasting and network planning optimisation methods have been developed for these purposes.

3.5 EXAMPLES OF A STEPWISE, PRAGMATIC DIGITALISATION

3.5.1 *Introducing digital tandem and local exchanges*

Let us assume we have decided to start digitalisation in a metropolitan area by introducing a digital tandem (see Figure 14). In this case, all existing routes are analogue from the start. In other cases, some of them might be already digital.

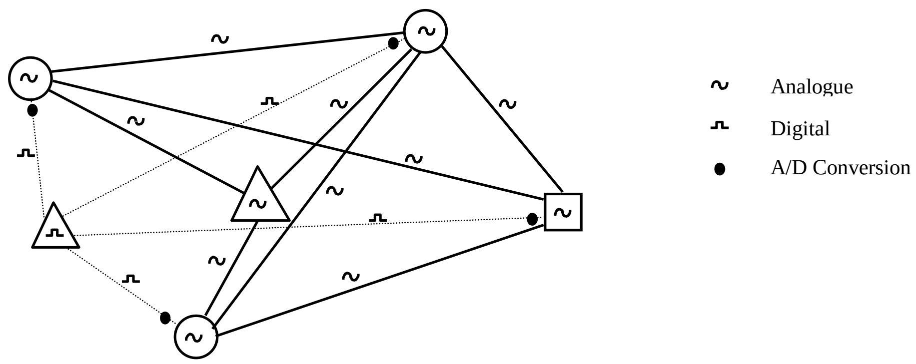

Figure 14: Introduction of digital tandem

In Figure 15, the analogue tandem has been phased out but this is not always necessary.

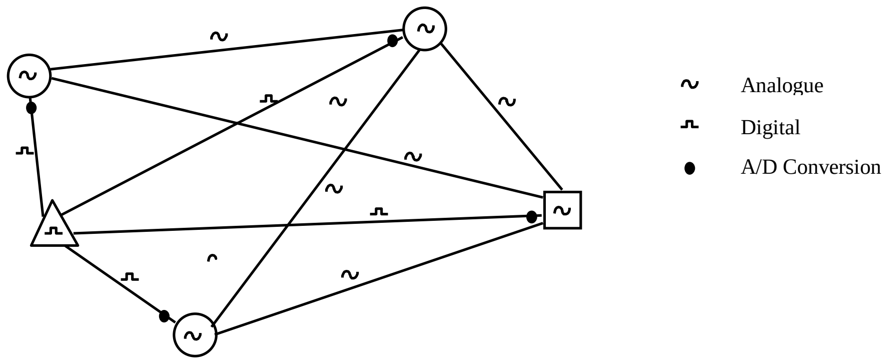

Figure 15: Analogue tandem phased out

The network could be extended with new local exchanges which are connected to tandem and existing local exchanges if economical (see Figure 16).

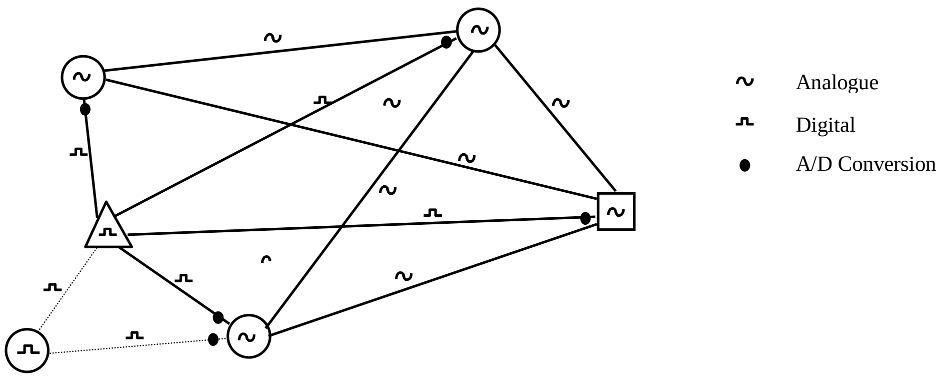

Figure 16: Extension with new local exchange

Let us study a direct route between 2 local exchanges and see if PCM is interesting (see Figure 17). If PCM systems on the routes up to the tandem exchange from the two exchanges have spare capacity, this capacity could be utilised for a direct route between exchanges, by-passing the tandem (see Figure 18).

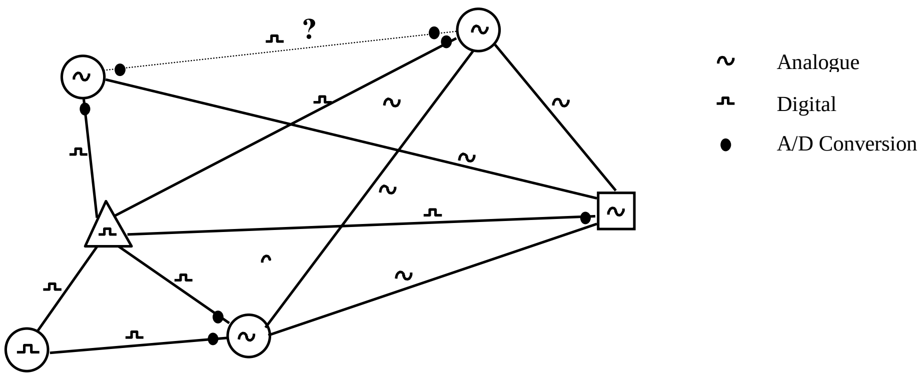

Figure 17: Is PCM on indicated route interesting?

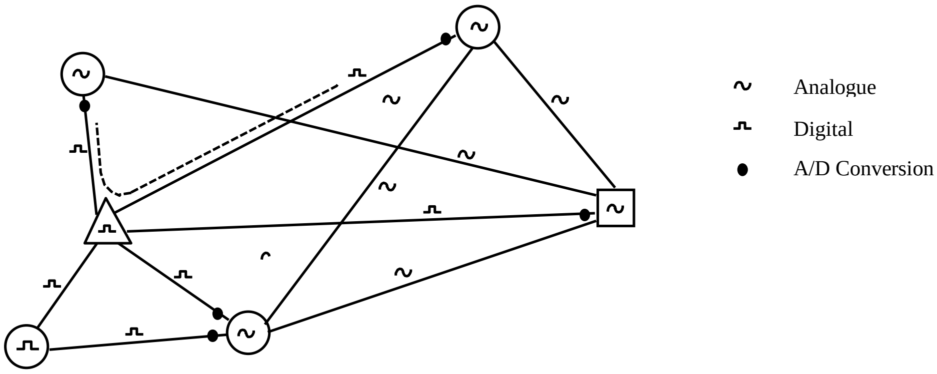

Figure 18: Direct Route by-passing tandem

Figure 19 shows an example of extending an analogue exchange with a remote subscriber switch connected to the digital tandem exchange. A more detailed picture of this situation is shown in Figure 20. Growth in the analogue exchange is taken up by a digital overlay network.

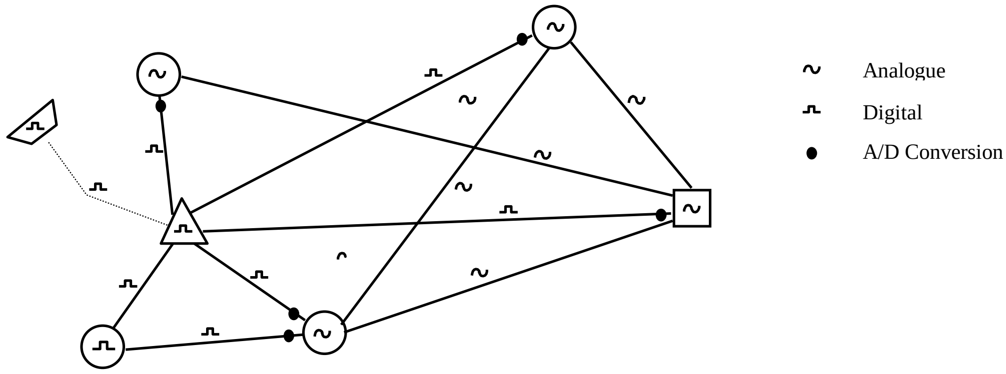

Figure 19: Extending an analogue exchange with a remote subscriber switch

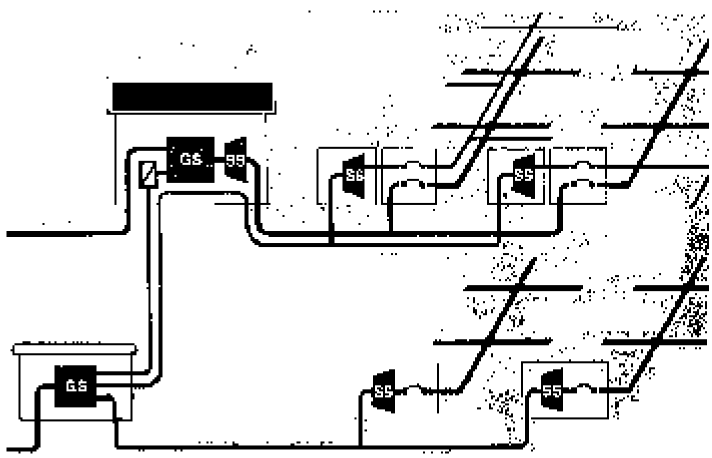

Figure 20: Digital overlay network

Figure 21 shows the replacement of an analogue local exchange with a digital local exchange. The arrows indicate re-use of PCM terminals.

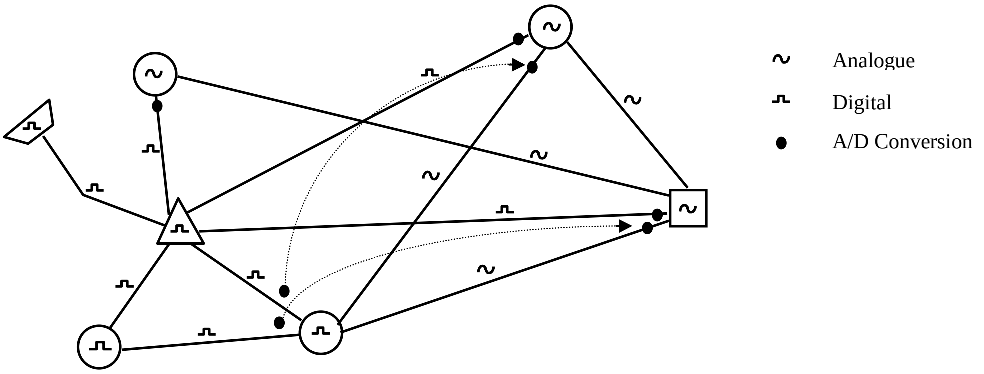

Figure 21: Replacement of analogue exchange.
(arrows indicate re-use of PCM terminals)

Figure 22 shows in more details the procedure used to replace an analogue exchange by a digital exchange while both exchanges are in service.

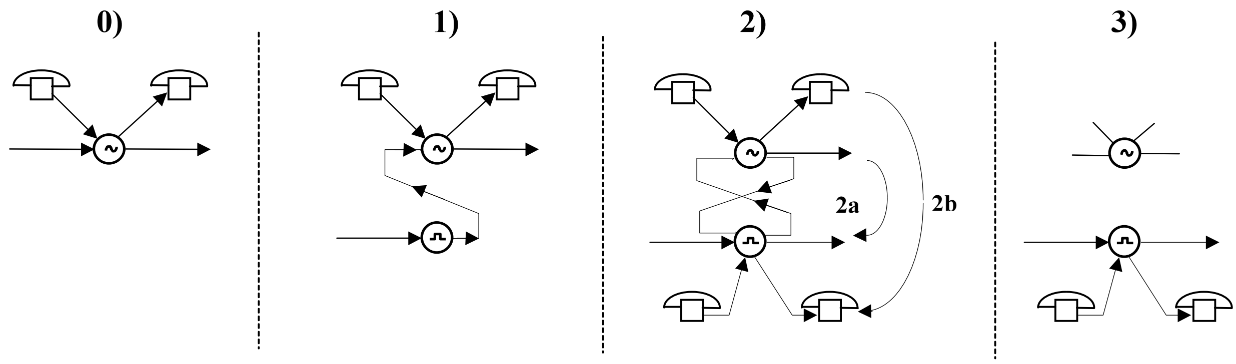

Figure 22: Replacing an analogue exchange by a digital exchange

3.5.2 *Introducing transit functions in the existing digital tandem exchange*

Figure 23 shows an example of introducing transit functions in the existing digital tandem exchange. The cost of extending the existing analogue transit exchange as the long distance traffic increases were in this case not justified in the long run compared to introducing transit functions in the existing tandem exchange, which could easily be converted to a combined tandem/transit exchange.

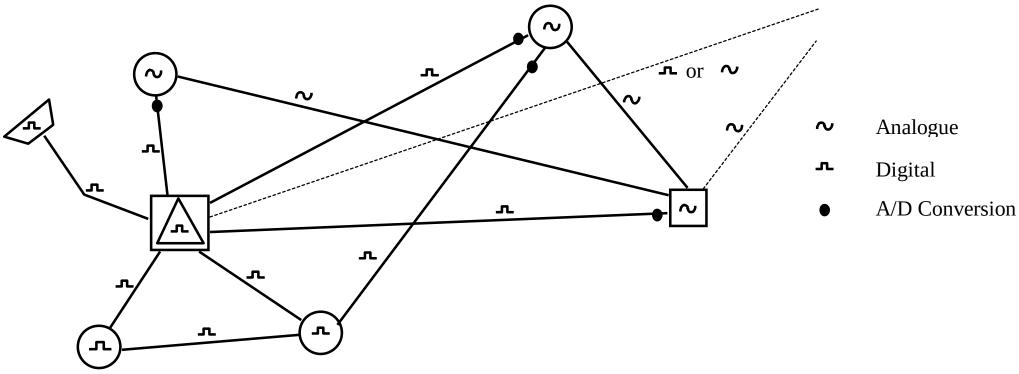

Figure 23: Introduction of transit functions in an existing digital tandem exchange

The previous tandem routes are extended to carry long distance traffic as well. The long distance route between the analogue transit exchange and one of the digital local exchanges is removed. This creates free ports in the analogue transit exchange, ports that can be used for the now necessary extension of the route to the combined tandem/transit exchange.

All new trunk circuits, both digital and analogue, are connected to the digital tandem/transit exchange because the hardware is cheaper and the expensive rewiring and restrapping work in connection with extensions of trunk routes connected to the analogue exchange is avoided.

Figure 24 shows the routing of long distance traffic in this mixed analogue/digital network. The main principle is to separate digital and analogue traffic as much as possible to minimise the number of analogue/digital conversions. Only in case of congestion, traffic from the digital "path" is allowed to overflow to the analogue "path" and vice versa.

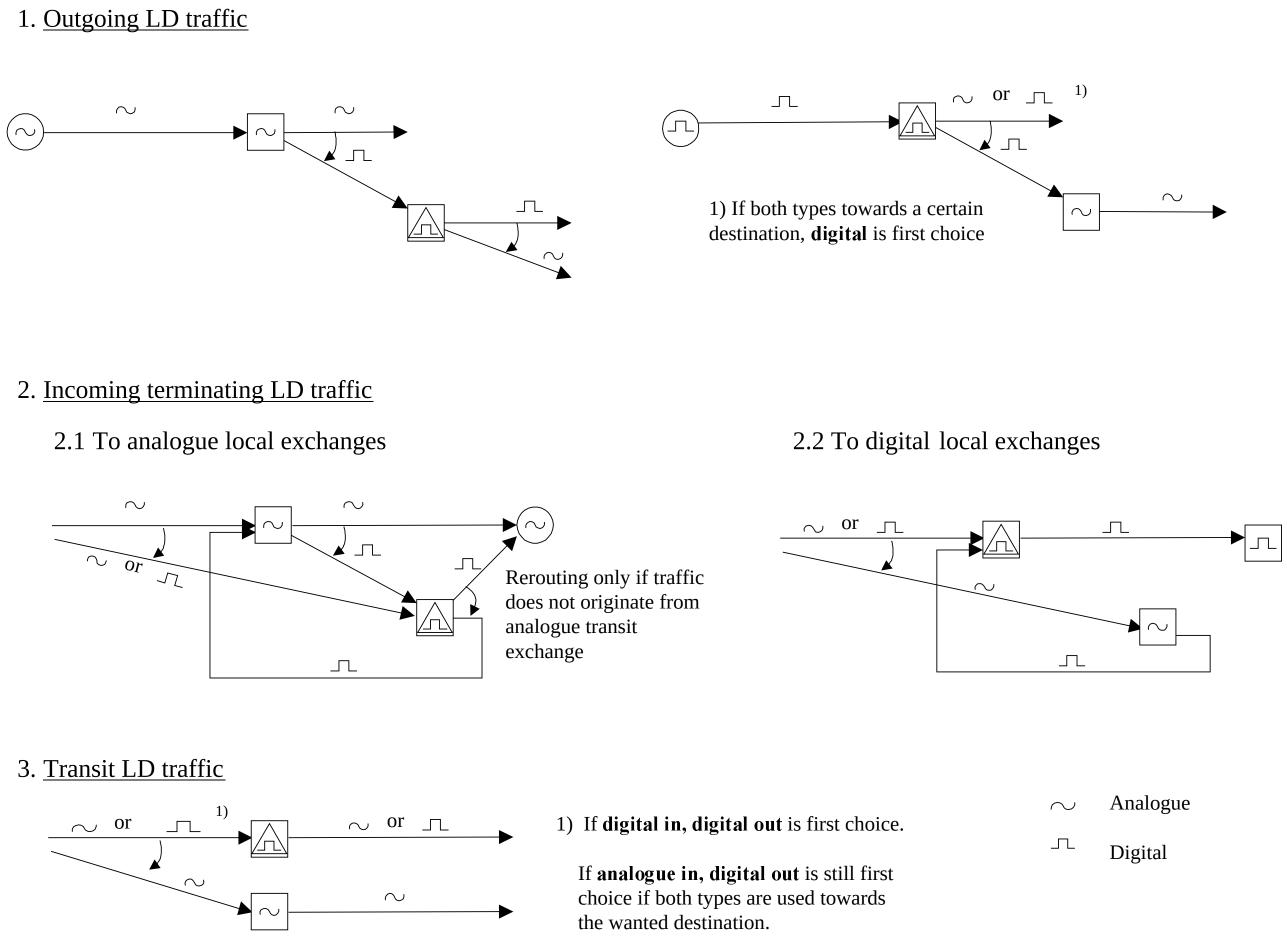

Figure 24: Routing of LD-traffic

Figure 25 shows the situation after the analogue transit exchange has been dismantled.

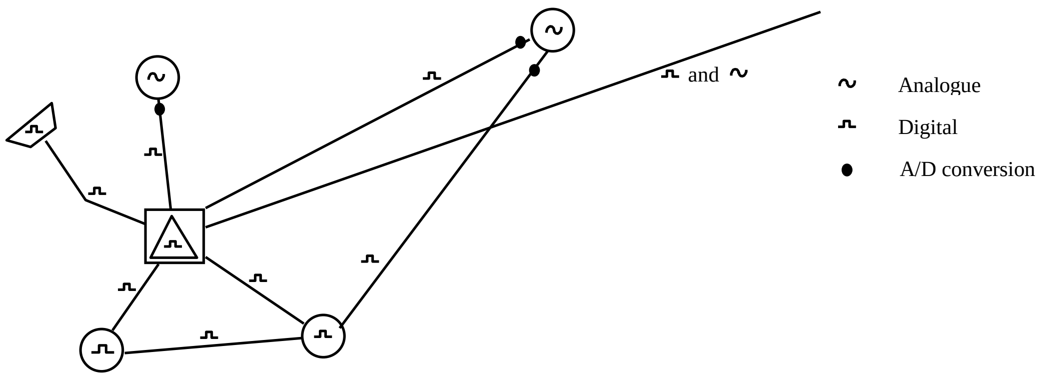

Figure 25: Analogue transit exchange dismantled

Figure 26 shows the final network structure with the combined tandem transit exchange.

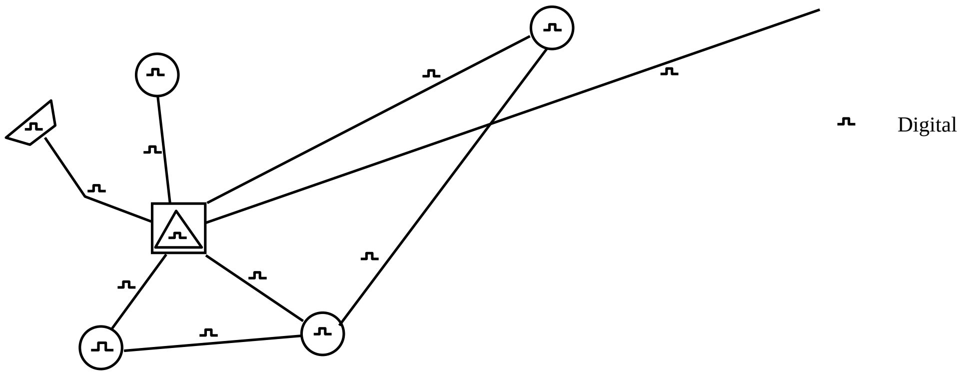

Figure 26: Final network structure with combined tandem /transit exchange

3.5.3 *Introducing a separate, digital transit exchange*

There are cases when local traffic and long distance traffic cannot be combined in the same exchange, for instance in countries where local traffic and long distance traffic are handled by different administrations. In other cases, the same administration handles both local and long distance traffic but wants to separate the two types of traffic for policy and/or administrative reasons.

In all these cases, a separate digital transit exchange will have to be introduced in the same background situation as described in section 3.5.2 (see Figure 27). The routes from the local exchanges to the transit exchange carry transit traffic only. The previous direct route from one of the digital local exchanges to the analogue transit exchange has been moved to the new digital transit exchange to separate analogue and digital traffic as much as possible.

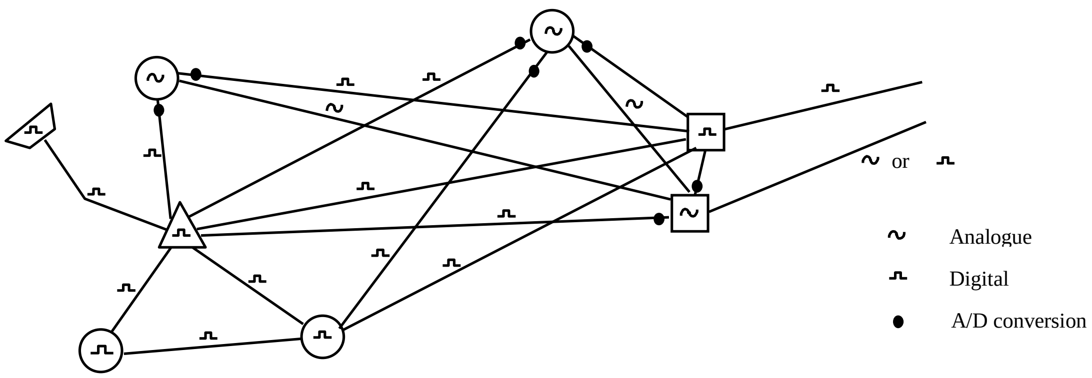

Figure 27: Introduction of a separate digital transit exchange

There is no difference in the routing principles compared to the case when the transit and tandem functions are combined in one exchange.

Figure 28 shows the situation after dismantling the analogue transit exchange.

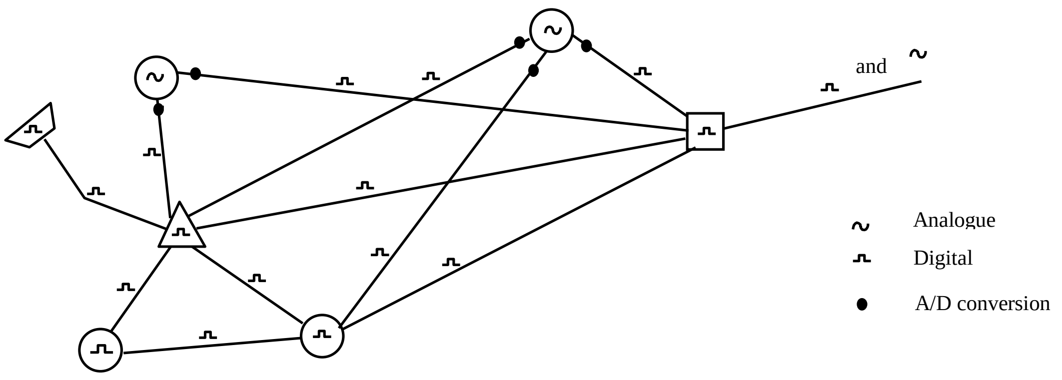

Figure 28: Analogue transit exchange dismantled

Figure 29 shows the final network structure with the separate transit exchange.

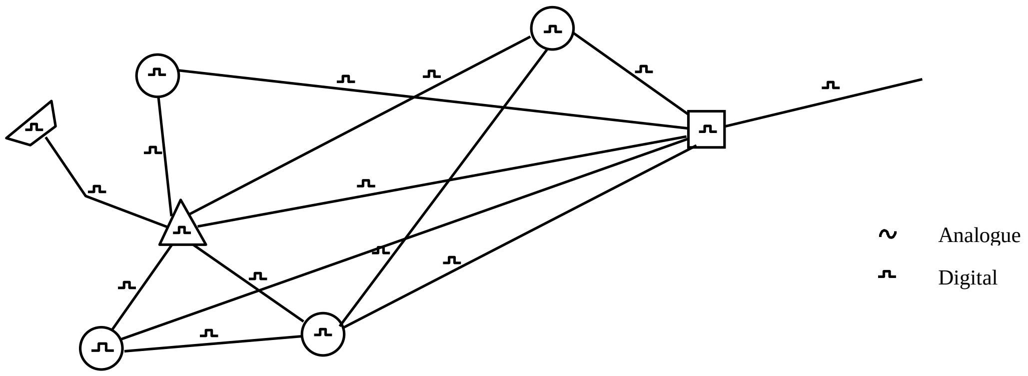

Figure 29: Final network structure with separate transit exchange

4. COMPARISON ANALOGUE/DIGITAL NETWORKS

Figure 30 shows the traditional network hierarchy of an analogue network. The hierarchical structure of a digital network in Figure 31 contains fewer levels because the primary exchanges could be used as tandem exchanges. Furthermore, the level with tertiary exchanges is in most cases not needed because the new digital exchanges have larger switching capacity.

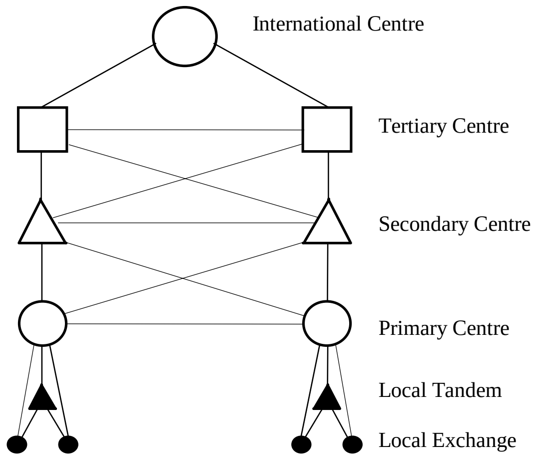

Figure 30: Hierarchy of analogue network

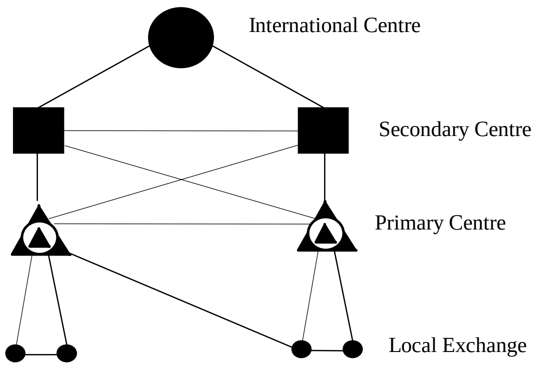

Figure 31: Hierarchy of digital network

Figure 32 shows the structure of a fully digitalized network. Compared to the analogue network structure in Figure 3, the metropolitan network contains fewer exchanges because of the possibility to cover larger subscriber areas by using remote subscriber switches and because of the larger switching capacity of the digital exchanges. Fewer but larger exchanges lead to fewer but larger exchange areas and larger routes.

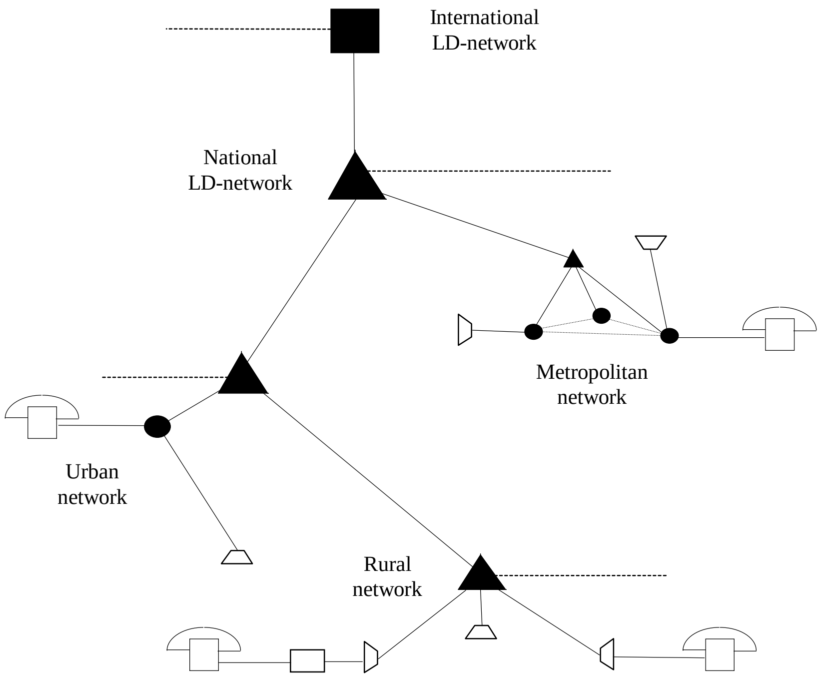

Figure 32: Structure of digital network

The tendency is the same in urban and rural networks where existing smaller exchanges are replaced by remote subscriber switches and remote subscriber multiplexors connected to larger digital exchanges.

To summarise, the digital network structure is characterised by:

- integrated transmission and switching;
- extensive use of remote subscriber switches;
- use of combined exchanges (local/tandem/transit).

This leads to:

- lower average cost per subscriber line;
- reduced number of levels in the network;
- reduced number of exchanges;
- larger exchanges;
- larger exchange areas;
- larger routes.

5. FURTHER DEVELOPMENT TRENDS

Today, the trends are towards:

- increased use of optical fibre communication systems;
- higher order PCM systems;
- Integrated Services Digital Network, ISDN.