Backhaul Network Switching Systems

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Introduction

The original purpose of Backhaul Network based switching systems was to connect any CAN to any other CAN so that a call connection could be set-up, established / held and then pulled down (and the usage be charged to a subscriber).

The first Backhaul Network based switches were Operator controlled cord connect Switchboards where the calling subscriber cranked a magneto-generator to cause a 'drop indicator' to show the calling number. The Operator would then connect to the calling subscriber and ask for the called number and arrange to connect to that subscribers number, then crank the switchboard magneto-generator to ring the bells on the called subscribers number – then switch the call through. To say the least this was highly labour intensive requiring staff 24 / 7, and local maintenance crews on the ready too. In Australian rural and remote areas, this technology was not replaced until at least 1974.

The Backhaul Network-CAN demarcation point was the feed bridge in the switchboard, where the CAN signalling interfaced with the Backhaul Network signalling. If calls were not local they were 'transit' connected from local switchboards to trunk switchboards and direct or alternate paths were sought out to make the calls connect. A series of technology improvements were introduced into these switchboards including the use of a Central Battery (CB) to replace the Magneto Phone Ring-Up signalling with Loop Disconnect signalling in the CAN and the use of a motor generator to produce a standardised ring current (and ring tone cadences).

In major metropolitan areas (Capital cities), Step-by-Step (SxS) automated switching equipment was introduced in the 1920s to replace Operators and Switchboards. This was highly mechanical (read high maintenance) equipment that line searched automatically through a series of rotary selectors whose rotor's vertical position was controlled by decadic dialling, and the horizontal position automatically homed on the first available transit route towards the desired number.

There was virtually no alternate routing facility, so switch congestion was quite common – without network congestion. Over decades, the vibrations caused by the switch mechanism caused the ductile copper cabling to become brittle and it was common to have wire multiples in the backs of these switches literally crystallising and falling apart - causing horrendous maintenance issues. The last SxS exchanges were pulled out in the late 1970s

A major change in Backhaul Network switching strategy came with the introduction of Crossbar technology in 1960. This form of automated switching had a series of primitive relay-based processors in it so that the switch could formulate alternate routing if the direct route(s) were network congested, and there were alternate routes available. Although Crossbar switching technology had considerably more components in them, their maintenance reliability far exceeded that of Step-by-Step technology, reducing overhead maintenance labour requirements by at least 5 to 20 times.

The switched path for a connection through a “Crossed Bar” switch that had horizontal bars with flexible locking whiskers on them so that a number of calls and the associated signalling could be simultaneously be switched and held independently through the one common switch.

This switching technology was utilised in local switches - connecting to the CAN; as Tandem Switches - connecting loaded cable pairs between local and other Tandem exchanges in metropolitan areas; as Minor Switching Centres - connecting local exchanges to FDM transmission equipment in country cities; as Trunk Exchanges connecting FDM transmission systems between cities and for alternate network interconnect. Several technology developments in network engineering involving queuing theory, traffic density (Erlang) and traffic pattern analysis made Crossbar switching a very successful technology, but it was mechanical and it was analogue.

In about 1970 the technologies of reed relay switches combined with digital computing brought in 10C exchanges that had software/firmware Stored Programme Control (SPC).

This electronic technology was at least 10 to 200 times more reliable than Crossbar, and it was primarily employed as Main/Primary Trunk/Interconnect switches in the largest capital cities. Electronic processing was a very big half-step as the transmission was still analogue, but many of the ancillary functions in Network Management were beginning to show their effectiveness, by significantly eliminating a large amount of (until then) manual process work and moving this to automated computer processes.

In 1980 another major change in Backhaul Network switching technology was introduced with "AXE" digitally switched telephony exchanges in Australia.

The first version emulated the Crossbar processors with a dual computer, but used reed relays for subscriber switching and included common analogue to digital stream G.703 conversions. These switches had maintenance requirements that were 10 to 500 times less than Crossbar switches, making digital switching very cost-effective.

This picture shows a couple of suites of AXE equipment. With all the circuit boards vertically mounted, air convection was utilised to flow air from the lower front to the upper rear.

In 1982 the next generation of AXE digital switches replaced reed switches with electronic subscriber line cards eliminating a major overhead, and required about 100 to 2000 times less maintenance than for Crossbar switches.

By 1985 Node and Primary digital exchanges were introduced to totally replace the earlier Minor Switching Centre / Tandem (Crossbar) exchanges and totally replace the Main / Trunk 4-wire switches by about 1988, and it still took until about 1992 before the entire Backhaul Network was entirely digital!

As the computing power in the switches had considerably increased, two major technology improvements became possible between 1990 and 1995. Firstly it was now possible to set up an Out Of Band (OOB) Network that could communicate with control the switches, so that grading tables and other registers in the switches could be accessed and altered remotely. This meant that network switching faults could be analysed and maintenanced from a common Network Management location – with vastly reduced operating costs.

Secondly, digital switching control and reporting called Common Channel Signalling Number 7 (CCS7) was implemented about 1985 and became highly effective by about 1990 so that all switches spoke a common control language, and they could then work in synergy to provide much better alternate routing, and the billing data could be automatically downloaded in almost live time.

In about 1990 mobile phone technology was launched and the Backhaul Network structure had to deal with roaming mobile numbers (hopping to and from Mobile Base Stations - which is part of the CAN). The structure of the Backhaul Network was slightly changed so that the CCS7 now carried the Mobile User Part (MUP) to centralised locations where large databases could track and transfer mobile phones between Mobile Base Stations.

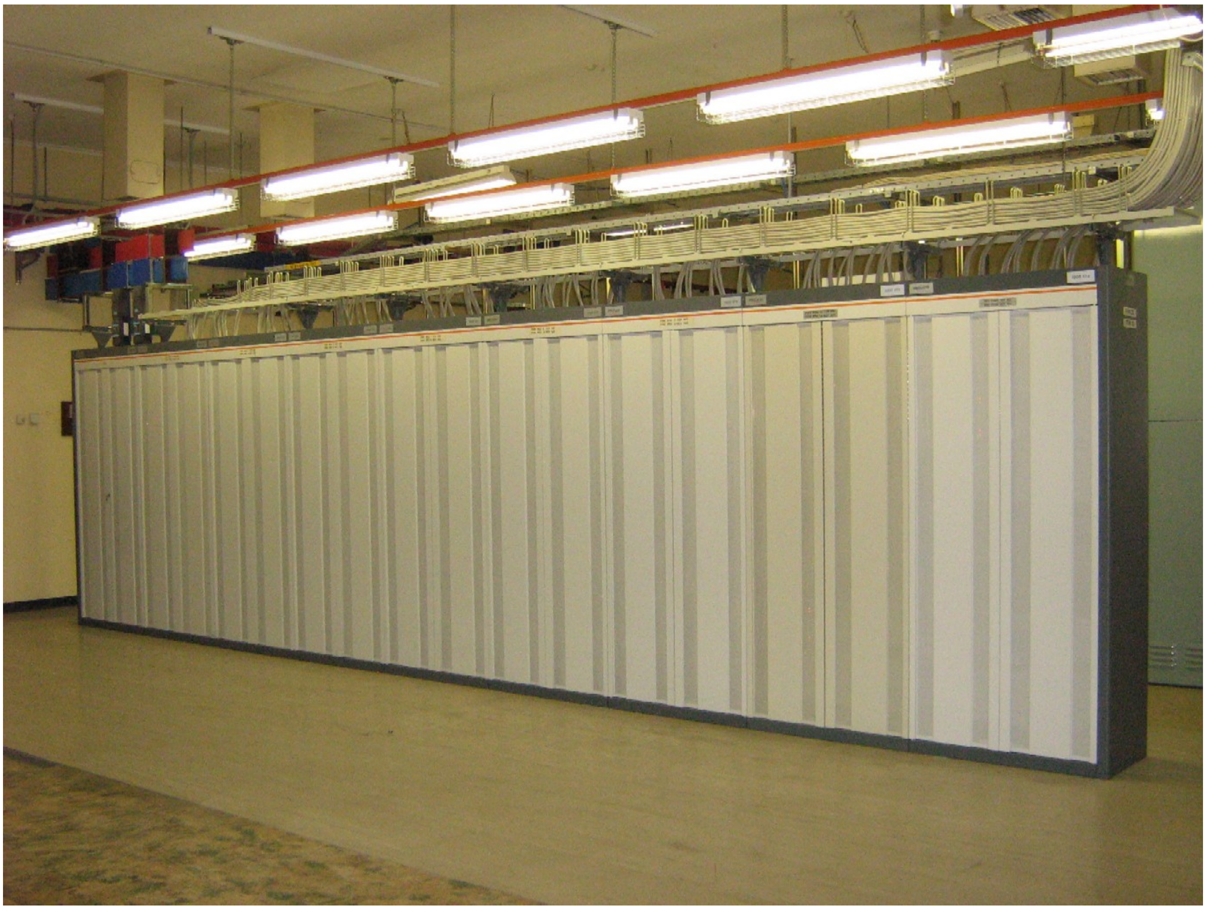
It is the CCS7 that directs the switches to establish, hold and pull down the call connections, and these CCS7 commands come from the Transmission Control Points (TCP); which are special computers that are programmed to perform network-switching control. The CCS7 also provides the metering data in raw form and network performance statistics.

CCS7 brought with it a whole range of advanced network switching possibilities that technologically were not possible a few years before. One of those functions was number translation, so that a common National number could be automatically translated to another number depending on the location of the calling number.

Another advanced function was to dynamically change routing with time, so that depending on the dialled number, the translated number could be time of day and week day dependent. In about 1985, Nortel DMS100 switches were specifically installed and commissioned in the Backhaul Network component in most cities to provide 1800, 13, etc. calling route dependent switching facilities.

Around 1990 a different type of digital switching was introduced and this was the Alcatel System 12 (S12) switch. This switch has a much smaller footprint per 10,000 customer lines because the packing density was much greater, and the heat dissipation was managed by fan cooling.

The standout difference between this and earlier digital exchange switches was that this switch passed packets of serial data that had 'address headers' making it forward compatible to Internet Protocol (IP).



The picture above shows a typical 10,000 line local exchange switch. A Crossbar 10,000 line local switch would cover this entire floor. Typically this Alcatel System 12 (S12) equipment has a very low maintenance requirement as it is not mechanical and a small team could remotely manage all sites nationally.

Backhaul Network Switching and Transmission Hierarchy

The Connectivity Model described in Telecommunications 101 is an ideal reference for base-level comprehension of the Australian Telecommunications Network because it closely aligns with the real physical network structures and it is simplistic enough to show how and where the connections are made, both switched and transported.

As most CAN designs have an engineered maximum physical limit of about 4 km, it is therefore obvious that thousands of local exchanges are necessary, and that these local exchanges need to be connected in such a manner that transmission through the Backhaul Network usage is minimised. Traffic studies show that with telephony, most calls are local, then district, then regional, then interstate, and with a switching hierarchy set up to emulate that calling pattern, then most calls can be connected with a minimum network. So the Backhaul Network is usually engineered into four structural levels;

- Local/("Chief" in USA terminology) - (to switch CANs that are in the local geographic area);
- District/Node (to connect down to Local switches and across to other Node/District switches);
- Regional/Main/Primary (to connect down to Node switches and across to other Regional/Main/Primary switches);
- Interconnect (to connect competitive / international carriers, and to down to Regional/Main/Primary switches).

The transmission structures that are associated with each of these partial Backhaul Network networks are physically very different, and this is described in The Six Network Structures - where these four network structures are explained.

At the Local switch level, the associated transmission bit rates are 2.048 Mb/s (otherwise known as 2 Mb/s or E1) and sometimes 8 Mb/s (or E2) and the bearers are usually (shielded) twisted pair to the parent Node switch if it is co-sited. If the parent Node switch is not co-sited, then the transmission bearer is usually optical fibre or occasionally point-to-point radio, and the bit rate is typically 155 Mb/s.

At the Node switch level, if the parent Regional/Main switch is not co-sited, then the transmission bearer is usually optical fibre ring or occasionally radio, and the bit rate is typically 625 Mb/s or 1.2 Gb/s.

At the Regional/Main and Interconnect switch levels, if the parent Interconnect switch is not co-sited, then the transmission bearer is usually an optical fibre multi-ring or occasionally radio, and the bit rate is typically 10 Gb/s or 40 Gb/s. Similarly the peer Regional / Main switches are connected with SMOF SDH transmission systems running at typically 10 Gb/s or 40 Gb/s.

At the Gateway / Interconnect switch levels, the peer Interconnect transmission bearer is usually an optical fibre ring and the bit rate is typically 625 Mb/s or 1.2 Gb/s. With 'competition' it is necessary to interconnect competing carriers through these Gateway switches, and this introduces incredible inefficiencies in switching, transmission systems and signalling processes.

Non-Metropolitan Backhaul Network

Historically, the non-metropolitan geographic areas were provided with a ‘tiered star’ Backhaul Network that was parented on the State Capital cities, and there were very sound business engineering reasons for this.

Before Crossbar switching was introduced in 1960, virtually all non-metropolitan call connections were through local and district switchboards through what was termed the ‘Transit Network’. In this era, all transmission and switching equipment was hand-made.

The electronic stability and reliability of this equipment was very low by today’s standards, and consequently the installation and maintenance labour costs were naturally very high, (and this is one main reason why competition had absolutely nothing to do with bringing 'efficiency' into the telecommunications industry)!

A series of technology breakthroughs over the past 40 years were the catalyst to provide high capacity, long distance, low overhead, transmission and switching telecommunication systems. Detail of this is covered in Australia's Converging Network Technologies. Unfortunately the savings created by these technology breakthroughs were not relayed to the end-users, but were squandered on highly questionable multi-national business practices and then competition war-chests / advertising. Details on this are covered in Efficient Business Structures and Models. Most networks followed the main roads (which also were tiered star, parented on capital cities) and world-wide, engineers were struggling with techniques to increase the capacity of transmission links and bring the operating costs down.

Comments and Corrections are welcome