Integrating Analogue into Digital into IP

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Digital Encoding for Speech

For telephony and dial-up data services, the Backhaul Network is essentially digital, based on bi-directional streams of 64 kb/s Pulse Code Modulation (PCM) using a 8 kHz clock and 8 bits with logarithmic encoding to maximise the signal to noise ratio over a nominal 30 dB acoustic range.

The 8 kHz clock rate is vital as it defines the Nyquist upper frequency limit of 4 kHz, and consequently the international standard of 3.4 kHz as the upper frequency limit. This is the International Telecommunications Union – Telephony (ITU-T) standard recommendation G.703. Virtually all of Australia's Telecommunications standards are based on industry standards as recommended by the ITU. (Historically, many smaller competing carriers, and manufacturers have sought to introduce far lower operating standards for quick-profit reasons. To date; most of these short-sighted ploys have been thwarted.)

The ITU-T Recommendation G.703 defines the Voiceband channel for telephony and dial-up data transmission over the Backhaul Network; and the ITU has defined the interface between the essentially analogue CAN to the digital Backhaul Network; which is optimised for voice transmission. Digital transmission at 64 kb/s is the maximum rate that the CAN will pass - because there is a 3.4 kHz Low Pass Filter between the CAN and the PCM modulator / demodulator on the line card.

On the Backhaul Network side of the line card, separate 64 kb/s channel wiring is uneconomic, and it is commonplace to multiplex several channels into a common digital stream. ITU-T recommendation G.710 has the details for a 2.048 Mb/s stream that carries 32 channels: one for synchronisation, another for common channel signalling, and the remaining 30 channels for Voiceband 64 kb/s channels.

One solution to speed up the transition from analogue to digital transmission was to introduce Loop (signalling) multiplexers like the one above. These were connected off the 'back' of Crossbar subscribers switching stages and connected via the DDF to the Node switch.

If the Node switch was not co-sited with the Terminal/Local switch, then an (Optical Fibre or Radio) transmission system would be necessary to transport the digital streams between the Node and Terminal/Local sites.

From around 1980 until 1992, the Australian telecommunications Backhaul Network (BN) migrated itself from an entirely analogue (Frequency Division Multiplex - FDM) arranged switched transmission network, into an entirely digital (Time Division Multiplex TDM) arranged switched transmission network. This transmission network that integrates with the telephony switch hierarchy is called the Integrated Digital Network or IDN.

The Integrated Digital Network

The IDN is essentially an hierarchy structured switched transmission network that followed the general structure of the mechanical / analogue / FDM based switching network (called the Backhaul Network - BN) but all the switches are digital and the transmission systems are also digital; and all use the common 64 kb/s channel as the integrated base channel switched path.

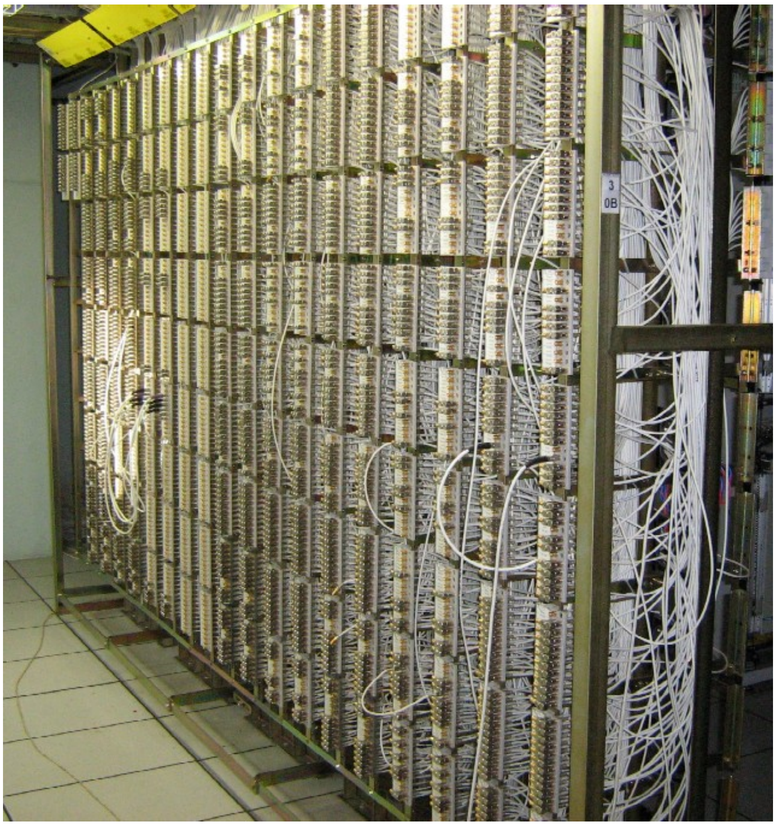
The term IDN came about as these digital transmission networks and digital switches were directly integrated with each other - unlike the earlier FDM and mechanical contact switches - which were not anything like the same or similar technologies. The IDN also integrated the earlier Digital Data Network (DDN) into itself, so that virtually permanent 64 lb/s data links were programmed in as infinity held calls - inside the IDN.

Local / Terminal switches group their connections into bi-directional 2.048 Mb/s (2 Mb/s) transmission streams that carries 32 Voiceband (64 kb/s) channels per 2 Mb/s stream. One channel is always set aside for channel synchronisation, and depending on the switch configuration, a second channel may be set aside for Common Channel Signalling for the remaining 30 bearer channels or up to about 400 bearer channels in a common transmission path.

Many Local / Terminal switches utilise 8 Mb/s bi-directional streams, because it is bearer efficient, cutting the hard wiring through DDFs down by 75% and carry about 120 channels per coax cable.

The picture below is a typically small Digital Distribution Frame (DDF) as would be found in most smaller (Local / Terminal) exchange sites. This DDF would also be the interconnection point for the ISDN (see below) all based on 2 Mb/s streams

The Local / Terminal telephony switches also through connect here with 8 Mb/s streams, and some of that is in the white coaxial cable seen at the near end of this DDF.



It is normal to have several Local / Terminal switches parented onto two geographically diverse Node / District switches so that if there is a major problem, then calls can still get through by the other Node switch. With this dual parent structure most local and district calls will not have to travel very far to make through connections to the distant end CANs.

For co-sited Local and Node switches, the connections would be twin shielded or coax cable direct wiring (via the DDF). For all other situations, where the Local switch was not co-sited with the parent Node switch, there would have to be a transmission system between the Local and Node exchange switches, and this would usually be on optical fibre, as part of an SDH ring that would cross through both parent Node exchanges, and pick up two or more Local Exchanges.

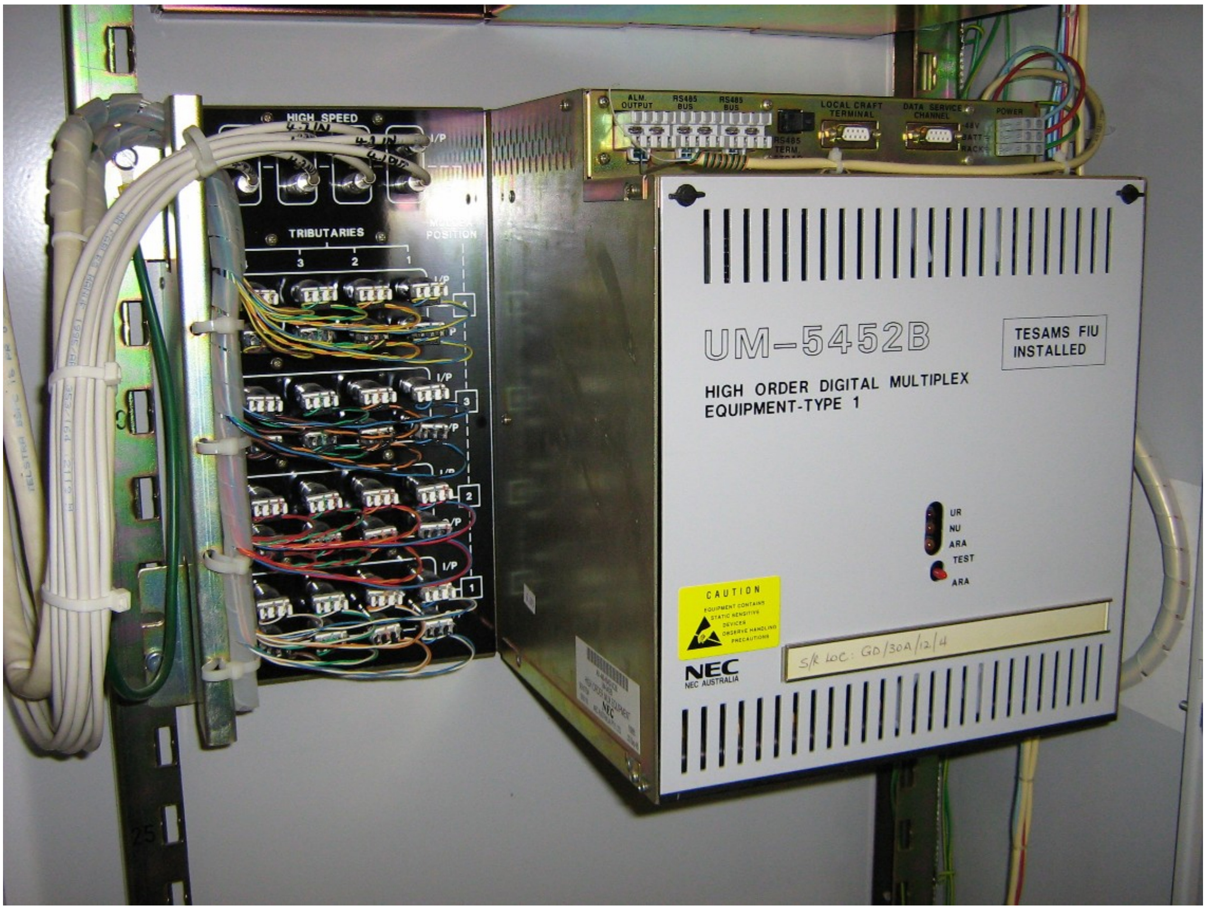
As the base transmission unit for an SDH system is the STM-1 (which clocks at 155 Mb/s), special Add-Drop Multiplexers are used to link up to sixteen 8 Mb/s streams into a single STM-1 stream. With this technology, local exchanges were integrated into the self-healing/repairing SDH transmission structure with a minimum of physical re-arranging, and bringing down operational costs.

A typical SDH ring for Terminal / Local exchange switches to connect with a Node/ District switch would probably runs at 625 Mb/s and hold 4 STM-1 virtual containers, capable of carrying 15,360 digital Voiceband circuits at 64 kb/s. While this might sound a lot of capacity, there is route redundancy and Internet requirements may easily occupy a couple of STM-1 virtual containers for their needs. One of the roles of professional telecommunications Engineers is to plan the design of these networks so there is availability, redundancy and a commercially effective forward growth plan.

This is a typical Higher-Order PDH Multiplexer, located in a Local exchange site. The white coax cables would connect to a DDF at 8 Mb/s and the dual pairs of twisted pair cable connect to separate 2 Mb/s streams also connected at the DDF.

These separate 2 Mb/s streams could be from Mega Links or from ISDN modems, so that these data links and/or multiple Voiceband transmission links can connect to switches and/or routers at a distant telecommunications site.

This technology is now largely outdated as one of the beauties of SDH is that the 2 Mb/s streams can be managed by software within the SDH ring, and contingencies can be programmed in so that if there is a network fault, the system is virtually self-healing - self-repairing until the physical repair is done, and then the SDH system can then automatically revert to its normal operating structure.



For calls beyond the District geographic area, these calls need to connect via a Regional switch, and this is usually through coax cable if the Regional switch is co-sited with a Node switch, or through another SDH optical fibre ring. In these cases the SDH ring can exceed 200 km in circumference (depending on the regional structure) to pick up the District/Node switch sites.

These SDH rings may intersect with SDH rings in Districts, and with other Regional SDH rings. Typically, these SDH rings would run at 2.5 Gb/s and carry sixteen STM-1 Virtual Containers. The switches associated with this traffic provide a backbone alternate route if there is no direct (SDH) transmission link between the two District switches.

The DDF at Regional and Main Exchange sites is usually much larger than those in Local telephone exchange sites, simply because they aggregate the streams from several local exchanges, and form cross connects.

This DDF is reasonably big and would probably be from a site that had Regional, District and Local switches co-sited (as well it would probably be in a Commercial Business District, so there would be a large amount of business interfacing and some of the verticals in this DDF would interconnect to Mobile Base Station transceiver equipment for cellular mobile phones.

For calls beyond the Regional geographic area, these need to connect via a Main or Primary switch, which are usually located in pairs in each major capital city - usually at the biggest telecommunications sites. These switches carry interstate and inter-Regional traffic (if there are no intersecting SDH rings connecting adjacent regions, or if those routes are fully occupied, and a backbone alternate path is required).

If the Regional and Primary switches are co-located, then this is usually connected via a DDF usually through coax cable, else these switches are connected by large transmission systems with long paths usually several 100 km between ends. In these cases the SDH ring can exceed 2000 km in circumference (depending on the regional structure) to pick up other Main / Primary switches - often interstate. These SDH rings may intersect with SDH rings in other Regional SDH rings. Typically, these SDH rings would run at 10 Gb/s and carry 64 STM-1 Virtual Containers.

The network structure above the Main / Primary mesh contains the Competitive Interconnect / Gateway Switches and these switches are the competitive inter-carrier connect points. All calls that connect to and from a competitor's network must pass through this switch, and sift through the Backhaul Network hierarchy of switches and transmission links, before it connects to the CAN at the other end - and in the competitor's network, the call would have to do the same! This is one prime reason why competitive telecommunications is so highly inefficient.

In the competitive world is commonplace for dirty tactics to abound and in telecommunications spamming with virus-like signalling (with the full intention to cripple the oppositions telecommunication systems) is an everyday event. One of the prime functions of a Gateway / Interconnect exchange is to restrict the (CCS7) signalling instruction set through this switch, to prevent rouge signalling sequences from entering or leaving a network - which will have the capacity of crashing all or critical parts of the switching, metering, or network configurations.

ISDN Confusion

Many people have confused the ISDN with the IDN, and incorrectly lumped the ISDN service connection as part of the IDN. Most of those people are also still thinking 'pre-1965' when the PSTN connectivity model actually worked; because the Backhaul Network and CAN were both analogue, the Backhaul Network portion was basically multiple star networks, and there was no automated alternate routing to form complex meshes. But that was then!

Since about 1965, when automatic alternate routing in the Backhaul Network became commonplace (to bring down connection costs), the PSTN connectivity model did not match reality and the PSTN connectivity model was split into two diametrically different network structures - the Backhaul Network (BN) and the Customer Access Network (CAN). With this split - the Connectivity Model closely matched network reality and this provided an ideal stepping stone for the IDN connectivity model to sit very comfortably inside the Connectivity model structure.

As said before, the IDN integrated the base switching clock rate of 64 kb/s Voiceband and Data channels into 2.048 Mb/s (usually abbreviated as 2 Mb/s) data streams, carrying a total of 32 channels per stream through transmission equipment. These 2 Mb/s transmission paths are very similar (but not the same as) Integrated Services Digital Network (ISDN), which also uses 2.048 Mb/s.

The big difference is that with ISDN the signalling channel uses a customer-based Local Area Protocol (LAP-D), and this is terminated from the CAN at the District / Node switch. In the IDN, almost all signalling is done with Common Channel 7 Signalling (CCS7) which is a Backhaul Network/IDN signalling protocol. Remember, ISDN is a CAN technology where the IDN channels are extended in a 2 Mb/s stream as a Customer based service over the CAN to the CPE, but the signalling is customer based - not network based.

IDN Telephony Signalling

Common Channel Signalling No. 7

With a telephony based call / connection in the IDN; it is the Common Channel Signalling No 7 that: sets up, manages and clears down a connection between two CANs. The switched connections are controlled by commands to the switches through the CCS7 network. In return, the switches talk network CCS7 to each other to report on bearer occupancy and availability so that the routes for subsequent calls can be established, and avoid network congestion.

CCS7 was a very comfortable fit with the IDN and it was a clear generation ahead and beyond the in-band Multi-Frequency Coding (MFC) that was used in Crossbar exchanges less than a decade before. With MFC signalling, it was possible to establish several call routes and then choose the one with least switching and connect the call - but in this process several links were held up between several switches before the decision was made - and that could take several seconds.

CCS7 had its own network talking between the various switches and controlling computers called Service Termination Points (STPs) and Service Switching Points (SSPs). As the dialled number was sent into the IDN, the local switch converted the Dual Tone Multi-Frequency (DTMF) back to the requested number, and then the SSP passed this request to the STP, which then surveyed the network switches and established the call route, then passed the control data back to the switches via the SSPs and the switches then effected the connection. With most calls this process takes about 0.2 seconds before the distant end exchange starts sending out ring current into the distant end CAN.

Competing Infrastructures - 1

If the distant end number is in another competing infrastructure, then the call path has to traverse via the Gateway exchange, and then down through the competition network. If the competing infrastructure is in the same geographic region, then it is very obvious that this process is extremely inefficient, and very expensive to operate.

If anybody after reading this still thinks that competitive infrastructures is good for the economy, then they have not grasped the basics of infrastructure business, and just how efficient infrastructure businesses are, in comparison to most competitive businesses involving infrastructure management.

Mobile Cellular Phones

With Mobile telephones the calling structure is almost the same but with a slight twist. Because of the roaming nature of mobile cellular telephones, every mobile cellular telephone is 'homed' onto one CAN-based Mobile Base Stations' Tower / Antenna, and that data is transferred by the CCS7 to a large database that keeps a track of mobile phones and their cell base.

While the phone moves, or atmospheric conditions change, the mobile phone continually sends out "I'm here" messages and the District network compares signal strengths and re-homes the mobile phone to the strongest radio connection - and again this data is relayed back using CCS7 to the database with the mobile STP beside it.

When a mobile cellular phone initiates a call the called data is relayed to the STP via the CCS7 network and the STPs negotiate the best path to connect the call to the distant end. If the distant end is a fixed access CAN then the call is connected from the nearest regional switch (for the cellular mobile phone) to the nearest regional switch for the fixed access CAN and then the call is connected in the usual manner.

If the distant end is another mobile cellular phone, then the STP interrogates the mobile database to find out under which Regional switch the distant end mobile is located and then with that data, connects to the nearest Regional switch and connects to the Node, then into the CAN to the Mobile Base Station to the cellular mobile phone.

Competing Infrastructures - 2

When calling to or from a competitive telecommunications infrastructure, it is necessary to pass the call up through the Gateway to the competitive carrier, and then back down through the competitive carriers infrastructure. (Zero points for so called efficient competitive infrastructures.)

Mobile Number Portability

With mobile number portability, the inefficient mess becomes even more entangled. Every telecommunications infrastructure provider now needs to carry another database (field) to tell which provider has that particular number. If the wanted number is not internal, then the call has to pass all the way up to the Gateway switches and then all the way back down. This might not be a major problem in major capital cities, but in regional and remote areas, this unnecessarily ties up double the number of available channels to create a call connection.

Connecting to the Internet - Dial-Up

Calls to and from the Internet from/to a fixed access or mobile cellular phone also fit very comfortably in the Backhaul Network/IDN. For Dial-Up Internet - in a very similar fashion to using a Fax machine, a Dial-Up modem makes connection with a distant end modem and that modem has a connection to the Internet. With that link established a personal computer can then talk directly through the Internet.

Connecting to the Internet - ADSL

At the Local telecommunications facility level there is a local router that feeds to the DSLAMs in the CAN to provide ADSL over copper pair CAN (or point-to-point radio in regional areas) to CPN. Within the DSLAM there a bank of High Pass / Low Pass filters that merge the CAN side of the local telephony path with the Modems that translate SMOF based IP into ADSL carrier frequencies for transmission in the copper CAN.

The theoretical CAN-Backhaul Network demarcation point is in this Modem interface – but that it impractical – so the practical demarcation point is on the equipment (DSLAM) side of the Ethernet Panel or ODF feeding to the DSLAM. This makes the entire DSLAM as part of the CAN.

With ADSL (DSLAM equipment in the CAN at Local exchange sites) - this is another scenario. The ADSL Modem has a virtually permanent connection through the CAN to the Digital Services Line Access Multiplexer (DSLAM) as discussed in The Customer Access Network (CAN), and the DSLAM has a transmission link connecting to a local Router / Switch which then connects into the Internet Protocol Network (IPN).

The usual arrangement is that the CPE ADSL Modem has a MAC (Media Access Number) and the Internet Infrastructure Provider has a remote database that recognises that modem and then allows it to connect through to the main Internet, providing the service with Web, Email, FTP and other protocols for Internet communications.

Comments and Corrections are welcome