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Datapath Message Protocol Implementation Notes

Document #DAN001-02 Preliminary,
May 1987.

Datapath Technology
Licensing
Program

Datapath
Application
Notes

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Glossary

ACK----------- Acknowledge (sometimes referred to as PACK, Positive Acknowledge).
bps------------- Bits per second.
BNR----------- Bell-Northern Research, subsidiary of Northern Telecom.
CC ------------- Central control (of a switch).
C.O. ----------- Central Office (Class 5 telephone office or exchange).
command------ An instruction from the TE to the DLC, or vice versa, encoded in 8 bits. Commands are packaged in a 16-bit envelope called a message (q.v.).
CPE ----------- Customer Premises Equipment. Common term for the DTE (q.v.) and/or the TE (q.v.).
CTS------------ Clear To Send.
Datapath------- Northern Telecom circuit switched digital data system.
DCE ----------- Data Circuit-terminating Equipment (also known as the TE).
DLC ----------- Data Line Card.
DMS-100 ----- Northern Telecom Digital Multiplex Switch, used as a central office.
DTE------------ Data Terminal Equipment. Normally a dumb terminal, personal computer, host computer, facsimile machine, etc. Functionally different from the TE (q.v.), although may be physically integrated with the TE in some cases.
DTR ----------- Data Terminal Ready.
FDHP --------- Full Duplex Handshaking Protocol.
kbps ----------- Kilobits per second.
message ------- An envelope of 16 bits, containing a 4-bit address, 4-bit information, and an 8-bit command (q.v.).
ms-------------- Milliseconds.
NACK--------- Negative Acknowledge (also known as NAK).
NT ------------- Northern Telecom.
PACK --------- Positive Acknowledge.
RACK--------- Request Acknowledge.
TE------------- Terminating Equipment, sometimes known as the DCE (q.v.). The TE is that part of the CPE (q.v.) which interfaces to the telephone loop. Note that some vendors may physically integrate the TE with the DTE (q.v.).

1. DLC FDHP Receive/Transmit

1.1 Introduction

The **Full Duplex Handshaking Protocol** (FDHP) commands, messages, etc. are described in the Datapath Service Interface Specification (Reference 1). The following are some notes on implementation details.

1.2 Notes on DLC FDHP Receive

a) The TE should never send the unused code 11 in the transmit state, because the DLC would return NACKs until an *Idle* (00)[1] is received.

b) Once the DLC is in the NACK receive state, only the TE transmit *Idle* (00) will get the DLC back to CTS state. Therefore, a message from the TE can only be retransmitted by first going back to *Idle*.

1.3 Notes on DLC FDHP Transmit

TE PACK/NACK messages to the DLC are only with respect to the FDHP, ie:

a) PACK should always be sent if the format (checksum) is received correctly, even if the TE does not support the command in the message.

b) NACK must be sent from the TE only if there is an error in the format (checksum) or the TE is not ready to receive.

To reiterate, if the DLC sends a message which the TE does not support, but was received with the correct format, then the TE must PACK this message when the RACK is received.

1.4 TE to Switch Messages

a) The DLC sends NACKs if it is not ready to receive messages. This can occur if the DLC buffer to the Central Control (CC) is full.

b) The TE must send messages to the DLC at a rate no faster than one new message every 130 milliseconds.

1.5 Switch to TE Messages

a) The maximum Switch to TE message rate is one new message every 27 milliseconds. If the DLC does not receive a PACK, the DLC will keep trying to send the message for 128 milliseconds. After this time, the message is discarded. **Warning: failure to PACK the message withing 128 milliseconds may result in errors.**

b) Messages to the TE, received during a bulk data download, will be interleaved with messages comprising the download sequence. Priority is given to the outgoing messages to the TE.

[1]All message codes are given in hexadecimal notation.

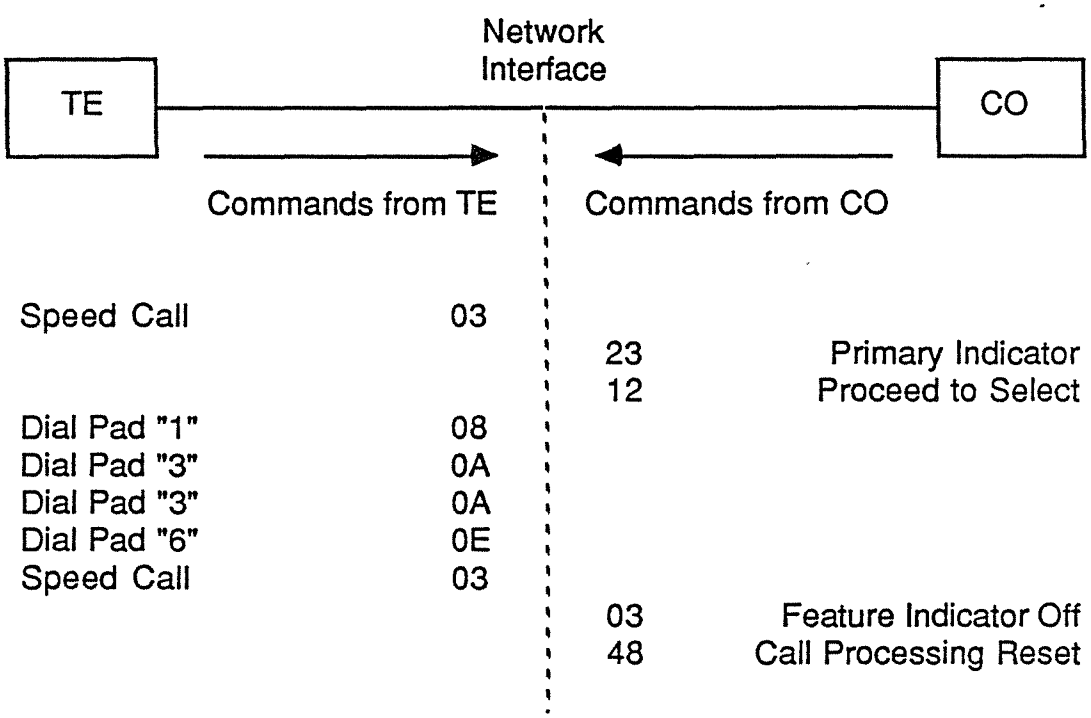
1.6 Feature Activation through FDHP

The following are examples of the high-level command procedure for CO features such as Ring Again, Auto Dial, Speed Call, and Resource. The commands are in hex and represent the FDHP commands which would be sent within the FDHP format. These are typical examples. Note that FDHP messages/commands received by the TE which are not supported must be PACKed if the message format was correctly received.

1.6.1 Speed Call Programming Sequence

Situation: Speed Call 1, DN = 336

Assumptions:
1) TE is idle.
2) DTR on.
3) Indicator 1 is off.



Note: The CO can interleave additional messages which the TE vendor may wish to ignore but must PACK if correct FDHP format has been received. Commands from the TE must be separated by at least 130 ms.

1.6.2 Using Speed Call

Situation: Speed Call 1

Assumptions:
1) TE is idle.
2) DTR on.
3) Square brackets, [], indicates mu-law encoded voiceband signal on the 64kbps TE receive channel.

Network Interface

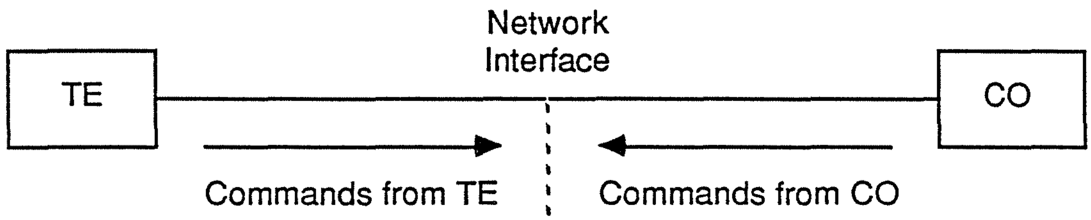
TE			CO
Commands from TE			Commands from CO
DN Command	00		
			[Dial Tone]
		60	Feature Indicator ON
		12	Proceed to Select
		6C	Progress Tone Alert ON
Speed Call	03		
		63	Feature Indicator ON
Dial Pad "1"	08		
			[Dial Tone OFF]
		03	Feature Indicator OFF
		70	Data Alert ON
Inband Sync - Found	25		

Note: The CO could send Connection in Progress (32), and/or Far End Answered (7E) following the Data Alert On (70) message.

1.6.3 Auto Dial Programming Sequence

Situation: Auto Dial

Assumptions:
1) TE is idle.
2) DTR is on.
3) Indicator 1 is off.



Commands from TE		Commands from CO	
Auto Dial	02		
		22	Primary Indicator
		12	Proceed to Select
Dial Pad "5"	0D		
Dial Pad "5"	0D		
Dial Pad "5"	0D		
Dial Pad "1"	08		
Dial Pad "2"	0A		
Dial Pad "3"	0C		
Dial Pad "4"	09		
Auto Dial	02		
		02	Feature Indicator OFF
		48	Call Processing Reset

Note: The CO can interleave additional messages which the TE vendor may wish to ignore but must PACK if correct FDHP format has been received.

1.6.4 Using Auto Dial

Situation: Auto Dial

Assumptions:
1) TE is idle.
2) DTR on.
3) Indicator 1 is off.
4) Square brackets, [], indicates mu-law encoded voiceband signal on the 64kbps TE receive channel.

TE — Network Interface — CO

Commands from TE			Commands from CO
DN Command	00		
			[Dial Tone]
		60	Feature Indicator ON
		12	Proceed to Select
		6C	Progress Tone Alert ON
Auto Dial	02		
			[Ringing]
			[Ringing Stops]
		70	Data Alert ON
		32	Connection in Progress
		7E	Far End Answered
Inband Sync - Found	25		

Note: The CO may or may not send the 32, 7E messages.

1.6.5 Ring Again Activation Sequence

Situation: Ring Again

Assumptions:
1) TE is receiving a Busy Indication (52) from the CO..
2) DTR is on.
3) Square brackets, [], indicates mu-law encoded voiceband signal on the 64kbps TE receive channel.

Network Interface

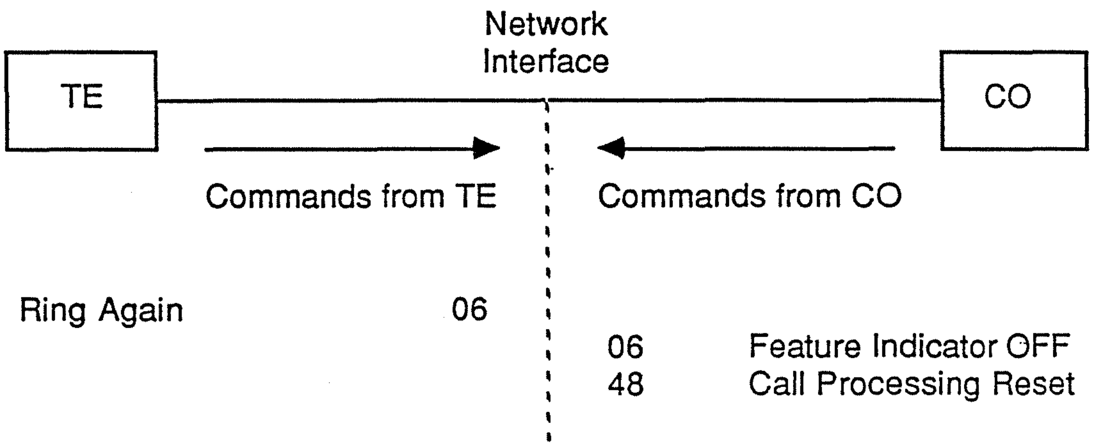
TE — CO

Commands from TE		Commands from CO	
Ring Again	06		
		66	Feature Indicator ON
		48	Call Processing Reset
		00	Feature Indicator "1" OFF
		48	Call Processing Reset
When called party becomes idle.			
		6E	Feature Alert ON
		26	Primary Indicator
		0E	Feature Alert OFF
DN	00		
		60	Feature Indicator ON
		12	Proceed to Select
		6C	Progress Tone Alert ON
			[Dial Tone]
RAG	06		
			[Ringing]
		06	
		0E	
			[Ringing OFF]
		70	Data Alert ON
		32	Connection in Progress
		7E	Far End Answered
Inband Sync - Found	25		

1.6.6 Ring Again Deactivation Sequence

Situation: Ring Again

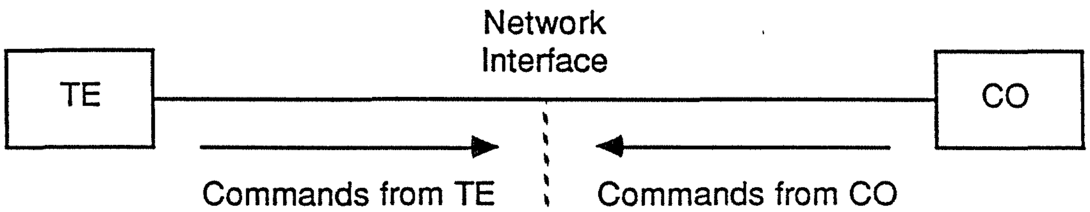
Assumptions: 1) TE is idle with Ring Again indicator on.
2) DTR is on.



1.6.7 Resource Command Sequence

Situation: Resource

Assumptions:
1) TE has dialed an analogue facility.
2) Analogue facility is 1200bps modem.
3) DTR is on.
4) Square brackets, [], indicates mu-law encoded voiceband signal on the 64kbps TE receive channel.



Commands from TE		Commands from CO	
		41	Secondary Indicator [Ringing]
		70	Data Alert ON
		32	Proceed to Select
		7E	Far End Answered [Modem Answer Tone]
Resource	01		
		61	Feature Indicator ON [Modem Tones OFF]
Inband Sync - Found	25		

2. References

1. Datapath Service Interface Specification, Northern Telecom, NIS S204-2, October, 1986.

2. Datapath Building Blocks - Overview, Northern Telecom, Document #TL87-0003-01, Preliminary, March, 1987.

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Datapath Building Blocks Overview

Document # TL87-0003-02,
Preliminary,
May 1987.

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ACK---------- Acknowledge (sometimes referred to as PACK, Positive Acknowledge).
AMI----------- Alternate Mark Inversion.
baud ---------- transmission rate for asynchronous bytes (not data rate).
BNR---------- Bell-Northern Research, subsidiary of Northern Telecom.
byte----------- A group of 8 bits.
CCITT-------- Comite Consultatif International de Telephonie et de Telegraphie.
CH0 ---------- Channel 0 (data).
C.O. ---------- Central Office (Class 5 telephone office or exchange).
command------ An instruction from the TE to the DLC, or vice versa, encoded in 8 bits. Commands are packaged in a 16-bit envelope called a message (q.v.).
CPE ---------- Customer Premises Equipment. Common term for the DTE (q.v.) and/or the TE (q.v.).
CPI ----------- Computer to PBX Interface.
CTS----------- Clear To Send.
Datapath------- Northern Telecom circuit switched digital data system.
DCE ---------- Data Circuit-terminating Equipment (also known as the TE).
DCP ---------- Datapath Call-control Protocol.
DDP ---------- Datapath Data-transmission Protocol.
DIT ----------- Datapath Interworking Tester.
DLC ---------- Data Line Card.
DMS-100 ----- Northern Telecom Digital Multiplex Switch, used as a central office.
DNI----------- Datapath Network Interface (=Datapath physical layer protocol).
doc------------ Document.
DTE----------- Data Terminal Equipment. Normally a dumb terminal, personal computer, host computer, facsimile machine, etc. Functionally different from the TE (q.v.), although may be physically integrated with the TE in some cases.
DTL----------- Datapath Technology Licensing (program).
DTR ---------- Data Terminal Ready.
DU------------ Data Unit.
EIA ----------- Electronics Industries Association.
EPROM------- Electrically Programmable Read Only Memory.
FDHP -------- Full Duplex Handshaking Protocol.
FDX---------- Full Duplex.
HDLC-------- High-level Data Link Control.
ISDN--------- Integrated Services Digital Network.
kbps ---------- Kilobits per second.
KHP---------- Kuhn Harting Protocol, now known as T-Link (q.v.).
LSI------------ Large Scale Integration.
message ------- An envelope of 16 bits, containing a 4-bit address, 4-bit information, and an 8-bit command (q.v.).
NACK--------- Negative Acknowledge (also known as NAK).
nibble--------- 4 bits, half a byte.
NT ------------ Northern Telecom.
octet---------- A group of 8 bits.
OEM---------- Original Equipment Manufacturer.
PACK -------- Positive Acknowledge.
PBX ---------- Private Branch Exchange telephone switch.
PSDS--------- Public Switched Digital Service (U.S. term).
QMV98C----- Northern Telecom's TCM LSI integrated circuit (also known as X14E).
Q.931--------- CCITT Recommendation on a Call-control protocol for ISDN.
RA ------------ Rate Adaption.

RACK--------- Request Acknowledge.
ROM---------- Read Only Memory.
RS-232C ------ EIA Recommended Standard for the DTE-DCE interface.
SL-100 -------- Northern Telecom's Stored Logic PBX (similar to DMS100).
TA ------------- Terminal Adaptor.
TBB ----------- T-Link Building Block.
TCM----------- Time Compression Multiplexing.
TE------------- Terminating Equipment, sometimes known as the DCE (q.v.). The TE is that part of the CPE (q.v.) which interfaces to the telephone loop. Note that some vendors may physically integrate the TE with the DTE (q.v.).
T-Link--------- Northern Telecom's rate adaption protocol (previously known as KHP).
T1-------------- Digital transmission carrier (1.544 megabits per second).
us -------------- micro-second.
U.S. ----------- United States (of America).
USART ------- Universal Synchronous Asynchronous Receiver Transmitter.
V.24 ----------- CCITT standard for the DTE-DCE interface (essentially same as RS-232C).
V.110---------- CCITT Recommendation for rate adaption.
X14E ---------- Northern Telecom's TCM LSI integrated circuit (part number QMV98C).
2Q87----------- second quarter 1987.

1. Objectives

This document is intended to give an overview description of the building blocks or packages which will be provided by Northern Telecom as part of the Datapath Technology Licensing program to designers of Terminating Equipment (TE).

A reference table listing the packages is given in Section 8.

2. Datapath Overview

Northern Telecom is a leading manufacturer of digital switches for use in central offices (C.O.) and PBX locations. These switches, which belong to the DMS-100 and SL-100 family of products, convert analog voice or voice-band signals into a 64 kbps digital stream and then switch and transmit the information digitally through the network. This results in very high quality communications, even when the end-to-end distances are very large. However, since analog technology is employed between the customer's premises and the switch, voice-band data transmission is limited to data rates up to a maximum of 19.2 kbps. Even at speeds well below 19.2 kbps, the analog terminating equipment (TE), called a modem, is expensive and its error performance is marginal.

There is a growing demand for high-speed and accurate transmission of data for a variety of applications, e.g. computer communications, facsimile and image transmission, and video conferencing. In anticipation of this demand, Northern Telecom has developed a special digital data transmission technology called Datapath to allow the user to transmit data at 64 kbps from his office or home over the regular 2-wire telephone loop plant. This technology has been developed and tested since 1980, and Datapath-based services are now being tariffed and introduced by corporations and common carriers in the U.S. and Canada. In particular, the Bell Operating Companies (BOCs) in the U.S. are now tariffing a special digital communications service called Public Switched Digital Service (PSDS), while common carriers all round the world are doing field trials with an allied concept called the Integrated Services Digital Network (ISDN).

The removal of regulatory barriers in the supply of the DTE and TE devices has expanded the market available to the terminals manufacturing industry. Northern Telecom has therefore prepared its Datapath Technology Licensing (DTL) program to make Datapath technology available to manufacturers of Terminating Equipment (TE). This technology will be made available to licensees in the form of building blocks, or packages, of documents and components in order to reduce their development cycle and product costs. The licensees may use the technology to build either standalone TE devices or to combine them with DTE equipment.

This document describes the Datapath system, the Datapath protocols, the functional areas of the Datapath system's Terminating Equipment (TE), and the corresponding building blocks or packages offered by Northern Telecom.

The Datapath system, Datapath protocols, and Datapath overview packages are reviewed in Sections 2.1, 2.2 and 2.3 respectively.

2.1. Datapath System Overview

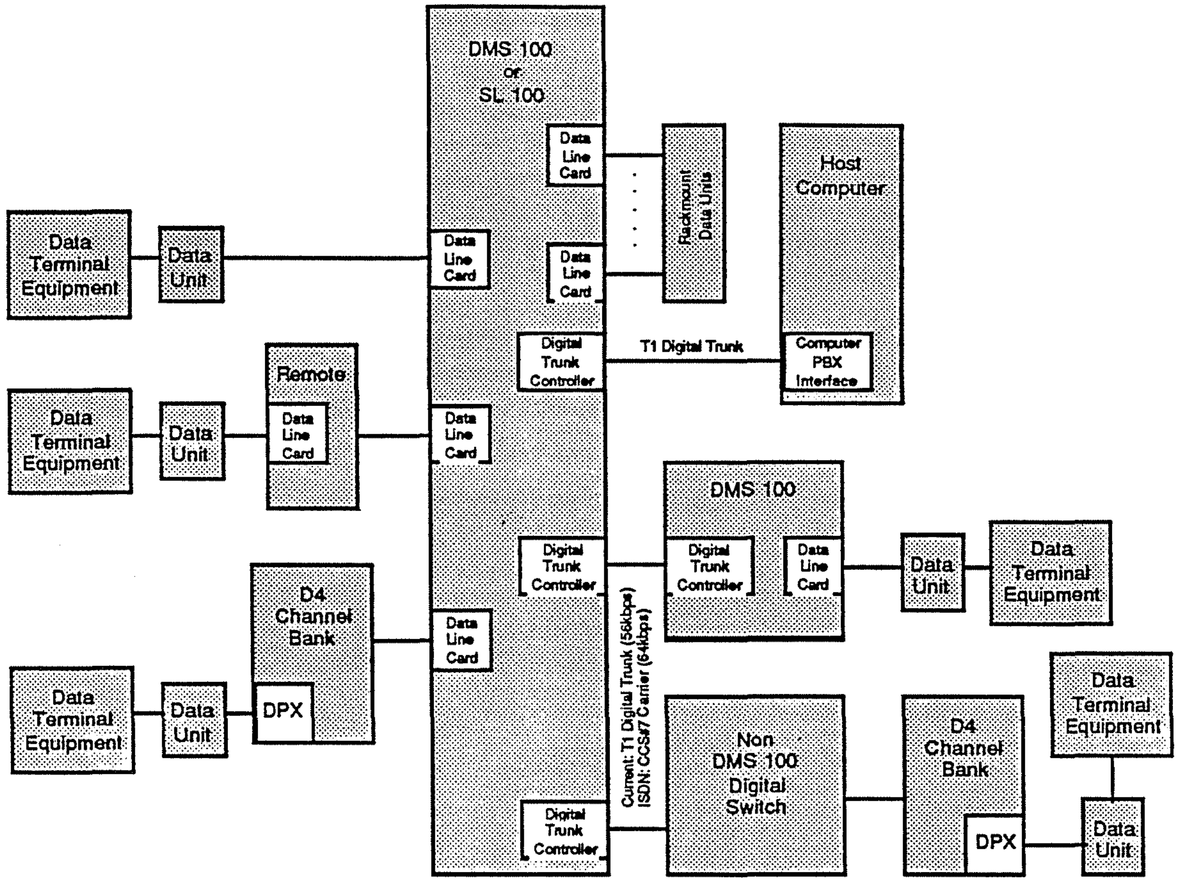

Figure 2-1. Datapath System

As shown in Figure 2-1, the Datapath system consists of several devices. At the customer's premises is the Data Terminal Equipment (DTE) and a special digital Terminating Equipment (TE), called a Data Unit (DU). The DU connects to the Data Line Card (DLC) at the central office or the PBX digital switch (DMS-100 or SL-100 respectively) via a 2-wire telephone loop. The digital switch is also equipped with special Datapath call-control software and special facilities for operations, administration and maintenance. The digital switches are interconnected via special digital trunks to provide an extended network. The digital trunks in common use to-day are based on T1 technology which limits the useful data rate to 56 kbps; T1 trunks will be eventually replaced by digital trunks with 64 kbps clear channel capability.

The DTE could be a dumb terminal, a personal computer, a host computer, a facsimile machine or an image or video communications terminal. Although the Terminating Equipment (TE) is shown separate from the DTE in Fig. 2.1, it is entirely possible that many licensees will wish to integrate the DTE and the TE into one unit in order to reduce costs and space. For the purposes of this document, the term TE will refer to that part of the customer premises equipment which connects to the 2-wire loop, regardless of whether or not the TE is physically integrated with the DTE.

The Datapath system thus provides a digital, 64kbps, octet-structured transmission capability between the Terminating Equipment (TE) at the customers premise and the network. Most existing data terminal equipment (DTE) cannot yet operate directly at this high speed, and its low-speed data must therefore be rate adapted up to the 64kbps data rate of the network . Rate Adaption (RA) is the term used to describe the technique used to adapt sub-64kbps terminals to the digital byte-structured synchronous 64kbps network.

Datapath's Rate Adaption protocol is known as T-Link. It can rate adapt DTE devices with asynchronous rates from 300 bps to 19.2 kbps or with synchronous rates from 1200 bps to 64 kbps. It operates on a TE to TE basis and has been designed such that it passes transparently through the transmission networks and facilities in use today. In particular, it allows for 2 major restrictions of the present T1 digital trunks, namely:

- bit-stealing of the 8th bit in each octet (to allow for inter-switch signalling), and,
- meeting 1s density requirements (to maintain line synchronization on T1 trunks).

These T1 restrictions limit the DTE data rate to a maximum of 56 kbps. However, when 64 kbps clear channel capability becomes available (as in common-channel signalling trunks which will be deployed for ISDN), the T-Link protocol will pass data at up to 64kbps without any modification of the TE.

The Bell Operating Companies (BOCs) are now filing tariffs for a Public Switched Digital Service (PSDS). There will be two versions of PSDS, one using NT's Datapath system and the other, AT&T's Circuit-Switched Digital Capability (CSDC). CSDC operates at a data rate of only 56 kbps; moreover, it provides no rate adaption capability to deal with the existing base of sub-56 kbps terminals. Datapath has been designed to interwork with CSDC at 56 kbps, and also to interconnect with the existing base of DTEs.

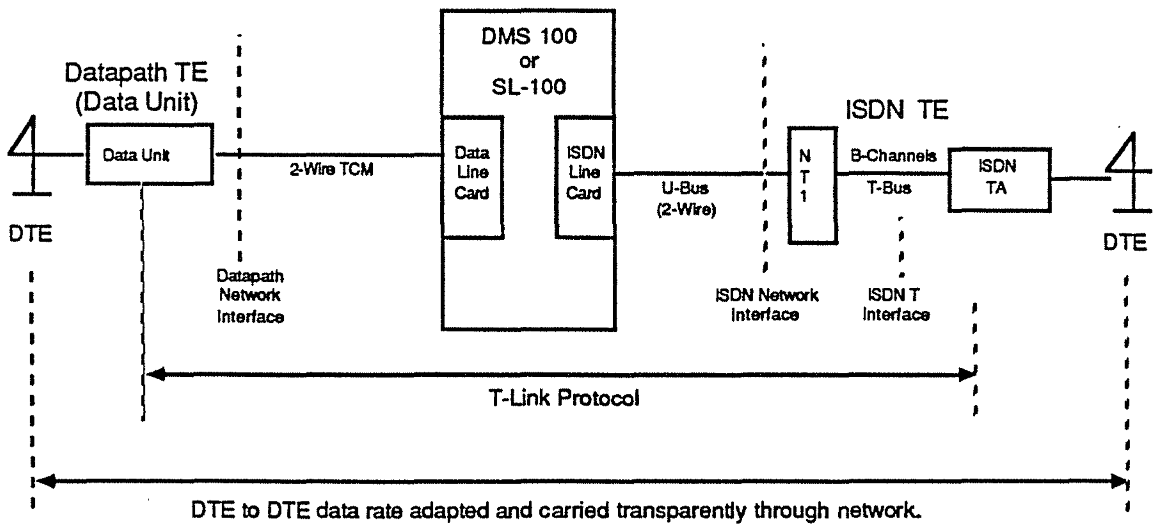

Figure 2-2. Datapath/ISDN Interworking

The Integrated Services Digital Network (ISDN) will eventually provide access to all digital communications services. In order to allow non-ISDN DTE devices to connect to the ISDN network, a special functional device called the Terminal Adaptor (TA) has been defined by the CCITT. For rate adaption, the CCITT has recommended the V.110 protocol; however, the protocol deals only with synchronous DTEs and leaves out the enormous, and growing, base of asynchronous DTEs.

The network interface for any system is unique to the type of switch that the TE is attached to. The network interface for the Datapath TE carries a full duplex 64kbps data channel and a full duplex 8kbps signalling channel. The ISDN TA connects to the Network Termination 1 (NT1) via a 4-wire T-bus interface; while the NT1 connects to the ISDN switch via a 2-wire U-bus interface. The ISDN U-interface carries 2 B-channels (each 64 kbps full-duplex) and a D-channel for call-control (16 kbps full duplex).

It should be noted that the network interfaces are of local significance, in that they determine how the TE interacts with its local switch. Once a call is set up between two TEs, interworking between them is possible if they share the same rate adaption protocol. As the PSDS service becomes more entrenched, interworking between it and ISDN will become possible if, as shown in Figure 2-2, the T-Link Rate Adaption protocol that is used today in the PSDS network is also used in the ISDN.

Datapath technology and the T-Link protocol thus allow the TE manufacturers to exploit the PSDS market to-day and to interwork with, and migrate to, the ISDN system when it becomes available in the future.

2.2.Overview of Datapath Protocols

This section provides an overview of Datapath protocols. Further details of the protocols are to be found in Sections 4, 5 and 6, and in the documents listed in Section 8.

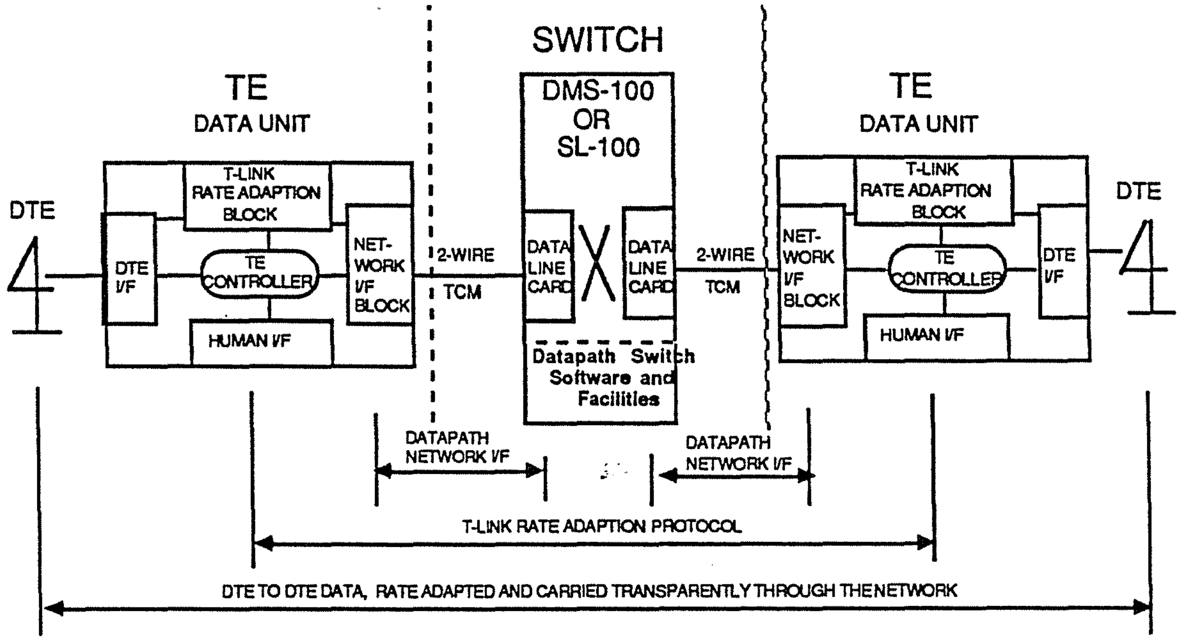

Figure 2-3. Overview of Datapath System

In order to design Terminating Equipment (TE) which will operate correctly in the Datapath system, the TE designer must obey the Datapath protocols. The DTL packages will help the TE designer implement these protocols with minimum development and product costs and with minimum restrictions on his freedom in other areas such as integration with the DTE, the man-machine interface, etc..

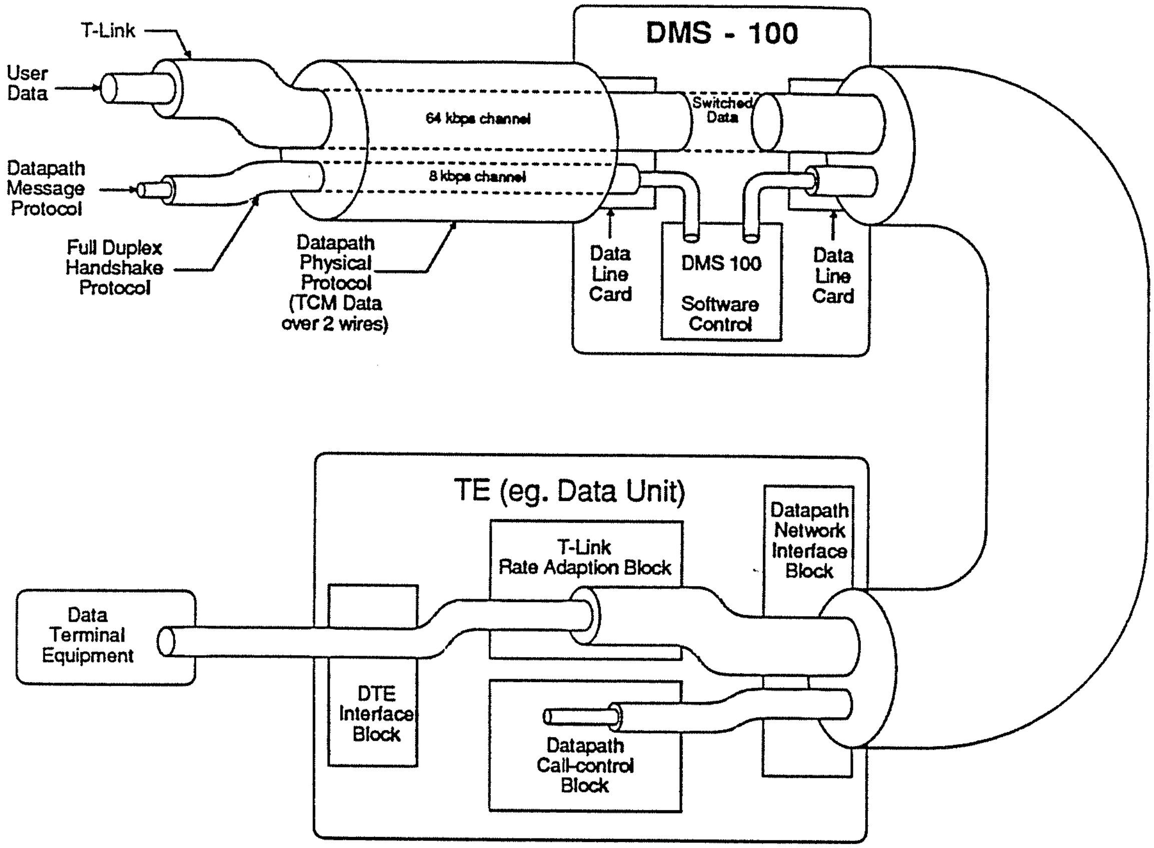

Figure 2-4. Representation of Datapath Protocols

Datapath may be viewed as a series of nested pipes that transport information through the network. The outer "pipe" is the **time compression multiplexing** (TCM) of the physical layer, which contains the other two "pipes". Call control (ie. TE / switch communication) is carried using the **full duplex handshaking protocol** (FDHP) over an 8 kbps signalling channel between the TE and the switch. The actual users' data is carried using **T-Link** over a 64 kbps data channel.

2.2.1. Datapath Physical Protocol

This protocol specifies the data format on the two-wire link between the TE and the switch. It is often briefly referred to as Time Compression Multiplexing (TCM), although it also involves several other Layer 1 functions such as scrambling the call control (and data) information, combining the information into frames, equalising the loop, and modulation and demodulation.

Section 4 of this document describes the Datapath physical protocol along with the corresponding building blocks or packages which will be supplied to licensees of the DTL program.

2.2.2. Datapath Call-control Protocols

These are the protocols that govern signalling between the TE and the switch. They are divided into two levels:

1) **Full Duplex Handshake Protocol (FDHP).**
This defines how the call-control bytes are encoded, decoded and transferred reliably between the TE and the DLC.

2) **Datapath Message Protocol (DMP).**
This is the highest level of the Datapath signalling protocols. It defines the messages that are passed between the TE and the switch to control such things as dialing, ringing, and special features.

Section 5 of this document describes the Datapath call-control protocols along with the corresponding building blocks or packages which will be supplied to licensees of the DTL program.

2.2.3. Datapath Data Transmission Protocol

This protocol is known as **T-link** (for transmission link), although in some older literature it is also known as the *Kun-Harting Protocol (KHP)*. The T-Link protocol performs two functions:

1) It adapts the data rate of sub-64 kbps DTE devices to the 64 kbps data channel and is therefore also known as the Datapath **rate adaption** protocol.

2) For asynchronous DTE rates up to 19.2 kbps and synchronous rates up 40.8 kbps, it transmits the status of the DTE-TE interface leads (also known as the EIA leads) to facilitate features such as modem pooling and maintenance.

Section 6 of this document describes the T-Link rate adaption protocol along with the corresponding building blocks or packages which will be supplied to the licensees of the DTL program.

2.2.4. User Data Protocols

These are the higher level data protocols which are determined by the DTE and the user application (e.g. ASCII, HDLC, facsimile or image compression code, etc.). They are carried transparently through the system by the Datapath physical layer and data transfer protocols, being neither part of nor restricted by Datapath.

2.3 Datapath Overview Packages

The DTL building blocks or packages, listed in Section 8, provide the TE designer with information and components to implement all of the above protocols.

As far as an overview of Datapath is concerned, the following packages are available:

1) **BNR Miscellany 1.**

This is a collection of articles by the BNR Datapath team on the Datapath system, products, protocols, markets and applications. It was published in the November 1986 issue of BNR Miscellany.

2 **Datapath Service Interface Specification.**

This is a Northern Telecom document, reference number NIS S204-2, issue 2, October 1986. It was sent to BellCore in November 1986 for publication by BellCore as a regulatory document disclosing the Datapath Call-control Protocol Set and the T-Link protocol. It should be possible for a TE vendor to develop a Datapath TE using this document alone.

3 **Datapath Building Blocks Overview.**

This is the title of this document, reference #TL87-0003-02, which gives an overview description of the various Datapath building blocks and packages available to the licensees of the Datapath Technology Licensing program.

3. Datapath Building Blocks

The DTL building blocks or packages, listed in Section 8, provide the licensees of the DTL program with information and components to implement the Datapath protocols. This section provides an overview of the packages available.

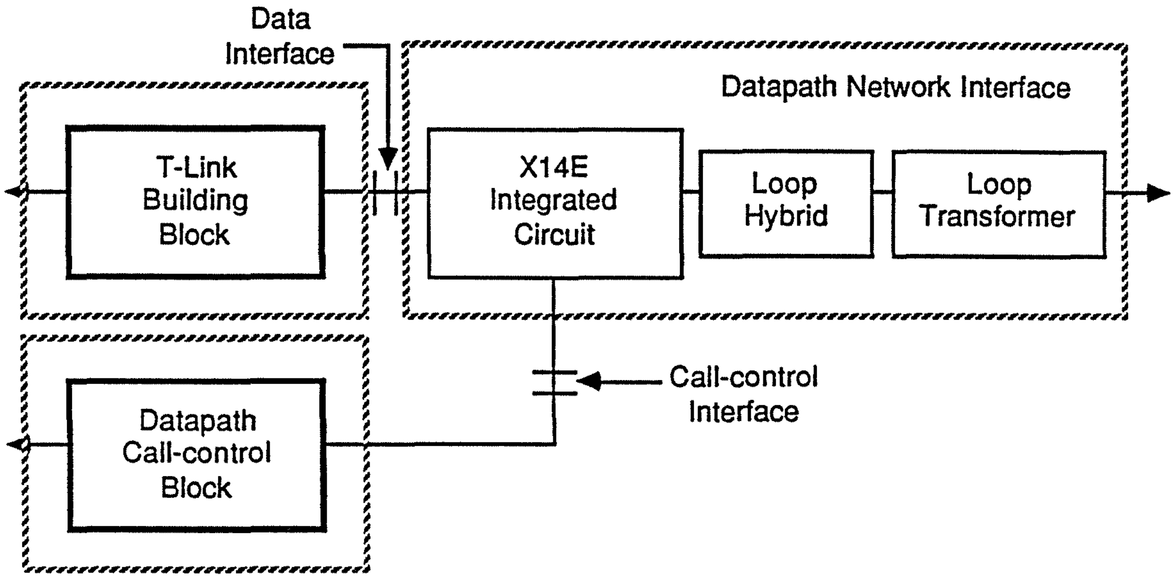

Figure 3-1. Overview of Datapath Building Blocks

The folowing building blocks are offered by **Northern Telecom:**

1) **Datapath Physical Interface Blocks** (Section 4)

   a) **Loop Transformer**

   b) **Loop Hybrid**

   c) **X14E**

2) **Datapath Call-control Block** (Section 5)

   This block is a tentative part of the program and is not critical for vendor implementation of Datapath.

3) **T-Link Building Block** (Section 6)

The following sections describe the various Datapath protocols and the building blocks offered by **Northern Telecom.**

4. Datapath Physical Protocols

This section will give a brief description of the Datapath Physical Protocols and the building blocks and packages available to assist DTL licensees in their implementation.

4.1. Brief Description

The Datapath Physical layer protocol consists of two parts, the physical/electrical specification and the Time Compression Multiplexing (TCM) Framing specification. This protocol can be compared with the Open Systems Interconnection (OSI) model as follows:

1) Datapath physical protocol — OSI layer 1

4.2. Physical/Electrical Specification

Compatibility with the physical/electrical specification is necessary to interface the TE to the 2-wire loop. It essentially performs the functions of line conditioning, modulation and demodulation. It creates a bipolar Alternate Mark Inversion (AMI) Return To Zero (RTZ) signal with an instantaneous data rate of 160 kbps as shown in Figure 4-1.

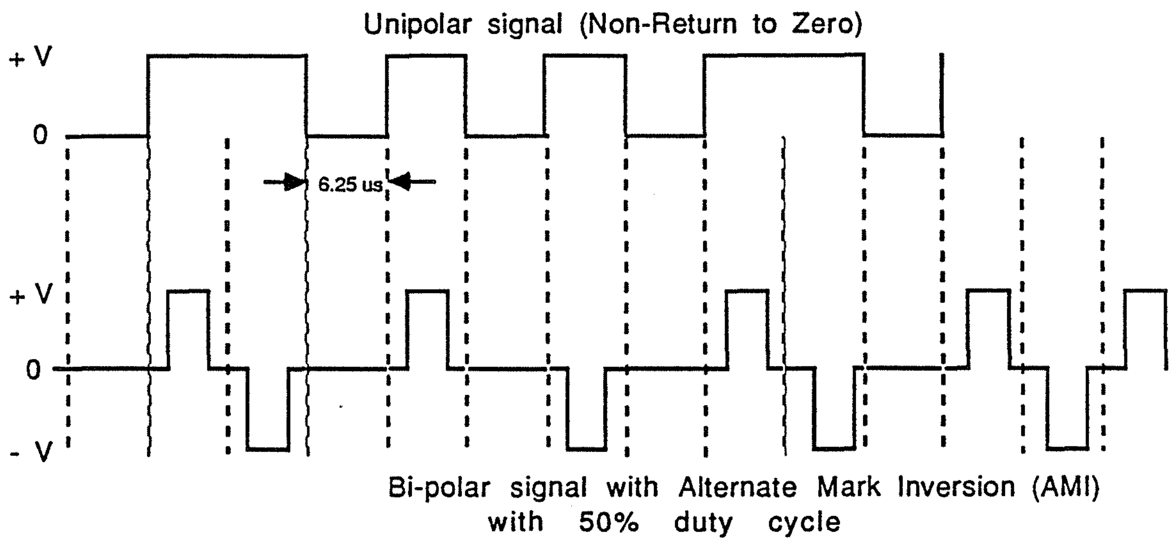

Figure 4-1: Line Signal

4.3. TCM Framing Specification

A Time Compression Multiplexing(TCM) protocol is used to provide full-duplex transfer of the data channel (64 kbps) and call-control channel (16 kbps) information. The DLC, which acts as the master, operates the TCM protocol on a frame rate of 1 ms. During each frame period, the DLC sends a sub-frame of 74 bits to the TE and receives another subframe of 74 bits in response from the TE, at an instantaneous data rate of 160 kbps. This gives rise to the term "ping-pong" that is often used to describe the TCM protocol.

Each 74-bit subframe consists of 1 start bit, 8 bits of the call-control channel information, 64 bits of data channel information, and 1 stop bit. A maximum one-way signal propagation delay of 0.0375 ms is theoretically possible if no guard time is allowed for processing delays at the TE or the DLC. However, allowing for a practical value of 0.00625 ms for the guard time, the maximum one-way signal propagation delay is 0.03125 ms. The total bidirectional full frame transfer (transmit subframe, receive subframe, 2-way propagation delays and guard time) takes 1 millisecond, and reoccurs continually. The timing for transfer and the data recovery is derived from the DLC.

The data channel carries the DTE data and, if possible, the status of the DTE/TE interface leads. Since each sub-frame is transmitted (and received) every 1 ms, the 64 data channel bits in each subframe are mapped into the full-duplex 64kbps data channel while the 8 call-control channel bits are mapped into the 8 kbps full-duplex signal channel.

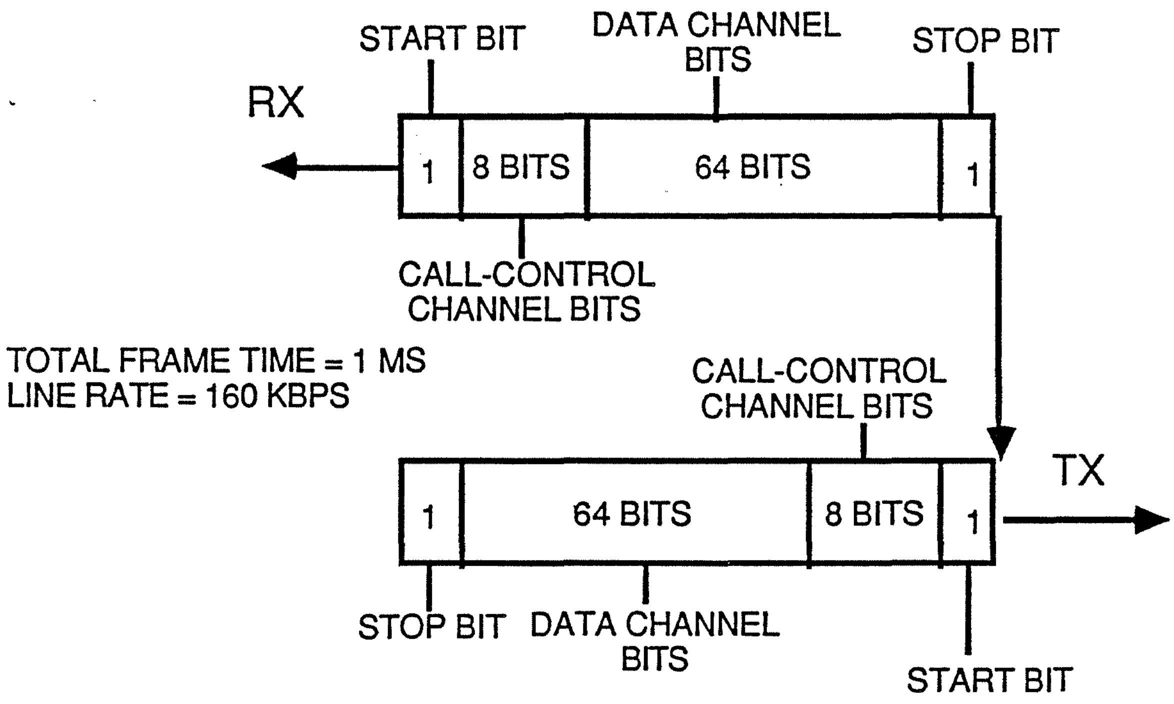

Figure 4-2. TCM Framing

4.4. Datapath Physical Protocol Packages

The DTL building blocks or packages, listed in Section 8, provide the licensees of the DTL program with information and components to implement the Datapath protocols. This section describes the packages available to implement the Datapath Physical Protocol.

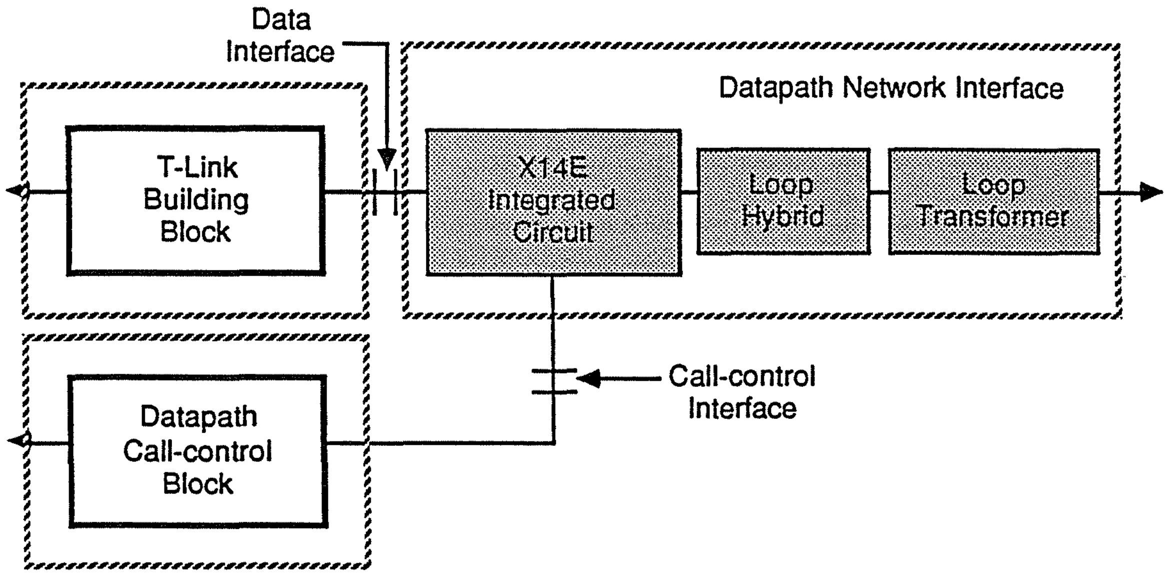

Figure 4-3. Datapath Network Interface Building Blocks

1) **Datapath Network Interface (DNI) Information Package**

The Datapath Network Interface (DNI) is defined here as the interface for the Datapath physical layer protocol. The DNI Information package therefore describes, in block diagram format, how to create the loop interface to the DMS100/SL100 switch, using the DNI components, which the licensee may purchase.

The DNI Information Package consists of DNI Specification and Developer Guide.

This document includes the specification sheets for the DNI components described below. In addition, a network schematic and description are provided showing how the DNI components are interconnected. Test procedures are outlined for each component.

The interconnected DNI blocks are then considered together as a black-box and the inputs and outputs of the black box are described in detail. Since the heart of the black-box is the X14E (TCM LSI integrated circuit), a detailed description is provided on how to control it. The Appendices of the DNI Developer Guide contain details of the following items:

a) **X14E LSI (Part #QMV98C).**

This NT custom integrated circuit provides the TCM framing protocol. In its transmit mode, it combines the 64 kbps full duplex data channel and the 8 kbps call-control channel into the single channel for transmission on the loop; the reverse function is performed in the receive mode. It therefore has 3 interfaces: the data channel interface to the rate-adapted DTE data, the call-control interface to the Datapath call-control block, and the loop hybrid interface to the Loop Hybrid circuit (see Figure 4-3).

The data channel interface is a serial 2.56 Mbps full-duplex burst channel. The X14E generates both the 125us interrupt signal (i.e. at 8 KHz rate) that indicates the start of data transfer and the bit clock used to recover the data.

The call-control interface to the Datapath call-control block is a standard microcontroller bus interface. An interrupt is generated every 1ms by the X14E to indicate that another FDHP byte is waiting to be read.

The loop hybrid interface passes the 74-bit sub-frames prepared by the X14E to the Loop Hybrid for modulation and demodulation. It also controls the analog line conditioning circuits in the Loop Hybrid as well as the Loop Transformer.

b) **Loop Hybrid (Part #QMS91B).**

The Loop Hybrid consists of the analog line- conditioning circuits that are controlled by the DNI logic. It also performs the modulation and demodulation functions (see Figure 4-3).

c) **Loop Transformer (Part #QTK260A6).**

This is a center-tapped transformer that is controlled by the DNI logic to match the impedance of the Loop hybrid to that of the loop (see Figure 4-3).

2) **Datapath Network Interface (DNI) Components Package**

The DNI components package includes the following components:

a) **X14E LSI Integrated Circuit (Part #QMV98C).**

b) **Loop Hybrid(Part #QMS91B).**

c) **Loop Transformer (Part #QTK260A6).**

These components may be purchased as required from Northern Telecom.

5. Datapath Call-control Protocols

As described in Section 2.2, there are two Datapath Call-control Protocols:

1) Full Duplex Handshake Protocol

2) Datapath Message Protocol

Together these protocols provide a method for the Datapath TE to interact with the switch to set up and take down a call, as well as activating special features such as "Ring again". These protocols can be generally compared to the Open Systems Interconnection (OSI) model as follows:

1) Full Duplex Handshake Protocol .... OSI layer 2

2) Datapath Message Protocol .... OSI layer 3

A detailed description of the Datapath call-control protocols is given in the **Datapath Service Interface Specification** (listed in Section 8). However, a brief description os provided in the following section for the sake of completeness.

5.1. Datapath Full Duplex Handshake Protocol

The 8 bits in the TCM subframes in Figure 4-2 are used in byte format as shown in Figure 5-1. The lower-order bits, D0 to D3, are used to carry either Datapath messages, a checksum or are unused. Bits D4 and D5 are used to indicate the state of the receiver. Bits D6 and D7 indicate the state of the transmitter. One of these bytes is exchanged every 1 ms, thus creating an 8 kbps full-duplex call-control channel.

	Transmit State		Receive State					
TRANSMIT STATES	TxS1 D7	TxS0 D6	RxS1 D5	RxS0 D4	D3	D2	D1	D0
IDLE (no data)	0	0	Rx	Rx	X	X	X	X
CH0 (data on Channel 0)	0	1	Rx	Rx	data nibble			
RACK (Request ACK)	1	0	Rx	Rx	checksum nibble			
RECEIVE STATES								
CTS (Clear To Send)	Tx	Tx	1	1	X	X	X	X
PACK (Positive ACK)	Tx	Tx	1	0	X	X	X	X
NACK (Negative ACK)	Tx	Tx	0	0	X	X	X	X

Figure 5-1. Call-control Channel Byte Structure

In order to ensure that all call-control information is received without error, a low level byte-transfer protocol, called the Full Duplex Handshake Protocol (FDHP) is used. Figure 5-2 shows the successful operation of the FDHP byte-transfer sequence for one direction only. As FDHP is a full-duplex protocol, this sequence could be simultaneously present in the other direction as well.

TRANSMITTER				RECEIVER		
Tx State	Rx State	Data		Tx State	Rx State	Data
			←	Tx	PACK/NACK	X
IDLE	Rx	X	→			
			←	Tx	CTS	X
CH0	Rx	nibble0	→			
			←	Tx	CTS	X
CH0	Rx	nibble1	→			
			←	Tx	CTS	X
CH0	Rx	nibble2	→			
			←	Tx	CTS	X
CH0	Rx	nibble3	→			
			←	Tx	CTS	X
RACK	Rx	checksum	→			
			←	Tx	PACK	X
RACK	Rx	checksum	→			
			←	Tx	PACK	X
IDLE	Rx	X	→			
			←	Tx	CTS	X

Figure 5-2. Successful FDHP byte-transfer sequence

As long as there is no Datapath message information to send, the transmit state passed every 1ms shows "idle". As long as the receiver at the other end is ready, it sends back the state "CTS". The transmitter passes message data by changing its state code to CH0 and placing a nibble of message data in the lower 4 bits. Each message is comprised of 16 bits and takes 4 bytes to pass. After passing the message bytes, the transmitter changes its state to the request acknowledge (RACK) code with a checksum in the data field, thus indicating that the receiver should acknowledge the message. The receiver checks the checksum and, if it is correct, sends back the positive acknowledge (PACK) code. The checksum is repeated for redundancy. If the checksum is incorrect, the receiver returns a negative acknowledge (NACK) and the whole FDHP byte-transfer sequence is repeated.

5.2. Datapath Message Protocol

The TCM and FDHP protocols serve as transmission vehicles for the Datapath Message Protocol, which is the highest level of the Datapath Call-control Protocol Set.

The nibbles passed with the FDHP are concatenated into commands, which are packaged into messages as shown in Figure 4.3. Each message consists of 16 bits, divided into 4 bits of address, 4 bits of information, and 8 bits specifying the command. The TE and the DLC exchange message sequences to carry out a useful interaction (e.g. to set up a call).

The information carried by the FDHP can thus be arranged into 3 ascending levels:

1) Datapath Commands , where each command corresponds to a unique byte.

2) Datapath Messages, where each 16-bit message carries a command.

3) Datapath Message Sequences, where each message sequence corresponds to a useful interaction between the TE and the DLC (e.g. TE goes off-hook).

A full description will be found in the Datapath Service Interface Specification listed in Section 8. These 3 levels of the Datapath Message Protocol will be described briefly below.

1) **Datapath Commands**

The nibbles passed by means of the FDHP are concatenated into commands, which are then packaged into messages as shown in Figure 5-3. Each command is specified by a unique byte. A Datapath command is an instruction from the TE to the DLC, or vice versa.

The Datapath Command set consists of over 40 DLC-to-TE commands and over 30 TE-to-DLC commands. A typical DLC-to-TE command is "proceed to select" while a typical TE-to-DLC command is "here is dial digit N". The command may be enlarged in the future to add new features of to support other devices.

2) Datapath Messages

A Datapath command is never sent on its own; it is packaged into a Datapath Message first. Each Datapath message consists of 16 bits, divided into 4 bits of address, 4 bits of "information", and 8 bits specifying the command, as shown in Figure 5-3. The 4 address bits allow the DMS-100/SL-100 switch to direct the command either to the DLC (address binary 1000) or to the TE (address binary 0000). The 4 "information" bits are usually set to 0000, unless the bulk data transfer option is used (for routine maintenance diagnostics).

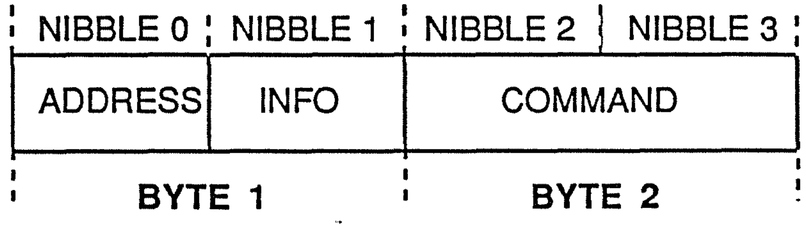

Figure 5-3. Structure of Datapath Message

3) **Datapath Message Sequences**

The messages passed by the FDHP are concatenated into message sequences to set up calls and invoke features and maintenance. Each message sequence thus corresponds to a useful interaction between the TE and the DLC.

A sample of a Datapath message sequence is shown in Figure 5-4 in which the TE sends the "DN key pressed" message to the switch, indicating that it has gone "off-hook". The switch responds with a message sequence of 4 messages which give "dial-tone" to the TE, telling it to proceed to dial the destination number.

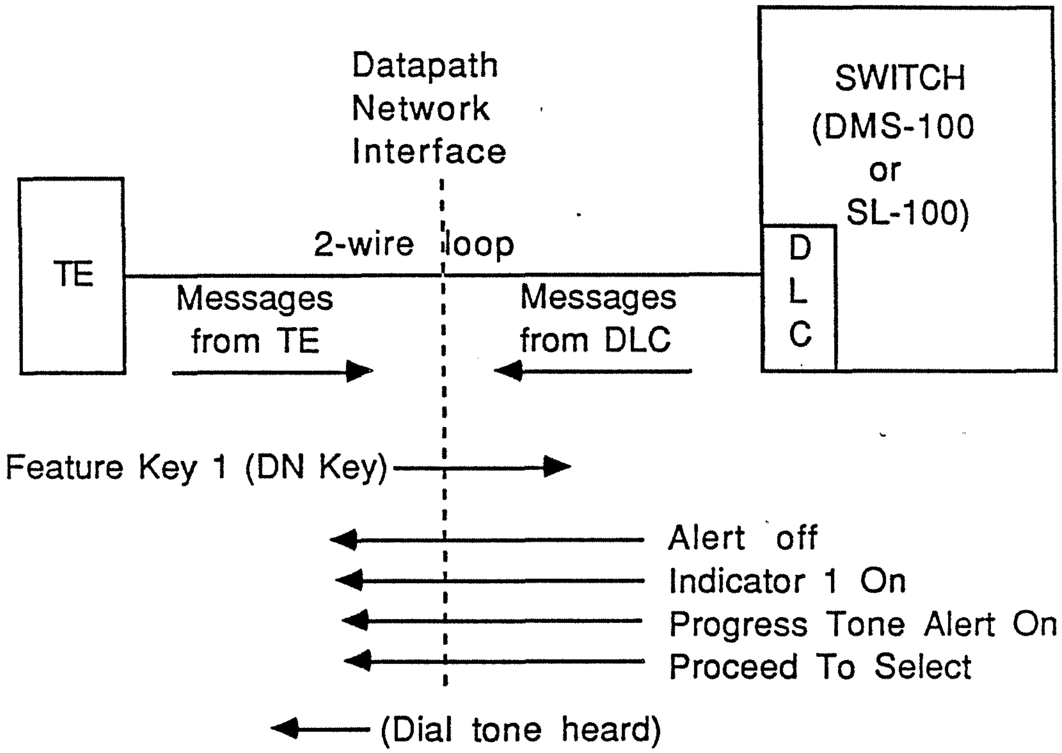

Figure 5-4. Typical Datapath Message Sequence

5.3. Datapath Call-control Packages

The DTL building blocks or packages, listed in Section 8, provide the licensees of the DTL program with information and components to implement the Datapath protocols. This section describes the packages available to implement the Datapath Call-control Protocols.

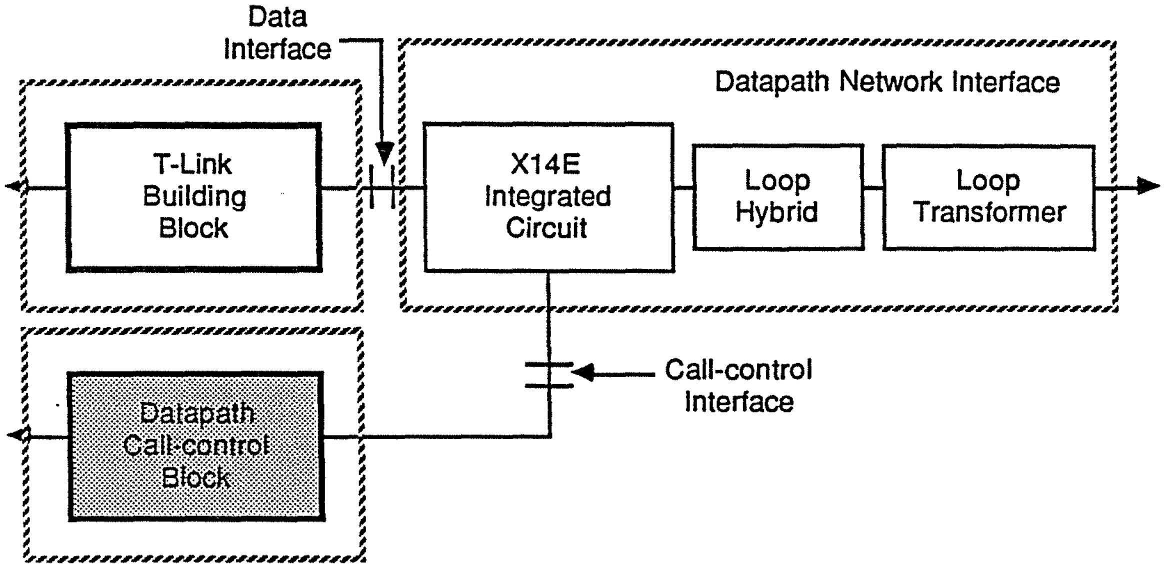

Figure 5-5. Datapath Call-control Building Block

1) **Datapath Call-Control Protocols Information Package**

   This package consists of 2 documents, namely:

   a) **Datapath Service Interface Specification.**

      This is the same document that is listed in Section 4. It gives details of the Datapath physical layer protocol, the FDHP protocol, and the Datapath Message Protocol.

   b) **Datapath Message Protocol Implementation Notes.**

      This document gives some practical notes on how to implement the rich variety of Datapath features. In particular, it will emphasize that the switch may often send messages which the TE will be unable to interpret; these "meaningless" messages are used by the switch to support devices other than the Datapath TE. The Datapath TE should acknowledge these messages but should otherwise treat them as *no operation* codes.

2) **Datapath Call-control Building Block Information Package.**

This package is not yet part of the current Datapath Technology Licensing program.

3) **Datapath Call-control Building Block.**

This package is not yet part of the current Datapath Technology Licensing program.

In order to reduce the design effort by the licensees, Northern Telecom is considering the possibility of preparing and offering a **Datapath Call-control Building Block.** It will attach directly to the X14E call-control interface, handle the X14E control and interrupt signals and gather/formulate the FDHP bytes into Datapath Commands and Messages. It will also attach to the standard bus of the TE's microprocessor and present a simplified interface that will allow all the DU features to be invoked.

The Datapath call-conrol block will be based on a standard microcontroller with a custom program in its ROM.

6. Datapath Data Transmission Protocols

The User data protocols (e.g. ASCII, HDLC, facsimile codes) depend on the DTE and the user application. Datapath is totally transparent to them, hence they will not be discussed further here.

However, the T-Link protocol is a very specific, though flexible, protocol. Therefore, this section will concentrate on the T-Link protocol and the packages available to assist licensees in its implementation.

6.1. Brief Description of the T-link Protocol

The T-Link Protocol allows asynchronous terminal up to 19.2 kbps and synchronous terminals up to 64 kbps to communicate through the 64 kbps digital network. A detailed description of T-Link is found in the documents referred to in Section 8. The following description refers to Figure 6-1.

The switched data call operates in the following stages:

1) The connection between the TEs is established through the network by the Datapath Call-control protocols. (In the case of an ISDN TA, the appropriate call-control protocol, defined in CCITT Q.931, would be used).

2) The T-Link protocol starts off by establishing TE to TE synchronization. This is achieved by repeatedly sending a special synchronous byte in both directions and waiting for the proper return byte. This process is similar to the use of the answer tone familiar in dial up modems to-day.

3) Next, a handshake is used to exchange and verify protocol versions between the T-Link TEs. This is done by first sending a special indicator byte which tells the receiver that a protocol version identifier will follow; the special synchronous byte from step 2 above is the indicator byte for the protocol version identifier. The protocol version identifier byte is then sent by splitting it into 2 nibbles and encoding each nibble into a special octet. Three copies of the 2 coded octets are sent so that the receiver can use majority voting to determine the correct protocol version even in the presence of errors. Both ends will then utilize the highest mutually supported protocol version, or will reject the call if no common protocol version exists.

4) The handshake continues to exchange operational parameters of the DTEs (to agree on such options as the sync/async mode of the DTE , the speed, etc.) before the TEs allow the DTEs to inter-communicate. This handshake consists of 5 mandatory parameter bytes that are sent and received using the same method as used for the protocol version identifier. A stream of parameter indicator bytes is sent followed by the actual parameter byte. Each actual parameter byte is split into 2 nibbles which are encoded into 2 octets; 3 identical copies of these encoded octets are sent. This procedure is performed for each of the parameters 0 to 4. Following the parameter exchange, a decision is made to accept the operating parameters or to force

another round of parameter exchange with new parameters. This negotiation process allows one TE to adapt to the other TE's parameter settings.

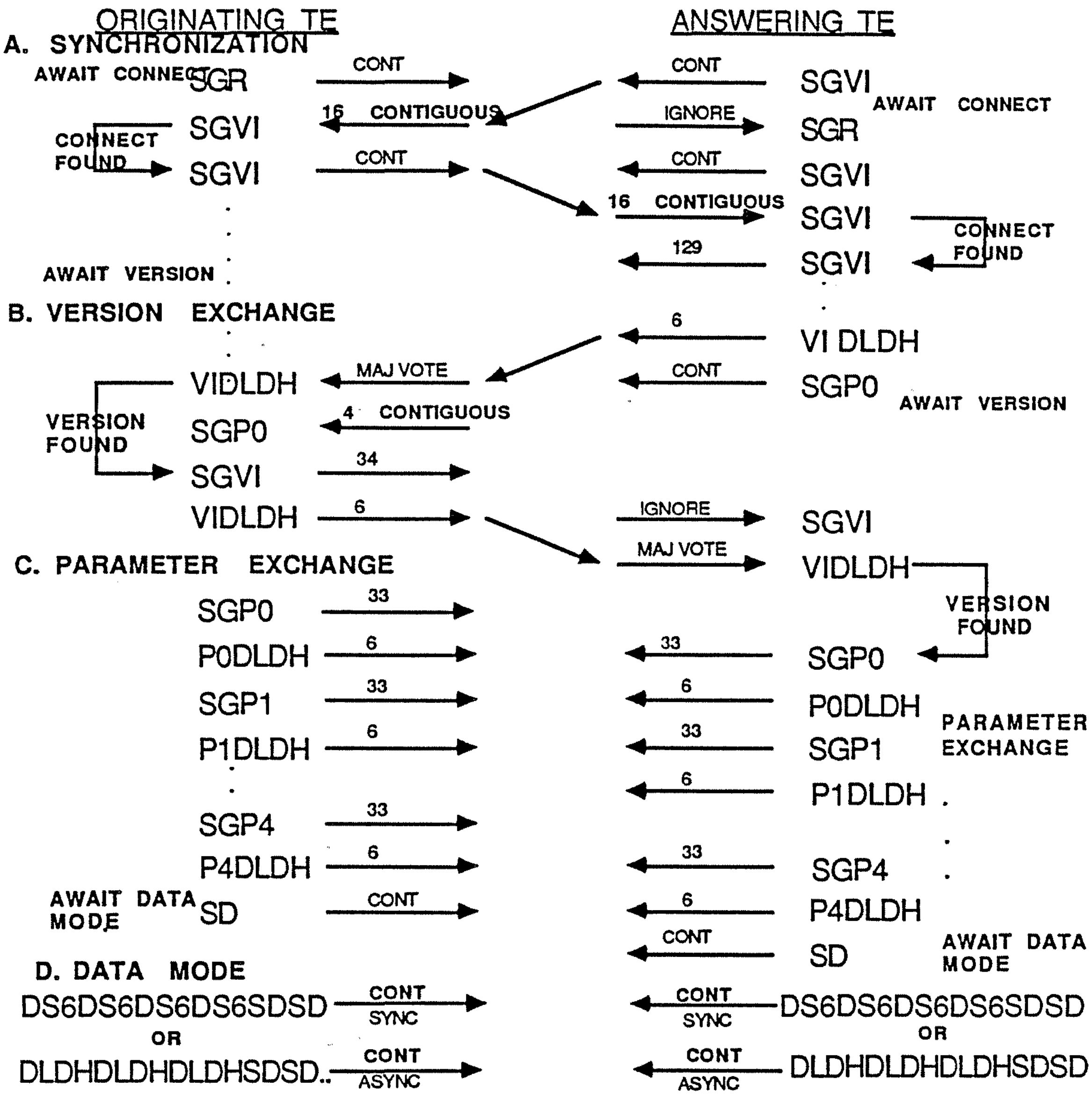

Figure 6-1. T-Link Protocol.

5) Once both ends are in a compatible data mode, actual DTE data transfer can take place using the T-Link Rate Adaption method.

In the asynchronous mode from 50 bps to 9.6 kbps, each data byte is split into 2 nibbles as in the handshake. The nibbles are then coded into octets, multiple copies of which are sent so that the receiver can use majority voting to determine the correct data in the presence of noise. In the asynchronous mode at 19.2 kbps, only a single copy of the data octet can be sent and majority voting is not possible. At all asynchronous speeds, special bytes carrying the status of the DTE-TE interface leads are used as fill between the coded bytes that carry the DTE data.

In the synchronous mode from 1.2 kbps to 48 kbps, 6 bits of the 8-bit octet are used to carry data. At synchronous speeds from 1.2 kbps to 9.6 kbps, multiple copies of these octets are sent and the receiver uses majority voting to determine the correct data. Special octets carrying the DTE-TE interface leads status are used as fill to maintain the data rate. From 14.4 kbps to 40.8 kbps, majority voting is not possible, but the DTE-TE interface leads status is sent. At 48, 56 and 64kbps, every bit of each octet is occupied and no majority voting or DTE-TE leads-status carrying is possible.

6) When the data transfer phase is over, the connection between the TEs is terminated through the network by the Datapath Call-control protocols. (In the case of an ISDN TA, the appropriate call-control protocol, defined in CCITT Q.931, would be used).

6.2. T-Link Packages

The DTL building blocks or packages, listed in Section 8, provide the licensees of the DTL program with information and components to implement all the Datapath protocols. This section describes the packages available to implement the T-Link protocol.

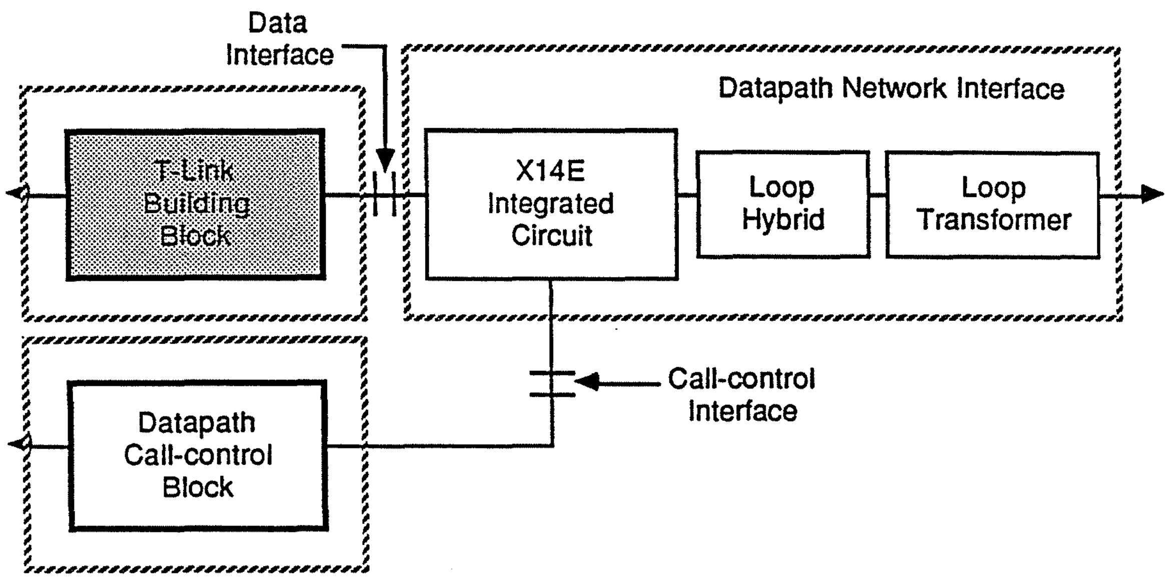

Figure 6-2. T-Link Building Block

1) **T-Link Protocol Package.**

This package consists of the <u>Datapath Service Interface Specification</u> Appendix A of that specification describes the T-Link protocol in detail. Any TE vendor may develop a T-Link product by using this document alone.

2) **T-Link Building Block (TBB) Circuit Information Package.**

This is an information package giving details of the T-Link Building Block (TBB) Circuit. The TBB is a self-contained printed-circuit pack which implements the T-Link protocol. It consists of an 8-layer board approximately 8 inches by 3.7 inches in size, and contains a microprocessor, an EPROM, a RAM, and several digital "glue" circuits such as shift registers, counters and gates. ***The TBB itself will not be offered to the DTL licensees.*** However, the TBB Circuit Information Package, along with the TBB-EPROM, will enable the licensee to integrate the TBB design into his TE and thus implement the T-Link protocol. The TBB Circuit Information Package consists of the following documents:

a) **T-Link Building Block (TBB) Specification.**

This is currently available as a document, reference number TL86-0099-02. It is a detailed specification that covers the circuit description, interfacing, control, and power requirements of the TBB. The TBB circuit has 3 interfaces, namely:
- The DTE interface which provides input/output for the standard V-series/RS-series interface leads;
- A network interface which provides a serial method for transferring the rate-adapted data to and from the 64 kbps data channel;
- A control/status interface which consists of a standard microprocessor interface that is used to control the TBB.

b) **T-Link Building Block (TBB) Circuit Schematic.**

This is currently available as document, number TBB00. It is a circuit schematic of the tested hardware implementation of the T-Link Building Block (TBB) described in the TBB Specification in (a) above.

3) **T-Link Building Block (TBB) Circuit Components Package.**

T-Link components are shown in Figure 6-3. This package will make available the TBB-EPROM (containing the T-Link protocol code) and related information. It consists of two items:

(a) **TBB-EPROM.**

This is currently available as Part #TBAC02, March 1987. It is a 16 Kbyte EPROM, and can be copied, subject to the licensing agreement, by the DTL licensee.

(b) **TBB-EPROM Initialization Notes.**

This is currently available as a document #TBIN-02, May 1987.

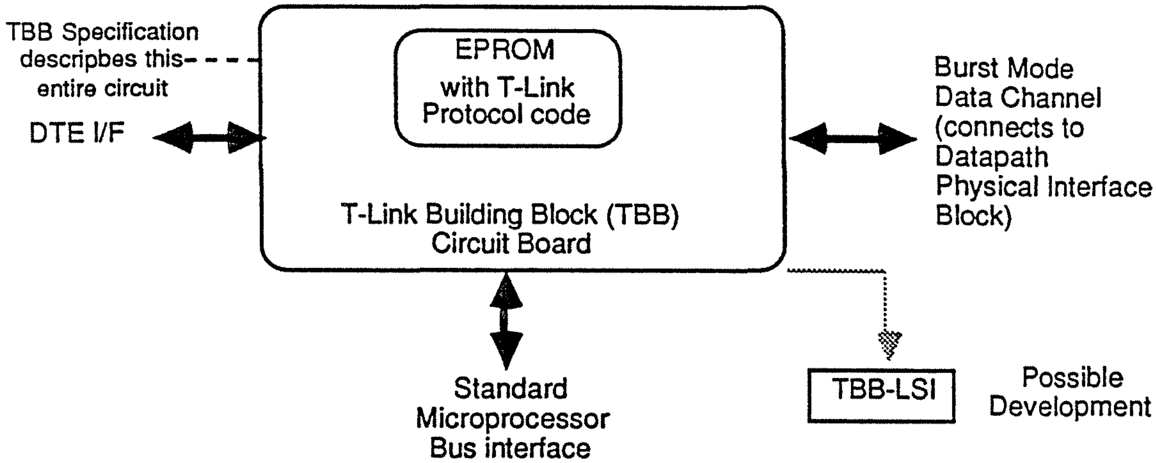

Figure 6-3. T-Link Components

4) **TBB-LSI Information Package**

This package is not yet part of the current Datapath Technology Licensing program.

5) **TBB-LSI Components Package**

This package is not yet part of the current Datapath Technology Licensing program.

In order to reduce TE product costs and the design effort by the licensees, Northern Telecom is considering the possibility of preparing a TBB-LSI.

The TBB-LSI is expected to be a regular-sized 40-pin DIP device which will perform all the functions of the TBB. The TE designer will be able to use it as a single plug-in component to implement T-Link rate adaption, just as he would use an HDLC or a USART chip.

6.3. Application of the T-Link Packages

The various T-Link packages allows a licensee to choose the level of development complexity.

The **T-Link Protocol Package** allows a "from scratch" implementation. This would require a large development effort.

The **TBB circuit packages** and **TBB-EPROM** will allow the licensee to lay out the required hardware design into a particular product and be assured that, when the TBB-EPROM is plugged in, the circuit will function and provide the complete pre-tested NT version of T-Link. This will considerably reduce the required development effort.

If and when the **TBB-LSI** become available, they will provide the T-Link protocol implementation in a single package that can be easily integrated into the TE design.

7. Datapath Vendor Test Program

7.1. Test Program Objectives

This program is being undertaken to:

1) **Assist DTL licensees to test their products.**

   NT will provide comprehensive testing facilities to test the TE product developed by the DTL licensee. The tests will include the Datapath Call-control Protocol Set as well as the T-link protocol.

2) **Ensure vendors compatibility with NT Datapath products.**

   Tests will be conducted on the T-Link protocol to ensure compatibility with Northern Telecom's Datapath products and on the Datapath Call-control Protocol Set to ensure compatibility with the NT DMS100/SL100 switch and the Datapath system.

3) **Maintain records of each vendors implementation.**

   NT will maintain test records (in strict confidence) to ease further testing and future problem debugging.

7.2. Scope of Tests

7.2.1 Range of testing

The tests for TE products from licensees will cover the following range:

1) **Datapath physical protocol.**

   These tests will check the electrical levels over a variety of different loop simulations with bridge taps, and different wire gauges and lengths. These tests will also check the AMI and TCM protocols on the loop.

2) **Datapath call control protocol.**

   These tests will check the vendor's implementation of FDHP, commands, and messages.

3) **Datapath message protocol.**

   These tests will check the message sequences between the DMS/SL-100 switch and the TE used to invoke the various Datapath features.

4) **T-Link Rate Adaption Protocol.**

   These tests will check the vendor's implementation of the T-Link protocol.

7.2.2 Depth of Testing

TE products from licensees will be tested to the following depth:

1) **Compatability Testing.**

These tests will check an implementation to ensure that the protocols described in the Datapath Service Interface Specification are followed rigidly.

2) **Exception Testing.**

These tests will check to see how an implementation handles abnormal conditions that can occur due to noise, corruption, or different implementations of the protocols.

3) **Features Testing.**

These tests will check all the features that are provided by the vendor in his implementation of T-Link (e.g. data rates, loopbacks, parity) and the Datapath Call-control Protocols (e.g. ring-again,speed call).

7.3. TE Testing Program Packages

The program will consist of:

1) **Documents to guide the testing.**

The vendor will receive following documents as part of the program:

a) **Datapath TE Vendor Test Specification**
This document describes in detail all the tests that will be performed on the vendors device.

b) **Datapath Call-control Protocol Vendor Questionnaire.**
This document is used to provide the NT testing team with early information on the vendor's implementation of the Datapath Call-control Protocol set . This will save time and effort during testing by allowing the testing to be customized to each vendor's implementation.

c) **T-Link Protocol Vendor Questionnaire**
This document is used to provide the NT testing team with early information on the vendor's implementation of the T-Link protocol . This will save time and effort during testing by allowing the testing to be customized to each vendor's implementation.

2) **Technical Assistance**

Contact **Northern Telecom** to arrange limited technical assistance.

3) **Test Report.**

Upon completion of the testing, the NT testing team will prepare a report that will review the testing results. This report will be given only to the vendor, with a copy being kept by NT. The report will be proof that NT has tested the product for the tests listed in the report. However, it will not indicate, either explicitly or implicitly, that NT has certified the product.

At the present time it is envisioned that the vendor will have to travel to NT facilities to perform the testing. It may be possible in the future to bring the testing facilities to the vendors premises or to do remote testing. NT will announce this facility when if and when it becomes available.

8. Datapath Building Blocks

FIGURE 7-1. DATAPATH BUILDING BLOCKS PACKAGES

PACKAGE	REFERENCE #	ISSUE	DATE
1. Overview			
Datapath System Overview	BNR Miscellany	Issue 1	Nov. 1986
Datapath Service Interface Specification	Doc# NIS S204-2	Issue 2	Oct.1986
Datapath Building Blocks Overview (this document)	Doc# TL87-003-03	Preliminary	May 1987
2. Datapath Call-control Protocols			
Datapath Call-control Protocols Information Package			
Datapath Service Interface Specification	Doc# NIS S204-2	Issue 2	Nov. 1986
Datapath Message Protocol Implementation Notes	Doc#DAN001-02	Preliminary	May 1987
Datapath Network Interface (DNI) Information Package			
DNI Developer Guide (includes the following appendices) - X14E LSI SpecificationSheet - Loop Hybrid Specification Sheet - Loop Transformer Specification Sheet - Loop Interface Schematics	Doc#TL87-0033-01	Preliminary	March 1987
Datapath Network Interface (DNI) Components Package			
DNI Components			
- X14E LSI	Part# QMV98C	Eng.Sample	1Q87
- Loop Hybrid	Part# QMS91B	Production	1Q87
- Loop Transformer	Part# QTK260A6	Production	1Q87

3. T-Link Rate Adaption Protocol

T-Link Protocol Package

T-Link Protocol Specification (Appendix A of Datapath Service Interface Specification)		Issue 2	Nov.1986

T-Link Building Block (TBB) Circuit Information Package

TBB Specification	Doc# TL86-0099-02	Issue 2	Oct.1986
TBB Circuit Schematic	Doc#TBB00	Issue 2	Oct.1986

T-Link Building Block (TBB) Circuit Components Package

TBB EPROM	Part # TBAC02	Issue 2.2	March 1987
TBB EPROM Initialization Notes	Doc# TBIN	Issue 2.2	March 1987