LonWorks®
Solutions for Street Lighting

October 2004

Introduction

Outdoor lighting is used to illuminate the roads we drive on, the pedestrian paths we walk down, and the public areas where we gather. It provides us with safe roads, stylish and inviting public areas, and enhanced security in our homes, businesses and city centers. Unfortunately, while traditional public lighting systems provide significant benefits to all our lives, they do so at significant expense to the community.

Public lighting managers have known that they could lower the operating costs of their systems if they could cost effectively collect the critical data needed to make better planning decisions. Lighting engineers have conceived of new designs to improve public safety and reduce energy consumption only to be stymied by an inability to economically control every luminaire in the system. Without a suitable network to gather the information and exercise control, these designs could not be implemented in a public lighting system.

Today, a proven, cost-effective solution, LONWORKS® device networking[1], can achieve significant operating cost savings while improving both the reliability and the quality of public lighting systems. The LONWORKS device networking platform has been playing a pivotal role in transforming vertical markets in the automation world since its introduction over 10 years ago. From commercial buildings, public transportation systems, and semiconductor plants, to home automation, electricity metering infrastructure, Olympic venues and Broadway, applications built on the LONWORKS platform are literally everywhere that we work, live and play.

Millions of LONWORKS power line devices have been installed around the world in home, building and utility automation systems. The LONMARK® International trade association has certified over 560 interoperable products[2] and established standards in other major markets. The platform has a proven system architecture that scales to millions of LONWORKS devices in a network has already been implemented.

A wide range of economic benefits attributed to networking their solutions using the LONWORKS platform have been identified by users worldwide. Today, these benefits are currently being quantified in street lighting projects around the world. In fact, over 40,000 street lights are already being monitored, controlled, measured and diagnosed using LONWORKS power line-based device networks with early, positive return on investment calculations.

This paper will explore the business and technical opportunities that the use of LONWORKS device networking can deliver to the outdoor lighting industry –

[1] Detailed information about the LonWorks device networking platform is not within the scope of this document for the sake of brevity. Refer to http://www.echelon.com for information regarding the LonWorks platform.

[2] LonMark certified devices are based on the LonWorks platform and are designed in accordance with the LonMark Interoperability Guidelines maintained by LonMark International. Certified products can be installed and managed by software tools from multiple vendors – giving integrators and end-users the ability to create multi-vendor automation systems.

effectively outlining how this off-the-shelf solution can help transform the industry.

Outdoor Lighting Economics

Conversion to energy saving lamps and fixtures via a mass re-lamping process can provide significant energy savings. But real-time data to support the decision to invest in the re-lamping project and to optimize the operating costs over the life of the system has not been available. As a result, many such conversion decisions are delayed or denied because the underlying assumptions and estimates supporting the decision are questioned. In many other instances, public lighting installations using the latest energy saving lamps are not even considered because the return on investment can not be measured, let alone assured. Let's look at how the economics of public lighting management would change through the adoption of a standard communication network by first looking at the common problems of a standard re-lamping project.

Once a city or government agency decides to upgrade the lighting in an outdoor area, they face the expense of installation. Installation costs can include public inconvenience caused by closing off of the area or roadway; bucket trucks needed to reach the fixture; as well as trained and certified linemen to replace old fixtures with modern optically efficient ones that accommodate the latest energy saving lamps. Once lamps are in place, the energy cost is reduced to a point, but not optimally. The payback period for the re-lamping is not as short as it could be for the following reasons:

1. Energy saving lamps burn brighter than their specified rated output for some period of time after they are first installed, thus consuming more energy and producing more light than is really needed.
2. Energy saving lamps use dramatically more energy after their rated number of hours, a problem compounded by such lamps taking a significant amount of time to burn out after they have exceed their optimal hours of usage. Maintenance personnel cannot know the optimal time to change them out without knowing the actual hours run.
    a. Often, by the time the lamp burns out, additional expense is incurred to replace the ballast as well. This is due to the lamp, as it is failing, cycling the ballast rapidly and causing a subsequent ballast failure.
3. A common means for lamp control is a photo cell mounted on top of the fixture. When cells are blocked by dirt or snow they continue to operate in the "on position," regardless of time of day. This means lights burn much longer than they should, and more importantly do not all burn at the same time, making the scheduling of the next re-lamping more difficult.

While there are a number of technical solutions to such problems, the lack of accepted standards slows the growth of the entire industry. A standard network approach would enable many manufacturers' devices to share the same network and provide data across a single infrastructure to the many applications used to manage the public lighting system–effectively expanding the value of each installation. Such a standard would provide an open communication network–enabling monitoring, control, metering and diagnostic applications that can transform the economics of operating public lighting systems.

If a network were available to monitor the age and condition of every lamp, that information would eliminate the guesswork inherent to cost benefit calculations. Decisions could be made with confidence that the real-time data from the public lighting system supported the return on investment. Furthermore, if the network were used to monitor failed lamps and report their location, maintenance expenses (materials, routing, labor, etc.) could be minimized by considering the remaining life of nearby lamps that might be replaced during the same service call. Finally, data collected via the network that tracks the hours of illumination for each lamp can be used to claim warranty replacement, establish unbiased product and supplier selection criteria, and validate energy bills for the system. These are just a few examples of how a network can deliver economic benefits from simple monitoring applications. Many other applications will be discovered once system managers begin taking advantage of the network.

The combination of industry cooperation and technical innovation creates a better value proposition for intelligent "network ready" devices and new services to replace the commodity "dumb" devices in use today. Building automation and electricity metering are two industries that deliver greater benefits to their customers by using the LONWORKS standard for devices and new innovative applications targeting unmet needs. The LONWORKS power line communication network is cost effective today for monitoring, control, metering and diagnostic applications that save energy, reduce maintenance costs and improve system reliability.

Improving the Return On Investment

A significant portion of any lamp conversion program is installation cost. By installing "network ready" control devices at the same time as a new lamp, additional savings in energy, maintenance, and public safety can be achieved. The benefits of networked controls exceed the minor initial installation costs. Adding a LONWORKS based Power Line Carrier (PLC) device network to an already scheduled lamp upgrade can dramatically improve the payback on the investment in the following ways:

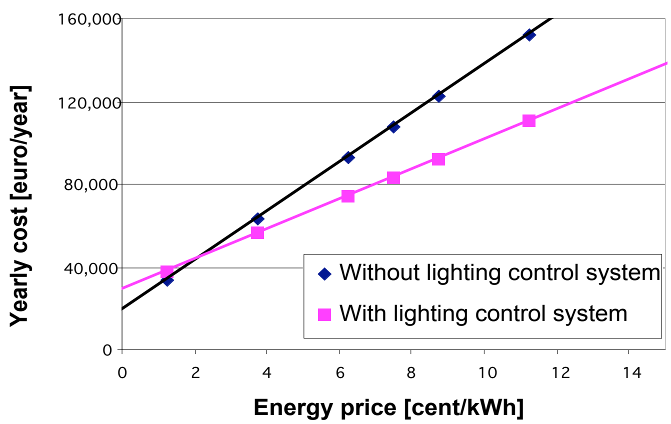
1. Direct cost reductions through dimmable ballasts and networked controls
    a. Controlling light intensity to correctly engineered levels throughout the lamp's entire life to minimize energy consumption

   b. Operating the lamps at less than full intensity for the dawn and dusk periods significantly extends the useful life of equipment and delays the time when future re-lamping is needed
2. Direct cost reductions through measuring each lamp's energy consumption at the fixture
   a. Detecting lamps that are nearing the end of their economic life and replacing them prior to the excessive energy consumption that occurs in lamps prior to burning out
   b. Eliminating excessive wear on the ballast and starter caused by lamp cycling that usually results in replacing the fixture or gear rather than just the lamp if undetected
3. Direct cost reductions through a centralized database that integrates data from the control network with a wide area network, (such as GPRS), in turn making the data available to central office GIS software
   a. Contains timely status information on every fixture that the GIS-software then links to standardized location co-ordinates. The result is alarm messages from the fixtures and their precise locations can be easily combined into optimized maintenance and refurbishment route plans with an estimated 30% increase in efficiency.[3]
   b. Graphical User Interface to the city-wide GIS system can be used to detect power outages and inform the utility, create ad hoc lighting schedules for special events or prioritize the response to safety critical alarms such as ground faults
4. Direct cost reductions through embedding intelligence in each control device can deliver diagnostic information with alarm messages
   a. Reporting the exact repair needed, with customized instructions, and even the replacement part number to the technician eliminates spurious lamp replacements and minimizes time on each job
   b. Interfacing with software applications that generate work orders, order spare parts and manage inventory reduces the total amount of labor time per repair across the organization. Cost savings can be achieved in many parts of the enterprise as a result of data integration
   c. Creating a "closed loop" system essential to lower inventory levels of spare parts

[3] Mr. Eirik Bjelland, Viken Nett, Norway; Intelligent Road Lighting – "Light on the Road"; CIE Session 2003

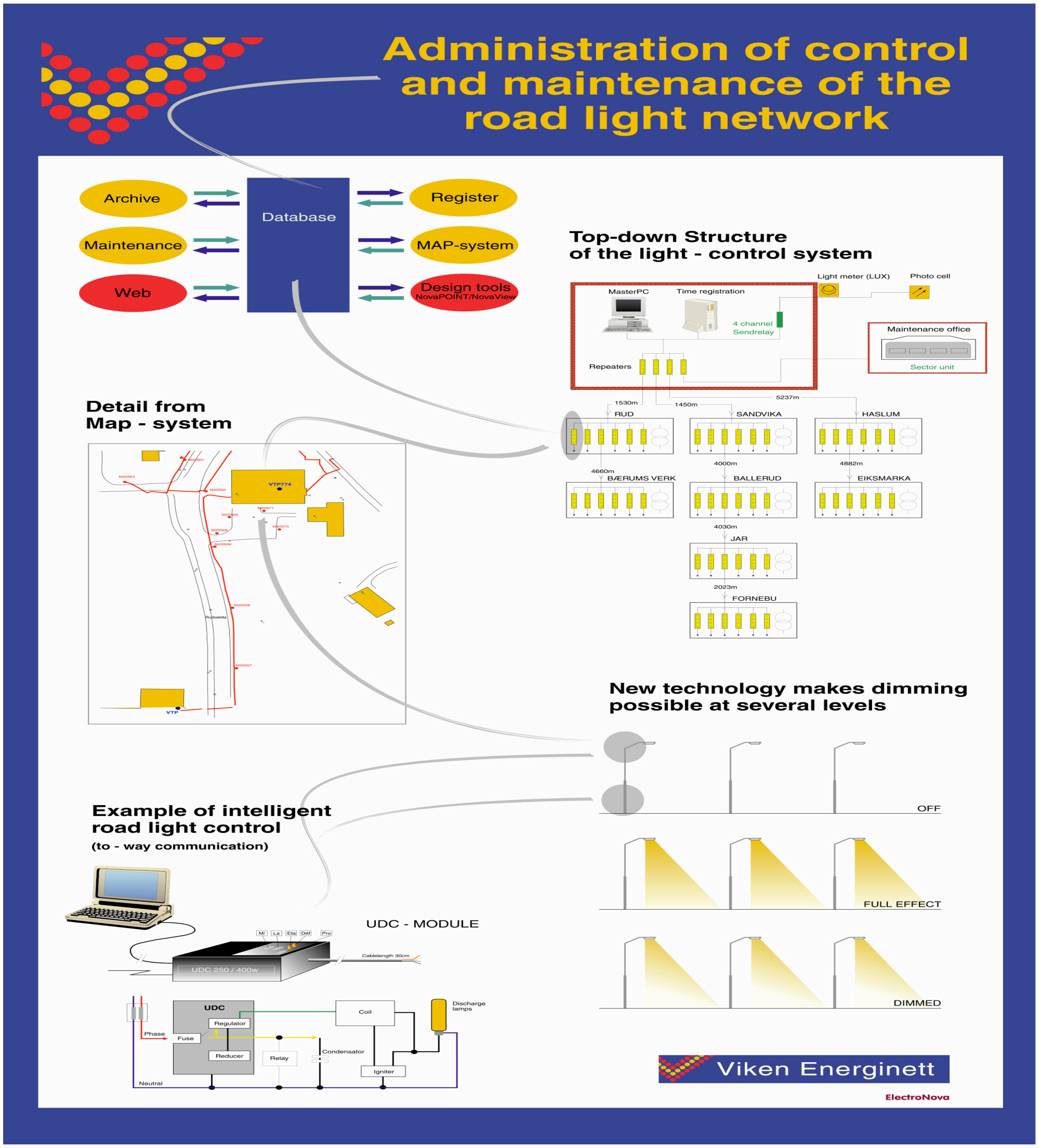
The suite of applications and benefits drive the economics of networked public lighting. Deploying comprehensive management applications will reduce energy consumption by 30% over the 4-6 year life of the lamp, plus provide additional savings of up to 50% in deferred maintenance by extending lamp life and optimally scheduling repairs[4]. The return on investment in public lighting management networks can be clearly documented. Consider the following real world example of energy and costs savings by the Municipality of Oslo in Norway.

E18 Asker- Oslo



Oslo by Light – integrated approach to efficient running and maintenance of street lighting in Oslo Partners: Viken Nett, the Norwegian Public Roads Administration, ENOVA and the Municipality of Oslo.

[4] Mr. Eirik Bjelland, Viken Nett, Norway; Intelligent Road Lighting – “Light on the Road”; CIE Session 2003



(Diagram illustration provided by Eirik Bjelland of Viken Energinett)

Viken Nett, who is owned by Hafslund ASA, is Norway's largest distribution company with 575 000 customers. Viken, together with the daughter company Østnett, are in addition responsible for the running and maintenance of 250 000 street lighting points in the greater Oslo area. In recent years Viken has been involved in the development of new concepts especially adapted to a deregulated electricity market, involving running, control and administration of street lighting. Viken has initiated several studies both on the concept and more on the organisation of the street lighting activities in general[5].

Putting it Together: A LONWORKS Solution

A street lighting system that makes for a compelling return on investment and provides the benefits listed above can be largely achieved today with the integration of "off-the-shelf" products. The basic infrastructure consists of an intelligent ballast controller, a scheduling/control/data logging/access device, power line routers, and software middle-ware that ties the systems access devices back to service center applications.

Specifically, a standard *i*.LON® 100 e2 controller to schedule the light operation and log the energy consumption may be used directly. Routers that route the *i*.LON 100 messages to the power line and couple to all 3 phases of the power line are commercially available today, as is the LonMaker® Integration tool to configure the *i*.LON 100 and the power line network. Additionally, the Panoramix® server software, GSM or GPRS modems, and GIS software can be added to integrate multiple *i*.LON 100 systems into a single management infrastructure for outdoor lighting.

A LONWORKS power line carrier enabled ballast controller is one fundamental piece of this solution not available today and stimulating the development of such a controller is a purpose of this document (ideas for implementing such a controller are presented in Appendix 1). The mechanical design for such a controller could take several forms: It could be made to fit inside the ballast compartment of the fixture, screw into the fixture like photocells today, screw into the top of light fixtures, or it could be mounted in an access panel at the base of the light poll. Certainly, other options are possible as well.

Phases of a LONWORKS Outdoor Lighting Deployment

The level of control and management afforded by a LONWORKS solution extends from the control center to individual ballasts a breadth and level of granularity of data virtually unknown today in the outdoor lighting industry. Given that the market is in its infancy, municipalities and other public entities responsible for outdoor lighting should begin with trials that verify system functions, reliability and cost savings rather than large deployments.

The likely scenario is that a trial is confined to a single or small group of distribution transformers, each with at most a few hundred lights on them. The *i*.LON 100s would be provisioned by the integrator prior to installation in the field. In the field, the *i*.LON 100s, power line to twisted pair routers, phase couplers, and the new ballast controllers would be placed in the field and would work as self-contained networks that provide simple on/off and

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[5]Mr. Eirik Bjelland, Viken Nett, Norway; Intelligent Road Lighting – "Light on the Road"; CIE Session 2003

dimming control according to a schedule. A WAN connection to the *i*.LON 100 would be required for the outage alarm function as well as the LonMaker integration tool to accomplish the network provisioning in trial step 2.

At some point after this initial trial is successful, the individual networks could be enhanced to collect more information from the ballast controllers, and could be integrated with Panoramix and a GIS system to provide additional capabilities such as monitoring lamp life, aggregating the energy usage across the system, and scheduling daily maintenance routes according to physical location.

Bandwidth Management on the Power Line

Power line communications bandwidth is a precious resource. Care must be taken in the design of the ballast control nodes so that they do not saturate the network. For this reason, LONMARK certified nodes can be configured to limit their bandwidth utilization. This degree of configurability works well in a commercial building or industrial environment where there are trained integrators installing the system. In the outdoor lighting environment, such trained integrators may not be available, and it is desirable to get a trial system installed and running very quickly with minimal installer interaction.

The frequency of communications can be set and controlled to eliminate the need for an integrator to configure each node due to two factors – the ballast control nodes only initiate communication on an alarm condition and the primary functions of the system (energy savings and outage detection) are pre-determined. For normal status updates, energy consumption data, and other values, the ballast control nodes wait to be polled by the *i*.LON 100. In this way, power line bandwidth is conserved so that the system design is not overly sensitive to the number of nodes on a distribution transformer. While it takes longer to poll more nodes, the information coming from the polled communications transactions is not time critical, so the polling can be done at a low duty cycle leaving plenty of bandwidth available for higher priority tasks such as prompt alarm condition reporting.

Phased Installation Scenario

While the percentage of energy savings is significant for every installation, the large, absolute monetary payback comes from changing over a large area to using the LONWORKS controlled system. However, a large-scale deployment involves a large, up-front expense. Until the savings are widely proven and accepted, the customers for outdoor lighting controls will want to do trials of a relatively small number of units and measure the savings from the trial. This limits the initial expenditure and perceived risk while allowing for direct experience with the system.

If we assume that the first full deployments will start as proof of concept trials, then there must be a phased installation scenario to support that need.

In particular, there must be a way to get a segment of luminares upgraded and running without special tools, wide area networking connections or a back-end service center integrated with the segment of luminares. While the functions of such a system will be limited, they will be sufficient to demonstrate the economic benefits of a full deployment.

Once these economic benefits are verified, the trial can proceed to its second phase,adding wide area networking, a head-end system, and possibly a GIS system. At this point additional system functionality can increase the value and return on the system as applications become available. These could include functions such as individual lamp metering, outage alarms, seasonal scheduling, individual luminaire remote control, and system mapping.

Once the operational aspects of end-to-end management of a small number of segments (luminaires to service center) are proven in the trial and understood, deployment on a large scale can begin.

Installation Scenario – Trial, Phase 1

LONWORKS enabled luminaire controllers are purchased by the installer along with *i*.LON 100s, FT to PL routers, and 3 phase couplers for each transformer. The *i*.LON 100s are all set up in an office. This includes the setting of the real time clock and setup of the lighting schedules along with the creation of the output network variable that is sent to the luminaires to control the light level. The output network variable on the *i*.LON 100 must be set up to be a broadcast update so that it will not matter how many luminaries are controlled by the *i*.LON 100.

The luminaires are programmed at the factory to accept the network variable transmitted by the *i*.LON 100 and once powered up, are ready for *i*.LON 100 control. The luminaires are taken to the field and installed and powered. As each luminaire is installed, the serial number that is bar coded on the luminaire is attached to a work order form or read by a hand held bar code reader. This step is in preparation for the later integration with a GIS system and server software. Should this step be omitted or forgotten, the information can be recovered in the next phase, but at the expense of a field visit with manual control of each luminaire to correlate its position on a map.

The *i*.LON 100 and the router/coupler are then installed and powered on at the distribution transformer and the system immediately begins scheduled lighting operation with gradual dimming from dawn to day and then gradually ramping up the light level from dusk to night. No special installation tools are used in the field for this phase.

Installation Scenario – Trial, Phase 2

The next phase of the trial involves selecting a wide area networking (WAN) technology such as GSM or GPRS modems so that remote communication to the *i*.LON 100s is possible from a central location.

Once the WAN modems are in place, the *i*.LON 100s can be contacted remotely to configure both the *i*.LON 100s and the ballast controllers for more advanced features over the network. In this step, the LonMaker for Windows integration tool is used to establish a connection to each *i*.LON 100 and recover the network. This will upload the unique IDs stored in each ballast controller into the network database. At this point, the management of the network is switched from “self-installed” to “managed” and every device is assigned an address. The *i*.LON 100 is also configured to alarm when a device does not communicate, and to log lamp on time and energy utilization. At the service center, the ballast control serial numbers are correlated to GPS map coordinates and entered into the GIS system. Panoramix is set up to periodically upload the log files generated by each *i*.LON 100 and to propagate alarms to other systems.

Installation Scenario – Deployment, Final Phase

In this last phase, the work in the two trial phases is replicated as a combined, single-field visit per transformer to lower costs. Otherwise, the techniques and skills acquired in phases 1 & 2 are directly applied, using the same methodology and tools.

Such economies are unique to the LONWORKS device networking platform and the infrastructure products described in this paper.

Conclusion: LONWORKS Device Networking Opens the Market

Public Lighting Management Networks can become a high volume and high value market for photosensor, ballast and device controller manufacturers by designing LONWORKS networks into your products. The adoption of a networking standard by all the key players in the outdoor lighting market will lead to new categories of intelligent networked lighting products – a boon to all the market constituents.

Technology is no longer limiting the development of the market.

Trials of networked lighting can be supported today through a channel of trained LONWORKS Network Integrators using off the shelf products. LONMARK certified devices can quickly be set for self-installation behavior and common data sharing so innovative network applications can be developed and deployed through your existing channels.

We believe the only thing missing is your vision and your drive to take advantage of this opportunity to add value to your company.

Call us today to see what Echelon can do for you.

References and Supporting Information

About Echelon Corporation

Echelon Corporation is the creator of the LONWORKS platform, the world's most widely used standard for connecting everyday devices such as appliances, thermostats, air conditioners, electric meters, and lighting systems to each other and to the Internet. Echelon's hardware and software products enable manufacturers and integrators to create smart devices and systems that lower cost, increase convenience, improve service, and enhance productivity, quality, and safety. Thousands of companies have developed and installed LONWORKS products and nearly 40 million LONWORKS devices are in use today in buildings, homes, factories, trains, and other systems worldwide. In the past 4 years, Echelon has worked with utilities to use our power line communication smart transceivers, our Internet access devices, and our network management software to create networked energy management systems on a massive scale.

More information about the LONWORKS platform can be found at **http://www.echelon.com**.

LONWORKS Building Automation

http://www.echelon.com/solutions/building/buildingapps.htm

LONWORKS Utility Automation

http://www.echelon.com/solutions/utility/default.htm

Echelon Products

General
http://www.echelon.com/products

i.LON 100 e2
http://www.echelon.com/*i*.LON

Panoramix Software -
http://www.echelon.com/products/enterprise/Panoramix/default.htm

LonMaker for Windows Installation Tool
http://www.echelon.com/LonMaker

Enel Metering Application

http://www.metering.com/archive/014/16_1_1.php

LONMARK International

http://www.lonmark.org

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Appendix 1

Developing a LONWORKS Ballast Controller

Developing the firmware for a LONWORKS enabled ballast controller involves the investigation of the system characteristics, including the installation scenario, as well as the application knowledge of ballast control, lamp life, energy consumption measurement, and lamp and ballast fault detection. Developing the control hardware to host this firmware requires the application knowledge of where the product will be mounted, environmental and power considerations, and measurement circuitry – just to scratch the surface. This level of product definition information is beyond the scope of a system overview discussion, so the remainder of this section will only cover the logical network interface of the ballast controller, how the self-installation support is provided, and what needs to be a part of the ballast controller to support the migration between the trial phases, discussed previously, to the full deployment phase. This part of the ballast design, the logical network interface, can remain consistent for a wide variety of outdoor light controllers that can be mounted in various places (photo cell screw-in, base of the pole, within the ballast, etc.) and for a wide variety of lamps.

Supporting Installation

The ballast controller must have a network interface that supports self-installation and conversion from self-installation to a managed network. This interface and the code behind it is described in Echelon's guidelines for self-installed nodes. These guidelines can be found at: http://www.echelon.com/support/selfinstall.htm.

These guidelines explain in detail how a node can be manufactured with a built-in address that is the same for all nodes and still be integrated onto a network. It also describes how network variable selectors may be set by the node application program to implement "self-binding" of the network variables. This feature will be used in the first phase of the trial.

In the first phase of the trial, only scheduled on/off control of the lamps is provided. To support this phase, the ballast controller must set the network variable selector for its input light setting variable (type SNVT_switch) to 1024. It is important that this value be chosen, as the *i*.LON 100 does not support self-installation, so when it is set up with LonMaker for Windows, the LonMaker tool will pick this selector first.

A second choice to be made is the selection of the LONWORKS Network Domain address. This address is the top level of the LONWORKS addressing hierarchy. A self-installed system needs to pick a domain address that is unlikely to conflict with other node's domain addresses within communication range. In addition, the domain address must be known to easily recover the network for the second phase of the trial. For these reasons, a single domain address should be picked on which all ballast nodes self-install. Domain addresses can be 0, 1, 3 or 6 bytes long. For open media, like power line, Echelon recommends a 6 byte domain to minimize the likelihood that another, different system within communication range would pick a like domain address. For this outdoor lighting application, the binary representation of the characters: L I G H T S is chosen as the 6 byte domain address for self-installed nodes.

Ballast Network Interface

The ballast network interface will include two objects, the LONMARK standard node object, and a second Outdoor Light Controller object that will be manufacturer defined (a LONMARK standard for outdoor lighting controls does not exist today).

The node object will contain the following interfaces:

1. An output variable of type SNVT_Alarm_2 to report alarms on either the ballast or the lamp
2. A standard configuration property of type SCPTnwrkCnfg to control whether the node installs itself or is managed by a network manager
3. A configuration property of type SCPTlocation that is set to the GPS coordinates of the ballast controller in phase 2 of the trial installation
4. The mandatory interfaces described in: http://www.lonmark.org/profiles/0000_20.PDF.

The Outdoor Lighting Controller object must contain the following interfaces:

1. An input network variable of type SNVT_switch to control the level of the lighting from the *i*.LON 100
2. An output network variable of type SNVT_elec_kwh_l that provides the cumulative kilowatt hours of electricity used by the ballast and lamp.

The Outdoor Lighting Controller object may have the following optional interfaces:

1. An input network variable of type SNVT_scene to control a ramped, gradual dimming or brightening operation. For example, to use during dawn and dusk
2. Manufacturer specific configuration properties to use for the calculation of lamp life and lamp light level throughout the useful life

3. Manufacturer specific network variable interfaces to inform the controller that a new lamp has been installed so that the light level can be controlled for a new lamp.