

ANSI/ISA-S72.01-1985

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American National Standard

PROWAY-LAN Industrial Data Highway



The International Society for Measurement and Control

ANSI/ISA-72.01 — PROWAY-LAN Industrial Data Highway

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Preface

This standard has been prepared as part of the service of ISA toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static, but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms, and asks that they be addressed to the Secretary, Standards and Practices Board, ISA, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709, Telephone (919) 549-8411.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards. The Department is further aware of the benefits to U.S.A. users of ISA standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Toward this end, this Department will endeavor to introduce SI-acceptable metric units in all new and revised standards to the greatest extent possible. *The Metric Practice Guide*, which has been published by the Institute of Electrical and Electronics Engineers as ANSI/IEEE Std. 268-1982, and future revisions will be the reference guide for definitions, symbols, abbreviations, and conversion factors.

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The information contained in the preface, footnotes, and appendices is included for information only and is not a part of the standard.

Foreword

Efforts to develop a standard for data communications to support process and industrial control began in 1976. This work was centered in Working Group 6 of Subcommittee 65C of the International Electrotechnical Committee, supported by SP72 of the Instrument Society of America and committees in Japan and Germany. This work led to development of the PROWAY A&B (token-passing bus) draft standards.

Through ANSI, members of ISA's SP72 committee continue to serve as members of the International Electrotechnical Commission (IEC) Subcommittee 65C Working Group 6 on intersubsystem computer communications. These experts have made significant contributions to the development of a series of IEC draft standards currently under consideration for worldwide acceptance. ISA-S72.01-1985 is in complete harmony with the comparable IEC document, Draft IEC Publication 955.

In 1980, Project 802 of the Institute of Electrical and Electronics Engineers began work on a general standard for Local Area Network (LAN) communications. Several members of SP72 joined the 802 committee and thus many 802 concepts were drawn from the PROWAY effort.

In January 1983, SP72 evaluated the Token-Passing Bus proposal of the IEEE 802.4 committee and concluded that it could be made suitable for industrial control. SP72 also concluded that both the general welfare and standards harmonization would be enhanced by minimizing the number of Token Bus LAN standards.

In April 1983, SP72 began a cooperative effort with the IEEE 802 committee. This effort led to development of the ISA-S72.01-1985 PROWAY-LAN Industrial Data Highway standard for industrial process control. This standard is known as PROWAY-C by the IEC.

PROWAY-LAN is compatible with (but more restrictive than) the IEEE 802.2 and 802.4 standards for general LANS. Significant enhancements were made to both the IEEE 802.2 and 802.4 standards to allow a compatible implementation of features that provide the reliability and timeliness required for industrial control.

The following is an alphabetical list of those who participated in developing the PROWAY-LAN standard. Those marked * were active members of SP72 as of the date shown on this document.

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This standard was approved for publication by the ISA Standards and Practices Board in June 1985.

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Standard

PROWAY-LAN

Industrial Data Highway

I. Introduction and overview

I.1 Scope. This standard specifies those elements which are required for compatible interconnection of stations by way of a Local Area Network (LAN) using the Token-Bus access method in an industrial environment. These elements include

- 1) the electrical and Physical characteristics of the transmission medium
- 2) the electrical transmission signaling method used by the Physical protocol
- 3) the services and signals provided at interface between the Physical and Media Access Control entities
- 4) the frame formats transmitted
- 5) the Token Bus Media Access protocol
- 6) the services provided at the conceptual interface between the Medium Access Control (MAC) sublayer and the PROWAY Link Control (PLC) sublayer above it
- 7) the PROWAY Link Control (PLC) protocol
- 8) the services provided at the conceptual interface between the User of PROWAY and the PROWAY Link Control (PLC) sublayer
- 9) management of PROWAY stations

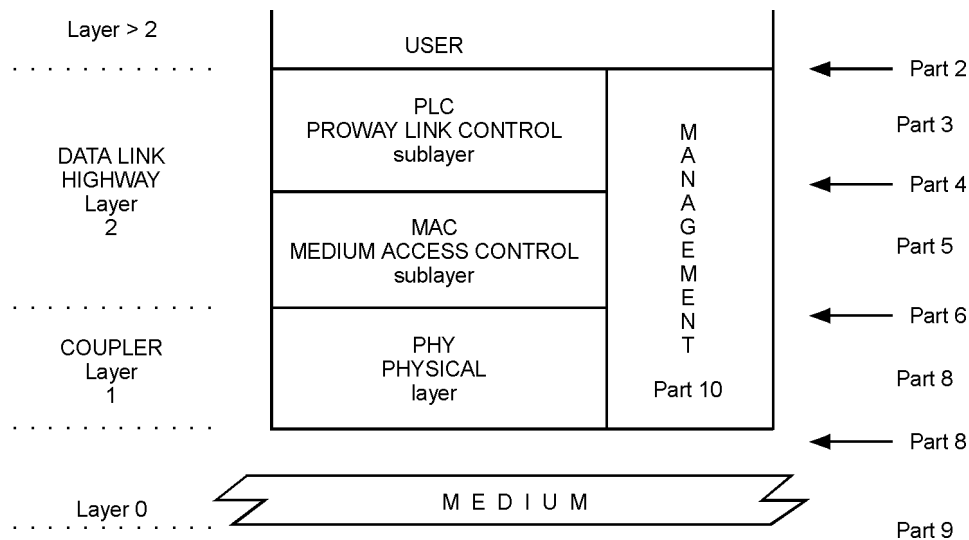


Figure I-1: LAN model

I.2 Introduction

I.2.1 Layering. Within this standard the operation of a station is specified in terms of the layered model shown in Figure I-1. The figure also shows which parts of the standard specify interfaces between layers and which parts specify the operation of the layers themselves. This figure is repeated in each part of the standard to indicate the relationship of that part to the remaining parts of the standard and to the LAN model.

I.2.2 Precedence. Sections I and 1 are introductory and explanatory in nature. Sections I and 1 are not intended to convey precise specifications. In case of a conflict between Sections I and 1 and any other part of the standard, the specifications of the other part shall take precedence.

I.2.3 Definitions. Terms that are used in a specific or specialized manner in any part of this standard are defined at the beginning of that part. General definitions are given in [References 1 and 2](#), Appendix I-A.

I.2.4 References. Documents referenced by this standard are listed in Appendix I-A

I.3 Compliance

I.3.1 Classes of stations. This standard defines three classes of stations:

INITIATOR stations perform all functions of the Local state machine and the reception functions of the Remote state machine.

RESPONDER stations perform all the functions of the Remote state machine and none of the functions of the Local state machine. A simple device (such as an instrument) can be connected to the Local Area Network as a **RESPONDER**.

INITIATOR/RESPONDER stations perform all functions of both the Local and Remote state machines.

I.3.2 Compliance requirements. Implementations may claim compliance with this standard as one of the classes of stations given in I.3.1. Implementations that claim compliance with this station shall

- 1) offer the mandatory PLC-user interface and services specified in this standard for that class of station
- 2) support the PROWAY Link Control protocol specified in this standard for that class of station
- 3) support the mandatory PLC-MAC interface and services specified in this standard for that class of station
- 4) offer the mandatory station management services specified in this standard for that class of station
- 5) support the mandatory features of the Token Bus Medium Access protocol specified in this standard for that class of station
- 6) support the MAC-Physical interface services specified in this standard

It is strongly recommended that **INITIATOR** stations support reporting of the list of stations participating in the logical token ring.

A number of options are specified in this standard. An implementation must indicate which, if any, of these options are supported and the supported values of each station attribute.

I.4 PROWAY organization

The PROWAY Data Highway has three primary functional layers or entities:

- **PROWAY Link Control _ PLC**
- **Media Access Control _ MAC**
- **Physical Signaling _ PHY**

Each of these layers is briefly introduced in the following sections.

The PLC and MAC sublayers together comprise the Data Link (Highway) level of the ISO Model. The PHY level comprises the Physical level of the ISO Model.

I.5 Overview of the PROWAY Link Control (PLC) layer

I.5.1 PROWAY Link Control services. PROWAY provides four basic services to its users:

- **Sending data using a confirmed (immediate response) protocol** from one local (originating) station to one remote (responding) station. This service is known as **Send Data with Acknowledge or SDA**.
- **Sending data without acknowledge or retry** from one local station to one, some, or all remote (receiving) stations. This less secure service is known as **Send Data with No Acknowledge or SDN**.
- One local station **requesting previously submitted information** from one remote station using the confirmed (immediate response) protocol. This service is known as **Request Data with Reply or RDR**.

I.5.2 PROWAY link control sublayer organization. The PLC sublayer functions are logically divided into two independent state machines:

- 1) Local state machine
- 2) Remote state machine

I.5.2.1 Local state machine functions. The Local state machine handles all requests from and confirmations to the local PLC user. These local requests result in transmission of request frames. Functions of the local PLC state machine include:

- accepting local user requests (excluding update_requests)
- generating request frames
- receiving response frames
- passing confirmations to the local PLC user (excluding update_confirmations)

I.5.2.2 Remote state machine functions. The Remote state machine passes indications to the remote PLC user, manages the shared data areas, and returns requested data to the local machine. Functions of the remote PLC state machine include:

- receiving request frames
- passing indications to the remote PLC user
- generating response frames
- accepting remote user requests to update a shared_data_area
- passing update confirmations to the remote PLC user

I.6 Overview of the token bus access method

I.6.1 The essence of the token bus access method

- 1) A token (or baton) controls the right of access to the Physical medium; the station which holds (possesses) the token has control over the medium.
- 2) The token is passed by stations residing on the medium. As the token is passed from station to station a logical ring is formed.
- 3) Steady state operation consists of a data transfer phase and a token transfer phase.
- 4) Ring maintenance functions within the stations provide for ring initialization, lost token recovery, new station addition to logical ring, and general housekeeping of the logical ring. The ring maintenance functions are replicated among all the token-using stations on the network.

Shared media generally can be categorized into two major types. These types are broadcast and sequential. This standard deals exclusively with the broadcast type. On a broadcast medium, every station may receive all signals transmitted. Media of the broadcast type are usually configured as a Physical bus.

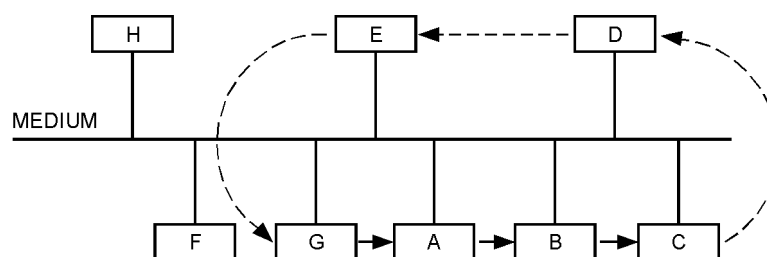


Figure I - 2: Logical ring on Physical bus

In Figure I-2, note that the token bus access method is always sequential in a logical sense. That is, during normal steady state operation, the right to access the medium passes from station to station. Further, note that the Physical connectivity has little impact on the order of the logical ring and that stations can respond to a query from the token holder even without being part of the logical ring. (For example, stations H and F can receive frames but cannot initiate a transmission since they will never be sent the token.)

The Medium Access Control (MAC) sublayer provides sequential access to the shared bus medium by passing control of the medium from station to station in a logically circular fashion. The MAC sublayer determines when the station has the right to access the shared medium by recognizing and accepting the token from the predecessor station, and it determines when the token must be passed to the successor station.

I.6.2 General MAC sublayer functions

- 1) lost token timer
- 2) distributed initialization
- 3) token holding timer (for multiple classes of service and ring maintenance)
- 4) token rotation timer (for multiple classes of service and ring maintenance)
- 5) limited data buffering
- 6) node address recognition
- 7) frame encapsulation (including token preparation)
- 8) Frame Check Sequence (FCS) generation and checking
- 9) valid token recognition
- 10) new ring member addition
- 11) node failure error recovery
- 12) allowing an immediate PLC response to or acknowledgment of a frame sent by the token holder
- 13) retry transmission for certain classes of service

I.7 MAC layer internal structure. The MAC layer performs several functions which are loosely coupled. The descriptions and specifications of the MAC sublayer in this standard are organized in terms of one of several possible partitionings of these functions. The partitioning used here is

illustrated in Figure I-3, which shows four asynchronous logical "machines," each of which handles some of the MAC functions, as discussed below.

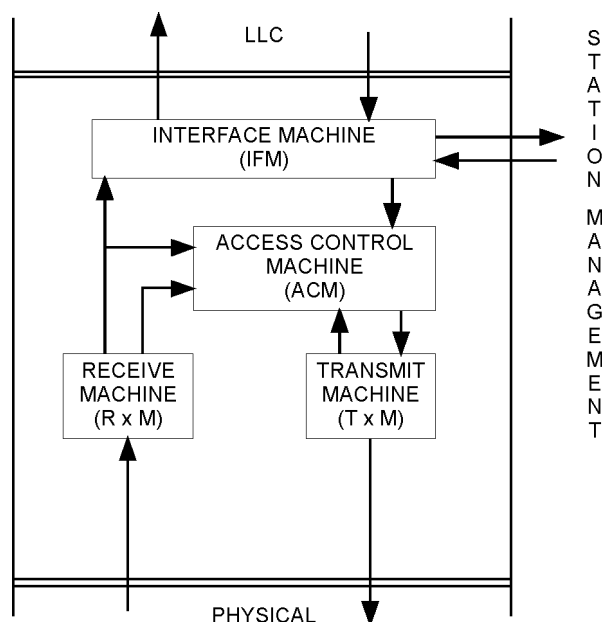


Figure I - 3: MAC layer functional partitioning

I.7.1 Interface Machine (IFM). This machine acts as an interface and buffer between the PLC and MAC sublayers and between Station Management and the MAC sublayer. It interprets all incoming service primitives and generates appropriate outgoing service primitives. This machine handles the mapping of "quality of service" parameters from the PLC view to the MAC view, and generation of a response frame when required. The IFM handles queuing of service requests sent to a PLC protocol data unit. It performs the "address recognition" function on received PLC frames, accepting only those addressed to this station. Finally, it generates an immediate response when requested by the initiating station.

I.7.2 Access Control Machine (ACM). This machine cooperates with the ACMs of all other stations to control transmission on the shared bus medium. The ACM manages multiple MAC access classes in order to provide different levels of "quality of service" to the PLC layer. When required, it will wait for a response or acknowledgment of a transmitted frame from the remote station. If the required response is not received, the local ACM will retry the transmission. The ACM is also responsible for initialization and maintenance of the logical ring, including the admission of new stations. Finally, it has responsibility for the detection of and, where possible, recovery from faults and failures in the token bus network and for informing station management of changes in the membership of the token ring. The ACM is not required in a **RESPONDER** station.

I.7.3 Receive Machine (RxM). This machine accepts atomic symbol inputs from the Physical layer, assembles them into frames, which it validates and passes the frames to the IFM and ACM. The RxM accomplishes this by recognizing the frame Start Delimiter (SD) and the frame End Delimiter (ED), checking the Frame Check Sequence (FCS) and validating the frame's structure. The RxM also identifies and indicates the reception of **noise_bursts** and the **bus_quiet** condition.

I.7.4 Transmit Machine (TxM). This machine generally accepts a data frame from the ACM and transmits it, as a sequence of atomic symbols in the proper format, to the Physical layer. The TxM

builds a MAC protocol data unit by prefacing each frame with the required preamble and SD, and appending the FCS and ED.

I.8 Token bus access method characteristics

An understanding of the basic characteristics of the token bus access method assists in understanding where and when a token-passing bus is an appropriate LAN technology.

Some of the important features of the token bus access method are as follows:

- 1) The method is efficient in the sense that under high offered load the coordination of the stations requires only a small percentage of the media's capacity.
- 2) The method is fair in the sense that it offers each station an equal share of the media's capacity. It does not, however, require any station to use its full share.
- 3) The method permits multiple priorities.
- 4) The method supports open loop (no response) and closed loop (with response or acknowledgment) data transfers.
- 5) The method coordinates station transmissions to minimize and control interference with other stations.
- 6) The method imposes no additional requirements on the media and the modem capabilities over those necessary for transmission and reception of multi-bit, multi-frame sequences at the specified bit error rate.
- 7) In the absence of system noise, the method provides computable, deterministic, worst case bounds on access delay, for the highest priority class of service, for any given network and loading configuration.
- 8) Periods of controlled interference are distinguishable; system noise measurements are possible during the remaining periods.
- 9) The method places minimal constraints on how a station which momentarily controls the media may use its share of the media's capacity. In particular, the access method allows a station to use request/reply access methods during that station's access periods.
- 10) The method permits the presence of a large number of low-cost reduced-function (**RESPONDER**) stations in the network with one or more full-function (**INITIATOR**) stations. (It is assumed that at least one **INITIATOR** station is needed to make the system operational, for example, to initialize.) A **RESPONDER** station does not require Media Access Control logic.
- 11) Use of the immediate response feature in conjunction with the confirmed (SDA or RDR) data transfer services allows protection against loss or duplication of frames at any desired level of assurance.

I.9 Overview of the Physical layer and media

I.9.1 Summary of phase continuous FSK (Frequency Shift Keying) Physical layer

Transmit level: +64 to +66 dB (1 mV, 75 ohm) (dBmV); i.e., approximately 2 V rms.

Receiver sensitivity: +4 to +50 dB (1 mV, 75 ohm) (dBmV), and the ability to receive one's own transmissions.

Noise floor: ≤ -15 dB (1 mV, 75 ohm) over a 3-7 MHz band.

Data rate: 1 Mbits/sec.

Signaling: Manchester encoding of **data**, **non_data**, and **pad_idle** symbols. The transmission symbol representations are

{HL} = **zero** }

{LH} = **one** } **data**

{LL}{HH} = pairs of **non_data** symbols containing no frequency transitions for one full MAC symbol period

Octets of consecutive **ones** and **zeros** = **pad_idle** (preamble)

Modulation: Phase continuous FSK (Frequency Shift Keying) (a form of frequency modulation).

- 1) Higher frequency = 6.25 ± 0.08 MHz = [H]
- 2) Lower frequency = 3.75 ± 0.08 MHz = [L]

Clock recovery: From transitions generated by the Manchester encoding.

I.9.2 Summary of single-channel coaxial cable bus medium

Topology: Omnidirectional bus

Cable: 75 ohm coaxial trunk cable, such as types RG-6 and semi-rigid, with flexible drop cables such as RG-59.

Recommended cable configuration: Semi-rigid trunk and flexible drop cable.

Trunk connection (TAP): 75 ohm nondirectional passive impedance-matching tap.

Repeaters: Active repeaters and amplifiers are not used in a PROWAY system.

I.9.3 Alternate Physical and media implementation. Additional Physical layers, data rates, and compatible media (e.g., 5 Mbits/sec, phase coherent or fiber optics) as defined in Chapters 12/13 and 16/17 of Reference 4 are compatible implementations of this standard.

I.10 Standard organization. This standard is organized in 10 parts, which are summarized below.

Part I serves as an introduction. It begins with a general discussion of the PROWAY link control services and token-passing bus access methods. The PLC and MAC sublayer functional partitioning used in subsequent parts is introduced here. Features of the token-passing bus access method are next reviewed. The Physical layer and Media are then surveyed.

Appendix I-A lists standards referenced by this standard.

Part 1 gives the functional requirements for industrial local area networks.

Part 2 outlines the user interface to the Process Data Highway (PROWAY).

Part 2A details the user interface for transmission of data through PROWAY; i.e., it details the user interface to the PROWAY Link Control (PLC) sublayer.

Part 2B defines the user interface to station management functions.

Appendix 2-A provides an overview of the operation of the Data Link layer (PLC and MAC sublayers combined) and the user interactions with PROWAY.

Part 3 specifies the PROWAY Link Control (PLC) sublayer.

Part 3A gives definitions that are applicable to the PLC state machines and specifies mandatory requirements of the PLC sublayer.

Part 3B defines the functionality of the PROWAY Link Control (PLC) sublayer by means of state tables.

Part 3C details the format of Protocol Data Units (L_pdu) exchanged between cooperating PLC entities.

Part 4 details the interfaces between PLC and MAC sublayers. It defines the services and interfaces provided to the PLC sublayer.

Part 5 specifies the Medium Access Control (MAC) sublayer and details the format of frames exchanged between cooperating MAC entities.

Part 5A discusses the basic concepts of the medium access protocol and provides an informal description of the actions in each state of the Access Control Machine.

Part 5B contains definitions of essential MAC terms and components and specifies those requirements for the MAC sublayer protocols which are not covered elsewhere. It specifies the Interface machine and references the Receive and Transmit machines in [Reference 4, Appendix I-A](#).

Part 5C specifies the MAC Access Control Machine in Reference 4. This is the definitive specification of the token-passing bus-MAC cooperation.

It also describes the MAC layer variables, functions and procedures used in the state machine.

Part 5D details the MAC frame structure including delimiters, addressing, and the FCS. All of the frame formats which MAC handles, including MAC control frames, are enumerated.

Appendix 5-A gives an example configuration for a PROWAY network that meets the requirements of Part 1.

Appendix 5-B gives examples of 16 bit station addresses.

Part 6 details the interface between the MAC sublayer and the Physical layer.

Part 6A specifies the MAC-Physical interface services in an abstract manner and provides descriptions of the interface symbols, requests, and indications.

Part 6B defines the MAC-Physical interface implementation required when the MAC and Physical entities are separate pieces of equipment.

Part 7 is reserved for future use.

Part 8 specifies the Phase-Continuous-FSK Physical layer entity and its interface to the medium.

Part 9 gives requirements for a single-channel coaxial cable bus medium.

Appendix 9-A gives guidance for configuring and installing single-channel coaxial cable bus networks.

Part 10 defines PROWAY station management.

Part 10A informally defines the activities of the station management entity with respect to local requests by means of tables of required actions.

Part 10B defines the interface between the station management entity and the PLC sublayer.

Part 10C details the interface between the station management entity and the MAC sublayer.

Part 10D details the interface between the station management entity and the Physical layer.

Part 10E specifies maintenance of the list of stations participating in the token ring (the active station list) and the format of Protocol Data Units (Mgt_pdu's) exchanged between cooperating management entities in maintaining this list.

Part 10F specifies a communications reset capability.

Appendix 10-A gives examples of active station list activity.

Appendix 10-B provides recommendations for preconditions to entering and leaving the logical token ring.

I.11 Correspondence between the PROWAY and IEEE 802 standards. The parts of the PROWAY-LAN standard are related to the following sections of IEEE 802 standard.

PROWAY-LAN Part IEEE Standard and section

PROWAY-Lan Part I	802.4—Section 1
PROWAY-Lan Part 2A	802.2—Section 2
PROWAY-Lan Part 2B	_____
PROWAY-Lan Part 3A	802.2—Definitions
PROWAY-Lan Part 3B	802.2—Section 6 and Single-Frame
PROWAY-Lan Part 3C	802.2—Section 3,5
PROWAY-Lan Part 4	802.4—Section 2
PROWAY-Lan Part 5A	802.4—Section 5
PROWAY-Lan Part 5B	802.4—Section 6
PROWAY-Lan Part 5C	802.4—Section 7
PROWAY-Lan Part 5D	802.4—Section 4
PROWAY-Lan Part 6A	802.4—Section 8
PROWAY-Lan Part 6B	_____
PROWAY-Lan Part 8	802.4—Section 10
PROWAY-Lan Part 9	802.4—Section 13
PROWAY-LAN Appendix 9-A	802.4—Appendix 13A
PROWAY-Lan Part 10A	_____
PROWAY-Lan Part 10B	802.2—Management Proposal
PROWAY-Lan Part 10C	802.4—Section 3
PROWAY-Lan Part 10D	802.4—Section 9
PROWAY-Lan Part 10E	_____

I.12 Compatibility with IEEE 802. This standard defines the features which are mandatory for conformance to PROWAY specifications. Conformance to IEEE 802 specifications requires additional features as defined in the IEEE 802.1, 802.2, and 802.4 standards (see [References 2-4 of Appendix I-A](#)).

Implementation specifics for Chapters 2, 3, 6, and 10 are subject to harmonization with the future work of the IEEE 802 committee.

In any case, where there is a direct conflict between this standard and a requirement of an equivalent part of one of the above IEEE 802 standards, the requirement of the IEEE 802 standard shall take precedence. Where this standard imposes additional requirements beyond those of the above IEEE 802 standards, the additional PROWAY requirements shall take precedence.

Appendix I-A

References

Ref. No.	Section No.
1) ISO 7498-1984. Information Processing Systems Interconnection - Basic Reference Model.	All
2) IEEE Std 802.1, Local Area Network Standard - Overview, Interworking, and Management. (Draft standard, publication pending)	I,10
3) IEEE Std 802.2 (1985), Logical Link Control. IEEE 802.2 Proposed Draft Addendum — Acknowledged Connectionless Service, Draft 13, Oct. 1986.	I,2,3
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5) Department of Defense, MIL Standard 1851A (1983), ADA Programming Language.	I
6) ADA TM Programming Language.	I,5
7) IEC Publication 79-10 (1972) Part 10: Classification of Hazardous Areas.	1
8) IEC Publication 79-1 (1971) Part 1: Construction and Test of Flameproof Enclosures of Electrical Apparatus.	1
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11) ISO 4902:1980, Data Communication — 37-Pin and 9-Pin DTE/DCE Interface Connectors and Pin Assignments.	6
12) CCITT Yellow Book, Vol. 11 (1980), Characteristics for Balanced Double Current for General Use with Integrated Circuit Equipment in the Field of Data Communications.	6
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14) FCC Docket 20780-1980 (Part 15) Technical Standards for Computing Equipment. Reconsidered First Report and Order, April 1980.	8
15) NFPA National Electric Code, Article 250: Grounding; Article 800: Communication Circuits; Article 820: Community Antenna Television and Radio Distribution Systems.	8,9

16) IEC 716-1983, Expression of the Properties of Signal Generators.	
17) UL 94, Test for the Flammability of Plastic Materials for Parts in Devices and Appliances (Rated under V-0).	8,9
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24) CCITT Yellow Book, Vol. 8, Fascicle VIII.2, Data Communication Networks.	8
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31) RCA/Cablevision Systems: <i>Design and Construction of CATV Systems</i> , Van Nuys, CA.	9
32) <i>Basic CATV Concepts</i> , Theta Com CATV/TEXCAN, Phoenix, AZ.	9
33) EIA CB8-1981, Components Bulletin, List of Approved Agencies, US and Other Countries, Impacting Electronic Components and Equipment.	8
34) IEC Publication 255-4 (1976), Single Input Energizing Quantity Measuring Relays with Dependent Specified Time.	I
35) US Military Standard — MIL C 39012.	8,9

1 Functional requirements

1.1 Overview. The PROWAY standard defines the protocols, interfaces, and media for layers 1 and 2 of the ISO reference model. Compliance with this standard, and with complementary standards at the higher layers will allow unambiguous communication between the devices that comprise a Distributed Industrial or Process Control System over a shared Process Data Highway (PROWAY). Compliance with these standards will enable devices from different manufacturers to cooperate in the same control system. The PROWAY-LAN standard is applicable to control systems for both continuous and discrete processes and to a wide range of factory automation systems. Industrial control systems are distinguished from other on-line, real-time computer networks in that control systems' outputs cause material or energy to move.

This standard applies to serial transmission over a single shared electrical transmission line; i.e., a coaxial cable. However, future revisions may define alternative transmission media, such as fiber optics.

The Functional Requirements given in Part 1 were developed prior to the other parts of the standard and were the primary basis for evaluating the technical merits of proposals for use in Parts 2 through 10 of this standard. If there are conflicts between Part 1 and other Parts of this standard, the requirements of the other Part take precedence.

1.2 Application environment and main features.

1.2.1 Application characteristics. The characteristics of the data highway should be such that they provide optimum features for use in industrial control systems and shall be applicable to both continuous and discrete processes. An industrial data highway is characterized by the following:

- 1) event-driven communication which allows real-time response to events
- 2) very high availability
- 3) very high data integrity
- 4) proper operation in the presence of electromagnetic interference and differences in earth potentials
- 5) dedicated intra-plant transmission lines

1.2.2 Economic versus technical factors. To achieve broad applicability it is essential that industrial data highways should be economically viable in control systems under the following conditions:

- 1) with low or high information transfer requirements
- 2) within a control room and/or while exposed to the plant environment
- 3) in geographically small or large plants

The economic and technical factors may need to be reconciled to achieve a balance of transmission line length versus data signaling rate.

1.2.3 Main features of PROWAY

Number of stations	≤ 100	Length of highway	$\leq 2000\text{m}$
Data signaling rate			$\geq 1 \times 10^6 \text{ bits/sec}$
Data circuit bit error rate			$< 1 \times 10^{-8}$
Residual error rate			$< 3 \times 10^{-15}$ at a bit error of 1×10^{-6}
Maximum user data in frame			$\leq 1000 \text{ octets}$
Information transfer rate			$\geq 3 \times 10^5 \text{ bits/sec}$
High Priority media access time			$\leq 10 \text{ millisec}$

1.3 Device types

1.3.1 Communications between control devices. Communications shall be provided among commonly used devices in process or industrial control applications.

It is intended that this standard will provide optimum performance when intelligent control devices are communicating.

1.3.2 Communications with other devices. An industrial data highway is not intended to provide an optimized interface for high-speed computer memories or peripherals. However, no devices or types of devices are excluded from exchanging data over an industrial data highway, provided they conform to the requirements of this standard.

1.3.3 Classes of stations. The data highway shall support full function (**INITIATOR**) stations and reduced function (**RESPONDER**) stations. Simple devices may be directly connected to the data highway as **RESPONDERS**.

1.4 System structure

1.4.1 Control system structure. An industrial data highway shall be capable of supporting control systems with centralized intelligence, distributed intelligence, hierarchical intelligence and combinations thereof.

1.4.2 Data highway mode of operation. The data highway shall be capable of supporting transmission of event oriented data in real time. The normal mode of operation uses transaction message pairs, such that each request message is followed by its related response or acknowledgment message; i.e., by an immediate response.

Any two stations on a single data highway shall perform direct data interchange without involving store and forward at a third station.

1.4.3 Configuration changes. The data highway shall support reconfiguration of the control system while the process is operating. During reconfiguration, a transient disturbance to the exchange of frames is permitted, provided that the data highway is able to detect such disturbance and that it can recover full operation within a time appropriate to the application.

Examples of these configuration changes are as follows:

- 1) extending, shortening or rerouting transmission lines
- 2) connecting or disconnecting stations from the transmission line

1.5 Maintenance and service features

1.5.1 Testing and fault diagnosis. An industrial data highway must include means for carrying out test and fault diagnoses on line.

1.5.2 Effect of state transitions. Any station shall be able to perform transitions from one state to another without generating bit errors between other stations. Examples of such transitions are as follows:

- 1) On-line/off-line
- 2) Power-on/power-off
- 3) Ready/not ready
- 4) Busy/not busy
- 5) Local/remote

1.6 Safety

1.6.1 Electrical faults. All devices used in the data highway shall be capable of withstanding the application of an allowable fault potential appropriate to the application. Application of this potential to the device's connection to the transmission line shall not damage the device nor cause it either to damage other devices, or become hazardous to personnel. Three classes of installation can be identified. They are as follows:

- 1) The fault potential is the power mains voltage in the area traversed by the transmission line(s).
- 2) The fault potential is represented by a pulse typically 2.5 kV peak with a 1 microsec rise time and 50 microsec decay time, the test procedure is given in [Reference 34, Appendix I-A](#).
- 3) The fault potential is that which is generated by a lightning strike to an arbitrary point near the transmission line(s). Such a fault is typically characterized by a 10 microsec rise time to 5,000 amps and a 20 microsec fall time to half that value. This is referred to as a 10/20 microsec pulse.

1.6.2 Intrinsic safety. The design of the data highway shall include consideration of possible extensions to use the equipment, or sections of it, in hazardous atmospheres.

The supplier shall state which of the four categories below his equipment will meet:

- 1) not suitable for hazardous atmospheres (See Reference 7, Appendix I-A)
- 2) flameproof construction (See Reference 8, Appendix I-A)
- 3) intrinsically safe (See References 9 and 10, Appendix I-A)
- 4) claimed to meet the requirements for intrinsic safety certification but not actually certified

For categories (2) and (3), the supplier shall give the name of the approving authority, the class of certification and the approval certificate number.

1.7 Performance in industrial environment

1.7.1 Industrial environment

1.7.1.1 Induced noise. The noise floor on a main trunk cable installed in a typical industrial environment in accordance with Part 9 may be as high as 0 dBmV measured over a 3 to 7 MHz bandwidth.

1.7.1.2 Electromagnetic environment. The industrial environment may include an ambient plane wave field of

- 1) 2 volts/meter from 10 kHz through 30 MHz
- 2) 5 volts/meter from 30 MHz through 1 GHz

1.7.1.3 Differences in earth potential. Typical differences in earth potential for an industrial environment are as follows:

- 1) When the transmission medium is entirely contained in a protected area, this difference in earth potential is typically less than 10 V peak-to-peak at frequencies less than 400 Hz.
- 2) When the transmission medium is exposed to the plant environment, this difference in earth potential is typically less than 50 V peak-to-peak at frequencies less than 400 Hz.
- 3) When the transmission medium is exposed to a severe plant environment (for example a power station), this difference in earth potential may typically rise to 1000 V peak-to-peak at frequencies less than 10 MHz.

1.7.2 Data circuit bit error rate. The data highway, when installed in a typical industrial environment and in accordance with Part 9, shall exhibit a data circuit bit error rate of no more than 1×10^{-8} . The manufacturer shall provide a graph relating data circuit bit error rate to the noise floor, differences in earth potential, data rate, and other relevant factors.

1.7.3 Residual error rate. The data highway shall achieve a residual error rate of no more than 3×10^{-15} when the data circuit bit error rate is 1×10^{-6} . The manufacturer shall provide a graph which relates the residual error rate to the data circuit bit error rate.

NOTE: The corresponding rate of undetected frame errors is one error per 1000 years of data highway operation, assuming 100% utilization of a data signaling rate of 1×10^6 bits/sec.

1.7.4 Information transfer rate. The data highway shall achieve an information transfer rate of at least 3×10^5 bit/sec, when data circuit bit error rate is 1×10^{-6} and the data rate is 1×10^6 bits/sec. The manufacturer shall provide a graph which relates information transfer rate to the data circuit bit error rate and data signaling rate.

1.7.5 Media access and highway transaction times. The manufacturer shall provide information relating average and maximum media access time and highway transaction time to highway configuration, loading, priority, and other relevant factors.

1.7.5.1 Media access time. An industrial control data highway shall have a maximum media access time of no more than **10 millisecond** for a frame submitted at the highest priority by an arbitrary station under any set of conditions equivalent to those listed below.

- 2000 m highway length

- 1×10^6 bits/sec data signaling rate
- 20 stations participate in the token ring
- 10 stations initiate SDA messages with an average user data length of 16 octets simultaneously
- address length = 16 bits
- no more than one error occurs during each token rotation

One set of conditions under which this media access time may be achieved is given in [Appendix 5-A](#).

At a given data rate, error rate, address length and propagation delay, the maximum media access time is determined by the number of token holding stations, the offered load at the highest priority, and the maximum frame length allowed.

1.7.5.2 Highway transaction time. The highway transaction time, when using the SDA or RDR services, is determined by the queuing delay within the initiating station, the media access time, the user data length and the number of retries required.

1.7.5.3 Definitions

- **Media access time** is defined as the period of time between a request becoming next to be transmitted and the time when the first bit of the SD for the corresponding request frame appears on the common bus medium.
- **Highway transmission time** is the period of time between submission of a request at the PLC-user interface and the appearance of the corresponding confirmation at that interface.

1.8 System availability

1.8.1 Effect of failures. No single failure of any part of any device used within or connected to the data highway shall cause failure of the entire control system, or of any function except those in which the failed device is directly involved.

It shall be possible to configure an industrial control system which can tolerate without the loss of communication function, changes of configuration, failure of any one transmission line, or failure of any one station.

1.8.2 Internal status and error reporting. The data highway shall have an internal status and error reporting capability.

1.8.3 Automatic recovery. The data highway shall be capable of automatic recovery after commonly occurring failures are corrected.

1.8.4 Control of stations. The data highway shall support loading, starting, stopping, reloading, and resetting of any station.

2 The interface to PROWAY

2.1 Organization

Part 2A specifies the data transfer services provided to the PROWAY user by the PROWAY Link Control sublayer of the Data Link (Highway) layer of the ISO reference model.

Part 2B specifies the administrative services provided to the PROWAY user by the station management entity.

2A. User-PLC interface and service specification

2A.1 Scope and field of application. This part specifies the data transfer services provided to the user of PROWAY (PLC user) by the PROWAY Link Control (PLC) sublayer at the boundary between the user of PROWAY and the PROWAY Link Control sublayer of the Data Link (Highway) layer of the ISO reference model. This standard specifies these services in an abstract way. It does not specify or constrain the implementation entities and interfaces within a computer system. The relationship of this part to other parts of this standard and to LAN specifications is illustrated in Figure 2A-1.

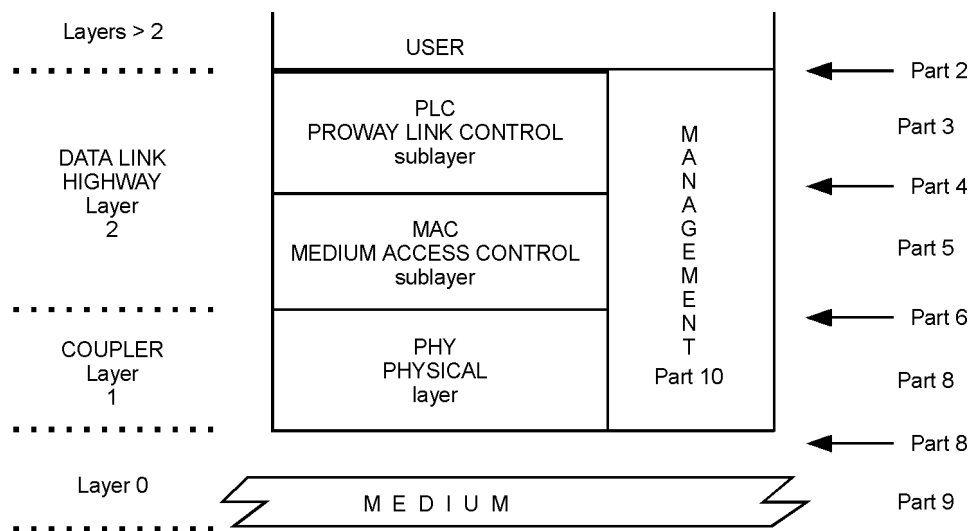


Figure 2A-1: Relationship to LAN model

2A.2 Overview of PROWAY services

2A.2.1 General description of services provided. This section describes informally the services provided to the user of PROWAY by the PROWAY Link Control (PLC) sublayer of the Highway layer. These services provide data transfer and control services between peer PLC entities. They provide the means by which PROWAY Link Control entities can exchange Link service data units (L_sdu) over the shared Process Data Highway, i.e., PROWAY Local Area Network (LAN). The data transfer can be open-loop or closed-loop, point-to-point or multipoint.

2A.2.2 Model used for the service specification. The general model and descriptive method are given in [Reference 1, Appendix I-A](#). The specific application of this model to each service is given in [2A.4](#).

2A.2.3 Overview of services. The data transfer services provided to a user of PROWAY are:

- **Send Data with Acknowledge (SDA)**, compatible with the Single Frame service of Reference 3, Appendix I-A (when data is not requested).
- **Send Data with No Acknowledge (SDN)**, equivalent to and inter-operable with the Unacknowledged Connectionless service of Reference 3, Appendix I-A.
- **Request Data with Reply (RDR)**, compatible with the Single Frame service of Reference 3, Appendix I-A (when no data transmitted).

NOTE: That a compatible Connection-Oriented service may be implemented in some stations on a PROWAY-LAN. This standard does not specify the Connection-Oriented service, which is specified in Reference 3, Appendix I-A.

The SDA and RDR services provide **confirmed** data transfers.

2A.2.3.1 Send Data with Acknowledge (SDA). This service allows a local user of PROWAY to send user-supplied data (Link service data unit, L_sdu) to a single remote station. The local user receives a confirmation of the receipt or nonreceipt of the data. At the remote station, this L_sdu (if received correctly) is passed to the remote user of PROWAY. If such an L_sdu is presented to a remote user, it is known to be correct and identical to the L_sdu presented at the local station. If an error in transmission occurs, the local PROWAY station will attempt to retransmit the data.

2A.2.3.2 Send Data with No Acknowledge (SDN). This service allows a local user of PROWAY to send user-supplied (Link service data unit, L_sdu) to a single, a group of, or all remote stations. The local user receives confirmation of transmission completion but not of receipt of the data. At the remote station(s) this L_sdu (if received correctly) is passed to the remote user(s) of PROWAY. If such an L_sdu is presented to a remote user, it is known to be correct and identical to the L_sdu presented at the local station. However, there is no acknowledgment that such a delivery was made.

2A.2.3.3 Request Data with Reply (RDR). This service allows a local user of PROWAY to request data (Link service data unit, L_sdu) previously submitted by the user at a single remote station. The local user receives either the data requested or an indication that the data was not available. If the data is presented to the local user, it is known to be correct and identical to the L_sdu presented earlier at the remote station. In the event of transmission errors, the local PROWAY station will make additional requests for the data.

2A.2.4 Overview of interactions. These services are accomplished using a set of primitives. A request primitive is used by the local user to request a service. A confirmation primitive is returned to the local user when the service is completed. An indication primitive is passed to the remote user whenever an unsolicited event is noted. The primitives used for each of the above services are:

- **Send Data with Acknowledge (SDA)**
 L_DATA_ACK.request
 .indication
 .confirm
- **Send Data with No Acknowledge (SDN)**

L_DATA.request
 .indication
 .confirm

• **Request Data with Reply (RDR)**

L_REPLY.request
 .indication
 .confirm

 L_REPLY_UPDATE.request
 .confirm

The local user of PROWAY can have only one outstanding request (i.e., awaiting a confirmation) for each invocation of the local PLC entity supported by this station. A station must support one invocation of the local PLC entity for each priority and SSAP that it supports (see [Section 3B.1.1](#)).

2A.2.5 Overview of data highway operation. An overview of the combined operation of the Data Link layer (PLC and MAC sublayers) is given in [Appendix 2-A](#).

2A.3 Mandatory features. The primitives which are mandatory for **INITIATOR** and **RESPONDER** stations are listed as M in the table below. Optional primitives are listed as O, and non-applicable primitives are listed as —.

	INITIATOR	RESPONDER
Send Data with Acknowledge (SDA)		
L_DATA_ACK.request	M	—
.indication	M	M
.confirm	M	—
Send Data with No Acknowledge (SDN)		
L_DATA.request	M	—
.indication	M	M
.confirm	O	—
Request Data with Reply (RDR)		
L_REPLY.request	M	—
.indication	M	M
.confirm	M	—
L_REPLY_UPDATE.request	O	M
.confirm	O	M

2A.4 Detailed specification of PLC interactions with the user of PROWAY

2A.4.1 Send Data with Acknowledge (SDA)

2A.4.1.1 Description of operation. The local PLC user prepares a Link service data unit (L_sdu) containing process information or commands, both transparent to PROWAY, for one remote PLC user. This data is passed to the local PLC entity by an L_DATA_ACK.request primitive over the local PLC-user interface. The local PLC entity accepts this service request and attempts to send the L_sdu to the remote PLC entity. The local PLC entity provides a confirmation to the local PLC user indicating the success or a failure of the data transfer.

A positive acknowledgment is required from the remote PLC entity before the local PLC entity returns a positive confirmation to the local PLC user. If this acknowledgment is not received in a timely manner, the local MAC entity will make up to a predefined number of attempts to pass the L_sdu to the remote MAC. No other traffic occurs on the local area network between the original transmission of the data and its associated acknowledgment.

When the frame is correctly received, the remote PLC entity receives and passes the L_sdu to the remote PLC user over its PLC-user interface using a L_DATA_ACK.indication primitive.

2A.4.1.2 Definition of primitives of local user-highway interface

2A.4.1.2.1 L_DATA_ACK.request

2A.4.1.2.1.1 Function. This primitive is the service request primitive for the send_data_with acknowledge data transfer service.

2A.4.1.2.1.2 Semantics. The primitive shall provide parameters as follows:

L_DATA_ACK.request
(SSAP,
DSAP,
L_sdu,
remote_address,
service_class)

The SSAP and DSAP parameters specify the local and remote user link service access points involved in the data transfer service, as defined in [Part 3C](#).

The remote_address parameter specifies the MAC address of the remote station, as defined in Part 5D. The remote_address must be an individual address.

The L_sdu parameter specifies the link service data unit to be transferred by the PLC entity.

The service_class parameter specifies the MAC access_class and thus the MAC priority desired for the data transfer, as defined in [Part 5D](#). Recommended access_class assignments for PROWAY systems are as follows:

MAC Priority	Access_class	Usage
Highest	6	Urgent messages, i.e., those performing critical alarm, interlock, and control coordination functions
	4	Normal control actions and ring maintenance functions
	2	Routine data gathering and display, and data base update functions
Lowest	0	File and program transfers

2A.4.1.2.1.3 When generated. This primitive is passed from the local PLC user to the local PLC entity to request a L_sdu be sent to one remote PLC user using Send_Data_With_Acknowledge procedures.

2A.4.1.2.1.4 Effect of receipt. Receipt of this primitive causes the local PLC entity to send an L_sdu using Send_Data_With_Acknowledge procedures.

2A.4.1.2.1.5 Additional comments. Only one SDA, SDN, or RDR request may be concurrently outstanding (i.e., awaiting a confirmation) for each invocation, as defined in Part 3B, of the local PLC entity supported by this station.

2A.4.1.2.2 L_DATA_ACK.indication

2A.4.1.2.2.1 Function. This primitive is the service indication for the Send_Data_With_Acknowledge data transfer service.

2A.4.1.2.2.2 Semantics. The primitive shall provide parameters as follows:

L_DATA_ACK.indication

(SSAP,
DSAP,
local_address,
remote_address,
L_sdu,
service_class)

The SSAP and DSAP parameters specify the local and remote user link service_access points involved in the data transfer service, as defined in [Part 3C](#).

The local_address and remote_address parameters specify the source address and the destination address of the corresponding SDA frame, as defined in [Part 5D](#).

The L_sdu parameter specifies the link service data unit of the corresponding SDA frame.

The service_class parameter specifies the actual MAC priority of the corresponding SDA frame, as defined in Part 5D.

2A.4.1.2.2.3 When generated. The primitive is passed from the remote PLC entity to the remote PLC user when a MA_DATA.indication with L_pdu_type = **SDA** is received and the received L_pdu is not a duplicate.

2A.4.1.2.2.4 Effect of receipt. The effect of receipt of this primitive on the remote PLC user is unspecified.

2A.4.1.2.2.5 Additional comments. The contents of the L_sdu parameter are logically complete and unchanged relative to the L_sdu parameter in the associated L_DATA_ACK.request primitive.

2A.4.1.2.3 L_DATA_ACK.confirm

2A.4.1.2.3.1 Function. This primitive is the service confirmation primitive for the send_data_with_acknowledge data transfer service.

2A.4.1.2.3.2 Semantics. The primitive shall provide parameters as follows:

L_DATA_ACK.confirm
(SSAP,
DSAP,
remote_address,
L_sdu,
service_class,
L_status)

The SSAP and DSAP parameters specify the local and remote user link service_access points involved in the data transfer service. They are identical to the SSAP and DSAP parameters of the corresponding L_DATA_ACK.request primitive.

The link service data unit is **null**.

The remote_address parameter specifies the destination_address parameter of the MA_DATA.confirmation primitive.

The service class parameter specifies the priority parameter of the MA_DATA.confirmation primitive.

The L_status parameter indicates the success or failure of the previous associated send_data_with_acknowledge data transfer request and whether any error condition is **temporary** or **permanent**.

The values that the Command_status components of the L_status parameter can assume are as follows:

Code	Meaning	Temporary/ Permanent
OK =	Command L_sdu accepted	—
TE =	No acknowledgment from remote station after specified retries (possibly due to a non-PROWAY station)	T
DS =	Local station disconnected from line	P
WD =	Local station watchdog timed out	P
IV =	Invalid parameters in request	P
RS =	Request for an unimplemented or unactivated service at remote DSAP: no action taken	P
LS =	Unimplemented service at local SSAP	P
UN =	Resources not available to remote PLC or MAC entity: no action taken	T
UE =	User-PLC interface error	P
PE =	Protocol error	T/P
IP =	Permanent implementation dependent error	P
IT =	Temporary implementation dependent error	T

In [Reference 3, Appendix I-A](#), an additional Response_status component of L_status may be present.

2A.4.1.2.3.3 When generated. This primitive is passed from the local PLC entity to the local PLC user to indicate the success or failure of the previous associated send_data_with_acknowledge data transfer request.

2A.4.1.2.3.4 Effect of receipt. The effect of receipt of this primitive on the local PLC user is unspecified.

2A.4.1.2.3.5 Additional comments. If the transfer was unsuccessful, this primitive indicates that the remote PLC sublayer entity received and positively acknowledged the L_sdu. If an error in transmission occurs, the local MAC entity will make up to a predefined number of attempts to retransmit the data.

If L_status indicates a **Temporary** error, the local PLC-user entity may assume that a future retry of the associated request may be successful.

If L_status indicates a **Permanent** error, the local PLC-user entity should assume that management intervention may be required before a retry of the associated request may be successful.

It is assumed that sufficient information is available to the local PLC user to associate this confirmation with the corresponding request.

2A.4.2 Send Data with No Acknowledge (SDN)

2A.4.2.1 Description of operation. The local PLC user prepares data (process information or commands, both transparent to PROWAY) for any or all remote users. This data is passed by the L_DATA.request primitive over the PLC-user interface. The local PLC entity accepts this service request, attempts to send this data to the specified remote PLC entities, and returns a local transmission confirmation to the local PLC user. This confirmation reports only local failures.

There is no guarantee of delivery to the remote PLC entities addressed, since no remotely generated acknowledgments or local retries are employed. The data is transmitted once on the line and is received (subject to the propagation delay of the line) simultaneously by all addressed stations. Each remote PLC entity which receives the data passes it to the remote PLC user by an L_DATA.indication primitive.

2A.4.2.2 Inter-operability. Inter-operability, with any station conforming to [References 3 and 4](#), [Appendix I-A](#), is achieved using SDN procedures.

2A.4.2.3 Definition of primitives at local user-highway interface

2A.4.2.3.1 L_DATA.request

2A.4.2.3.1.1 Function. This primitive is the service request primitive for the send_data_with_no_acknowledge data transfer service.

2A.4.2.3.1.2 Semantics. The primitive shall provide parameters as follows:

L_DATA.request
 (SSAP,
 DSAP,
 remote_address,
 L_sdu
 service_class)

The SSAP and DSAP parameters specify the local and remote users' link service_access points involved in the data transfer service.

The remote_address parameter specifies the MAC address of the remote station as specified in Part 5D. The remote_address may be either an individual address, a group address, or a broadcast address.

The L_sdu parameter specifies the link service data unit to be transferred by the local PLC entity.

The service_class parameter specifies the MAC priority desired for the data transfer as specified in Part 5D.

MAC Priority	Access_class	Usage
Highest	6	Urgent messages, i.e., those performing critical alarm, interlock, and control coordination functions
	4	Normal control actions and ring maintenance functions
	2	Routine data gathering and display, and data base update functions
Lowest	0	File and program transfers

2A.4.2.3.1.3 When generated. This primitive is passed from the local PLC user to the local PLC entity to request that a L_sdu be sent to one, a group, or all remote users using send_data_with_no_acknowledge procedures.

2A.4.2.3.1.4 Effect of receipt. Receipt of this primitive causes the local PLC entity to send a L_sdu using send_data_with_no_acknowledge procedures.

2A.4.2.3.1.5 Additional comments. Only one SDA, SDN, or RDR request may be concurrently outstanding (i.e., awaiting a confirmation) for each invocation, as defined in Part 3B, of the local PLC entity supported by this station).

2A.4.2.3.2 L_DATA.indication

2A.4.2.3.2.1 Function. This primitive is the service indication primitive for the send_data_with_no_acknowledge data transfer service.

2A.4.2.3.2.2 Semantics. The primitive shall provide parameters as follows:

L_DATA.indication
 (SSAP,
 DSAP,
 local_address,
 remote_address,
 L_sdu,
 service_class)

The SSAP and DSAP parameters specify the local and remote user link service_access points involved in the data transfer.

The local address and remote_address parameters specify the source_address and destination_address of the corresponding SDN frame, as defined in [Part 5D](#).

The L_sdu parameter specifies the link service data unit of the corresponding SDN frame.

The service_class parameter specifies the actual MAC priority parameter of the corresponding SDN frame, as defined in Part 5D.

2A.4.2.3.2.3 When generated. The primitive is passed from the remote PLC entity to the remote PLC user when a MA_DATA.indication L_pdu_type = **SDN** is received.

2A.4.2.3.2.4 Effect of receipt. The effect of receipt of this primitive on the remote PLC user is unspecified.

2A.4.2.3.2.5 Additional comments. The contents of the L_sdu parameter are logically complete and unchanged relative to the L_sdu parameter in the associated L_DATA.request primitive.

2A.4.2.3.3 L_DATA.confirm

2A.4.2.3.3.1 Function. This primitive is the confirmation of the send_data_with_no_acknowledge data transfer service.

2A.4.2.3.3.2 Semantics. The confirmation shall provide parameters as follows:

L_DATA.confirm
(SSAP,
DSAP,
remote_address,
service_class
L_status)

The SSAP and DSAP parameters specify the local and remote user link service_access points involved in the data transfer service. They are identical to the SSAP and DSAP parameters of the corresponding L_DATA.request primitive.

The remote_address specifies the destination_address parameter of the MA_DATA.confirm primitive.

The service_class parameter specifies the priority parameter of the MA_DATA.confirm primitive.

The L_status parameter indicates the local success or failure of the previous associated send_data_with_no_acknowledge data transfer request.

The values that the Command_status component of the L_status parameter can assume are:

OK = Transmission complete at local station

DS = Local station disconnected from line

WD = Local station watchdog timed out

LE = Invalid parameters (locally detected)

LS = Unimplemented service at local station

2A.4.2.3.3.3 When generated. This confirmation is passed from the local PLC entity to the local PLC user to indicate the local success or failure of the previous associated send_data_with_no_acknowledge data transfer request.

2A.4.2.3.3.4 Effect of receipt. The effect of receipt of this confirmation by the local PLC user is unspecified.

2A.4.2.3.3.5 Additional comments. It is assumed that sufficient information is available to the local PLC user to associate this confirmation with the corresponding request.

2A.4.3 Request Data with Reply (RDR)

2A.4.3.1 Description of operation. The local PLC user requests data from a remote PLC user by a L_REPLY.request primitive passed to the local PLC entity over the PLC-user interface. The local PLC entity accepts this service request and sends a request for the data to the remote PLC entity. The local PLC entity provides a L_REPLY.confirm to the local PLC user with the requested data or a failure indication.

The remote PLC entity receives the request for data and immediately responds by transmitting a copy of data that had been previously submitted by the remote PLC user with an L_REPLY_UPDATE.request for the corresponding DSAP. The remote PLC user is informed of this reply transmission by an L_REPLY indication.

If a response is not received in a timely manner, the local MAC entity may make up to a predefined number of attempts to obtain the requested data. Between the original transmission of the request and the associated response, no other traffic occurs on the local area network.

The remote PLC user is responsible for maintaining valid data available to the remote PLC entity. The remote PLC user may make a L_REPLY_UPDATE.request to update the shared_data_area, and a L_REPLY_UPDATE.confirm is returned by the remote PLC after the update is complete. Note that the data updating procedures occur asynchronously to any data transfer requests.

2A.4.3.2 Definition of primitives at local user-PLC interface

2A.4.3.2.1 L_REPLY.request

2A.4.3.2.1.1 Function. This primitive is the service request primitive for the Request_Data_With_Reply (RDR) service.

2A.4.3.2.1.2 Semantics. The primitive shall provide parameters as follows:

L_REPLY.request
(SSAP,
DSAP,
remote_address,
L_sdu,
service_class)

The SSAP parameter specifies the link service_access point of the local user requesting the data.

The DSAP parameter specifies which shared_data_area is requested from the remote PLC and thus which remote user will receive the indication primitive.

The remote address parameter specifies the MAC address of the remote station, as defined in [Part 5D](#).

The link service data unit is **null**.

The service_class specifies the MAC priority of the request as specified in Part 5D. Recommended access class assignments for PROWAY systems are as follows:

MAC Priority	Access_class	Usage
Highest	6	Urgent messages, i.e., those performing critical alarm, interlock, and control coordination functions
	4	Normal control actions and ring maintenance functions
	2	Routine data gathering and display, and data base update functions
Lowest	0	File and program transfers

2A.4.3.2.1.3 When Generated. This primitive is passed from the local PLC user to the local PLC entity to request data from one remote PLC entity.

2A.4.3.2.1.4 Effect of Receipt. Receipt of this primitive causes the local PLC entity to request the data specified by the DSAP parameter using the request_data_with_response procedures.

2A.4.3.2.1.5 Additional Comments. The remote PLC user is responsible for maintaining valid data available to the remote PLC entity in the shared_data_area. This data has been previously transferred to the remote PLC entity by an L_REPLY_UPDATE.request primitive with an identical DSAP parameter. The underlying PLC entity must prevent the remote PLC user and the remote PLC entity itself from accessing (one writes while the other reads) the shared_data_area at the same time.

Only one SDA, SDN, or RDR request may be concurrently outstanding (i.e., awaiting a confirmation) for each invocation, as defined in Part 3B, of the local PLC entity supported by this station.

2A.4.3.2.2 L_REPLY.indication

2A.4.3.2.2.1 Function. This primitive is the service indication primitive for the request_data_with_reply service.

2A.4.3.2.2.2 Semantics. The primitive shall provide parameters as follows:

L_REPLY.indication
 (SSAP,
 DSAP,
 local_address,
 L_sdu,
 remote_address,
 service_class)

The SSAP parameter specifies the link service_access point of the local PLC user requesting the data.

The DSAP parameter specifies the remote PLC-user link service_access point that receives this indication. It also specifies which shared_data_area was transmitted as a response to an RDR frame.

The local_address and remote_address parameters specify the source_address and destination_address of the corresponding RDR frame.

The link service data unit is **null**.

The service_class parameter specifies the actual MAC priority of the corresponding RDR frame, as defined in Part 5D.

2A.4.3.2.2.3 When generated. This primitive is passed by the remote PLC entity to the remote PLC user when a shared_data_area is transmitted as a response to an RDR frame.

2A.4.3.2.2.4 Effect of receipt. The effect of receipt of this primitive on the remote PLC user is unspecified.

2A.4.3.2.3 L_REPLY.confirm

2A.4.3.2.3.1 Function. This primitive is the service confirmation primitive for the Request_Data_With_Reply service.

2A.4.3.2.3.2 Semantics. The primitive shall provide parameters as follows:

L_REPLY.confirm
 (SSAP,
 DSAP,
 remote_address,
 L_sdu,
 service_class,
 L_status)

The SSAP and DSAP parameters specify the local and remote user link service_access points involved in the data transfer service. They are identical to the SSAP and DSAP parameters of the corresponding L_REPLY.request primitive. In addition the DSAP identifies the remote shared_data_area whose contents are the L_sdu that accompanies this confirmation.

The remote_address specifies the destination_address parameter of the MA_DATA.confirmation primitive.

The L_sdu parameter identifies the data returned by the remote PLC entity.

The service_class parameter specifies the priority parameter of the MA_DATA.confirmation primitive.

The L_status parameter indicates the success or failure of the previous associated request_data_with_response data transfer request and whether any error condition is temporary or permanent.

The values that the Response_status component of the L_status parameter can assume are follows:

Code	Meaning	Temporary/ Permanent
OK =	Response L_sdu accepted	—
TE =	No response from remote station after specified retries (possibly due to a non-PROWAY station)	T
DS =	Local station disconnected from line	P
WD =	Local station watchdog timed out	P
IV =	Invalid parameters in request	P
RS =	Request for an unimplemented or unactivated service at remote DSAP: no action taken	P
LS =	Unimplemented service at local SSAP	P
UN =	Resources not available to remote PLC or MAC entity: no action taken	T
UE =	User-PLC interface error	P
PE =	Protocol error	T/P
IP =	Permanent implementation dependent error	P
IT =	Temporary implementation dependent error	T
NE =	Response L_sdu never submitted at destination	P

In Reference 3, Appendix I-A, an additional Command_status component of L_status may be present.

2A.4.3.2.3.3 When generated. This primitive is passed from the local PLC entity to the local PLC user to indicate the success or failure of the previous associated request_data _with_reply data transfer request and to pass the requested data if the transfer was successful.

2A.4.3.2.3.4 Effect of receipt. The effect of receipt of this primitive on the local PLC user is unspecified.

2A.4.3.2.3.5 Additional comments. The local PLC entity delivers either the requested data or the reason for failure to the local PLC user. If an error in transmission occurs, the local MAC entity will make up to a predefined number of requests for the data.

If L_status indicates a **Temporary** error, the local PLC-user entity may assume that a future retry of the associated request may be successful.

If L_status indicates a **Permanent** error, the local PLC-user entity should assume that management intervention may be required before a retry of the associated request may be successful.

It is assumed that sufficient information is available to the local PLC user to associate this confirmation with the corresponding request.

2A.4.3.2.4 L_REPLY_UPDATE.request

2A.4.3.2.4.1 Function. This primitive is the update_request primitive of the request_data_with_reply service.

2A.4.3.2.4.2 Semantics. The primitive shall provide parameters as follows:

L_REPLY_UPDATE.request

(DSAP,
L_sdu)

The DSAP parameter specifies the remote PLC-user link service_access point making this update_request and which shared_data_area is to be updated.

The L_sdu parameter specifies the new contents of the shared_data_area identified by the DSAP parameter.

2A.4.3.2.4.3 When generated. The primitive is passed by the remote PLC user to the remote PLC entity to request update of a shared_data_area.

2A.4.3.2.4.4 Effect of receipt. Receipt of this primitive causes the remote PLC entity to attempt to update the specified shared_data_area.

2A.4.3.2.4.5 Additional comments. The shared_data_area can be updated only if the remote PLC entity is not attempting to generate a response by accessing the same shared_data_area.

This primitive has significance only to the station containing the shared_data_area, i.e., the remote station.

2A.4.3.2.5 L_REPLY_UPDATE.confirm

2A.4.3.2.5.1 Function. This primitive is the update_confirmation primitive of the Request_Data_With_Reply service.

2A.4.3.2.5.2 Semantics. This primitive shall provide parameters as follows:

L_REPLY_UPDATE.confirm

(DSAP,
L_status)

The DSAP parameter specifies the remote PLC-user link service_access point that receives this update_confirmation and which shared_data_area was the subject of the attempted update.

The L_status parameter specifies success or failure of the corresponding update_request. The values that L_status can assume are

Code	Meaning
OK =	shared data area updated
TE =	shared data area busy and not updated

2A.4.3.2.5.3 When generated. This primitive is passed from the remote PLC entity to the remote PLC user to indicate success or failure of the corresponding L_REPLY_UPDATE.request.

2A.4.3.2.5.4 Effect of receipt. The effect of receipt of this primitive on the remote PLC user is unspecified.

2B. User-management interface and service specification

2B.1 Scope and field of application. This section specifies the administrative services related to layers 1 and 2 of the ISO reference model that are provided by the Management entity of each station at the PROWAY management interface between the user of PROWAY and that management entity. This standard specifies these services abstractly. It does not specify or constrain the implementation of entities or interfaces within a computer system. The relationship of this part to other parts of this standard and to LAN specifications is illustrated in Figure 2B-1.

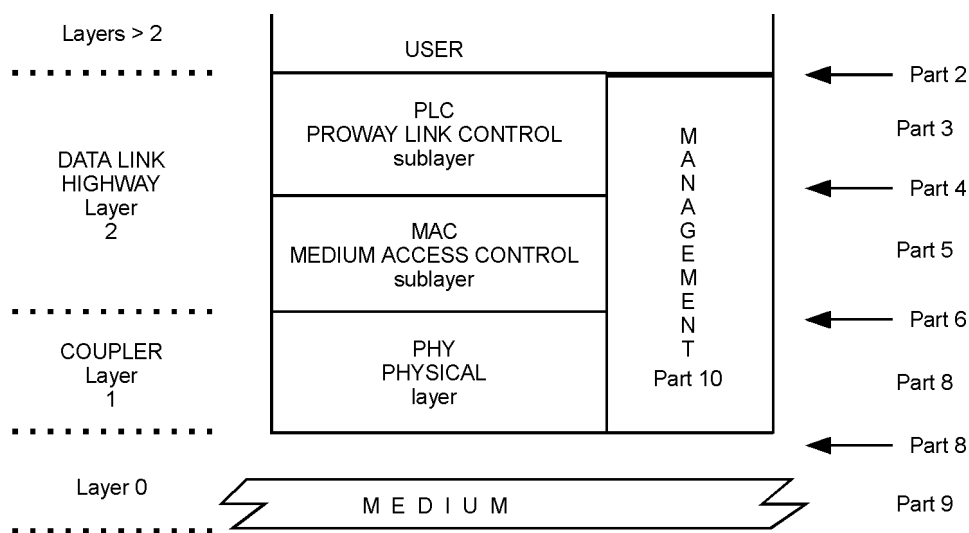


Figure 2B-1: Relationship to LAN model

2B.1.1 Mandatory features. The management functions described in Part 2B are mandatory if the corresponding PLC, MAC or PHY function is implemented. The specific primitives and codings given in Part 2B are subject to further study and harmonization with the work of the IEEE 802 committee.

2B.2 Overview of management services

2B.2.1 General description of services provided at the user-management interface

This section informally describes the L_MGMT services related to layers 1 and 2 of the ISO reference model provided to the user of PROWAY by each station's management entity. These services include the following:

- 1) changes in the configuration or status of the station
- 2) requests for information on token ring performance or membership
- 3) notifications of unsolicited changes in station or token ring status

- 4) request for the current value of PLC, MAC, or PHY entity parameters

The L_MGMT service has only local significance.

2B.2.2 Model used for the service specification. The model and descriptive method are given in [Reference 1, Appendix I-A](#).

2B.2.3 Overview of interactions. One set of primitives is provided at the user_management interface:

```
L_MGMT.request
    .confirm
    .indication
```

L_MGMT.request primitive is passed from the local user of PROWAY to the local management entity to request a change in the station's configuration or status or current information on token ring performance or membership.

L_MGMT.indication primitive is passed from the local management entity to a designated local user to indicate a change in station status or token ring membership.

L_MGMT.confirm primitive is passed from the local management entity to the local user of PROWAY to convey the results of the corresponding L_MGMT.request primitive and any requested information.

2B.3 Detailed specification of management interactions with the user of PROWAY

2B.3.1 L_MGMT.request

2B.3.1.1 Function. This primitive is the service request primitive of the L_MGMT service.

2B.3.1.2 Semantics. The primitive shall provide parameters as follows:

```
L_MGMT.request
(SSAP,
  code_type,
  arguments)
```

SSAP specifies the link service_access point of the entity requesting the corresponding L_MGMT service.

The code_type parameter can assume any one of the values shown in [Table 2-1](#).

The arguments are dependent upon the code_type chosen and are listed in Table 2-1 along with the corresponding code_type. The allowed format and range of values for each parameter are specified in Part 10B, 10C, or 10D, as appropriate.

2B.3.1.3 When generated. This primitive is passed from the local user of PROWAY to the local management entity to request a management action.

2B.3.1.4 Effect of receipt. Receipt of this primitive by the management entity causes the management entity to perform the requested action. This action may require the cooperation of the PLC, MAC, or PHY entity.

2B.3.1.5 Additional comments

2B.3.2 L_MGMT.confirm

2B.3.2.1 Function. This primitive is the service confirmation primitive of the L_MGMT service.

2B.3.2.2 Semantics. This primitive shall provide parameters as follows:

Table 2-1: Management request codes and arguments

Code_Type	Action Requested	Arguments
1	Return list of all stations participating in the token ring	None
2	Return value of PLC, MAC, or PHY parameter	L_user identifier, Parameter identifier, access_control information
3	Activate LSAP (except for RDR response component	SSAP, service activated at this SSAP, role in each service activated, maximum L_sdu length for each service activated
4	Activate RSAP (RDR response component of this LSAP	SSAP to receive L_REPLY.indications when a RDR request is received at this DSAP, DSAP associated with this shared_buffer_area, shared buffer_area identification (format is implementation dependent.)
5	Deactivate SAP	SAP
6	Enter line_disconnect state	None
7	Enter line_connect state	None
8	Enter configure state	None

L_MGMT.confirmation
(SSAP,
local_address,
code_type,
results,
Mgt_status)

SSAP specifies the link service_access point of the local user of PROWAY involved in the corresponding L_MGMT service.

Local_address specifies this station's MAC address as defined in [Part 5D](#).

Code_type can assume any of the values indicated in [Table 2.2](#).

Results provide information dependent on the code_type as listed in Table 2-2. The allowed range of values for each parameter is specified in Part 10B, 10C, or 10D, as appropriate.

Table 2-2: User-management confirmation codes and results

Code_Type	Action Attempted	Results
1	Return list of all stations participating in the token ring	Active_stations list. (format is implementation dependent)
2	Value of specified PLC, MAC, or PHY layer parameter	Status, parameter_value
3	Activate LSAP	Services activated at this SSAP, role in each active service, maximum L_sdu length for each service activated, shared buffer area identification, user to receive L_REPLY.indication
5	Deactivate SAP	SAP
6	Entry line_disconnect state	None
7	Entry line_connect state	None
8	Entry configure state	None

L_MGT_status indicates success or failure of the action requested in the corresponding L_MGMT.request. Mgt_status may assume the following values:

Code	Meaning
OK =	Requested action performed
CE =	Unimplemented code type
IP =	Invalid parameters
RJ =	Unable to perform requested action

2B.3.2.3 When generated. This primitive is passed from the local management entity to the requesting entity after the requested management operation is complete.

2B.3.2.4 Effect of receipt. The effect of receipt of this primitive on the user of PROWAY is unspecified.

2B.3.2.5 Additional comments. This primitive has local significance only.

2B.3.3 L_MGMT.indication

2B.3.3.1 Function. This primitive is the indication primitive of the L_MGMT service.

2B.3.3.2 Semantics. The primitive shall provide parameters as follows:

L_MGMT.indication

(SAP,
code_type)

SAP is the user notification service_access point of the entity that receives this service indication as defined in 3C.2.3.

Code_type specifies the change that has occurred. Table 2-3 itemizes each reported change.

Reason indicates the underlying cause of L_MGMT.indication.

Table 2-3: User-Management indication codes and reason

Code_Type	Associated Change	Reason
1	A change has occurred to the active stations list.	Defined in 10E
2	The station has entered the line_disconnect state spontaneously.	Defined in 10A

Additional changes to be reported are under study.

2B.3.3.3 When generated. This primitive is passed from the local management entity to the entity identified by the user_notification_SAP after the management entity has been notified of a change by the PLC, MAC or PHY layer.

2B.3.3.4 Effect of receipt. The effect of receipt of this primitive on the receiving entity is unspecified.

Appendix 2-A Overview of data highway operation

2-A.1 Organization of data highway overview. Figures 2-2 and 2-3 show the overall diagrams of the local and remote highway entities of a station that supports a single invocation of the local PLC entity. These figures show the combined actions of the PLC and MAC sublayers and the PHY layer as seen from the perspective of the local and remote users of PROWAY.

Figures 2-4 through 2-21 describe the operation of each service provided by the PROWAY data highway.

The description of each of the services begins with a topological and a sequential diagram which depicts the operation of the entire PROWAY data highway from the perspective of the PROWAY users. They are followed by example state diagrams for the local and remote users of this service. (These diagrams are included to clarify PROWAY_user interactions. They are not referenced in this standard.) The local and remote highway entity state diagrams show the operation of the Data Link (Highway) layer (PLC and MAC sublayers combined) as seen by the users of PROWAY. These diagrams show specific PLC-user and PLC-MAC interactions for this service.

The specifics of the PLC sublayer are given in [Part 3](#), while the specifics of the MAC sublayer are given in [Part 5](#).

In all highway state diagrams, the PLC states are identical to those of the same name defined in Part 3. In the topological diagrams, the solid arcs within PROWAY represent logical paths and the dotted lines represent frame transmissions. The value of the L_status parameter in a configuration depends on the logical path taken. In sequential diagrams, the time axis is shown as a pair of vertical lines with time increasing toward the bottom of the page and a malfunction indicated by an "X." All diagrams given in [Appendix 2-A](#) are for explanation only and are not a requirement of this standard. In case of conflict between Appendix 2-A and other parts of this standard, the other parts take precedence.

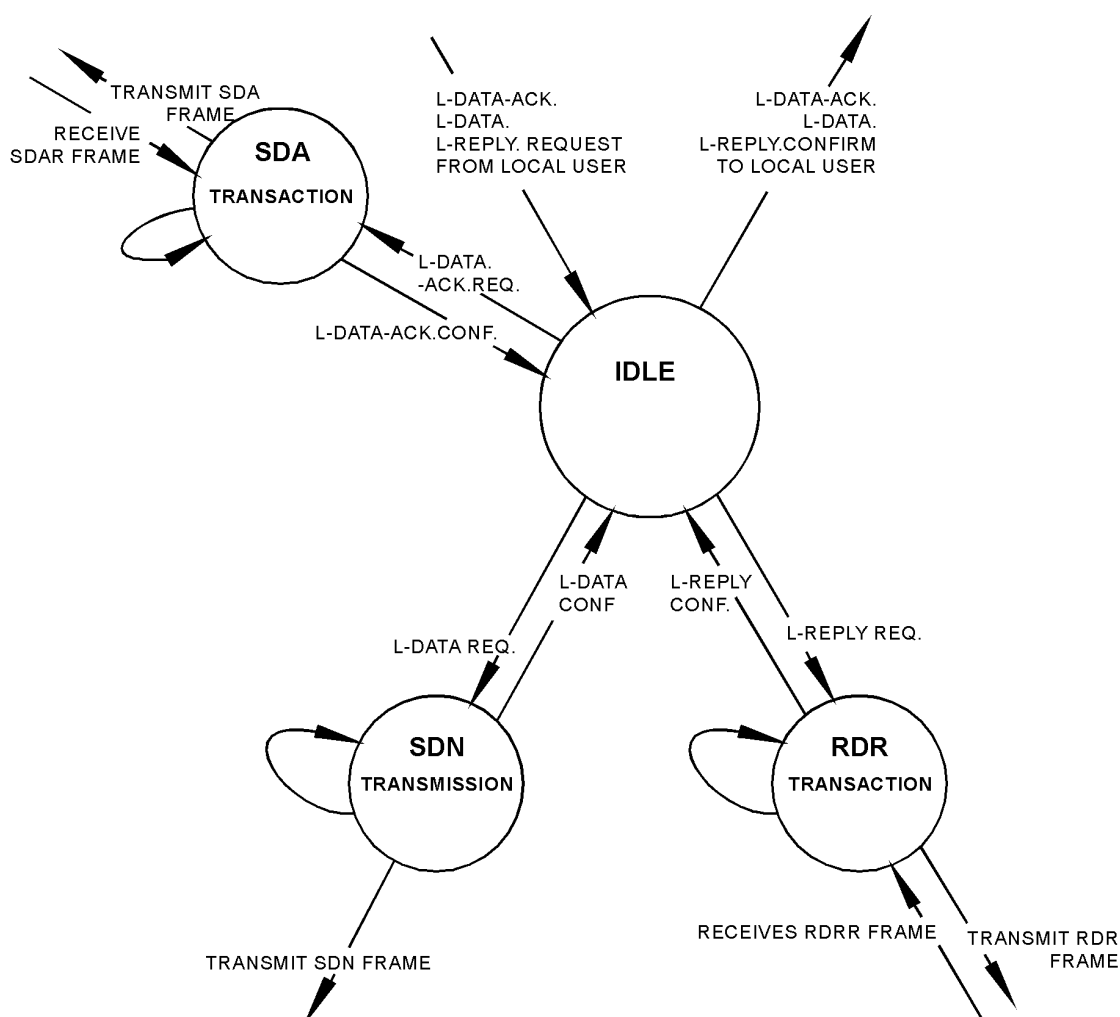


Figure 2-2: Local station interaction diagram

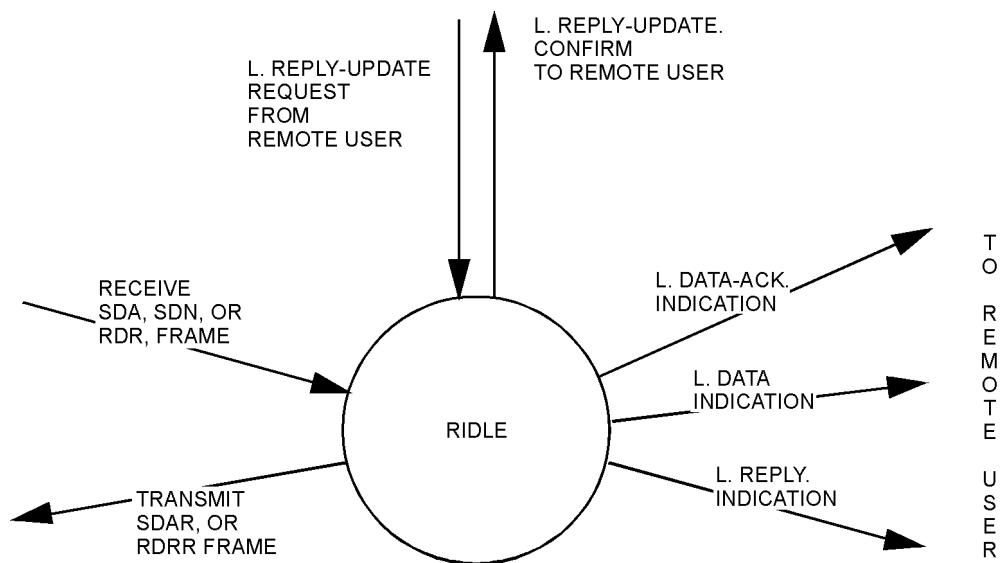


Figure 2-3: Remote station interaction diagram

2-A.2 Send Data with Acknowledge (SDA) service diagram

2-A.2.1 Topological and sequential relationships. The topological behavior of the send_data_with_acknowledge service is shown in Figure 2-4.

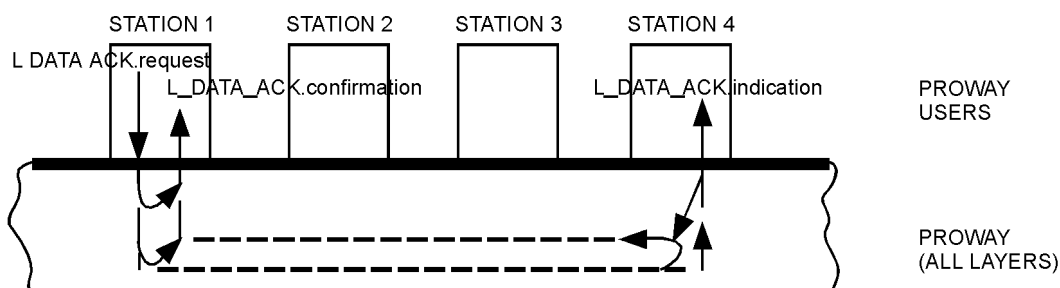


Figure 2-4: Topological behavior of the Send_Data_With_Acknowledge service

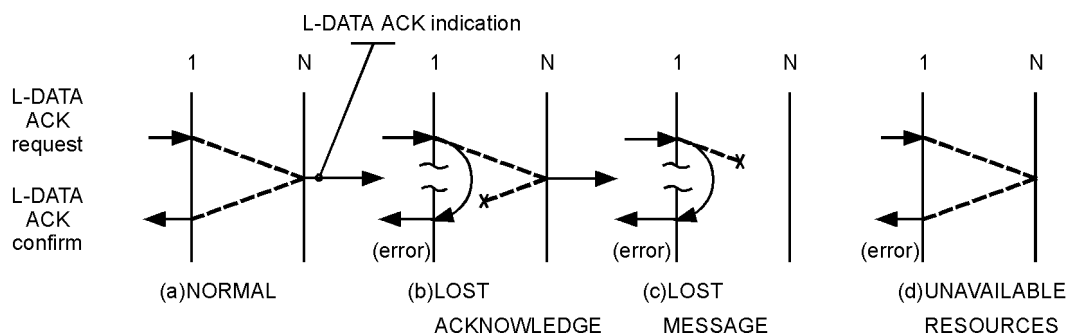


Figure 2-5: Sequential relationship of the Send_Data_With_Acknowledge service

2-A.2.2 Service state diagrams. The state diagrams for the send_data_with_acknowledge service are shown in Figures 2-6 through 2-9. Figures 2-6 and 2-7 show local and remote PLC-user state diagrams which indicate how PLC users interact at the PLC-user interface. Figures 2-8 and 2-9 show local and remote highway state diagrams to indicate how PROWAY processes the user service requests. Figures 2-8 and 2-9 correspond to sections of the overall highway entity state machines shown in Figures 2-2 and 2-3.

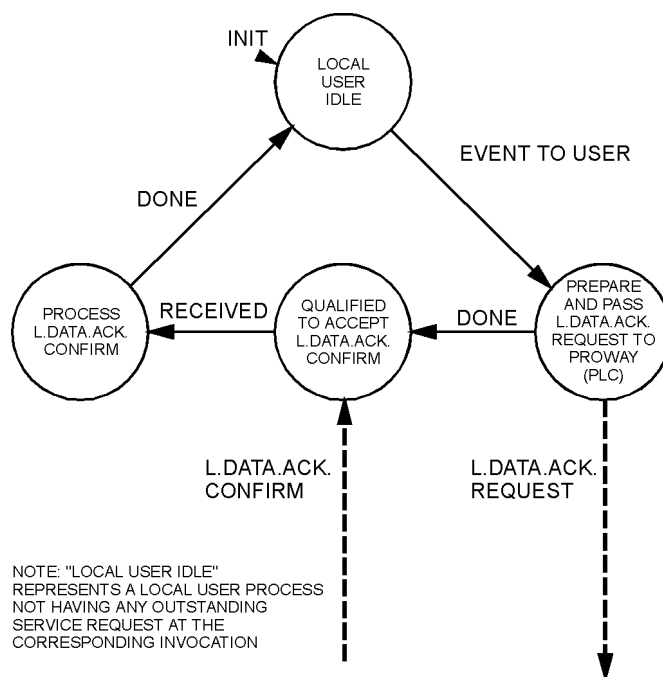


Figure 2-6: Local user state diagram for the Send_Data_With_Acknowledge service

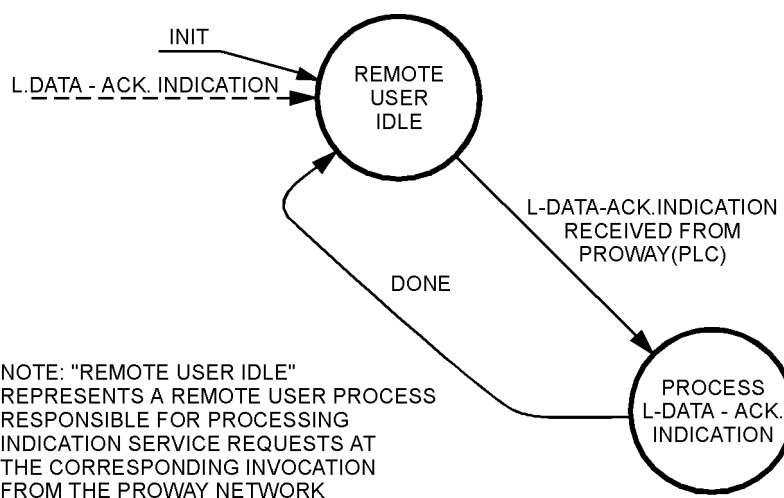


Figure 2-7: Remote user state diagram for the Send_Data_With_Acknowledge service

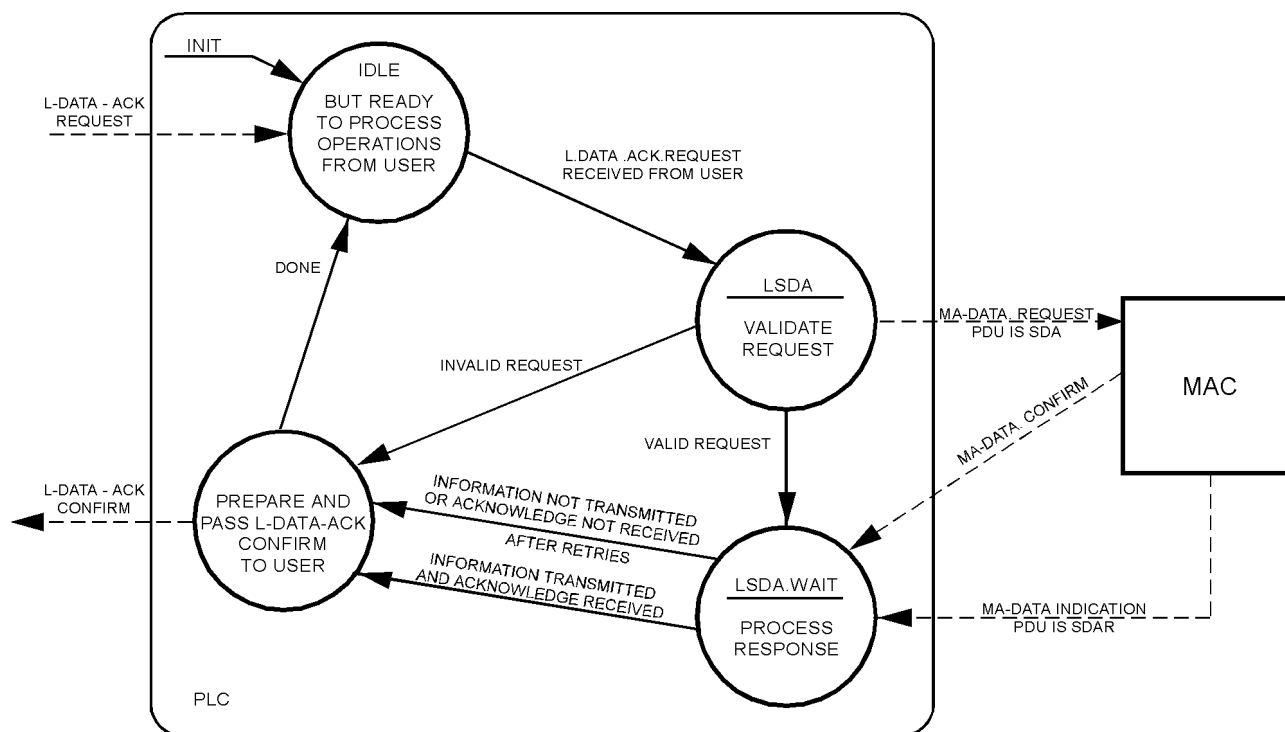


Figure 2-8: Local highway entity state diagram of the Send_Data_With_Acknowledge service

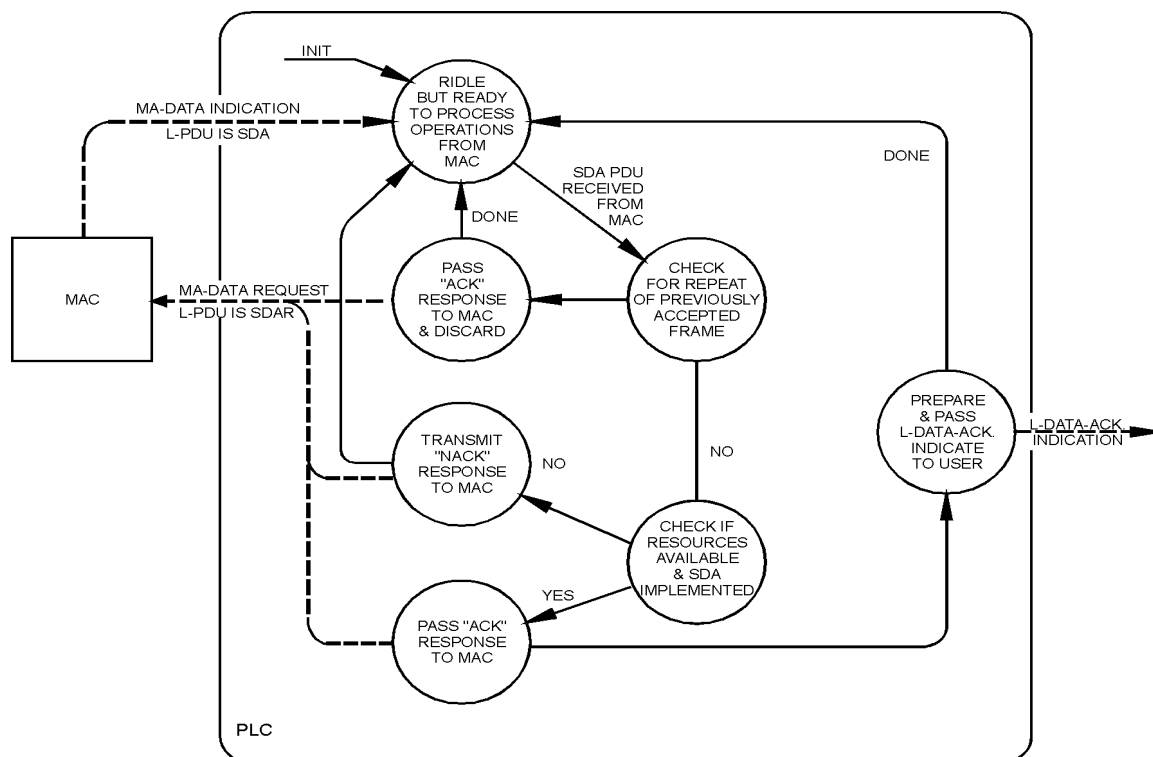


Figure 2-9: Remote highway entity state diagram for the Send_Data_With_Acknowledge service

2-A.3 Send Data with No Acknowledge (SDN) service diagram

2-A.3.1 Topological and sequential relationships. The topological behavior of the send_data_with_no_acknowledge service is shown in Figure 2-10.

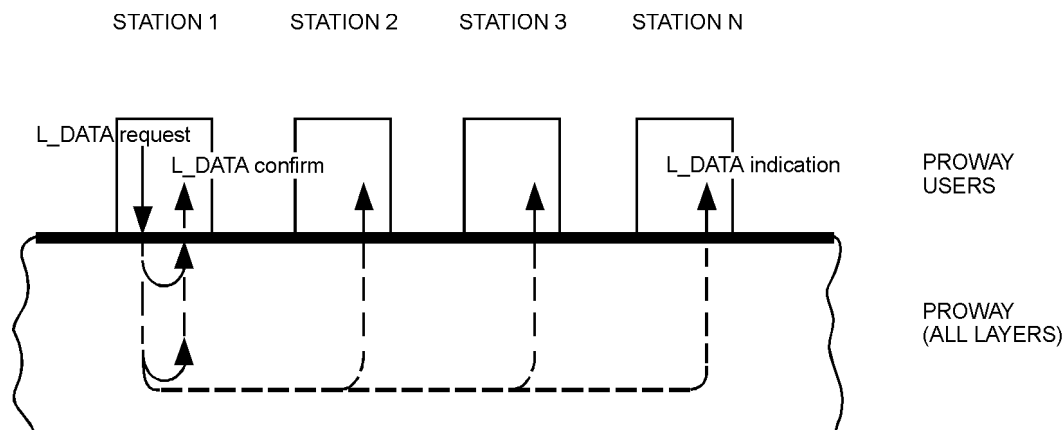


Figure 2-10: Topological behavior of the Send_Data_With_No_Acknowledge service

The sequential relationship of the Send_Data_With_No_Acknowledge service is shown in Figure 2-11.

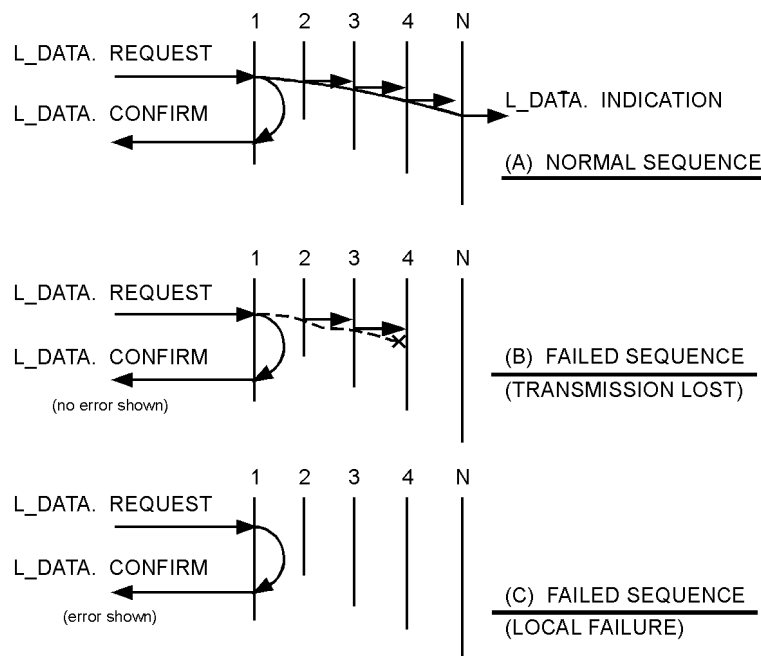


Figure 2-11: Sequential relationship of the Send_Data_With_No_Acknowledge service

2-A.3.2 Service state diagrams. The state diagrams for the send_data_with_no_acknowledge service are shown in Figures 2-12 through 2-15. Figures 2-12 and 2-13 show local and remote PLC-user state diagrams to indicate how the PLC-user interacts at the PLC-

user interface. Figures 2-14 and 2-15 show local and remote highway entity state diagrams to indicate how PROWAY processes the user service requests. These last diagrams correspond to sections of the overall highway entity state machines shown in Figures 2-2 and 2-3.

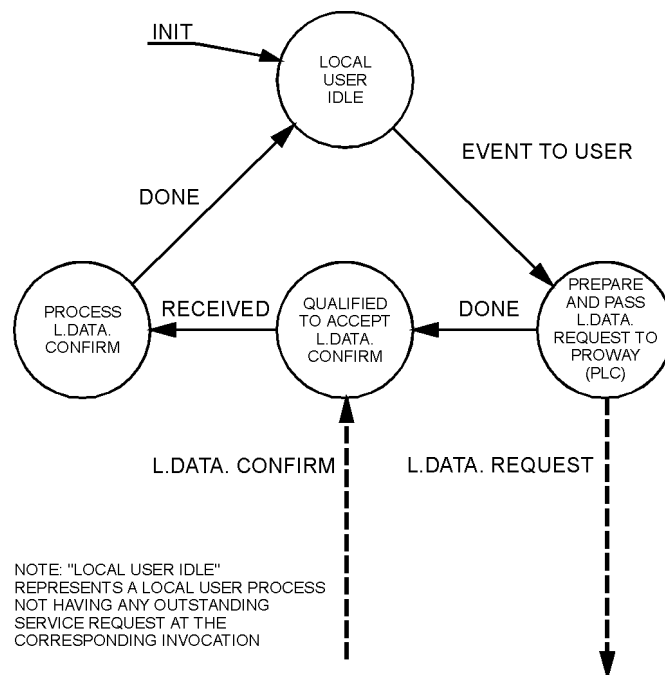


Figure 2-12: Local user state diagram for the Send_Data_With_No_Acknowledge service

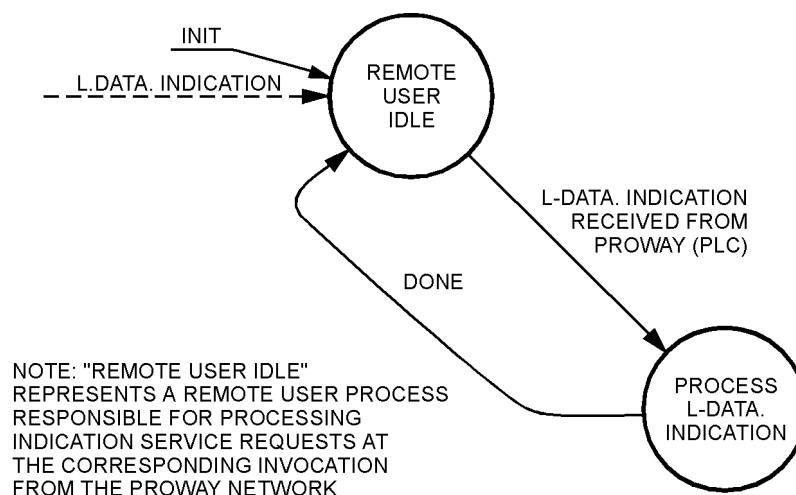


Figure 2-13: Remote user state diagram for the Send_Data_With_No_Acknowledge service

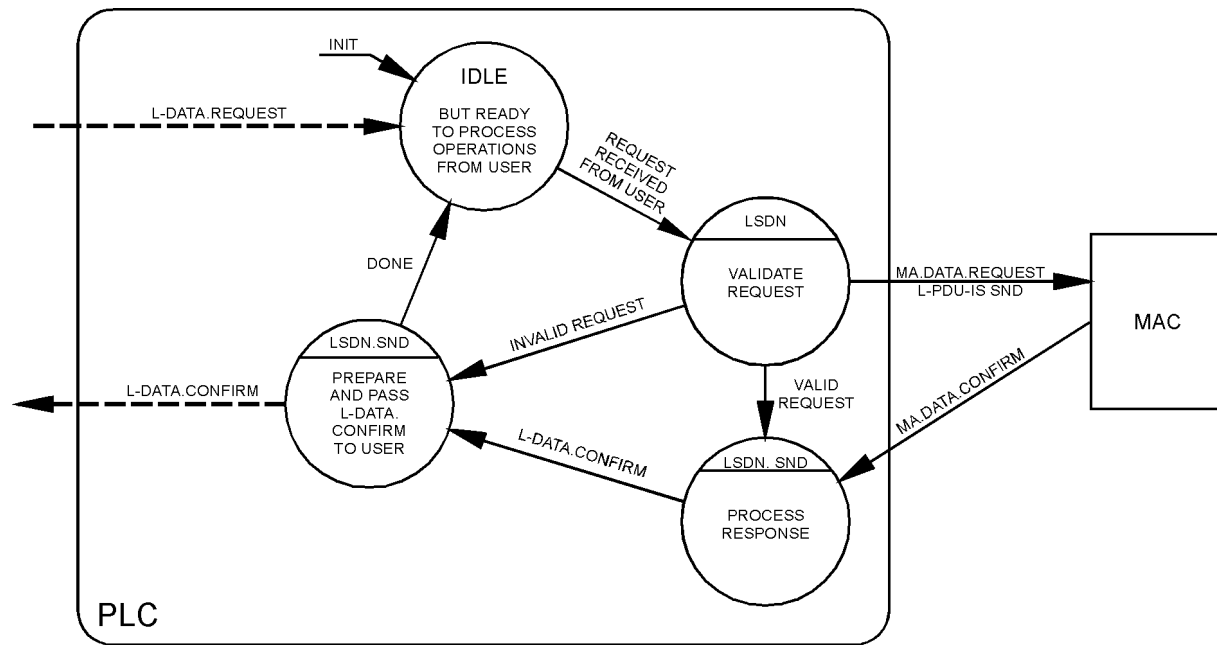


Figure 2-14: Local highway entity state diagram for the Send_Data_With_No_Acknowledge service

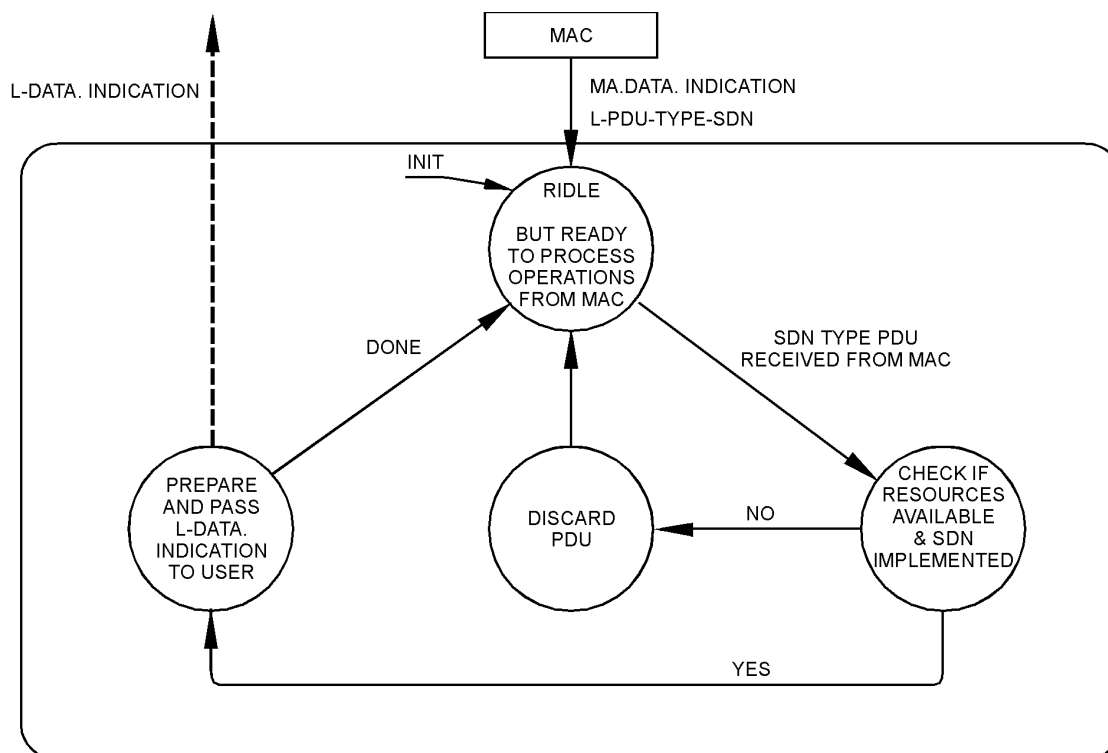


Figure 2-15: Remote highway entity state diagram for the Send_Data_With_No_Acknowledge service

2-A.4 Request Data with Reply (RDR) service diagram

2-A.4.1 Topological and sequential relationships. The topological behavior of the Request_Data_With_Reply service is shown in Figure 2-16.

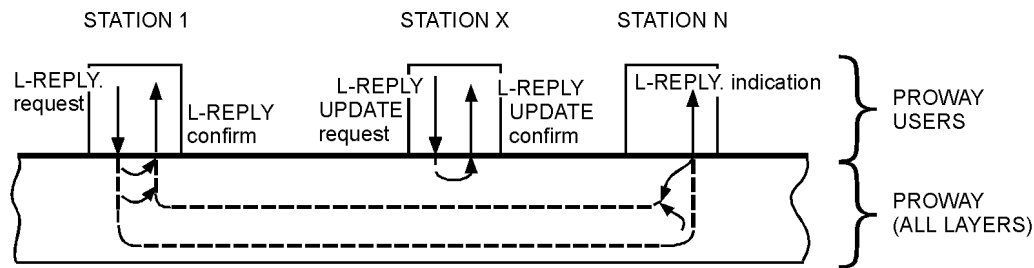


Figure 2-16: Topological behavior of the Request_Data_With_Reply service

The sequential relationship of the request_data_with_reply service is shown in Figure 2-17.

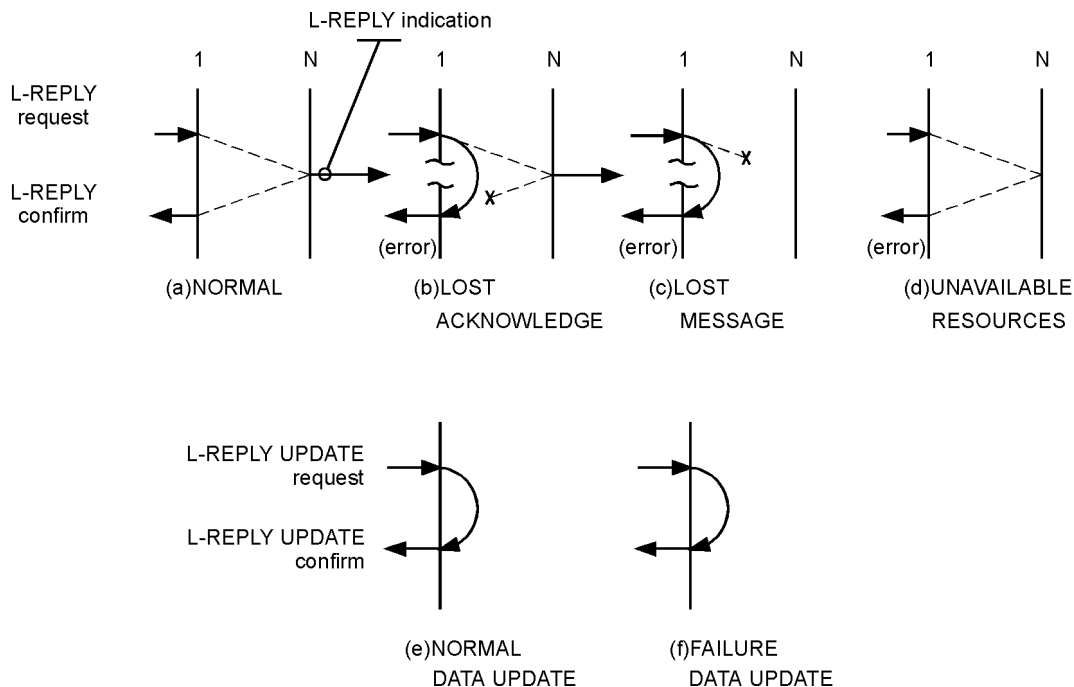


Figure 2-17: Sequential relationship of the Request_Data_With_Reply service

2-A.4.2 Service State Diagrams. The state diagrams for the request_data_with_reply service are shown in Figures 2-18 through 2-21. Figures 2-18 and 2-19 show local and remote PLC-user state diagrams to indicate how the user interacts at the PLC-user interface. Figures 2-20 and 2-21 show local and remote highway entity state diagrams to indicate how PROWAY processes the user service requests. These last diagrams correspond to sections of the overall highway entity state machines shown in Figures 2-2 and 2-3.