The developoment of an Access Network - A different approach

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Large investments are currently being made in access networks in South Africa to provide telephone access to both new and existing areas not previously serviced. This paper presents an access network developed by the Telkom Development Laboratory and the methods used to reduce the cost-per-port and maintenance costs of the network. Lower costs-per-port means more connections per budget.

1 Introduction

The access network is the most cost-sensitive area of any telecommunications network with high labour and maintenance costs. Other factors such as copper, battery and solar panel theft increases the running costs of access networks.

In this paper we present a solution developed by the Telkom Development Laboratory (TDL) to reduce to cost of the access network, from the exchange interface right down to the customer connection. The access network developed, DCR-300, not only concentrates on the equipment costs but also on the maintenance and running costs of the access network. A cost of R1000 per port was used as a target for the design of the access network.

2 The DCR-300 concept

The concept of DCR-300 was initiated in the search for a low cost telecommunication solution to provide POTS (Plain Old Telephone Service) to areas in South Africa where little or no infrastructure exists. Factors such as deployment time, maintenance cost, COE (Central Office Equipment) cost and copper theft were given a high priority in the access network design.

The system in it's basic form makes use of the best cost advantage by combining both copper and wireless technologies in the access network. DCR-300 makes use of a wireless connection (radio, optical fibre, optical laser etc) up to 300 metres of a customer, after which copper is used. By using this combination, the most cost effective solution is achieved at the same time providing the customer with a wire-line (64Kbit/s) quality connection.

2.1 Brief System Description

DCR-300 is based on short haul 2Mbit/s PCM links configured in a closed loop as shown in figure 1. The system is divided into two blocks : exchange equipment and field equipment.

The exchange equipment consists of a CPC (Central Point Controller) and a COMMS (Communications cards) card housed in a 19" EURO rack. The CPC card is used to interface with the exchange on a 2Mbit/s trunk group port using the R2 signalling system as a concentrating interface. All local loop control and exchange interfacing is controlled by the CPC card. A PC is used to control the system locally while a link to TMN, via the COMMS card, provides higher order control and monitoring.

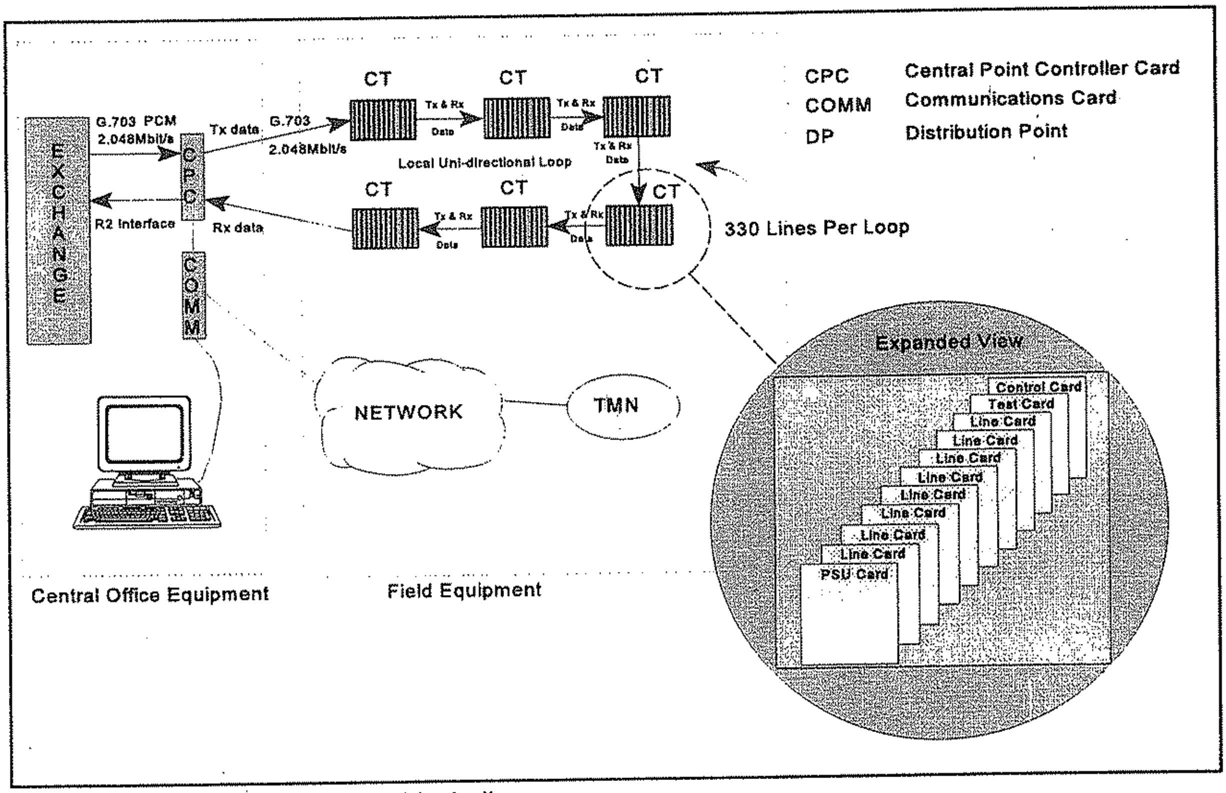

Figure 1 The DCR-300 system block diagram.

The field equipment consists of several CTs (Concentrator Terminals) from which the customers are serviced via a 'fish-bone' copper network and drop wire. The length of the copper run from the CT to the customer is typically less than 300m. Each CT contains a CC (Control Card), a PSU (Power Supply Unit), up to 8 line cards (16 ports per card) and a test card. Each CT can serve up to 128 customers irrespective of whether the power feed is mains or solar fed. The number of customers and CTs per loop is determined by the average calling rate per customer. With a typical calling rate of 45mE (originating and terminating traffic based on a traffic model associated with a typical residential area as supplied by Telkom) and a grade of service of 0,2%, it is possible to supply service to 330 customers per loop. Every customer on the loop has equal access to all the timeslots on the loop.

CTs are connected together in a closed uni-directional or simplex loop. Both transmit and receive data are conveyed in the same direction and in the same PCM G.703/4 frame. Initially the frame being transmitted from the CPC to the first CT contains only transmit data from the exchange. After the first CT, the frame contains a combination of both transmit (data for other CTs) and receive data (data from the preceding CT). Data between the last CT and the CPC contains only receive data for the exchange. The connection between DCR-300 and the exchange is seen as full duplex connection by the exchange, with a transmit and receive connection. By using a uni-directional loop, the required transmission equipment is halved.

Using a single loop in one direction renders the system vulnerable to an outage if any one of the links between the CTs are broken. The outage problem is overcome by using a second uni-directional loop in the opposite direction to the first loop providing self-healing capabilities. The second loop is used purely for redundancy and carries no traffic until the main loop is disturbed. The self-healing mechanism ensures undisturbed service even when both links are broken at the same point. The second loop is used as an option when reliability outweighs the cost of additional transmission equipment.

The main features of DCR-300 are:

- Low cost network with concentration
- Supports both R2 and V5.2 interfaces
- Supports all standard subscriber equipment
- Uses existing PSTN billing and numbering schemes
- 64Kbit/s line encoding/decoding
- Able to provide meter pulses to all ports on the system
- All system software is down loadable from a central point
- Field replaceable SLIC modules for low maintenance
- Supports TMN

3 Techniques used to reduce costs

When developing the DCR-300 network, the main design criteria were to reduce the network cost as far as possible without sacrificing functionality, quality or service. There are several areas in an access network were costs can be reduced. Following are the main areas in which the costs for DCR-300 are reduced.

3.1 Central Office Equipment

Currently, one of the highest cost components of access networks deployed by Telkom, is to be found in the central office, where the connection to the exchange is made using standard line cards on the exchange side with associated line looping circuitry on the access network side. Access networks typically have line cards in the field to connect customers to the system, and in this way, line card equipment is doubled, driving the cost of the access network up. The additional equipment requires larger buildings and airconditioning units to house the equipment, increasing the cost further.

The V5.2 interface, an ETSI / ITU specified open interface, would eliminate the additional central office equipment and space required to connect the access network to physical ports on the exchange. The V5.2 interface can therefore reduce the costs of interfacing access networks to the exchange.

Unfortunately, the V5.2 interface (which provides concentration) will only be available for use by late 1998 on a limited number of Telkom exchanges. It should also be kept in mind that both the software and hardware upgrades at the exchanges will have a significant price tag, adding a hidden cost to the access network.

The DCR-300 network uses the existing R2 interface as a concentrating interface to the exchange. By passing the A-party number to the exchange when an outgoing call is made, individual billing for every customer on the access network is possible. This method of access network interfacing is very similar to that of a PABX connection, with incoming calls being routed from the last three digits passed on by the exchange. The billing process is controlled by the exchange and not by the access network.

The main advantage of using R2 is that it is a reliable and stable interface supported by both the EWSD and E10 exchange types currently used by Telkom. Unlike the V5.2 interface, R2 requires no additional (and costly) software or hardware upgrades and is ready and available for use right now. R2 is possibly the only viable alternative in equipment cost reduction until V5.2 arrives.

3.2 Line Feed

When looking at the cost per port for a copper last mile access network, the highest contributor is usually the SLIC circuits and the line cards themselves. The cost of the central office equipment and controlling hardware of an access network (when 2Mbit/s access to the exchange is used) is distributed across the entire access network. The cost component is relatively low in relation to the costs associated with that of hardware closer to the customer connection.

When designing a line card, the more ports per card automatically reduces the cost per port of a system, since the cost of the controlling and routing hardware on the card is distributed amongst more ports. A sixteen port line card is therefore more economical than an eight port card.

Another area where costs can be reduced on the line card is in the power consumption. Where access networks are deployed in mains supplied areas, power consumption is not usually of great concern, however, at solar installations, power consumption plays a critical role in the costing of a access network. The more power a system consumes, the larger the solar array and battery bank become. The usual approach is to reduce the number of line cards at the solar site to balance the cost and size of the solar site.

For the DCR-300 development it was decided to keep the number on ports at the solar site the same (128 ports) as that for a mains fed site. There are two ways of achieving this; firstly to increase the number of solar panels and batteries used or secondly to reduce the power consumption of the line cards and system. Adding more solar panels is not a practical solution due to the cost involved. By reducing the power consumption of the SLIC circuits on the DCR-300 line cards to 10mW during standby and current limiting the loop current to 30mA @ 36V during calls, it has been proven to be possible to run 128 ports per solar site on four 55W solar panels and two 6V 200AH batteries for 5 days without sunlight. The cost per port is significantly reduced by simply reducing the power requirements of the system.

Further cost reductions can be achieved by supplying meter pulse injection at every SLIC on each line card, without the need for different line cards for public offices or SPM (Subscriber Private Metering) customers. On DCR-300, all ports can provide meter pulse injection and is software configurable. This reduces the need for additional hardware and additional support.

3.3 Power Management

DCR-300 makes use of an intelligent power supply unit that supplies the line feed to the customers (software adjustable to -36V, -42V or -50V), card voltage (+12), ring current generation (35Vrms) and meterpulse injection (16kHz at 1Vrms). Switching off the ring current generator and meterpulse generator when not in use reduces the power consumption important for solar installations.

During normal operation, the test card is completely powered down until required for line or SLIC testing.

3.4 Mechanical Construction

Many access networks, especially radio systems, use masts to which enclosures are attached to house their electronic hardware. Normally, a hole of 1,5mx1,5mx1,5m is manually dug for the mast installation. This is very costly in terms of labour, materials and time. In an effort to reduce the installation costs of these masts, TDL investigated using a 300mm manual auger (1.5m long) to drill the hole for the masts. In terms of labour, time and materials, a significant cost reduction can be achieved when installing masts this way.

For the DCR-300 network, a street cabinet was developed to house the electronics and batteries at mains sites. The cabinets are constructed with 7mm steel doors and safe type locks. The installation and cost of the cabinet is significantly lower than that of a mast installation. Ergonomically, the use of a street cabinet is far more pleasing to the eye when compared to a mast installation and offers a high level of security due to its construction. Figure 2 shows a view of the street cabinet that was used for the KwamHlanga pilot. A street cabinet is easier to access for maintenance than a mast installation and requires no ladders or safety harnesses.

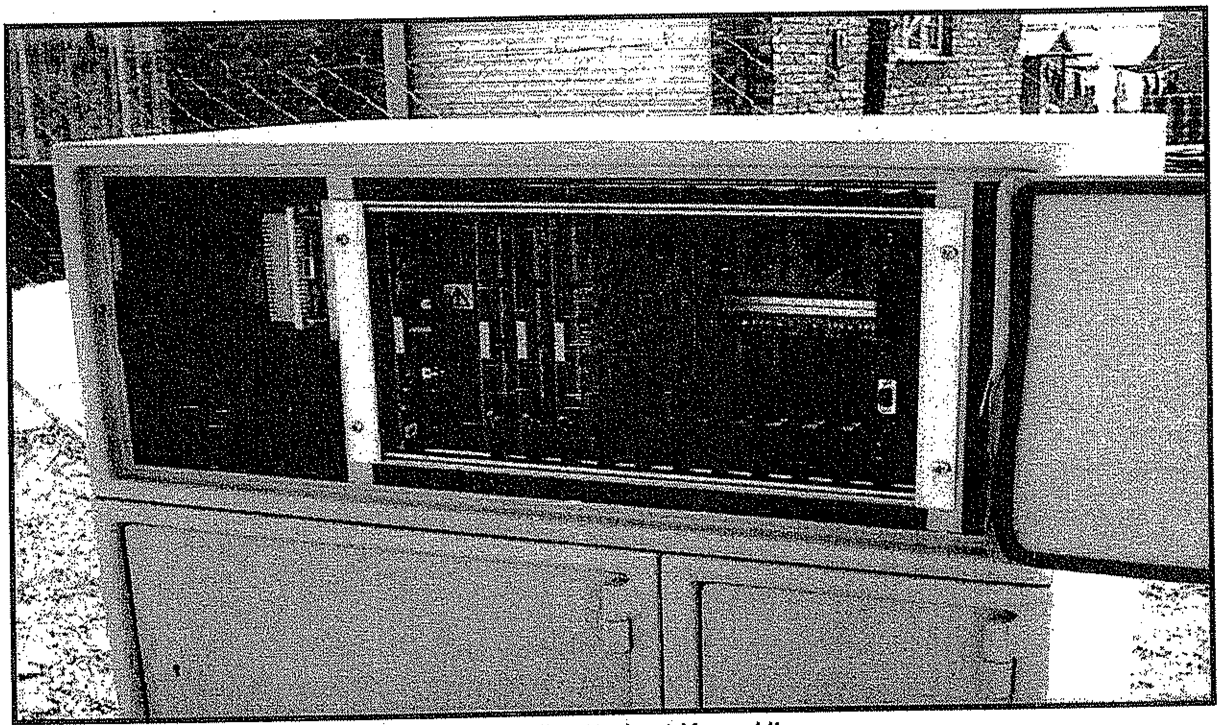

Figure 2 The street cabinet used for the pilot study at KwamHlanga

3.5 The Copper Network

For an access network using copper feeds to the home, the largest cost portion for the copper network installation, is the labour. Not only is the installation of a copper network labour intensive, but also very time consuming and is usually related to the planting of the poles or the digging of trenches. By entering an agreement with Escom and local municipalities, a large cost and time saving is achieved by sharing infrastructure. For the DCR-300 pilot project, a cost saving of more than 50% on the cooper network was achieved by sharing municipal poles with Escom. The network installation took less than two weeks to complete for 300 customers. This speed of deployment is comparable to that of radio access networks.

When using copper feeds from the CT (Concentrator Terminal) to the customer, the copper bundles used never exceed 50 pairs with an average length of about 100 metres before the first reduction in cable size. This reduces the risk of copper theft.

3.6 Maintenance

When looking at the cost of an access network, it is very important to look at the life expectancy and maintenance costs of a system. When a line card is found to be faulty, it is usually sent to a repair centre where a standard inspection fee is paid above the cost of any repairs that may be required. Due to the fact that faulty cards need to be sent to repair centres, Telkom is forced to keep spare cards in stock. The combination of the repair costs and the capital invested in replacement cards, results in a high maintenance costs.

For the DCR-300 development, it was decided to design the line card in a modular fashion, with the 16 SLIC modules individually mounted in sockets for easy replacement. The cost of the SLIC modules has been kept to a minimum, and in the case of a card failure, the fault is localised by the test card and the damaged SLIC can be extracted and replaced by a first line faults man in the field. The damaged SLIC can be discarded since the cost of the SLIC is far lower than the service fee and repair costs at repair centres. A significant cost saving can be achieved by using field replaceable modules, limiting the repair of boards. Only inexpensive modules need to be kept in stock for the field replacements. Figure 3 shows a DCR-300 line card with a removed SLIC module that is field replaceable.

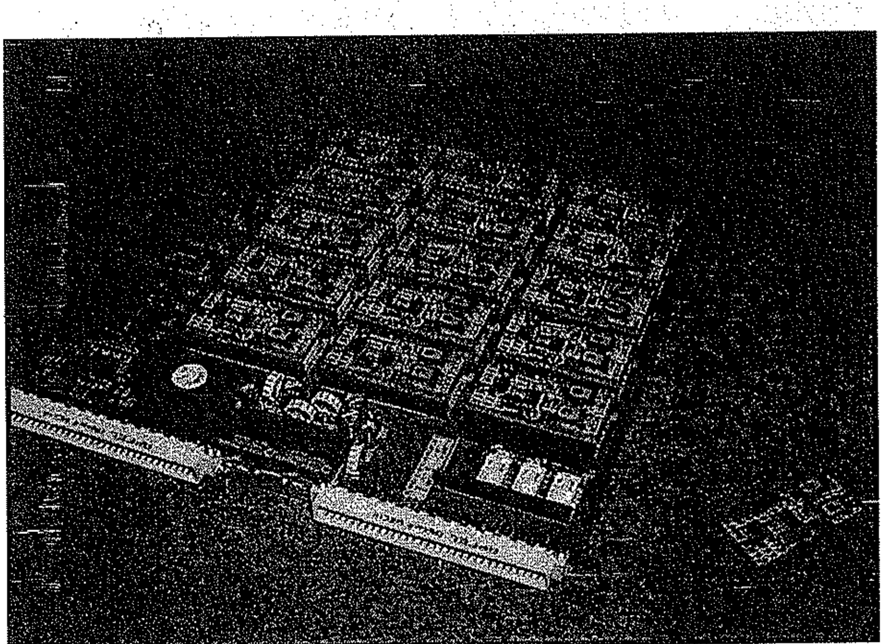

Figure 3 View of a DCR-300 line card with a SLIC module removed.

The test card in the system is used for the comprehensive testing of the line, customer terminal and the SLIC. Tests can be performed routinely by the system or on request from an operator at the control terminal or via TMN. The test card localises faults and enables repair personnel to quickly restore service in the minimum amount of down time.

If all access network software is up gradable from a central location, a large cost saving can be achieved when a software upgrade is required in term of time and labour. All software modules in DCR-300 are up gradable from a central location and has proven invaluable in the development and support of the system.

3.7 Transmission

There are many different types of access networks available today and each network utilises one form of transmission or other. DCR-300 was specifically designed to be able to use any transmission medium suitable for the topography of the installation area, while, at the same time allowing for a mix-and-match approach. Since all the transmission links between the exchange and on the local loop are G.703 compatible, any radio, fibre, optical or even copper based technology (such as HDSL and ADSL) can be used. This means that the best and most cost effective medium may be used to suit the area and conditions of the installation. Even copper dropwire can be used to transport the 2Mbit/s data for distances up to 500m which is very cost effective.

For the DCR-300 project, a low cost DSSS (Direct Sequence Spread Spectrum) point-to-point link (2,4GHz band) was developed. Spread spectrum techniques use low power densities to provide very robust communications.

3.8 Channel coding

Radio based access networks such as DECT systems mostly employ 32Kbit/s timeslots to the customer due to limited radio bandwidths. Unfortunately this is not very efficient when high speed data modems or fax equipment are used by the customer, since the transmission of such devices is limited to a baud rate of no more than 9600 bps on a 32Kbit/s channel. With the explosion of Internet access, desired connection rates of 28800 bps or higher are impossible with 32Kbit/s channel coding. For radio based networks (DECT etc) the only way to achieve these higher bit rates is to combine two radio channels to give a single 64Kbit/s channel capable of transporting data from an analogue modem at 28800 bps or higher. This will place additional loading on radio channels resulting in smaller cell sizes with lower customer concentrations and will drive the cost of radio based systems up.

Unlike DECT systems, DCR-300 uses full 64Kbit/s channel encoding-decoding on the analogue line to the customer, thus allowing high speed modem connections at no additional cost. Another factor influencing the decision to use 64Kbit/s channel coding is due to the fact that exchanges currently used by Telkom only support 64Kbit/s channel switching and to use 32Kbit/s coding would unnecessarily waste exchange bandwidth.

4 The DCR-300 pilot Project

A pilot project of the DCR-300 network was installed at KwamHlanga to prove that the concepts presented are feasible and that a cost reduction through careful design is possible.

The pilot loop serves 300 customers from 3 CTs, with the CPC card located in the KwamHlanga DLU. The link between the CTs and the DLU is via the DSSS radio link. CT interconnection (G.703 PCM) is made using drop wire. The DLU parent exchange is in Witbank and is linked via a 34Mbit/s optical fibre. The overhead copper network was installed making use of the power distribution poles.

A mixture of CT types are used, one solar site (mast), one mains site (mast) and a street cabinet running on mains power. In each case there are 128 ports per CT.

System administration is performed by a PC in the DLU, with a remote link to the Laboratories.

5 Results

By using cost reduction techniques during the design of the access network, it has been proven that it is possible to lower the cost of the access network without sacrificing functionality. During the construction and production of the DCR-300 pilot, an accurate account of all expenses was maintained to present a realistic cost-per-port figure very close to the design target of R1000 per port. All production for the pilot study was completed by external production houses and external contractors were used for the copper network installation.