LonWorks

- Understand LonWorks Control Network
- Understand LonTalk protocol

Reference:

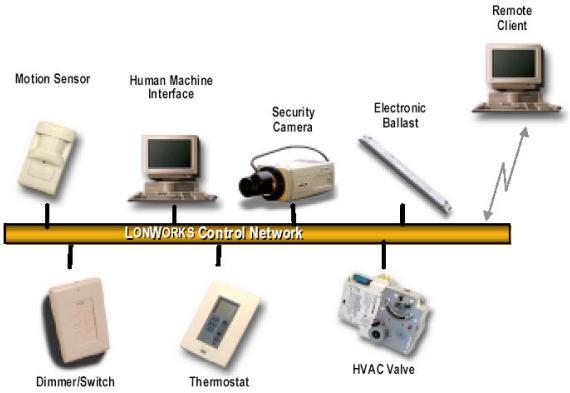
•Introduction to LonWorks System, http://www.echelon.com/support/documentation/Manuals/078-0183-01A.pdf

•LonWorks Technology: An Introduction, F. Tiersch

•http://www.ieclon.com/LonWorks/LonWorksTutorial.html

•Networking and Integration of Facilities Automation Systems, Chapter 10

LonWorks Control Networks



ECHELON

Channel Type	Medium	Data Rate	Max Devices	Max Distance
TP/XF-1250	Twisted pair, bus	1.25 Mbps	64	125m (bus length)
TP/XF-78	Twisted pair, bus	78 Kbps	64	1330m (bus length)
TP/FT-10	Twisted pair, flexible topology	78 Kbps	64 (up to 128 if link-powered)	500m (node to node)
PL-20	Power line	5 Kbps	No limit	Determined by attenuation

Control Network: LonWorks

Page 2

•www.echelon.com

•LONs stand for local operating networks.

•LonWorks technology, brought on the market by the Echelon Corporation, is a complete platform for implementing control network systems, These networks consist of intelligent devices or nodes that interact with their environment, and communicate with one another over a variety of communications media using a common, message-based (information-based) control protocol, called LonTalk.

Standards

- ANSI/EIA 709.1
  Control Networking Standard
- ANSI/EIA **709**.2
  Control Network Powerline (PL) Channel Specification
- ANSI/EIA 709.3
  Free Topology Networks Wiring Plan

•The LonWorks protocol is also known as the LonTalk protocol and ANSI/EIA 709.1

LonTalk Protocol

	OSI Layer	Purpose	Services Provided	Neuron Chip Processor
7	Application	Application Compatibility	Standard Objects and Types; Configuration Properties; File Transfer; Network Services	Application Processor
6	Presentation	Data Interpretation	Network Variables; Application Messages; Foreign Frames	Network Processor
5	Session	Control	Request-Response; Authentication	Network Processor
4	Transport	End-to-End Reliability	End-to-End Acknowledgement; Service Type; Packet Sequencing; Duplicate Detection	Network Processor
3	Network	Message Delivery	Unicast & Multicast Addressing; Packet Routing	Network Processor
2	Link	Media Access and Framing	Framing; Data Encoding; CRC Error Checking; Media Access; Collision Avoidance & Detection; Priority	MAC Processor
1	Physical	Electrical Interconnect	Media-Specific Interfaces and Modulation Schemes (twisted pair, power line, radio frequency, coaxial cable, infrared, fiber optic)	MAC Processor

Control Network: LonWorks

Page 4

•The LonTalk protocol is a layered, packet-based, peer-to-peer communications protocol

•It is designed for the specific requirements of control systems, rather than data processing systems

•The LonTalk tailors the protocol for control at each of the OSI seven layers to ensure a reliable and robust communications for control applications

LonWorks Channel

Widely-Used LONWORKS Channel Types

Channel Type	*Medium*	*Bit Rate*	*Compatible Transceivers*	*Maximum Devices*	*Maximum Distance*
TP/FT-10	Twisted pair, free or bus topology, opt. link power	78kbps	FTT-10, FTT-10A, LPT-10	64-128	500m (free topology) 2200m (bus topology)
TP/XF-1250	Twisted pair, bus topology	1.25Mbps	TPT/XF-1250	64	125m
PL-20	Power line	5.4kbps	PLT-20, PLT-21, PLT-22	Environment Dependent	Environment Dependent
IP-10	LonWorks over IP	Determined by IP network	Determined by IP network	Determined by IP network	Determined by IP network

Control Network: LonWorks

Page 5

•LONWORKS technology provides many different communications media options including 1.25 Mbps twisted pair, power line, fiber optic, coax, IR and RF transceivers. This media-independent feature provides the designer and end-user with a wide range of choices for communicating your data.

•The bit rate of a channel depends upon the properties of the medium and the transceiver design. In addition, the transceiver determines transmission distance, data throughput, node power consumption and node cost.

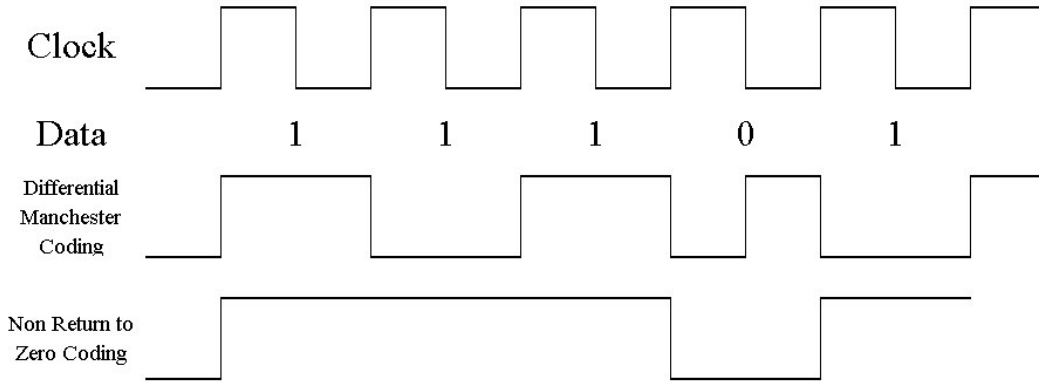
•For TP channels, 22- or 24- AWG cables should be used.

•For PL channel, the frequency range of transceivers is 100kHz to 450kHz.

•For RF channel, the currently approved transceiver is for a transmission speed of 4.883 kbps and frequency ranges conforming to the standard of region, e.g., ETS 300220 for European standard, MPT 1329 for UK standard, RCL 1993/1 for Australian standard, and FCC Part 90 for USA.

Data Encoding Methods

- Multiple data encoding methods are used in the LonTalk
- Each encoding scheme is media dependent



•Differential Manchester Coding used in direct mode:

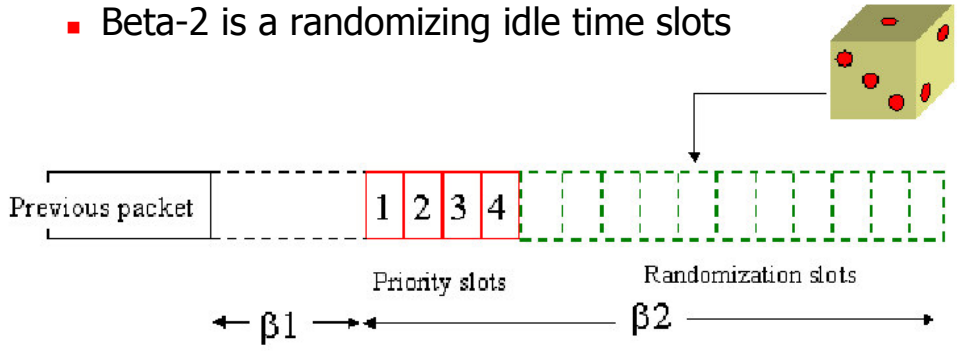
- •A transition at the beginning of every bit period provides a signal for synchronizing the receiver clock
- •The presence of a second transition halfway between clock transitions indicates a zero data
- •A “1” data is indicated by absence of a second transition in a bit period

•Non Return to Zero Coding (NRZ) used in special purpose mode:

- •“1” is high and “0” is low

Media Access Control

- Predictive p-persistent CSMA
- Carrier sense:
  - The idle time is divided into Beta-1 and Beta-2
  - Beta-1 is a fixed component in the idle time
  - Beta-2 is a randomizing idle time slots

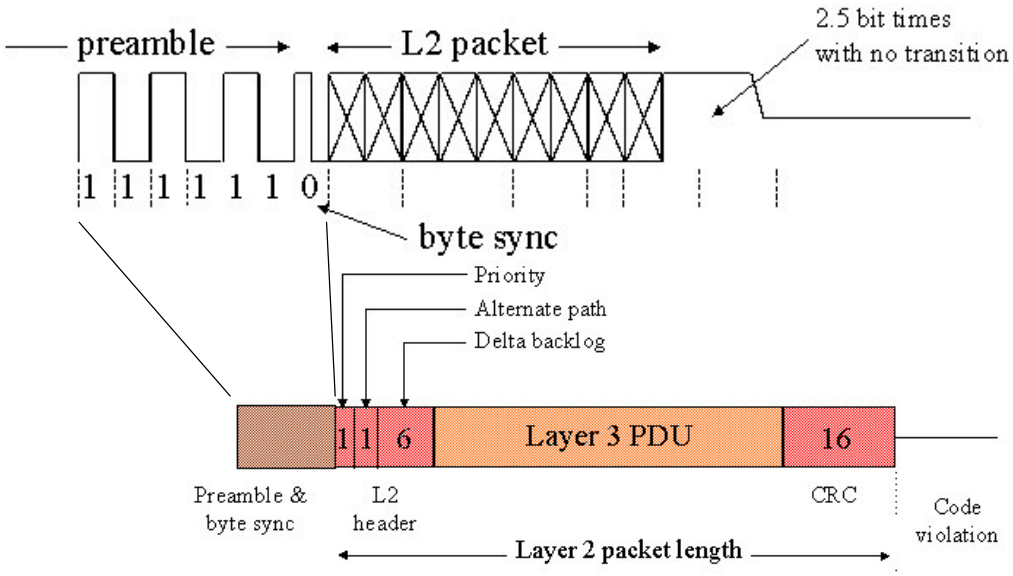


Control Network: LonWorks

Page 7

- The LonWorks modified the CSMA protocol for multiple communication media, sustained performance during heavy loads, and support large networks
- If the devices wait for the same duration after backoff and before retry sending data, repeated collisions will result. Thus, randomizing the access delay reduces collisions
- LonWorks devices randomize over a minimum of 16 different levels of delay
  - For example, 16 slots reduce the probability of two packets colliding to 1/16 = 0.0625
- A unique feature of the LonTalk protocol is that the number of available time slots is dynamically adjusted by every device, based on an estimate of expected network loading maintained by each device and hence number of randomization slots is increased as traffic increases (predicting the channel load)
- The number of randomizing slots = n * 16, where n = 1 to 63, the estimated channel backlog
- Each node that requires priority access is allocated a unique slot number on its Priority Channel
- Benefits
  1. Linearly increasing response time, up to 99 % of the bandwidth
  2. Supports open transmission media
  3. Adding and removing of devices does not disturb data transmission

Data Frames



•Preamble is a sequence of "1" bits that allows the other nodes to synchronize their receiver clocks. The length of it must be long enough for synchronization. It is user-selectable, but at least six bits long.

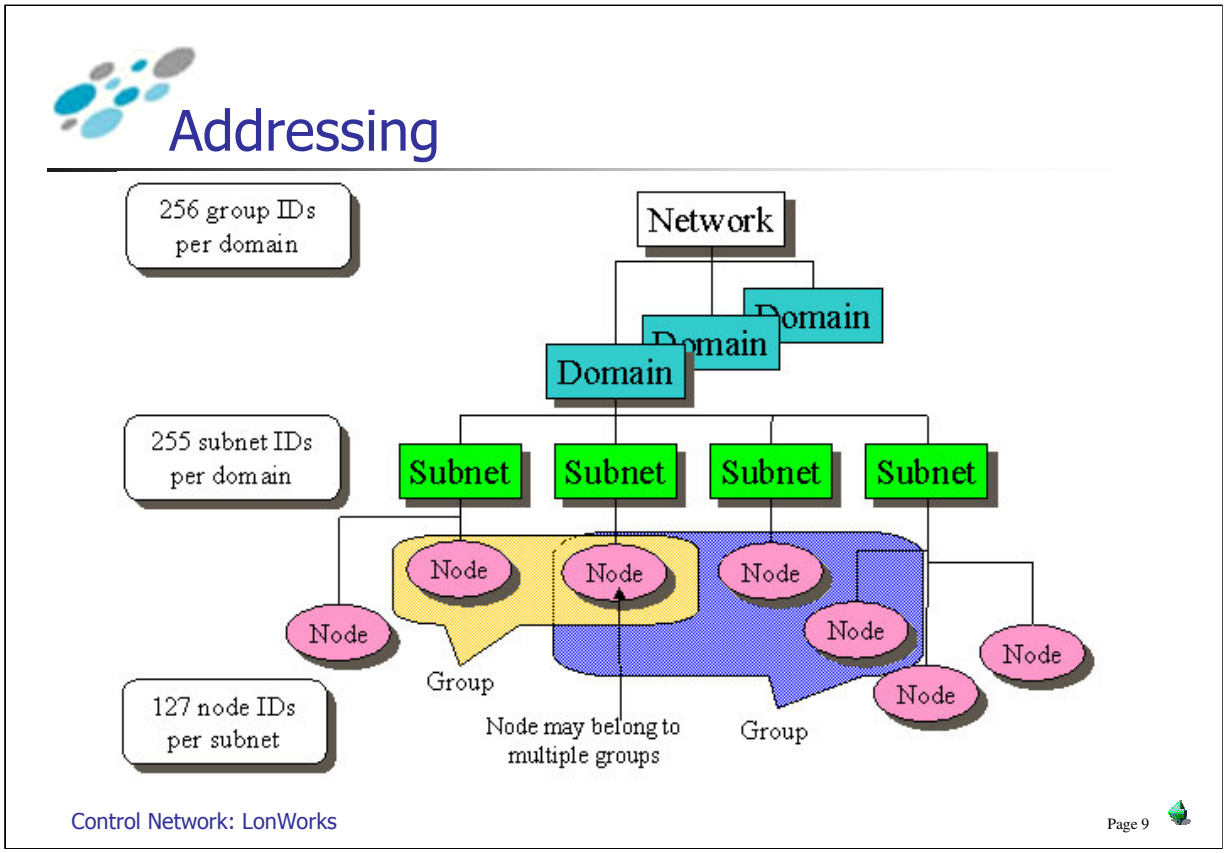
•Byte sync is a single "0" bit that marks the end of preamble and indicates the beginning of a frame

•Followed by up to 256 bytes of L2 data (MSB first)

•Packet ends with Manchester code violation

•Delta backlog field in Layer 2 header updates offered traffic estimate on receiving nodes

- •For example: For acknowledged message to a group of nodes, the expected traffic = 1 ACK from each receiver



•Packets can be addressed to a single device, to any group of devices, or to all devices.

•A LonTalk address is hierarchical structured as shown in the diagram above.

•*Physical Address*: Every LonWorks device includes a uniquie 48-bit identifier called the Neuron ID. The Neuron ID is typically assigned when a device is manufactured, and does not change during the lifetime of the device.

•*Device Address*: A LonWorks device is assigned a device address when it is installed into a particular network. Device addresses are used instead of physical addresses because they support more efficient routing of messages, and they simplify replacing failed devices. Device addresses consists of three components: a domain ID, subnet ID, and node ID. Devices must be in the same domain to exchange packets. The subnet ID identifies a collection of devices that are on a single channel, or a set of channels connected by repeaters. Subnet Ids are used to support efficient routing of packets in large networks. A node ID identifies an individual device within a subnet.

•*Group Address*: A group is a logical collection of devices within a domain. Groups are limited to 64 devices if acknowledged messaging is used; whereas any number of devices if unacknowledged messaging is used. A device is allowed to configure to be a member of up to 15 groups.

•*Broadcast Address*: It identifies all devices with a subnet, or all devices within a domain.

Logical Address Formats

Number	Address Format	Address Size (bytes)	Detination
0	Domain(Subnet = 0)	3	All nodes in the domain
0	Domain – Subnet	3	All nodes in the subnet
1	Domain – Group	3	All nodes in the group
2a	Domain – Subnet – Node	4	Specific (logical) node in the subnet
2b	Domain – Subnet – Node – Group – Member	6	Nodes of the group must send an acknowledgement
3	Domain – Neuron-ID	9	Specific physical node

•An address is assigned to a node during installation process. It is said that the node is configured.

•The total address size is computed by adding the appropriate number of bytes indicated in the table above.

•Every LonTalk packet contains the address of transmitting device (the source address) and the address of receiving devices (destination address) that can either be a physical address, a device address, a group address, or a broadcast address.

•Devices respond only to those packets corresponding to their domain ID and their own physical address, which is usually known only to the corresponding network installation tools.

Message Services

- Four different message services:
  - Acknowledged
  - Repeated
  - Unacknowledged
  - Authenticated
- A number of tradeoffs between efficiency, response time, security and reliability must be taken into account when using these message sevices

•*Acknowledged Messaging*: Acknowledgements are expected from each receiving device. If the sender do not receive acknowledgements, it times out and retries the transaction. The number of retries and timeout are both configurable.

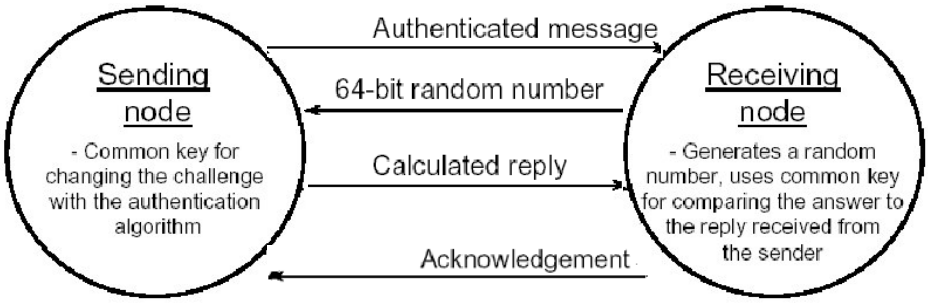
•*Repeated Messaging*: A message is sent to a device or group devices multiple times. This messaging service does not incur the overhead and delay of waiting for acknowledgements. This is especially important when broadcasting information to a large group of devices.

•*Unacknowledged Messaging*: A message is sent once and no response is expected. This messaging service has the lowest overhead.

•*Authenticated Service*: Allows the receivers to determine if the sender is authorized to send that message. This messaging service prevents unauthorized access to devices and is implemented by distributing 48-bit keys to the devices at installation time.

Authentication

- Authentication provides security of communication

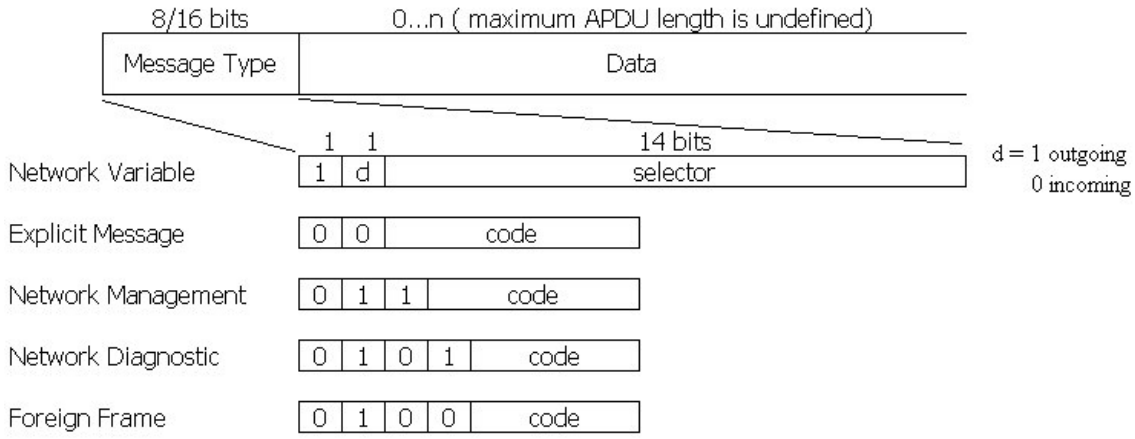


Control Network: LonWorks

Page 12

- Authentication prevents unauthorized access to nodes and their applications, e.g., a junior technician cannot operate on a security device if he is not authorized.
- Sender and receiver possess the same 48-bit encryption key.
- Authentication is set by a network management command at installation time.
- Authentication process:
    1. A receiver receives an authorized message
    2. The receiver sends a random number to the sender and challenges the sender to provide authentication
    3. The sender then uses the 48-bit encryption key, the data from the original packet and the 64-bit random number to perform a transformation on the challenge
    4. The sender returns the result of transformation to the receiver
    5. The receiver compares the response with its own transformation
    6. If the transformation match, the receiver sends ACK back to indicate the successful transaction

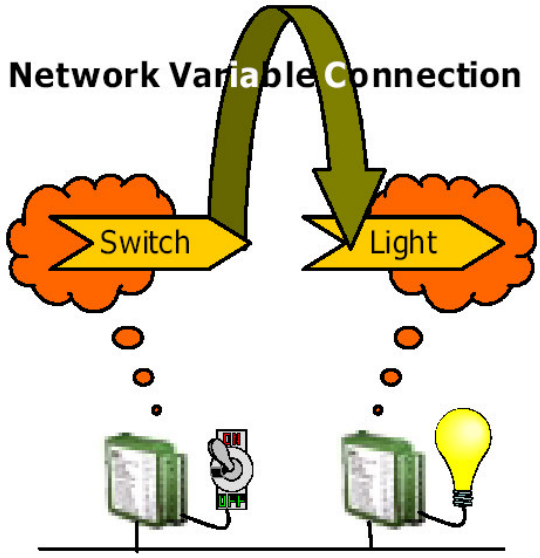
Upper Layers



- Network Variable Propagation: This header indicates network variable updates
- Explicit Message: It is used by the application program without restrictions. Thus, applications require a different data interpretation model other than network variables can send and receive this type of messages. It is also called Generic Message.
- Network Management: It is used for installing and configuring nodes and downloading software. For example:
    1. Find unconfigured nodes
    2. Download network addresses
    3. Start, stop and reset node applications
    4. Access node communication statistics
    5. Configure routers
    6. Download new application programs
    7. Extract the topology of a running network
- Network Diagnostic: It is used to test which nodes are fully operational, and to take corrective action around problem areas.
- Foreign Frame: It is provided as a means to use the LonTalk protocol as a gateway between two external nodes. Up to 229 bytes of data may be embedded in a message packet.

Network Variables

- Virtual wire (logical connection) is created by binding process during installation
- Created and changed with Network Tool
- Connection can be changed without reprogramming device
- Make moves, adds, and changes easy



•A Network variable (NV) is any data item (e.g., temperature, a switch value, or an actuator position setting) that a particular device application program expects to get from other devices on the network (an input network variable) or expects to make available to other devices on the network (an output network variable).

•In the binding process, the device firmware is configured to know the logical address of the other devices or group of devices in the network expecting that network variable, and it assembles and sends the appropriate packets to these devices.

•Every NV has a type that defines the units, scaling, and structure of the data contained. NVs must be the same type to be connected.

•The application program in a LonWorks device does not need to know anything about where input network variables come from or where output network variables go.

•NVs greatly simplify the tasks of designing LonWorks application programs for interoperability with multiple vendors' products and facilitating the design of information-based, rather than command-based, control systems.

- •Information-based control systems: each device application makes its own control decisions, based on information it collects from other devices about what is going on in the system.
- •Command-based system: devices issue control commands to other devices, so a command-issuing device, that is typically a centralized controller, must be custom programmed to know a lot about the system function and topology.

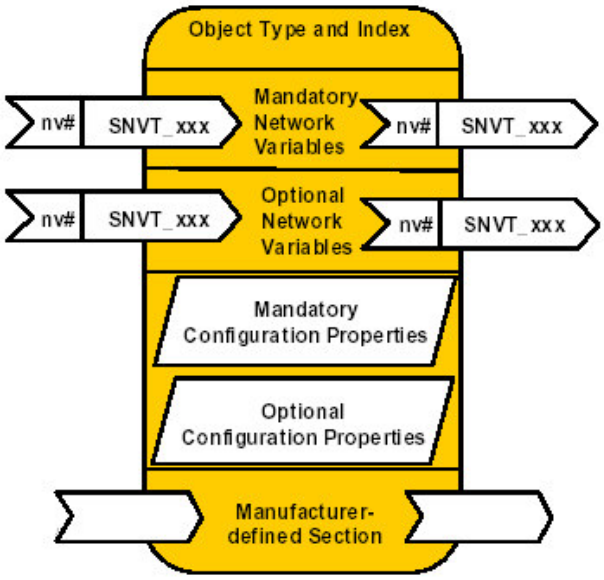
LonMark

- The LonMark Interoperability Association was formed in 1994 by Echelon
- The LonMark Association is dedicated to
  - developing standards for interoperability,
  - certifying products to those standards, and
  - promoting the benefits of interoperable systems
- Only LonWorks devices that have been certified by the LonMark Association – called LonMark devices – can carry the LonMark logo.

- www.lonmark.org
- The availability of LonMark products provides end-users, system integrators and equipment specifiers the benefits of open interoperable multi-vendor systems:
  1. Choice of vendors
  2. Use of third party tools
  3. Easy integration
  4. Easy additions and changes
  5. Reduced installation costs
- Where once end-users were locked into lengthy and costly service and upgrade agreements from a single vendor, they can now implement control systems using LonMark devices from multiple vendors picking and choosing devices that best suit their needs knowing they can be easily integrated.

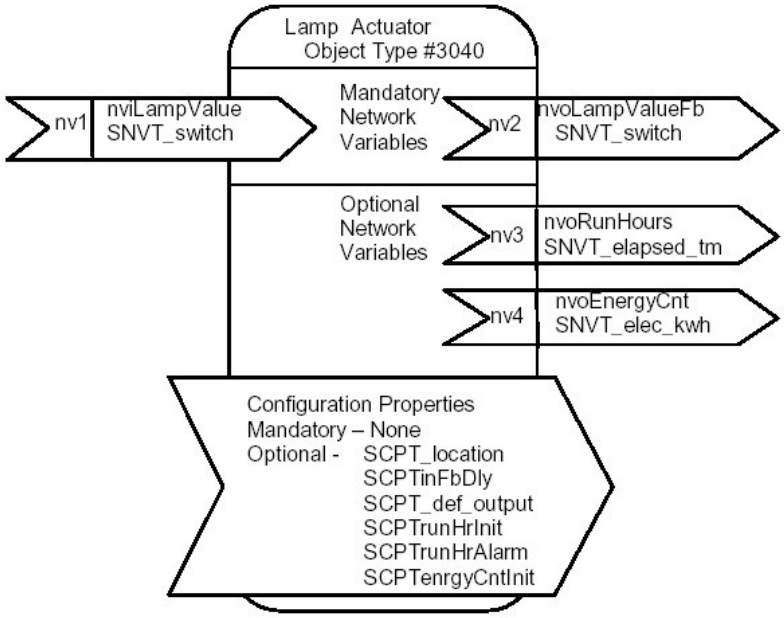
LonMark Objects and Functional Profiles

- Type of object
- Index on device
- Mandatory Network Variables
- Optional Network Variables
- Configuration Properties
- Manufacturer-defined section



- Functional profiles are implemented as LonMark objects on individual devices.
- LonMark objects are defined as a set of one or more input and/or output network variables, with semantic definitions relating the behavior of the object to the network variable values and to a set of configuration properties that specify configuration data for the object.
    1. Standard Network Variable Types (SNVTs): ensure the data within the network variable interpreted in the same way (e.g., all temperature values must be transmitted over the network media in a common format)
    2. Configuration Properties: provide standards for documentation and for the network message formats used to download the customization data to the device by network tools (e.g., hysteresis bands, default values, minimum and maximum limits, gain settings, and delay times). Other than Standard Configuration Property Types (SCPTs), manufacturers may also define their own User-defined Configuration Property Types (UCPTs)
- LonMark Functional profiles describe in detail the application layer interface including the network variables, configuration properties, and default and power-up behaviors required on LonMark devices for specific, commonly used control functions.

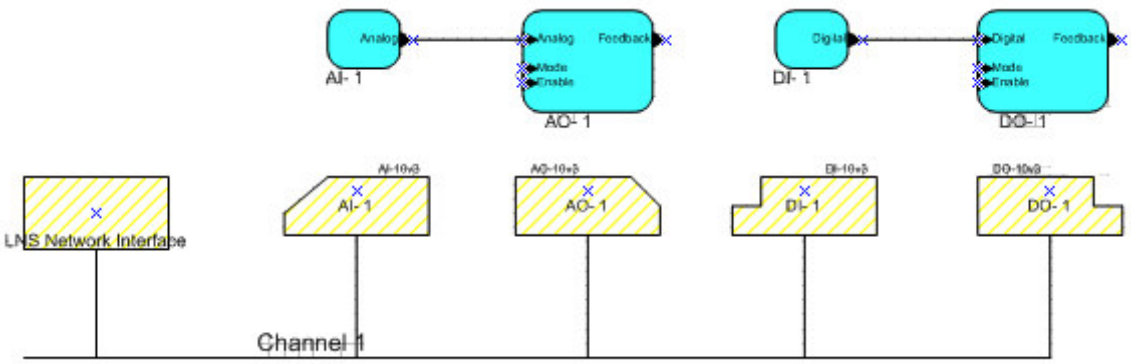
Example of Functional Profile



•http://www.lonmark.org/products/fprofile.htm

•The above example is the functional profile for a lamp actuator. The profile is used for devices that can control the illumination level of a lamp. Typical lamp actuators are dimmers, relays and controllable electronic ballasts.

Network Configuration



Control Network: LonWorks

Page 18

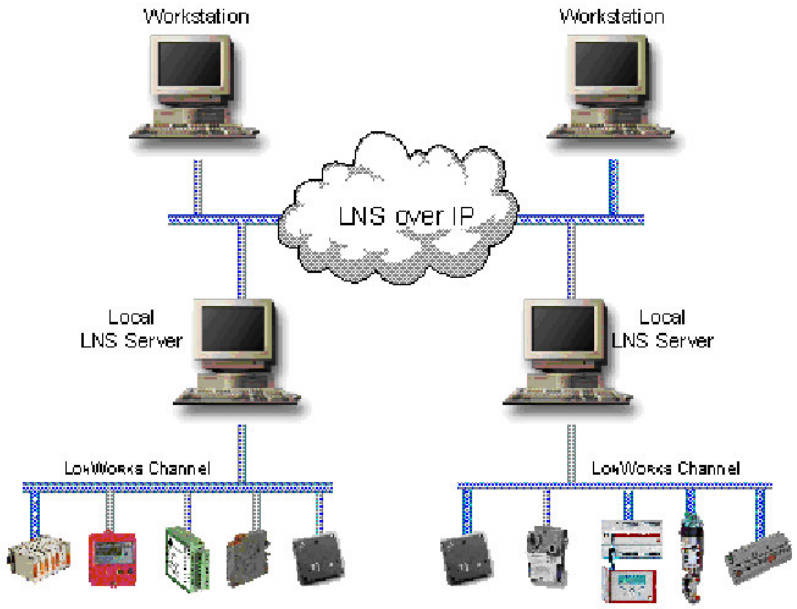
- Network configuration includes the following steps:
    1. Assigning domain ID and logical addresses to all devices and groups of devices.
    2. Binding the network variables to create logical connections between devices.
    3. Configuring the various LonWorks protocol parameters in each device for the desired features and performance, including channel bit rate, acknowledgement, authentication, and priority service.
- Network configuration may be quite complex, but the complexity is hidden by the network integration tools. LonMaker for windows offers a simple functional network design by simply dragging the devices' application functional blocks onto a drawing and connecting inputs and outputs to determine how functional blocks communicate with each other.
- Network configuration can be either an ad hoc process or a pre-engineered process: in the former method, the devices are already connected to the network and powered-up, and the configuration data is downloaded over the network as it is defined. In the engineered method, the information is collected into a database by the network integration tool and is downloaded to the devices at installation time.

Network Installation

- Install the physical communication media for the channels
- Attach the LonWorks devices to the channels
- Attach legacy I/O points to the LonWorks devices
- Using a network integration tool to download the network configuration data and application configuration data to each device, which is known as commissioning a device.
- For devices whose application programs are not pre-loaded by the manufacturer, the network tool downloads the application program into non-volatile RAM memory in the device.

•Refer to Lab

LNS-based LonWorks System



Control Network: LonWorks

Page 20

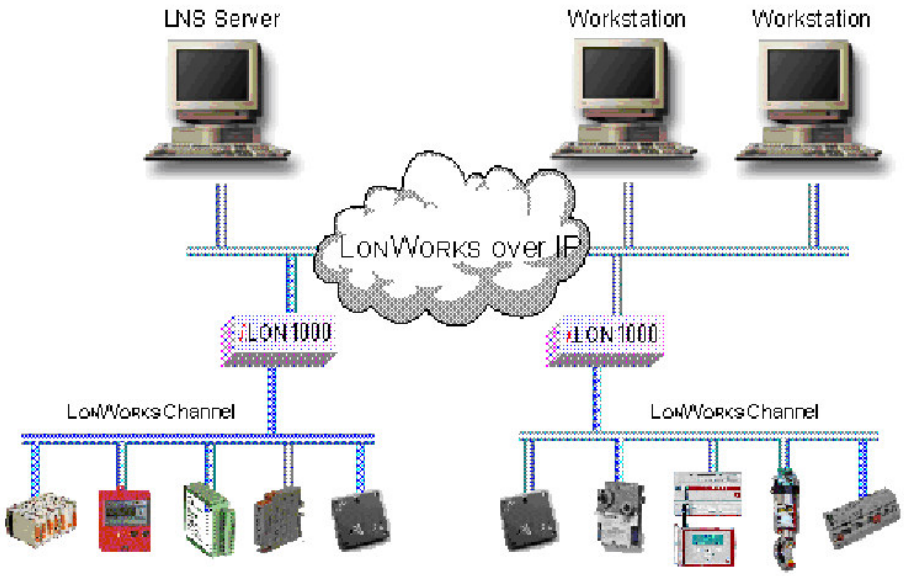
•LonWorks Network Services (LNS) is the NOS that provides a common, network-wide set of services supporting monitoring, supervisory control, installation, and configuration. In addition, it also provides programming extensions for easy use of network management and maintenance tools, data access services for HMI and SCADA applications as well as remote access via LonWorks or IP networks.

•With LNS, multiple system integrators, managers, and maintenance personnel can simultaneously access network and application management services and data from any number of client tools. It is because LNS uses a client/server architecture so that multiple applications can be active on a network at the same time.

•Using LNS, a manufacturer's device plug-in software (implemented as an ActiveX automation server) runs without modification in any PC, and can be seamlessly integrated with the installation tools on the PC (i.e., the LonMaker)

•The LNS Servers are local to each subsystem and the LNS Servers are used to provide connectivity to both the LonWorks channels as wells as the IP channel. This approach does not provide a cost savings for small systems that require a local PC for supervisory control or a local HMI application since the PC and support both the local application as well as provide IP connectivity.

LonWorks over IP



Control Network: LonWorks

Page 21

- An alternative implementation of LonWorks network as shown in the diagram above, in which, LonWorks to IP routers (i.e., i.Lon) are used to create IP channels. (Refer to Lab 5)
- In addition to data server, the i.Lon is also a web server such that you can develop web pages stored in the i.Lon to serve the LonWorks network.
- There are three different ways to access the LonWorks network by i.Lon:
    1. LNS
    2. i.Lon Web Tag
    3. xml

Limits

Devices in a subnet	127
Subnets in a domain	255
Devices in a domain	32,385
Domains in a network	2^{48}
Maximum devices in system	32K x 2^{48}
Members in a group	
♦ Unacknowledged or Repeated	No Limit
♦ Acknowledged or Request Response	63
Groups in a domain	255
Channels in a network	No Limit
Bytes in a network variable	31
Bytes in an application or foreign frame message	228
Bytes in a data file	2^{32}