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National Transportation Communications for ITS Protocol Point-to-Point Protocol over RS-232 Subnetwork Profile

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FOREWORD

NTCIP 2103 v02, a standards publication, is also an NTCIP Subnetwork Profile. Subnetwork Profiles provide the rules and procedures for exchanging data over a single physical communications link by referring to one or more base standards. NTCIP 2103 v02 uses only metric units.

NTCIP 2103 v02 defines the rules and procedures for using the point-to-point protocol over RS-232 like circuits. NTCIP 2103 v02 defines requirements that are applicable to all NTCIP devices that exchange data over this type of communications circuit. NTCIP 2103 v02 also contains optional and conditional clauses that are applicable to specific environments for which they are intended.

There are three normative and three informative annexes in this document.

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Approvals

This standards publication was separately balloted and approved by AASHTO, ITE, and NEMA after recommendation by the Joint Committee on the NTCIP. Each organization has approved this standard as the following standard type, as of the date:

AASHTO—Standard Specification; May 2006
ITE—Software Standard; August 2006
NEMA—Standard; April 2006

History

In 1996, an agreement was executed among AASHTO, ITE, and NEMA to jointly develop, approve, and maintain the NTCIP standards. In August 1997, the Joint Committee on the NTCIP formed a new working group to develop communications profiles that were more modular in order to meet the varied needs of different communication environments. The Profiles WG first met in September 1997.

The first task of the NTCIP Profiles Working Group was to develop the overall structure of profiles. After research into how national and international standards organizations combine protocols and standards to address all seven layer of the OSI Basic Reference Model, the committee adopted the approach defined in NTCIP 8003. Following that approach, a protocol stack is specified by Information, Application, Transport, and Subnet profiles. An Information Profile defines the data that an end system is required to support. An Application Profile addresses the Application, Presentation, and Session Layers of the OSI Basic Reference Model. A Transport Profile addresses the Transport and Network Layers. A Subnet Profile addresses the Data Link and Physical Layers.

Once the rules for defining profiles were established, work began on a series of profiles for different environments, in order of their assigned priority by the NTCIP Joint Committee. Work on the *Subnet Profile for the Point-to-Point Protocol over RS-232 (SP-PPP)* began in June 1998. NTCIP 2103 v02 was previously referenced as TS 3.SP-PPP. However, in order to provide a more organized numbering scheme, NTCIP 2103 v02 is now the reference.

NTCIP 2103 v01.05. November 1999—Accepted as a User Comment Draft by the Joint Committee on the NTCIP. April 2000—NTCIP Standards Bulletin B0050 sent NTCIP 2103 to AASHTO, ITE, and NEMA for comment.

NTCIP 2103 v01.13. September 2001—Version 01.12 was accepted as a Recommended Standard by the Joint Committee on the NTCIP. February 2002—NTCIP Standards Bulletin B0069 sent version 01.13 to AASHTO, ITE, and NEMA for ballot.

NTCIP 2103 v01 to v02. The BSP2 WG drafted a major version revision, which included:
Subclause 1.3.1 Normative References
ANSI 574, RFC 1317, and the ITU-T standards V.90, V92, and V.250 were added.

Subclause 1.3.2 Other References
Several Internet references regarding modems were added.

Clause 2.2 Multilink Operations
A reference to the configuration of type 22 was deleted.

Subclause 2.2.7 Modem Configuration and Control Protocol; subclause was added.

Clause 2.3 Physical Layer Requirements and following subclauses
Significant information related to modems was added.
Miscellaneous tabled were reformatted.

Annex A PRL

Significant information related to modems was added.
RS232 Asynchronous and Interfaces Object Group were added.

Annex B PPP MIB; Header was added.

Annex D Modem MIB; MIB was added.

Annex F Typical Modem Dialogs; Dialogs were added.

NTCIP 2103 v02.04, January 2005—Accepted as a User Comment Draft by the Joint Committee on the NTCIP. June 2005—NTCIP Standards Bulletin B0102 sent NTCIP 2103 to AASHTO, ITE, and NEMA for comment.

NTCIP 2103 v02.06, December 2005—Accepted as a Recommended Standard by the Joint Committee on the NTCIP. January 2006—after editing front matter and v01-to-v02 changes, NTCIP Standards Bulletin B0110 referred v02.06b for balloting.

NTCIP 2103 v02.07, December 2008—Prepared standard for publication; edited format, front matter, and style.

Compatibility of Versions

To distinguish NTCIP 2103 v02 (as published) from previous drafts, NTCIP 2103 v02 also includes NTCIP 2103 v02.07 on each page header. All NTCIP Standards Publications have a major and minor version number for configuration management. The version number syntax is "v00.00a," with the major version number before the period, and the minor version number and edition letter (if any) after the period.

NTCIP 2103 v02 is designated, and should be cited as, NTCIP 2103 v02. Anyone using NTCIP 2103 v02 should seek information about the version number that is of interest to them in any given circumstance. The MIB, the PRL, and the PICS should all reference the version number of the standards publication that was the source of the excerpted material.

Compliant systems based on later, or higher, version numbers MAY NOT be compatible with compliant systems based on earlier, or lower, version numbers. Anyone using NTCIP 1104 should also consult NTCIP 8004 v01 for specific guidelines on compatibility.

INTRODUCTION

NTCIP 2103 v02 defines a subnetwork profile that is a combination of standards intended to meet specific requirements for data transfers to and from processors in direct-connect or circuit-switched environments. The purpose of NTCIP 2103 v02 is to provide the information necessary to establish a connection using the Point-to-Point Protocol (PPP) via an RS-232 interface and/or a dial-up modem. This profile is a subnetwork specification and uses protocols and standards to address the Physical and Data Link Layers (i.e., Layers 1 and 2 of the OSI Basic Reference Model). NTCIP 2103 v02 can be used in combination with a variety of upper layer protocols. NTCIP 2103 v02 is a subnet profile for use in center-to-roadside and center-to-center communications.

NTCIP 2103 v02 contains mandatory requirement statements that are applicable to all devices claiming conformance to NTCIP 2103 v02. It also contains options and conditional requirements, which may be applicable to a specific environment in which a device is used.

The following keywords apply to NTCIP 2103: AASHTO, Dial-up, ITE, NEMA, NTCIP, PPP, Point-to-Point, RS-232, Subnetwork Profile.

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Section 1 GENERAL

1.1 Scope

NTCIP 2103 v02 is applicable to transportation related devices that operate in a point-to-point configuration where exactly two devices (called peers) are connected by a logical Physical Layer communications link. As a subnetwork profile, NTCIP 2103 v02 specifies a set of protocols and standards applicable to the Data Link and Physical layers of the Open Systems Interconnect (OSI) Basic Reference Model. The Subnet Profile for the Point-to-Point Protocol over RS-232 is intended to provide an interoperability standard for the Physical and Data Link Layer aspects of communications in transportation related devices for dialed-up circuits.

The protocol stack described in NTCIP 2103 v02 is appropriate for the reliable exchange of data between processing equipment on switched data networks. The primary feature of this profile is reliable data transfer with security between directly connected devices.

1.2 Scenario

The OSI Basic Reference Model defines seven layers within a communications stack, each performing a particular role in the transmission of data over a medium. Communication standards typically relate to one or more portions of the OSI Model.

NTCIP 8003 defines how to combine base standards to produce a variety of *profile* standards. Profile standards reference base standards and may restrict options within the base standards in order to encourage the development of fully compatible implementations. NTCIP 2103 v02 is a Subnet Profile, which is defined to be a combination of standards specifying the requirements for the first two layers of the OSI Basic Reference Model.

The first layer, the Physical Layer, deals with how the bits of information are transmitted over a communications channel. This layer deals with the mechanical and electrical interfaces, and the physical transmission medium.

The second layer, the Data Link Layer, has the task of transforming the information that came in over the wire into data that appears to be free of transmission errors. This layer should incorporate mechanisms to ensure the integrity of the data and provide a method of ensuring that no data is lost.

This subnet profile is based on the Point-to-Point Protocol over an RS-232 or dial-up modem link. The profile provides a peer-to-peer relationship between the connected devices. The profile requires full-duplex circuits and is independent of the bit rate of the circuit. SPs do not address higher layer functionality such as routing, segmentation, and re-transmission of data packets, nor is it concerned with the application(s) residing in the device.

This Subnet Profile provides a mechanism to identify higher layer protocols by means of the PPP Protocol Field. This provides a mechanism to permit "multiplexing" messages generated by multiple protocols using a single communications link. The values for the Protocol Field are assigned internationally by the Internet Assigned Numbers Authority (IANA, www.iana.org).

The layers, base standards, and profile taxonomy that make up this profile are shown in Figure 1. The Data Link Layer is defined by a variety of standards specifying various sub-layer components.

ISO LAYERS	BASE STANDARDS		PROFILE
DATA LINK LAYER	(Network configuration)	RFC 1332 (IPCP) NTCIP 2201 (T2 Profile)	PPP - Subnet Profile
	(authentication)	RFC 1994 (CHAP)	
	(DL configuration & multiplexing)	RFC 1570 (LCP Extensions) RFC 1661 (PPP)	
	(framing)	RFC 1662 (HDLC-Like Frame)	
PHYSICAL LAYER	ANSI/TIA/EIA-232-F and/or ITU-T V.34		

Figure 1 Subnet Profile for PPP Scenario

1.3 References

The following standards (normative references) contain provisions that, through reference in this text, constitute provisions of NTCIP 2103 v02. Other documents and standards (other references) are referenced in these documents, which might provide a complete understanding of the entire protocol and the relations between all parts of the protocol. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on NTCIP 2103 v02 are encouraged to investigate the possibility of applying the most recent editions of the standard listed below.

1.3.1 Normative References

ANSI/TIA/EIA-232-F-1997	<i>Interface Between Data Terminal Equipment and Data Circuit-Termination Equipment Employing Serial Binary Data Interchange</i>
ANSI/TIA/EIA-574-90	<i>9-Position Non-Synchronous Interface between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange</i>
RFC 1317	<i>Definitions of Managed Objects for RS-232-like Hardware Devices</i>
RFC 1321	<i>The MD5 Message-Digest Algorithm</i>
RFC 1332	<i>The PPP Internet Protocol Control Protocol (IPCP)</i>
RFC 1381	<i>SNMP MIB Extension for the X.25 Packet Layer</i>
RFC 1570	<i>PPP LCP Extensions</i>
RFC 1659	<i>Definitions of Managed Objects for RS-232 like Hardware Devices using SMIv2</i>
IAB STD 51	<i>RFC 1661, The Point-to-Point Protocol (PPP) RFC 1662, PPP in HDLC-like Framing</i>
RFC 1994	<i>PPP Challenge Handshake Authentication Protocol (CHAP)</i>
RFC 2153	<i>PPP Vendor Extensions</i>
ITU-T V.34	<i>A modem operating at data signaling rates of up to 33 600 bit/s for use on the general switched telephone network and on leased point-to-point 2-wire telephone-type circuits</i>
ITU-T V.90 (1998)	<i>A digital modem and analogue modem pair for use on the Public Switched Telephone Network (PSTN) at data signaling rates of up to 56 000 bit/s downstream and up to 33 600 bit/s upstream.</i>
ITU-T V.92 (2000)	<i>Enhancements to Recommendation V.90</i>

ITU-T V.92 Amendment1 (2001)	<i>Amendment 1 to Recommendation V.92 - Enhancements to Recommendation V.90</i>
ITU-T V.250 (5/99)	<i>SERIES V: DATA COMMUNICATION OVER THE TELEPHONE NETWORK- Control procedures - Serial asynchronous automatic dialing and control</i>

NOTE—A V.34 modem may work on either switched telephone and/or leased lines.

1.3.2 Other References

AASHTO / ITE / NEMA *Transportation Transport Profile*
NTCIP 2201:2003 published September 2005

AASHTO / ITE / NEMA *Internet (TCP/IP and UDP/IP) Transport Profile*
NTCIP 2202:2001 published December 2001

AASHTO / ITE / NEMA *NTCIP Guide*
NTCIP 9001 v03 published October 2002

AASHTO / ITE / NEMA *Profiles Framework*
NTCIP 8003

RFC 1663 *PPP Reliable Transmission*

RFC 1717 *The PPP Multilink Protocol (MP)*

RFC 2125 *The PPP Bandwidth Allocation Protocol (BAP) / The PPP Bandwidth Allocation Control Protocol (BACP)*

ISO/IEC 3309:1993 *Information technology -- Telecommunications and information exchange between systems -- High-level data link control (HDLC) procedures -- Frame structure*

ISO/IEC 4335:1993 *Information technology -- Telecommunications and information exchange between systems -- High-level data link control (HDLC) procedures -- Elements of procedures*

The following are additional informative references that may be helpful in further understanding the operations and requirements of current state-of-the-art modems.

The Hayes Modem Technical Reference Manual, 1990
<http://www.totse.com/en/technology/telecommunications/trm.html>, 10/14/04

Modem Initialization Strings, <http://www.modemhelp.org/inits/>, 10/14/04

An Overview of Analog Dialup Modem Performance, Environments, and Impairments. Compaq Computer Corporation Communication Products Division, Revised 7/20/98,
<ftp://ftp.compaq.com/pub/supportinformation/papers/prt005a0798.doc> , 8/9/02

1.3.3 Contact Information

1.3.3.1 NTCIP Standards

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for FTP sites, read <ftp://ftp.isi.edu/in-notes/rfc-retrieval.txt>

1.4 Terms

For the purposes of NTCIP 2103 v02, the following terms and definitions apply. For terms not defined in this clause, English words are used in accordance with their definitions in the latest edition of *Webster's New Collegiate Dictionary*. Electrical and electronic terms not defined in this clause or in *Webster's New Collegiate Dictionary* are used in accordance with their definitions in Institute of Electrical and Electronic Engineers (IEEE) Std 100-1996.

authentication	The process whereby a message is associated with a particular originating entity.
bit	Binary Digit. A single basic computer signal consisting of a value of 0 or 1, off or on.
byte	A group of bits acted upon as a group, which may have a readable ASCII value as a letter or number or some other coded meaning to the computer. It is commonly used to refer to 8-bit groups.
data	Information before it is interpreted.
Data Link Layer	That portion of an OSI Basic Reference Model (Layer 2) responsible for flow control, framing, synchronization and error control over a communications link.

datagram	A self-contained unit of data transmitted independently of other datagrams.
data packet	Another term for “information field” (as used within NTCIP 2103 v02). This term is mainly used with Network Layer Protocol describing all information that is passed from the Network Layer to the Data Link Layer.
Intelligent Transportation Systems (ITS)	A major national initiative to improve information, communication and control technologies in order to improve the efficiency of surface transportation.
Internet	A large collection of connected networks, primarily in the United States, running the Internet suite of protocols. Sometimes referred to as the <i>DARPA Internet</i> , <i>NSF/DARPA</i> , <i>Internet</i> , or the <i>Federal Research Internet</i> .
Internet Protocol (IP)	The network protocol offering a connection-less mode network service in the Internet suite of protocols.
IP address	A 32-bit quantity used to represent a point of attachment in an internet.
MD5 Hashing Algorithm	A hashing algorithm defined by the Internet Engineering Task Force (IETF) in RFC 1321. The algorithm is used to provide authentication services. It allows a system to challenge another system with a random string of characters. The receiving system appends a “secret” (i.e., a previously agreed code) to the challenge, along with other defined information in order to produce a 16-byte code. This new code is passed back to the challenging system and is verified. Experience has proven that it is very difficult for a third party to reverse engineer the secret, even if the third party observes a large number of valid challenges and responses.
network	A collection of subnetworks connected by intermediate systems and populated by end systems.
Network Layer	That portion of an OSI Basic Reference Model (Layer 3) responsible for data transfer across the network, independent of both the media comprising the underlying subnetworks and the topology of those subnetworks.
Physical Layer	That portion of an OSI Basic Reference Model (Layer 1) responsible for the electrical and mechanical interface between communicating systems.
point-to-point	A form of communications where data is transmitted between two devices without any other devices existing on the communication circuit.
proforma	A guide provided in advance to prescribe form or describe items.
protocol	A system of rules and procedures governing communications between two devices. File transfer protocols in a communications program refer to a set of rules governing how error checking is performed on blocks of data.
reserved	Reserved for future designation by the NTCIP standards effort.
Simple Network Management Protocol (SNMP)	A communications protocol developed by the IETF, used for configuration and monitoring of network devices.
Simple Transportation Management Framework (STMF)	Describes the organization of the information within devices and the methods of retrieving or modifying any information within the device. STMF also explains how to generate and use computer readable information organization descriptions.
subnet	A physical network within a network. All devices on a subnetwork share a common physical medium.
subnetwork	See subnet.

Subnetwork Profile	A suite of protocols combined in a profile that specifies the lower layers of the OSI Basic Reference Model. The only layers addressed within the SP are the Physical and the Data Link layer.
Transport Layer	That portion of an OSI Basic Reference Model (Layer 4) which attempts to guarantee reliable data transfers between two end-systems, using flow control and error recovery, and may provide multiplexing.

1.5 Abbreviations and Acronyms

For the purposes of NTCIP 2103 v02, the following acronyms apply.

ACCM	Asynchronous Control Character Map
bps	Bits per Second
CCITT	International Telegraph and Telephone Consultative Committee, now being referred to as ITU
CHAP	Challenge-Handshake Authentication Protocol
DARPA	Defense Advanced Research Projects Agency
DCE	Communications Equipment (i.e. modem)
DTE	Data Terminal Equipment (i.e. computer)
FCS	Frame Checking Sequence
FTP	File Transfer Protocol
HDLCL	High Level Data Link Control Protocol
IAB	Internet Activities Board
IANA	Internet Assigned Numbers Authority
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPCP	Internet Protocol Control Protocol
IPI	Initial Protocol Identifier
LCP	Link Control Protocol
MD5	Message Digest 5
MIB	Management Information Base
MRU	Maximum Receive Unit
NCP	Network Control Procedure
NEMA	National Electrical Manufacturers Association
NTCIP	National Transportation Communications for ITS Protocol
NTCITS IPI	National Transportation Communications for ITS Initial Protocol Identifier. This is the acronym that was recorded by IANA for the original NTCIP protocol identifier within PPP; due to the restructuring of NTCIP documentation; this now equates to the IPI for T2.
OSI	Open Systems Interconnection
PICS	Profile Implementation Conformance Specification
PPP	Point-to-Point Protocol
PRL	Profile Requirements List
RFC	Request for Comments
SNMP	Simple Network Management Protocol
SP	Subnetwork Profile

STD	Standard
STMF	Simple Transportation Management Framework
T2	Transportation Transport (Profile)
TCP	Transport Control Protocol
UDP	User Datagram Protocol

Section 2 CONFORMANCE

2.1 General Requirements

A Profile is a standard that combines one or more base standards and selects appropriate options or functions within them. A profile does this by referencing the base standard or standards and not by repeating the referenced text. A base standard may be a "standard" or another profile that references standards.

Combining standards into standardized profiles provides a number of benefits. Profiles can be used to specify major functional elements of a system that meets an end-user's specific needs. This enables system specifiers, implementers, and procurement agents to specify and quantify products or the functions of a product in terms of the desired needs, not the technical details. This abstraction allows a more general functional view.

The definition of a profile is used to:

- a) Document the functional requirement and the scenario in which they are required.
- b) Select the appropriate base standard(s).
- c) Select any appropriate sets of options or subsets from the base standards or profiles.
- d) Combine compatible base standards, by reference, to create a profile that meets a specific set of requirements.

Implementations claiming conformance to NTCIP 2103 v02 shall support the following elements as stated:

- a) All requirements in the remainder of this Section.
- b) All of the constraints specified in Annex A, Annex B, and Annex D (normative).
- c) All mandatory requirements of the standards referenced by this profile (unless specifically indicated otherwise in this profile).

2.2 Data Link Layer Requirements

The Data Link Layer for the Point-to-Point Protocol Profile is divided into a variety of sub-layers as follows:

- a) Network Control Protocol (NCP) for Internet Protocol (IP)
- b) Challenge-Handshake Authentication Protocol (CHAP)
- c) Link Control Protocol (LCP)
- d) Point-to-Point Protocol (PPP)
- e) High Level Data Link Control Protocol (HDLC)-Like Framing
- f) Modem Configuration and Control Protocol

Except for modem control and configuration, all data exchanged over the link shall be placed into a PPP packet (see Section 2.2.5, which shall be contained within an HDLC-Like Frame (see Section 2.2.6). Before any information is sent over the link, a connection must be made. If the communication is through a dial-up modem, a simple ASCII character stream is used to configure and setup the connection. Once the connection is made, the link shall be established through the use of LCP (see Section 2.2.4). Implementations conforming to this profile shall then authenticate the peer using CHAP (see Section 2.2.3). Finally, before any end-application data is exchanged, the implementation shall configure the chosen transport profile through the use of the appropriate NCP (see Section 2.2.1 and Section 2.2.2). An

implementation shall implement at least one of the transport profiles referenced within this section.

2.2.1 Network Control Protocol for Transportation Transport Profile

Implementations may exchange Transportation Transport (T2) Profile packets directly over PPP. Support for T2 Profile packets is optional, but if implemented shall conform to the requirements in this section.

NOTE—It is envisioned that most implementations are not bandwidth constrained and therefore use the Internet Transport Profile to be as consistent as possible with computer industry standards; however, the Transportation Transport Profile is defined for completeness.

2.2.1.1 General

Before any T2 Profile packets may be communicated, PPP must reach the Network-Layer Protocol phase. The Network Control Protocol for the T2 Profile, known as the T2 Control Protocol, is a null protocol and shall always be considered to be in the Opened state.

2.2.1.2 Sending T2 Profile Data Packets

Exactly one T2 Profile packet is encapsulated in the Information field of PPP Data Link Layer frames where the Protocol field indicates type 0x00C1 (NTCITS IPI).

The maximum length of a T2 Profile packet transmitted over a PPP link is the same as the maximum length of the Information field of a PPP data link layer frame. Larger packets must be embedded into a Transport Profile that supports fragmentation and reassembly.

2.2.2 Network Control Protocol for IP

If an implementation supports the exchange of IP packets over PPP, the implementation shall conform to the requirements in this clause.

Before exchanging any IP datagrams, PPP must send Internet Protocol Control Protocol (IPCP) packets to configure the IP layer.

2.2.2.1 IPCP General Procedures

There are no additional requirements to the IPCP General Procedures as defined in Clause 2 of RFC 1332.

2.2.2.2 IPCP Configuration Options

There are two IPCP options that may be applicable to this profile. Use of the IP-Addresses Option is not allowed by this profile as it has been deprecated in RFC 1332 by the IP-Address option as indicated below.

2.2.2.2.1 IP Compression Protocol Option

The IP-Compression-Protocol option allows the use of Van Jacobson Compression on the link. This compression algorithm is processor intensive and is not recommended for links with field devices, but may be useful for center-to-center dial-up links. If implemented, there are no additional requirements to the requirements defined in Clauses 3.2 and 4 of RFC 1332.

NOTE—This is an exception to RFC 1332. RFC 1332 recommends the use of this option (and thus would normally be translated as mandatory within NTCIP 2103 v02); however, NTCIP 2103 v02 recommends against this option for field devices and is silent as to its use for centers.

2.2.2.2.2 IP-Address Option

The IP-Address option allows negotiation of the IP address to be used on the local end of the link. An implementation conforming to this profile shall support and may use this option, as defined in Clause 3.3 of RFC 1332.

2.2.3 Challenge Handshake Authentication Protocol

LCP allows a PPP implementation to negotiate an Authentication Protocol for authenticating its peer. This profile requires support for CHAP. CHAP uses a random challenge, with a cryptographically hashed response that depends upon the challenge, the challenge identifier, and a secret key.

Implementations claiming compliance to NTCIP 2103 v02 shall conform to all of the requirements for CHAP as specified in RFC 1994. In addition, this profile places several restrictions on the implementation of this protocol as defined below.

2.2.3.1 Packet Format

There are no additional requirements to the Packet Format (and associated procedure) requirements as defined in Clause 4 of RFC 1994.

2.2.3.2 Name

The name field shall be used as an index to locate the proper secret in a table of secrets. This makes it possible to support more than one name/secret pair per system, and to change the secret in use at any time during the session.

For field devices, the names and secrets shall be stored as SNMP objects as defined in Annex B.

2.2.3.3 Secret

The secret shall be at least 16 octets long according to the recommended practice indicated in Clause 2.3 of RFC 1994 and shall be distinct for each direction of the PPP link.

For field devices, the names and secrets shall be stored as SNMP objects as defined in Annex B.

2.2.3.4 Hashing Algorithm

LCP allows the negotiation of a hashing algorithm. All implementations conforming to this profile shall support the Message Digest 5 (MD5) hash algorithm. There are no additional requirements to the MD5 hash algorithm requirements as defined in RFC 1321.

2.2.3.5 Timing of Challenges

There are no additional timing requirements to those defined in RFC 1994. Implementations shall challenge the other device during link establishment. Implementations shall be prepared to receive a challenge at any time after the link has been established.

2.2.4 Link Control Protocol

The Data Link Layer is managed through the use of the Link Control Protocol (LCP). Management includes:

- a) establishing and terminating the link
- b) negotiating various options for the link