ADAPTIVE LIGHTING CONTROLS PANEL:

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TOPICS

• Communication and Networking standards
• Commissioning
• Monitoring and Control System Features
• User Interface
Outdoor Lighting System

- LED Module
- Optics
- Heat management
- Controls/LED Driver
- Mounting/connectors

Typical system today: All inside the Luminaire
Future: Outdoor Lighting Networks

High performance sources

Remote monitoring & control
metering, status, energy reports

Connectivity
Wireless, scalability, security

Dynamic lighting control
schedules, presence, weather, traffic

Sensing
cars, pedestrians, bicycles, environment…
The System Architecture and Components

Wireless network

Gateway

RF

WAN

(Remote connectivity infrastructure, e.g. GPRS, 3G, WiFi, ...)

Commissioning Tool

Central Management System (CMS)

Wireless Outdoor Lighting Controller (OLC)
Wireless OLC

- Registration of burning hours
- Real energy consumption
- Lamp failure detection (DALI)
- System failure detection
- Switch power on/off
- Line voltage registration
- Time clock
- Stand-alone operation
- Delayed switching (avoid high inrush current)
Gateway

- Connectivity to backend
- Access point for the outdoor lighting network
- Secure communication
• Connectivity
  – Wired (Power Line) vs. Wireless

• Network Topology:
  – Mesh vs. Star
Mesh Networking – how it works

- Mesh networks use packet forwarding to increase range and robustness
- Most optimal for city deployments and currently used in most products
- Suitable for highways when correct choices are made:
  - communication range of nodes
  - interference robustness
  - scalability
  - security
No standard for outdoor/large scale lighting systems

Link + Physical Layers:
Open Standards (IEEE 802.15.4) vs Proprietary radios

Defines spec for 2.4 GHz and sub-GHz (900 MHz) radios

NTCIP 1213 ELMS and other Web-based solutions

Re-use standard Internet Protocols (e.g. HTTP, TCP/IP, ...)

WAN (IP Network)

WAN Interface (e.g. 3G)

Application Protocol

Gateway

CMS

802.15.4 (radio)

Lighting Control Application

Transport/Network (Mesh)

WLAN (Mesh)
Wireless Outdoor Lighting Connectivity Example
Example: Average hopcount
<table>
<thead>
<tr>
<th></th>
<th>IEEE 802.15.4</th>
<th>IEEE 802.11 family</th>
<th>Cellular (3G)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data rates</strong></td>
<td>20, 40, 100, 250 Kbps</td>
<td>Depends on standard version: 2, 5, 11, 54, 72, 150, and up Mbps ...</td>
<td>DL: 2-28 Mbps UL: 384 Kbps -11Mbps</td>
</tr>
<tr>
<td><strong>Spectrum</strong></td>
<td>868-870 MHz (EU) 902-918 MHz (US) 2.4 GHz (Worldwide)</td>
<td>2.45 GHz 5 GHz</td>
<td>Various</td>
</tr>
<tr>
<td><strong>Range/Coverage</strong></td>
<td>100 m – 1.5 Km Depends on frequency band</td>
<td>10 – 250 m</td>
<td>Growing coverage (depends on deployment)</td>
</tr>
<tr>
<td><strong>Primary Applications</strong></td>
<td>Building/home automation, sensor/actuator networks, healthcare, games, etc (usually low data rates and low power devices)</td>
<td>Wireless broadband/Internet access.</td>
<td>Mobile broadband, M2M applications in the future.</td>
</tr>
<tr>
<td><strong>Standard Development</strong></td>
<td>15.4 Complete 15.4g extension for smart utility networks completed (2012)</td>
<td>802.11a/b/g/n and others... New sub-GHz spec under development (11ah), expected 2015</td>
<td>Evolving (3G, LTE, LTE advanced/4G, ...)</td>
</tr>
</tbody>
</table>
Networking and Application Standards - ZigBee

Several Application Profiles

- Home automation
- Building control
- Smart Energy
- Medical sensing and monitoring
- Remote control of home entertainment
- …

Currently there is **no ZigBee application profile** for outdoor lighting management.

- ZigBee profile with 802.15.4 2.4 GHz is used in many control applications (home, buildings, etc.)
NTCIP 1213 started in 2001, latest version published in 03/2011

- Defines Data Objects/MIB (Management Information Base)
- MIB is a set of attributes/parameters that can be remotely managed
- Not widely adopted by the Lighting Industry
NTCIP Data Objects definition is based on SNMP (Simple Network Management Protocol), originally designed and mostly used to manage network equipment.

- UDP provides unreliable transport.
- NTCIP 1213 does not address end to end security (left to lower layers).
- Spec has still unfinished parts (e.g. asynchronous reporting is not specified).
Other Developments in Application Standards

• **Internet of Things (IoT) and Web services**
  - Devices/systems are being integrated with the Web
  - E.g. automation/control systems, smart metering, demand response, etc.

• **Re-use Web service technologies:**
  - The manipulation of remote resources using HTTP (REST), remote procedure call (RPC) style interactions (SOAP), XML is used as data description format
  - Not all Web services technologies are suitable for constrained devices and networks
  - Outdoor lighting and other applications based on wireless sensors and actuators have limitation in bandwidth and device capabilities

• **Several ongoing initiatives to design web-based protocols that help optimize communication and lower computational requirements**
Open vs. Proprietary Protocols

- **Open Standards**
  - IEEE 802.15.4 is widely used for low data rate wireless control
  - ZigBee is also a popular standard, but implemented features/stacks are not always clearly communicated
  - LonWorks® is the available standard for power line deployments
  - NTCIP 1213 is a lighting application standard, though not widely adopted by the Industry
  - Web based technologies are being used in several systems/solutions

- **Proprietary protocols can be optimized for performance**
  - E.g., vendors design protocols to enable more OLCs per gateway and robustness
  - Many leverage existing connectivity standards and open platforms (e.g. 802.15.4 radios)

- **Total solutions combining of open and customize protocols provide best performance today**
  - As industry evolves, closed parts of the system can become open/standard
Commissioning a system in 4 steps...
STEP 1

- If available, upload Light Plan in a Commissioning Tool
  - For example:
    - Pole numbers/names
    - GPS coordinates
    - Lamp type
STEP 2

• Every OLC has a unique identification, readable through a barcode

• Collect OLC information using the Commissioning Tool:
  – GPS location
  – Scan barcode
  – Enter system information (lamp, driver, OLC)
STEP 3

• Copy configuration (xml) file from Commissioning Tool to computer
• Start CMS and upload file
STEP 4

- Create switch on, switch off and dimming schedules
- Assign dim schedules to specific days
How is the wireless communication secured?

- Wireless communication is easily accessible and hence several security threats exist
- Need to safeguard performance of the lighting management system

- Secure deployment and commissioning
  - To prevent the addition of malicious devices in the system.

- Encryption of data
  - To prevent eavesdropping on the communications in the system

- Authentication
  - To prevent unauthorized people and devices to control and disrupt the network

- Secure software updates
  - To prevent hackers from uploading non-functional or adding malicious software
management software

- System commissioning
- Asset management
- Street map views
- Automatic failure reporting
- Real time lighting status reporting
- Manual overrides
- Energy use reporting
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Monitoring & Control System Features

• Asset Management
• Energy Management
• Adaptive Control (Dimming)
• Power Metering
• Ambient Sensing
Asset Management

• Improved Maintenance Efficiency
  • System Wide Inventory with accurate location
  • Prompt location of outage and “first trip” repair
  • Elimination of night patrols

• Supplier Performance
  • Collect on manufacturer warranties
  • Evaluate repair crew performance

• Improved Public Safety and Reduced Liability
  • Outage reduction means lights are on when needed
  • Historical burn times for defense against claims
Energy Management

- Prompt repair of day-burning fixtures
- Set on/off/dim schedules for individual and grouped fixtures
- Continuous Dimming – adjust lighting levels throughout the night
- Trimming – Offset from sunrise and sunset to optimize burn time
Dimming

• Different types of dimming controls:
  – 0-10 VDC
    • Currently most common in the US
    • Simple
    • Only one way communication – cannot send information from the ballast/driver back through the system
  – DALI (Dimmable Addressable Lighting Interface)
    • Becoming increasingly used in Europe
    • Offer two way communication – able to read information from the ballast/driver back through the system
    • DALI was designed for interior lighting... commands not ideal for street lighting
Two different fixtures showing their dimming response to a 0-10 volt control
Metering

- Ability to provide power measurement as well as calculated power
- Required by some utilities to capture energy savings
- Replaces bundled “fixed rate” of energy per night per light
- Many questions remain unanswered
  - Who owns the meter?
  - What level of accuracy is required? 2%, 1%, 0.5%
  - Who owns the audit process?
  - Who maintains the data?
  - How is data presented and used for billing?
    - In aggregate or by individual fixtures?
Factors Affecting Meter Accuracy

• Temperature
• Range (voltage, current, power)
• Power Factor
• Frequency
• Calibration
• Cost
Meter Accuracy

Figure 6. Active Energy Error as a Percentage of Reading (Gain = 1) over Power Factor with Internal Reference and Integrator Off

Figure 9. Active Energy Error as a Percentage of Reading (Gain = 8) over Temperature with External Reference and Integrator Off

Source: Analog Devices, Model: ADE7763
Ambient Sensing

- Ambient Temperature
- Ambient Light Levels
- Pedestrian Traffic Volumes
- Vehicle Traffic Volumes
- Ground Faults
- Wire Theft
User Interface

• Centrally Hosted vs. Customer Hosted Systems

• Standard Features
  • Mapping
  • Reporting
  • Scheduling
  • Grouping
  • Administration

• Extended Features
  • Work Order Management
  • Energy Use Display
Centrally Hosted Systems

- Web based with secure login (User ID and Password)
- Data from control network processed by service provider at central location
- Cost of hosting scaled over all deployments
- IT infrastructure and resources provided as part of service
- Patches and Upgrades supplied as part of service
- Security concerns about off-site data hosting
- On-going fees for service
Customer Hosted Systems

• Data remains on customers network
• Servers, databases and network owned and maintained by customer’s IT resources
• Web based
• Patches and Upgrades provided on “version specific” basis
• Reduced security concerns
• Elimination of on-going fees
Mapping

“At a glance” visual management of operational performance of each fixture

• Color coded outage reporting and display
• Display of grouped fixture performance
• Easy identification of system outages
• Dynamic map interface for zooming, panning, etc.
  • Mapping service updates required
• Static maps for small installations
  • Capability to import customer supplied images
  • No mapping service updates
Mapping Interface
Reporting

• Standard reports normally include
  • Asset listing and performance
  • On/Off times
  • Burn hour summary
  • KWh usage by fixture and system for specified period
  • Historical performance by fixture
  • Viewable on-line and exportable to PDF and Excel
• Ad-hoc reporting
  • Customized per user specifications
  • Storage of report templates
Reporting Interface
Scheduling

• User defined schedules for individual, group or total system control
• Time based and sunrise/sunset offset capabilities
• Event based for single day applications
• Schedule based for multi-day applications
• Customer defined priorities for fixtures in multiple groups
• Network feedback on success/failure of applied schedule
Scheduling Interface
Grouping

• Ability to create fixture groupings based on logical or geographical importance
• Feedback on operational status of groups
• Ability to issue immediate or override commands to any group
• Used as a filter for mapping and reporting
Administration

• Maintenance of user profiles including user permissions
• Asset maintenance to change fixture attributes, location and device ID
• Firmware upgrades for installed hardware
• Reports on system stability, file status, etc.
## Administration Interface

![Administration Interface](image)

<table>
<thead>
<tr>
<th>Database Key</th>
<th>Translation from English</th>
<th>Translation to English</th>
</tr>
</thead>
<tbody>
<tr>
<td>db.configuration2configurations.int.SC001.AWS</td>
<td>IP address SeCo</td>
<td>IP address SeCo</td>
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<tr>
<td>db.configuration2configurations.int.SC001.BSM</td>
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<td>Timserver SeCo</td>
<td>Timserver SeCo</td>
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<tr>
<td>db.configuration2configurations.int.SC001.PTZ</td>
<td>Timezone SeCo</td>
<td>Timezone SeCo</td>
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<tr>
<td>db.configuration2configurations.int.SC001.PTE</td>
<td>Sync. Interval Timserver</td>
<td>Sync. Interval Timserver</td>
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<td>db.configuration2configurations.int.SC001.PLA</td>
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<tr>
<td>db.configuration2configurations.int.SC001.PLD</td>
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<td>Timserver Communication Failure</td>
<td>Timserver Communication Failure</td>
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<td>Retries after Send Failure</td>
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<td>db.configuration2configurations.int.SC001.PUT</td>
<td>Internal Timestamp</td>
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<tr>
<td>db.configuration2configurations.int.SC001.PUC</td>
<td>Internal Group Commands</td>
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<td>Input Type</td>
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</table>
Controls Panel

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