Introduction of Crossbar Switching Equipment

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Abstract
A historic paper from the Journal in 1961 summarising the investigation and selection of Crossbar Switching Equipment for the Australian Telephone Network.

Introduction
Around the end of 1959, the Australian Post Office (APO, later split into Telecom Australia and Australia Post) made the decision to standardise on the L M Ericsson register-controlled crossbar switching system for the Australian Telephone Network. This was a controversial decision given the entrenched position of step-by-step equipment with its British heritage. The historic paper (Banks E. R. 1961 [5]) details the rigorous investigations over the previous three years to identify the type of switching system best suited to the requirements for economic and efficient expansion of the Australian Telephone Network.

The paper comprises three parts, namely:

1. the circumstances leading up to the investigation and the factors underlying the analysis and decisions;
2. the system adopted; and
3. the way in which the equipment will be integrated into the network.

It is evident to the reader that the APO were extremely thorough in their investigations and mindful of the need to accommodate a trebling of the subscriber numbers in the next twenty years. Similarly, the equipment needed to support future subscriber trunk dialling and the separation of routing and dialling for increased efficiency.

A number of key requirements were identified and used to rank the switching system alternatives. Taking all these requirements into consideration, it was clear that the most desirable switching system for use in the Australian network was a link-trunked crossbar system. The crossbar system was fully developed and tried in local, rural and trunk transit applications and worked successfully with step-by-step networks. Of the systems on offer, the L M Ericsson register-controlled crossbar equipment was chosen as most nearly fulfilling the requirements.

Initially, the Ericsson crossbar switches were manufactured under licence by STC and TEI in Australia, who were supplying the step-by-step equipment at that time. In 1960, Ericsson purchased Trimax Transformers Pty Ltd, which was renamed L M Ericsson Pty Ltd (Ericsson Australia) in 1963. Soon after, a new production plant was built by Ericsson at Broadmeadows in Victoria (Spongberg, C. A. 1967 [6]) and was the subject of a previous historic paper in this Journal (Moorhead S. 2015 [7]), which resulted in Ericsson capturing one third of the market for public
telephone exchanges in Australia.

References


The Historic Paper

E. R. BANKS, author of the article “Crossbar Switching Equipment for the Australian Telephone Network” joined the Department in 1948 as a Cadet Engineer and completed his training and the Degree of B.E.E. at Melbourne University in 1952. In this year, Mr. Banks shared the Dixon Scholarship in Electrical Engineering and won Monash, Newbigin, and Oral Presentation prizes of the Institution of Engineers Australia for two papers, one on Network Design and one on the Electrolytic Tank. After nine months on Country Installation work in Victoria Mr. Banks joined the Long Line Equipment Section at Central Office and was assigned the task of locating an intermittent fault on the Adelaide/Perth section of the Sydney Circuit as high-speed telegraph circuit. Following the successful completion of this assignment Mr. Banks spent 1953 and 1954 in England and Europe as the holder of a scholarship from the Federation of British Industries. During this time he visited and worked with Telecommunication Manufacturers and the British Post Office. On his return from England Mr. Banks took up duty as Divisional Engineer, Traffic, in the Telephone Equipment Section and later as Sectional Engineer, Network Planning. He was associated with the re-issue of Traffic Engineering Instructions as Chairman of the Traffic Engineering Committee and with the studies and work leading to the recommendation that the Department adopt Crossbar as the new standard switching system. Currently Mr. Banks is Chairman of the CCITT Working Party on National Automatic Telephone Networks with the responsibility for formulating guiding principles to assist new and developing countries in the development of their automatic telephone networks. Mr. Banks is an Associate Member of the Institution of Engineers Australia and an Editor of this Journal.
CROSSBAR SWITCHING EQUIPMENT FOR THE AUSTRALIAN TELEPHONE NETWORK

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INTRODUCTION

This paper is intended as a summary of an investigation carried out over the past three years into the type of switching system best suited to meet the requirement for economic and efficient expansion of the Australian Telephone Network. As a result of this work, a study of the existing systems of L.M. Ericsson design was adopted as standard. Part I of the paper describes briefly the circumstances leading up to the investigation and the factors underlying the analysis and decision. Part II describes the system adopted and Part III indicates the way in which the equipment will be integrated into the network.

PART I—CHOICE OF A SYSTEM

Local Network Problem

Since the first automatic exchange was installed in Geelong (Victoria) in 1912, the Post Office has progressively developed the automatic local networks using step-by-step equipment and employing the Strowger and, later, the British 2,000 type, and G.E. 5000 and 50000 bistable selectors. The basic step is a single group of 100 selectors and most widespread of methods of automatic switching and has its origins in the invention by Strowger of the 100-point selector (see Fig. 1). A group of these basic units can be used for a 100-line exchange. As the network develops succeeding stages are added for each digit required, and it is readily apparent that such a system is incapable of coping with the vast number of subscribers which can be used only in a certain area. Development of a network of the type shown in Fig. 2 can proceed without serious difficulty until the numbering limitations of six-digit working, a practical capacity of about 500,000 subscribers, are approached. By 1936 the Melbourne and Sydney networks were extended to a stage where they were using 600 selectors on a 1,000-line basis following the very rapid post-war development, and the cost of extending to seven-digit working, where required, was estimated at up to 60 extra per subscriber's line for the necessary additional switching stage.

The prospect of adding another switching stage also implied the upgrading of all links between existing switching stages in order to maintain the existing overall grade of service provided to subscribers. The grade of service or probability of call loss over the complete connection is, to a first approximation, the sum of the loss probabilities from the addition of an extra link would impose extra circuit provision on all previous links. Finally, impulses are required for a step-by-step network from exchange to exchange. The consequent restrictions on signalling limits on both subscribers’ and junction lines necessary to minimise impulse distortion and ensure successful operation of the switch at the distant exchange are of considerable interest and of some technical limitation with the present equipment.

Considerable savings were seen to be possible by the removal of the basic restriction that routing and numbering are tied together. One could be made of a given group of junctions for two traffic loads, one of which occurred during the day and the other at night, whereas at present, for example, the junction plant in the city areas is practically idle during the night while the adjacent country areas are busy. The second result of diversing routing from numbering would be that traffic could be moved between two exchanges on the most economic route rather than over a rigid backbone of links and switches. In many instances this would mean the bypassing of several intermediate switching stages and consequent plant savings. For example, in Fig. 2 the dotted route from the first exchange to the second exchange is avoided and the traffic destined for any one of 1,000 subscribers, bypassing two switching stages.

A limited amount of direct routing had already been possible with step-by-step equipment but only within the right exchange group of the calling subscriber.
It was clear that the possibilities for affecting considerable economies existed if a flexible and universal system of direct routing could be introduced. Improvement in signalling methods would also remove signalling limitations on junctions and subscriber lines.

These technical possibilities for economic expansion in the local networks can be seen to promise real potential in terms of national savings when the rates of growth in the Melbourne and Sydney networks are considered. Table I shows the present size and expected growth of these networks.

**Table I.** Development Statement at 1958

<table>
<thead>
<tr>
<th>Network</th>
<th>Numbers in use 1958</th>
<th>Present average rate of provision of additional numbers per annum</th>
<th>Estimated at 1980</th>
<th>Rate of growth per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney</td>
<td>332,000</td>
<td>25,000</td>
<td>1,124,000</td>
<td>79,000</td>
</tr>
<tr>
<td>Melbourne</td>
<td>273,000</td>
<td>20,000</td>
<td>1,105,000</td>
<td>77,000</td>
</tr>
</tbody>
</table>

It can be seen that by 1980 both networks will have more than trebled in size, in which case the present growth represents a doubling in every ten years. The present development of the switching equipment in the exchange and junction sections of a network is housed in the junction cabinet and cable conduits. The proportion at present is about 70 per cent. It is clear, therefore, that there is considerable scope for affecting economies in investment by adopting a switching system which will allow traffic to be carried on the shortest possible route to its destination.

**Trunk Network**

Since 1940, with the installation of semi-automatic transit trunk switching in Melbourne, the long distance trunk network has been developed using transit switching to eliminate the distant operators and to provide a greater speed of delivery. Figure 2 shows a simple schematic of the routing for a trunk call from Melbourne to Sydney. The Melbourne trunk operator can dial direct to the subscriber in the Sydney network without the assistance of the Sydney telephone office. This mode of operation has been introduced at capital cities and provincial centres throughout the Commonwealth in the past 20 years. However, the growth of trunk traffic and trunk network developments over the past ten years, together with the development of techniques in recent years to economically large blocks of long-distance channels by coaxial cable or radio, now make it feasible and necessary to consider the extension of subscriber control into the long-distance network. For subscriber-dialling of trunk traffic, Australia-wide numbering and charging schemes are necessary in order to simplify the routing and switching system design and operation. The question of direct registration at developing the Australian network for ultimate subscriber-dialling of all calls was commenced in 1956. This study soon highlighted the limitations of the present switching equipment in meeting this objective economically. In the Trunk Network the requirements for routing discussed for local networks apply also and, in addition, it will be necessary to automatically determine the charge rate for the call and to register the appropriate charge information on the subscriber's meter. The national number will be the local number plus one and three national digits, and this eight-digit number must be received by the operator of the remote switching equipment. For long built-up connections a high quality circuit must be assured, especially once the operator is removed altogether and is not available to reject the occasional noisy or low-volume connection, as she may do at present.

**Rural Networks**

The third problem facing the Post Office was the economic extension of continuous automatic service to rural...
The installation of the Rural Automatic Exchange (R.A.X.) in the post-war period went a long way towards eliminating the small manual exchanges of 200 lines or less. However, these units provided automatic services only between subscribers on the same exchange, and the manual exchange was still in common use. Some of these exchanges had as a parent the local provincial exchange which was manual. With the proposal to introduce a national numbering plan and extended dialling, and to remove manual working, it became apparent that the present R.A.X., due to its design and trunking, could not be integrated readily in the closed-numbering areas proposed for these districts. Furthermore, the existing manual exchanges were often found in the medium-size provincial towns with an exchange of 200-1,000 lines for which Magneto or Common Battery (C.B.) manual equipment was being employed. Here, as in the trunk exchanges, the costs of operation and telephones' facilities were rising to the level where it was economic to consider automating the system. In these areas subscriber distance-dialling and automatic multi-metering were essential, and the step-by-step operation was currently used in the large cities was not capable of providing for the economic introduction of such a scheme.

These three sections of the network, local, trunk and rural, were therefore all in need of a new switching system which would facilitate economic extension and provide for the ultimate complete automation of the system. To meet this requirement, a detailed examination of the various available systems was undertaken with a view to selecting the one most suited for the immediate and long-term Australian requirements.

Swapping System Types

It is necessary at this stage to pause and review very briefly the main types of electromechanical switching systems which have been employed in telephone exchanges in the past 30 years.

(i) The Sequential Selector (Fig. 6), developed from the original Siemens & Halske patent, has been used extensively in step-by-step switching systems and is the director systems which employs a common translating register.

(ii) The 500-point Planar Switch (Fig. 5) is used in a register-controlled common-control system on the rotate and thrust principle.

(iii) The Motor Unit Selector (Fig. 6), developed by Siemens & Halske later by A.E. Halske (now A.E. Woolwich), has 16 operating elements per line, providing a maximum of 200 four-wire outlets. This switch has been used in step-by-step and register-controlled systems, and may employ common drive as in the Rotary Systems used extensively in Belgium and France.

(iv) The Crosster Switch (Fig. 7), developed from the patents of Belafante in 1886, has been used in both step-by-step and register systems, and has received increasing attention in recent years.
for junctions are governed only by the
sensitivity of the pick-up and answer
signal relays, and the use of sensitive
relay relays for these functions will vir-
tually remove the signalling limitation
from the junction. However, as the result
of these improvements, the tolerance to
impulse distortion can be increased consid-
erably.

The present standard of 9-11 l.p.s. can be reduced to 5-12 l.p.s., thus considerably reducing the cost of the exchange.

Assembly
Rectangular assemblies
non-critical

Usage
Rectangular assemblies
non-critical

Careful jigs and con-

The second essential consideration is
that the cost of production of the switch-
ing system should be a minimum. It is
possible to assess the likely relative
cost of production of two switching sys-
tems, when the following factors are
realised:

(i) The labour cost represents 75 to
80 per cent of the total costs for
types of electromechanical
switching systems.

(ii) The number of control relays in
a switching system does not vary
significantly, between 3 and 6
relays per line. This is independ-
ent of the number of crosspoints
and applies equally to common

(iii) The main material component in
an exchange is the space path
connection equipment or the
Fig. 10.—Telemanning Principles.
a range of crossbar switches of various sizes. These switches differ from the binary selector since they are not capable of setting up a connection without the assistance of an external control circuit. This control circuit receives the dialled digits and decides which inlet must be connected to a given outlet and then operates the corresponding horizontal or vertical magnets to close the relay contacts at the required interconnects. Fig. 9 shows a crossbar switch of the type used by the A.P.O., and an arraignment of a typical bridge or vertical pick.

The switch in Fig. 9 has 10 inlets or 10 vertical bridges, and 20 outlets, which are derived from the horizontal bars. Each bar will operate either to the top or bottom magnet or the bottom magnet associated with it thus lifting the selector fingers up or down. From five bars, therefore, 10 contacts or outlets are derived. This switch operates in a water switching system. The switch may be offered free to provide a total of 20 outlets.

Fig. 12 shows in detail the method of operation of the vertical and horizontal magnets to close a connection. To operate springset No. 6 in Fig. 12 the selecting magnet 6 lifts the selecting bar so that the selecting finger moves upwards over the flange of the actuating spring 6. The actuating spring is compressed by the protruding stop. Attached to the armature of the holding magnet is a vertical holding bar which normally moves into the recess of the actuating spring and, hence, does not operate the spring plate. However, when a selecting finger is moved from its normal horizontal position by the operation of the selecting bar, the outer extremity of the finger bridges the recess in the actuating spring so that when the holding bar is operated, it comes into contact with the operated selecting finger and operates the appropriate springset. The selecting finger is held between the holding bar and the actuating spring by the pressure exerted by the holding magnet. Since the selecting finger is flexible, the horizontal bar can restore to normal and be used to assist in the setting of another call level and the free connection under the control of the holding magnet.

The Crossbar Switch as a Selector

Each vertical of the crossbar switch can be considered as a 20-outlet selector. Thus, a 10/20 crossbar switch consists of 10, 20-outlet selectors. Twenty outlets are not sufficient from a given selector stage to provide efficient trunking. An increase in the number of outlets available is one of the disadvantages of bilateral switches. Crossbar switches can be arranged to provide for any number of inlets and outlets by a method known as link trunks. An illustration of this principle is given in Fig. 13, which shows how access is gained to 400 outlets from a given inlet using two ranks of selectors. This principle of developing a selector stage from two partial stages of crossbar switches is used throughout the A.R.F. exchange system, the type normally used in large city networks. The connections between the first and second partial stages are known as links, and the marker controlling the complete stage selects not only a free outlet but also a free link to connect the inlet to the required outlet. Hence, both partial stages are set simultaneously. Using crossbar switches provides an easy method of setting up and clearing circuits with any desired number of inlets and outlets can be constructed.

Typical Crossbar City Exchange

The operation of a typical crossbar city branch exchange (A.R.F.) is described below, with reference to the schematic diagram (Fig. 14).

Subscribers are routed through two linefinder stages, S.L.A. and S.L.B., in groups of 200 to the S.R. relay set. From this relay set access is gained through register access equipment to the local registers. The S.R. relay set provides transmission of voice signals, supervision for the calling subscriber, and both the S.L.A. and S.L.B. stages consist of two partial stages of crossbar switches arranged in units, each unit providing 80 inlets and 400 outlets. From this group selector stage, direct access is gained to the S.L.C. and S.L.D stages of the subscriber's linefinder, final selector group. As well as these direct routes to 100-line groups, a backbone route connects each incoming group selector (G.S.) and this traffic is handled on the direct routes to the S.L stage. The full S.L stage provides access to 1000 subscribers. The S.L stage is under the control of the S.L marker (S.L.M) whilst the group selector or G.S. stage is controlled by the G.S. marker (G.S.M). Incoming calls from other exchanges are routed to the S.R. relay set, which connects the incoming calls to the S.L stage. Outgoing calls from the G.S. stage may be routed either to other crossbar exchanges or to step-by-step exchanges.

When a subscriber removes his handset his line relay "LB" operates and indicates the call to the S.L. marker of the 1000-line group to which he belongs. The S.L. marker selects a free S.R relay set and register and connects the calling subscriber through the S.L.A and S.L.B stages to this relay set and register, and then switches the register onto the required trunk to the subscriber. The register then transmits dial tone to the subscriber. The subscriber dials the wanted number, into the register. For a local call the register now controls the selection of the wanted subscriber.

First, the register selects the G.V. marker associated with the G.S. group selector and to which the S.R. relay set has access. A code receiver KM in the G.V. marker receives from the regulator, by means of a high-frequent signaling code, the digit required to select the destination of the call. This signal is transmitted to the S.L stage. The G.V. marker connects the call through the required outlet on the S.L.

Fig. 13.—Link Trunking in Crossbar.
stage, and the SI marker is then sized.

The GV marker releases as soon as it has completed the group selector con-
nection. If there are no free outlets on the hi-speed rap of the group
required, the GV marker goes the route to the next free hi-speed rap of the
required group and connects the call as before. The SL
marker calls for the digits required to locate the subscriber in the
particular 2000-line group already selected. These digits are also sent
forward, using high-speed code, and are received by the receiver in the SL
marker. The SL marker positions the digit selector to position the
required digit, and, having notified the register of the condition of the
called subscriber, releases. The complete connection is held from the SR relay set which now
transmits ringing current to the called subscriber and ring tone to the calling
subscriber. At this stage, SR takes over
trol of the call, and the register
releases. From this stage on, the super-
vision of the call under the control of the
register is continued all the way through supervision in our present stop-by-stop
exchanges.

For an outgoing call the GV marker
selects the required outgoing route and identifies what type of signalling is
required for the digits to be sent for-
ward. For a route to a stop-by-stop
exchange the digits would be sent for-
ward from the register at 10 l.p.s to
position the selectors. If the route
deps on another stop-by-stop exchange the
digits would be transmitted in high-
speed code direct to the code receiver of
the stop-by-stop exchange in question.

Incoming calls from stop-
exchanges enter Register I. This register
receives the digital information from
the stop-by-stop exchange and positions
the selectors in a similar manner to the
local register. If the call is incoming from another stop-by-stop exchange, the multi-frequency coded information is
taken into the code receiver (ARM) of
the GV marker direct, and the call is completed in a similar manner to a local

Trunk Exchange

If the subscriber requires to call a
destination outside the local network, for example a Melbourne subscriber
calling Sydney, on receipt of the code for
Sydney, "02", the Register L initiates
action to connect the subscriber to a net-
work register, Register N, at the trunk
exchange. The trunk exchange equip-
ment is of the multiple circuit type and
is stage built, according to requirements, of either two or four partial stages of
switches, and controlled by common
markers, registers and analysing code
receivers. These trunk exchanges can be
expanded in units of 200 lines up to a
total capacity of 4000 trunks in and out.

The Register L proceeds to transfer
the digital information into the Register
N at high speed, and Register N assumes
the control of the call. The answer
receiver (ARM) is called in to determine
the charge rate to be applied, and when
the called subscriber answers the receipt of the answer signal in the PBX causes
motor pulses to be applied to the
line at the rate appropriate to the call
distance and charge. The routing of the
call is controlled through the necessary
staging via Register N. At each transit point the local code re-
civer calls for the next stage in the
direct line circuit to be taken into use as the next link in the connec-
tion. Having completed the selection in the transit exchange, the transit
mark releases and the Register N
takes direct to the next transit code
receiver in the call.

Rural Areas

A smaller version of the ARM
exchange, the ARM80, employing two
partial stages, is used as the master of
a rural automatic network. Fig. 13
shows a typical rural network with the
ARM80 located at the provincial centre
associated with the local subscribers' ARK exchanges. Small ARKs (rural)
need only a single exchange Installation.
This is a modified form of the subscriber's line
stage element of the ARM exchange, relying on the ARM register for storage of the
subscriber's number, and control of
routing. These ARK exchanges vary in size from 30-90 and 100-250 lines
in two series, ARK51 and ARK52.

They have been engineered as unit type

Fig. 15.—Croseb Rural Network.
which has been designed for controlling a call through the step-by-step and crushor network in a crushor switcher and the step-by-step network to allow for the case when the call is routed through a step-by-step switching stage. In this case, the maximum flexibility is achieved if all digits are passed out in decimal and another selector is selected when the crushor network is re-entered. For calls to step-by-step equipment, one of signals A7.10 or A7.11 is sent, and for calls to switch-station network from the 3A series indicate from what digit the register must start when pulled into the network.

Incoming calls from the crushor network arrive on the GIV and may be destined either for the crushor or step exchanges. The first digit received will be the 3rd, and, if 1, the code receiver will call for the first X and route to the required 1,000-line group. If the digit is 2-0, the GIV will select a route to the appropriate rank of 4th selectors and send a return signal to the Register 4. If not a 4th and subsequent digit, the register must start when pulled into the network.

The third application of crushor equipment will be in the introduction of the first selector stage, which is in effect the essential elements of the crushor switching system. Thus, step-by-step exchanges instead of or to replace D.S.Rs. (discriminating selector repeaters). This application arises in one of two ways. Either an extension the D.S.Rs. (switching selector repeaters) are replaced, or a trunkline trunked exchange is converted to a group selector branch by the introduction of a crushor to group selector stage. A typical trunking diagram showing the replacement of the D.S.R, with a crushor group selector stage, is shown in Fig. 18. The D.S.R. is used in some step-by-step branch exchanges to provide direct routes to other exchanges in the same main exchange area, that is, possessing the same first code digit. All other calls are routed via the main exchange first selectors. The crushor GV stage provides no limit on the number of digits that can be established, and, thus, a large portion of the traffic load can be removed from the main exchange route. In addition, a direct route can be established from the GV stage to the trunk switching equipment to handle trunk traffic. This is not possible on the trunk code "Q" using the present 2,000 type D.S.R.

Rural Networks

In the rural networks, the first requirement will be to minimize purchase of further R.A.K. equipment which cannot be readily integrated in the national numbering and switching scheme. For this reason, the initial bulk orders of equipment will contain a proportion of ARK country terminal exchange equipment. These small units, ranging in size from 30-2,000 lines, will cover a very large proportion of the requirements in rural areas and will be designed to take the place of the R.A.K. and the medium-sized manual exchanges. Where the exchange will grow beyond 1,500 lines in the 20-year period, or the proportion of local traffic is high, an ARK exchange would be considered, especially where the rate of growth is high.

The introduction of ARK trunked exchanges will lead to ARK being planned to provide a core for the ARK exchange networks and to facilitate distance dialling.

Trunk Network

The present operator-controlled step-by-step trunk network of basically different character from the step-by-step local networks for two reasons:

(i) The crushor is a premiss, or, in other words, the operator to reach a certain location very, depending on the location of the operator and the route she chooses to take. For example, a Perth operator calling Sydney via Adelaide may dial 1051, whereas an operator at Adelaide only 351. In the national numbering scheme, subscriber exchanges have as their nearest exchange the dial 10 for Sydney, no matter where in the Commonwealth they were and how they reached their destination.

(ii) The present method of signaling on long distance carrier telephone channels using MVE has been designed especially for operator dialling, and the system would not be entirely suitable for use on a subscriber-dialled system with high-speed circuit closure.

For these reasons, it is generally considered that the objective should be to retain this network as an entity and to build up in parallel a subscriber-dialled long-distance network linking progressively the local networks. The present network would continue to handle the traffic not catered for by subscriber-dialling. If a subscriber requires a telephone to complete the call, the operator would...