LON® bus
LonWorks™ Network in Protection and Control Systems

User´s manual and Technical description

ABB

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LON® bus LonWorks™ Network in Protection and Control Systems

Contents

Introduction

This document describes the use of LonWorks Network and its protocol LonTalk protocol in our protection and control systems used in medium or high voltage substations, power stations or in industrial power distribution.

The LonTalk protocol is designed for communication in control networks. These networks are characterized by short messages (few bytes), very low per node cost, multiple communication media, low bandwidth, low maintenance, multivendor equipment, and low support costs. It is also desined to support the needs of applications spanning a range of industries and requirements.

The protocol follows the reference mode for open system interconnection (OSI) designed by the International Standardization Organization (ISO).

The speed of the network is dependent upon the medium and tranceiver design. With protection and control devices we are using fiber optic media, which enables use of the maximum speed of 1,25 Mbits/s. The protocol is a peer-to-peer protocol where all the devices connected to the network can talk to each other. The nodes are identified by their own subnet and node number (max. 255 subnets, 127 nodes per one subnet).

The LON bus links together the different parts of the protection and control system. The measured values, status information and event information is spontaneously sent to the higher-level devices. The higher-level devices can read and write memorized values, setting values and other parameter data when required. Additionally the LON bus enables the bay level devices to talk to each other in order to deliver e.g. interlocking information between the bay controllers and blocking signals between the protective relays.

The LonTalk protocol supports two types of application layer objects: network variables and explicit messages. Network variables are used to deliver short messages like measurement values, status information and interlocking/blocking signals. Explicit messages are used to transfer longer pieces of information like events and explicit read and write messages to access device data. Also SPA-bus messages can be transparently sent in explicit messages in order to transfer e.g. parameter data.

The benefits achieved by the use of LonWorks Network in protection and control systems include: direct communcation between all the devices in the system, support for multimaster or redundant system implementations and improved response times. Additionally LonWorks Network is an open system utilized in many application areas offering word-wide support for system integrators willing to utilize our relays and cotnrol units in their systems.

General description

LonTalk application protocol

The LonTalk protocol supports two types of application layer objects: network variables and explicit messages.

Network variables

The LonTalk protocol employs a data oriented application protocol. In this approach, application data items such as temperatures, pressures, states, text strings and other data items are exchanged between nodes in standard engineering and other predefined units. The command functions are then encapsulated within the application programs of the receiver nodes rather than being sent over the network. In this way, the same engineering value can be sent to multiple nodes which each have a different application for that data item.

The data items in the LonTalk application protocol are called network variables. Network variables can be any single data item or data structure with the maximum length of 31 bytes.

Network variables are addressed on application level using network variable selectors. The selector is a 14-bit number in the range 0...12287.

Explicit messages

Explicit messages containing up to 229 bytes of data can also be sent over the network. Different types of explicit messages are classified using an 8-bit message code.

A special range of message codes is reserved for foreign frame transmission. Up to 229 bytes of data may be embedded in a message packet and transmitted like any other message. The LonTalk protocol applies no special processing to foreign frames - they are treated as a simple array of bytes. The application program may iterpret the data in any way it wishes.

Some of the messages codes are reserved for LonTalk Network Management and Diagnostic services. So called "Foreign messages/responses" can be sent using messages codes 40H...4FH.

Use of LonTalk application protocol in protection and control systems

Process data like measurement values and indications are sent using either network variables or explicit messages. The explicit messages may be either LSG format events or AFD format messages. Control commands are sent using network variables or explicit messages of AFD format.

Setting values and other parameter data are sent using explicit messages or files. The format of explicit messages to transfer parameter data is SPA or AFD. Files are sent using LonTalk file transfer protocol. In simple nodes parameter data may also be sent using network variables.

LON network is configured using LonTalk Network Management messages.

The following "Foreign message" codes are used for our special use:

- LSG format event messages	40H
- transparent SPA-bus messages	41H
- LSG format configuration messages	43H
- AFD messages	4CH
- DMP messages	4AH

Layer 2...6 services

Transport services

The LonTalk protocol offers four basic types of message trasport services:

- acknowledged service
- unacknowledged repeated service
- unacknowledged service
- request/response service

Most of the messages are sent using acknowledged service. Unacknowledged repeated service may be used to transfer data from one node to many receivers.

Unacknowledged service is used e.g. for clock synchronization. Request/response service is used with network management messages and with network variable poll messages.

Network addressing

LonTalk addresses are hierachically structured. There are three basic address types with three components per address, as shown below:

(Domain, Subnet, Node)
(Domain, Subnet, Neuron_ID)
(Domain, Group, Member)

In our protection and control systems the application messages are sent using Subnet/Node addressing with Domain field = 0 (Domain address is not used).

Communication buffers

To enable the use of simple LON devices in the same network as more complex devices the max. length of communcation buffers is usually 66 bytes. Long explicit messages are sent in pieces of 32....45 bytes.

Timing parameters and priority channels

Each device which is sending interlocking/blocking messages or clock synchronizing messages must be assigned a priority channel to enable the use of priority with these messages. Priority messages may not be used for any other type of data.

The timing parameters must be set according to the LonTalk Interoperability Guidelines.

Collision detection

Collision detection is optionally used. All the devices connected to the system do not have to support collision detection. It should be used by devices which send interlocking or blocking messages or other similiar type messages. Collision detection together with priority assingment is used to quarantee deterministic transfer of these messages also in heavy load conditions.

Physical layer interface

Physical layer media of the LON bus is fiber optic cabling. The physical network is star network implemented using star couplers. The default speed of the network is 1.25 Megabits per second.

Interfaces to other types of network cabling (e.g. transformer isolated twisted pair) can be arranged using LonWorks Routers. Also network parts with different speed than 1.25 Mbits/s can be used in the system with the help of routers.

Fiber optic interfaces

The fiber optic LON bus is implemented using eihter glass core or plastic core fiber optic cables.

Specification of the fiber optic connections:

	Glass fiber	Plastic fiber
Cable connector	ST-connector	snap-in connector
Cable diameter	62.5/125 µm	1 mm
Max. cable length	1000 m	20 m
Wavelength	820-900 nm	660 nm
Transmitted power	-13 dBm (HFBR-1414)	-13 dBm (HFBR-1521)
Receiver sensitivity	-24 dBm (HFBR-2412)	-20 dBm (HFBR-2521)

When a device is not sending, no light is sent to the fiber. When device starts sending light transmitter is activated.

LON interface module of the devices

The fiber optic interface of a device is implemented using a "LON interface module", which is connected to a 9-pin, female D-connector of the device. The used signal levels are according to RS-485 standard.

The pin assingment of the RS-485 LON bus D-connector is:

Pin	Usage
1	DATA A, data signal A (+)
2	DATA B, data signal B (-)
3	RTS A, request to send signal A (+)
4	RTS B, request to send signal B (-)
5	COL A, collision detection signal A (+)
6	COL B, collision detection signal B (-)
7	GND, signal ground for the power supply
8	Service Pin connection (TTL level signal)
9	+5V, power supply for the module

The "LON interface module" is built to detect collision on the fiber optic connection. Collision will be detected and signalled to the attached device using COL signal pair, if the device keeps RTS active at the same time as ligth is received from the fiber optic receiver. (This is true, if the attached device attempts to send at the same time as some other device is sending.) The "LON interface modules" and also the star couplers are built so that they do not echo light back to the same fiber optic connection (transmitter/receiver pair) from which the light was received.

Star coupler

The star couplers contain 3 or more fiber optic connections, each connection being a transmitter-receiver pair. The star couplers may be hierarchically arranged in two layers as illustrated in the following figure. The arrangement shoud be done so that a message sent from any of the devices in the system should not go through more than three star couplers to reach any other device in the system.

Two devices may also be chained together using a LON interface module with two fiber optic connections. In this case one connectioin of the LON interface module is connected to a star coupler and the other is connected to another device's LON interface module. Care must be taken when building the system, a message sent by any of the devices in the system should not go through more than six fiber optic cables lines before reaching any other device in the system.

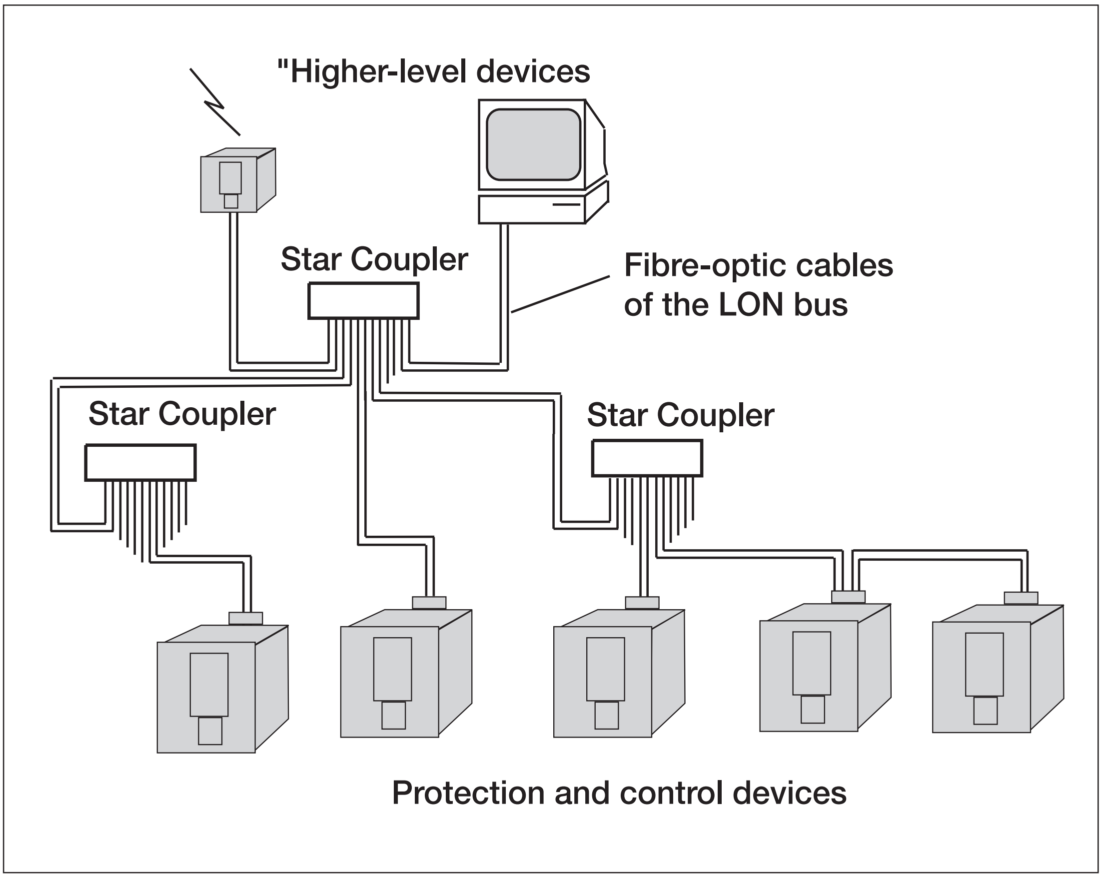

Figure 1. Structure of the system built using star couplers and fiber optic cables. Star couplers arranged hierachically in two levels. Two devices chained together (on the right).

The maximum recommended distance between any two devices connected with fiber optic cables to the same system is 2000m. That is, the system may include at most two 1000m fiber optic connections.

Redundant fiber optic interfaces may be built using suitable LON interface modules and star couplers.

Routers

The system may include LonTalk Routers to divide the network into smaller pieces. Routers may be configured to pass only selected messages from one part of the network to other parts of the network. Routers should be used e.g. to isolate big internal traffic of almost independently working subsystems (e.g. devices constituting a control circuitry) from the rest of the system. This kind of considerations should be made especially to relieve the possible overload problems of the "higher-level" devices.

The routers also enable the connection of devices with other type of physical LON interface (e.g. twisted pair 78kbit/s) to the fiber optic LON network.

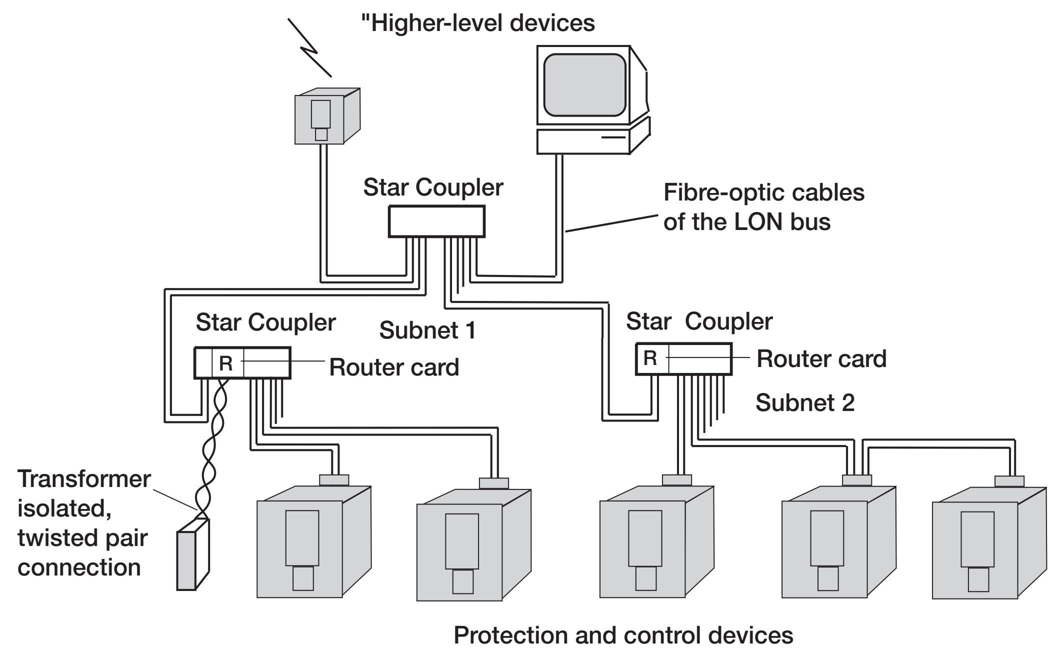

Figure 2. Example of a system utilizing routers. Router card in the rightmost star coupler isolates the internal traffic of subnet number 2 from the traffic of the rest of the system (subnet 1). Small device with twisted pair LON interface on the left is connected to the system using a router/repeater card in the leftmost star coupler.

Message formats

Network variables

Network variables contain the "value attribute" of the most frequently transferred data objects. In many cases (depending on the device cabablilities) data values which are sent as network variables can alternatively be accessed transparently using explicit messages of SPA or AFD format.

Those data objects, which are to be transferred as network variables must be assigned a network variable selector when system is configured. During configuration the data objects are addressed using a 8 or 16-bit network variable index - as in every standard LON node.

General Network Variable message format

The data part of a network variable message contains 2bits of control information and 14-bit network variable selector and the data itself.

1	X	network variable
		selector (14 bits)
		data 1...31 bytes

X = 0, variable update message
or response to a poll
X = 1, variable poll message

Network variable types

In our applications the analog values are sent as integer values using either 32 bit or 16 bit network variables. Digital data is sent using 16-bit network variables. The bit write (BWR) format is used in cases when e.g. mapping to ANSI X3.28 protocol's BitWrite command is required.

Also some other formats than formats defined in this chapter can be used, e.g. formats compatible with LonWorks Standard Network Variables. All the devices don't necessarily accept all the possible types, types must be checked when making network variable bindings or otherwise when one tries to read or write a variable. The Standard Nework Variables compatible with our 16-bit digital network variables (except BWR) are e.g. SNVT_count and SNVT_state.

32 bit analog values:

1	0	selector msb
		selector lsb
		data 4 bytes

32-bit analog value, 32-bit fixed point integer value with scaling factor 1000. (E.g. value 1.05 is sent as 1050)

Network variable types (continued)

16 bit analog values:

1	0	selector msb
selector lsb		
data 2 bytes		

16-bit analog value, 16-bit fixed point integer value with scaling factor 100. (E.g. value 1.05 is sent as 105)

1 to 16-bit digital values:

1	0	selector msb
selector lsb		
data 2 bytes		

16-bit binary value.

16-bit digital values can carry one or more bits of digital data. The data may be interpreted as one or more separate bits or one HEX value.

Bit write (BWR) message:

1	0	selector msb
selector lsb		
i i i i	x x x x	
x x x x	x x x	d

iiii = bit number (0..15)
xxxx xxxx xxx = not used
d = bit value (0 or 1)

Bit write message is used to set or reset one bit of a 16-bit bit string. The bit string is anyhow identified with one NV selector.

Note:
All the multi byte structures are sent msb-byte first and lsb-byte as last byte (in Motorola fashion).

Clock synchronization network variables

The real-time clock of the LON devices is synchronized by broadcasting network variables nv_warning and nv_clock to the network one after another. The delay between nv_warning and nv_clock may not exceed 100 milliseconds. The delays under approx. 30 ms cause significant amount of clock messages to be missed.

Network Variable nv_warning:

1	0	selector msb	default value for
		selector lsb	the selector is 2FFFH
		delay	delay between sending the warning message and the time synch message (30…100 ms)

Network Variable nv_clock:

1	0	selector msb	default value for
		selector lsb	the selector is 2FFFH
1 2		year	year in binary format
3		month	month in binary format
4		day	day in binary format
5		hour	hour in binary format
6		minute	minute in binary format
7		second	second in binary format
8 9		milliseconds and 100 microseconds	milliseconds and hundreds of microseconds as 16-bit binary number

Explicit messages

Explicit messages are used to transfer the "value attribute" and other attributes of the data objects. The format of the application data in these messages is one of the following: SPA-bus format, LSG-format, AFD-format or DMP-format.

General message format

The data part of the explicit messages contain the following:

0	message code (<80H)
	data 0...229 bytes

The format of the data part of the message is defined by the message code. The special explicit messages formats used in our protection and control systems are the following:

- LSG format event messages	40H
- transparent SPA-bus messages	41H
- LSG format configuration messages	43H
- AFD messages	4CH
- DMP messages	4AH

LSG format event messages

Event messages containing time-stamped event information from a device may be sent using explicit messages with message code 40H. The format of these messages is the following:

0	0 40H	Message code 40H.
1	event type (8 bits)	
2 3	object address (16 bits)	- SPA-event id. (type 0,7,8) or - 00 + 14-bit NV selector (type 1,2)
4 5 6 7	event data (32 bits)	- 32-bit integer (scale 1000) or - 16-bit mask + 16-bit data or - 16-bit slave number + 16-bit data
8 9 10 11 12 13 14 15 16	year (msb) year (lsb) month day hour minute second ms and 100 us (msb) ms and 100 us (lsb)	Bytes 15 and 16 contains a 16 bit number including milliseconds and hundreds of microseconds.

LSG format event messages (continued)

The following event types are used:

Type code	Event type
0	SPA-bus event, event generated from SPA-bus events.
1	Analog event, event with 32 bit analog data value. The data value is a 32-bit integer value scaled with 1000.
2	Digital event, event with 16 bit data. Bytes 4,5 contain 16-bit mask indicating the changed bits and bytes 6,7 contain the 16-bit data itself.
7	SPA-bus analog event, event generated from SPA-bus analog event. Analog data in data part (32-bit integer scaled with 1000).
8	Extended SPA-bus event, event generated from SPA-bus events. Full SPA-bus slave number in data part bytes 4 and 5.

With types 0 and 7 the the SPA-event identification (bytes 2,3) is as follows:
- 1 + 3-bit SPA slave index + 6-bit channel number + 6-bit event number

With type 8 the the SPA-event identification (bytes 2,3) is as follows:
- 1 + 9-bit channel number + 6-bit event number

Transparent SPA-bus messages

SPA-bus messages may be sent using explicit messages with message code 41H. Both the SPA-bus command messages (R or W) and the reply messages (D, A or N) are sent using the same message code. It is recommended that one device sends out only one message at a time and waits for the reply before sending the next message.

Byte	Content	Description
0	41H	Message code 41H.
	">" or "<"	Message start character ">" in messages to device "<" in reply messages from device
	ASCII character message following the rules of the SPA-bus protocol	
	":"	End of data part/header.
	CC	Two checksum characters.
	0DH	Message end character, carriage return.

Long SPA-bus messages are sent in pieces at max. 45 bytes. Each separately sent piece contains end characters '&', 0DH, 0AH (except the last piece.

LSG format configuration messages

LSG cofiguration messages are sent using explicit messages with message code 43H. These messages are used to send and read configuration data of LON/SPA-gateways.

The same message code can be used for similiar purposes also with other devices.

0	43H	Message code 43H.
Command/response message composed of ASCII characters.		
0DH		Command/response end character, carriage return.

LON bus performance figures

The following figures can be used as basis when calculating the performance of the bus. The actual performance in a specific system depends on the type of devices that are used as part of the network: types of network interfaces of the devices, types of possible gateways, routers, etc. Also the software implementation of the devices in question affect the final performance. The performace should be separately calculated for each system, if detailed performance figures are required.

When we assume that the LON bus speed is 1.25 Mbits/s and the average packet size is less than 10 bytes then the following can be said. The bus can handle a load of up to 500 packets per second. A node on the network can handle a maximum load of 300 packets per second. One node can receive up to 150 acknowledged messages per second. One node can send up to 70 acknowledged messages per second. If collision detection and priority is used then the packet throughput time through the network is less than 20ms (assuming no routers on the message path). The best case throughput time is about 6 ms.

To assure the proper performance of the bus the following precautions should be made: use as short messages as possible for frequently sent data; send long messages in smaller pieces; allocate as many communication buffers as possible in the nodes, gateways and routers; use routers to partition the network in an appropriate way.

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