EnLight
Möglichkeiten der Energieeinsparung durch intelligente Beleuchtung
EnLight Consortium

29 Partners
3 Years, Jun 2011-2014
EnLight Project

EnLight is a EU-wide project with 29 partners, funded within the ENIAC framework.

To exploit the full potential of solid-state lighting through breakthrough innovations on:

- non-conventional,
- energy efficient,
- intelligent lighting systems,
- beyond LED retrofit applications,
- with the aim of 40% additional energy reduction compared to LED retrofit systems.
EnLight Project

- **Energy efficient light source** -20%
  - Electrical efficiency
    - Integrated drivers
    - Power supply
    - Control
  - Optical efficiency
    - Higher LOR
  - Thermal efficiency
    - Lower $T_j$

- **Intelligent control**: -20%
  - The right light,
  - at the right amount
  - at the right place
  - at the right time
Outline

‣ System Architecture key concepts
‣ Bus Architecture
‣ Driver Electronics
‣ Results
System Architecture
Decentralized intelligence / Lighting Control Network (LCN)

‘Internet of Things’ Architecture

› **No central node** & no global knowledge of network topology is required
› **All decision processes take place locally** at each node and no global knowledge of the network is required a priori
System Architecture
Decentralized intelligence / Lighting Control Network (LCN)

Intelligent luminaire is cornerstone building block

- **Autonomously controls** brightness, CCT, color, beam shape, …
- **Reacts to events** instead of being instructed by e.g. a central controller
- **All nodes** in the network can raise events
- **Connection to Building** Control Network via area controller

“Intelligence by configuration”

- **Rules based behavior**: configured during commissioning phase
- **Flexible**: Ability to adapt/change behavior per node
- **Self learning**: Ability to adapt behavior as result of global data analysis and data mining
System Architecture

Rules example

Set of rules determines the behavior of each luminaire.

- Rule = event, condition, action

Desired behavior, e.g.
- Each luminaire is switch off in case of absence
- Luminaire is on (100%) in case of presence
- Luminaires are 70% dimmed if a neighboring luminaire is on.
Rules described in XML

```
.AreaLightingSystem
  <Luminaire Name="Power Balance" Address="00:0D:6F:00:02:78:C5:D0">
    <Rule Name="presence detected by luminaire">
      <Trigger Event Type="PresenceDetected" Address="00:0D:6F:00:02:78:C5:D1">
        <Action>
          <LuminaireSetting Command="SetDimmingLevel">
            <Level>1</Level>
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              <Constant u16>70</Constant u16>
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        <Action>
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            <Level>1</Level>
            <Argument>
              <Constant u16>70</Constant u16>
            </Argument>
          </LuminaireSetting>
        </Action>
      </Trigger>
    </Rule>
  </Luminaire>
</AreaLightingSystem>
```
Outline

- System Architecture key concepts
- **Bus Architecture**
- Driver Electronics
- Results
Intelligent Luminaire Architecture

**Intra Luminaire Bus (ILB)**

- I²C based
- Plug & Play
- To decouple lifecycles of independent technologies
- Enables market players to contribute, differentiate and compete

![Diagram of Intra Luminaire Communication (ILB) bus](image_url)
Network / Bus Technology

**Lighting Control Network:**
- **Wireless:** Zigbee Pro Stack, using a new EnLight Profile
- **Wired:** UDP / IP

**Intra Luminaire Network:**
- **Wired:** I²C Phy, using ILB message protocol

**Power Network**
- **24V** high power supply for LED driver
- **5V** low power supply for standby operation

Easy interfacing to building management over KNX and compatible with DLT (Ledotron), DALI via adapter
Outline

- System Architecture key concepts
- Bus Architecture
- Driver Electronics
- Results
Hardware Implementation

“Luminaire Lego”

- Intelligent Luminaire Modules
  - LED driver
  - ILB and Zigbee
  - Standard interfaces
  - Optional Controller
  - Expandable to form large luminaires

- Three modules which allow to build luminaires from spot size to wall size
  - 350mA Boost driver board (25…70V)
  - 1000mA Buck driver board (7…21V)
  - Control Board

- All modules can be equipped with a Jennic JN5168 as µController and Zigbee module
Hardware Implementation
Bus System on Board

Concept
- ILB connection via μController JN5168
- I²C communication with PWM expander
- PWM communication with LED driver

Advantages
- Standard interface to ILB
- Full flexibility of string length
- Standalone operation without μController

“luminaire #1 green 50%” (result of rule x)

Communication + luminaire controller

ILB

“LED Driver #1 green 50%”
Hardware Implementation
1000mA buck driver board

Configuration

› µController / Zigbee JN5168
› PWM expander PCA9685
› LED Driver UBA3070
› Standard interface / daisy chain of all bus systems

Bus Systems

› 24V LED supply
› ILB for intelligent luminaire
› I2C to operate LED driver
Luminaire Designs

Concept

- **Re-use** hardware modules
- Connect through bus system
- Create functionality by driver **software**

![Diagram of Luminaire Designs](diagram.png)
Hardware Implementation
LED Driver / DCDC converter

Voltage selection
- LED string voltages
  6…70V
- Efficiency scales with voltage ratio
- 24V bus voltage results in a ratio up to 3

LED driver topologies
- Buck converter
  UBA3070 (NXP) or ILD60150 (Infineon)
- Boost converter
  UBA3077 (NXP)
Hardware Implementation
LED Driver / DCDC converter

LED Driver Optimization
- Choice of Flyback Diode strongly affects system efficiency
- PMEG3050BEP offers high efficiency across whole voltage range
- Board operation above 90° C environment temperature possible

ILD6070 demo board
(Vin=25V, 6LEDs)

Reference Diode
100V 1A Schottky

Low forward voltage
PMEG3050EP

Low leakage
PMEG3050BEP
PMEG4050EP

Low capacitance
PMEG4020EP

Efficiency vs. Vout (V)
Efficiency vs. PWM duty cycle (%)

NXP
Outline

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Demonstrator Luminaires
using EnLight Hardware Platform

- Spot “Glow 100tm”
  INSTA

- Ceiling Light “Power Balance“
  PHILIPS

- Wall light “Wedge”
  OSRAM
Overall validation methodology

- Office (Philips, VTT) & hospitality (OSRAM) demonstrators
  - Comparison between the Baseline and EnLight
    - **Energy consumption** and illumination measurements
    - → *annual energy consumption of the lighting* (LENI)
    - **User acceptance** studies for light quality evaluation
    - → *user feedback*
# Energy saving strategies

<table>
<thead>
<tr>
<th>Office</th>
<th>Task tuning</th>
<th>Personal control</th>
<th>Occupancy</th>
<th>Time schedule</th>
<th>Daylight harvest</th>
<th>Load shedding</th>
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</thead>
<tbody>
<tr>
<td><strong>Open office</strong></td>
<td>Ambient / task tuning</td>
<td>Desk light</td>
<td>Local sensing with light bubble</td>
<td>Sunrise rhythm</td>
<td>Local constant lux</td>
<td>✓</td>
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<tr>
<td><strong>Meeting room</strong></td>
<td>5 Scenes</td>
<td>Scene selection</td>
<td>Local occupancy sensing</td>
<td></td>
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<tr>
<td><strong>Corridor</strong></td>
<td></td>
<td>Follow me Room Linking</td>
<td>Office hours</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

![Energy consumption graphs](image)
Energy consumption in Office VTT
Baseline

A lot of energy is wasted when nobody is there!

Data from 11.2.2013 - 29.11.2013.
Philips Open Office energy snapshot

Report of usage from 25-8-2014 to 27-8-2014 inclusive

Non-retrofit LED 2012

Enlight 2012
Meeting the Grand Challenge

LENI comparison

- Baseline (fluorescent)
- LED retrofit
- Enlight

Meeting
- LENI number [kWh/m² per yr]
- -44% decrease

Lounge
- LENI number [kWh/m² per yr]
- -46% decrease

Office
- LENI number [kWh/m² per yr]
- Same occupancy!
- Similar illuminance!
Enlight light quality: Office VTT

“Overall impression, quality of light, vista and visual comfort”
EnLight
http://www.enlight-project.eu/

Next Generation Lighting System with

‣ Decentralized intelligence in the luminaire and end nodes, rule-based, communicating via a Zigbee network,

‣ Modular intra-luminaire architecture with a ILB digital bus interface,

‣ Software-defined functionality and minimized hardware.

Acknowledgement: The project is sponsored in the framework of the joint undertaking ENIAC (ENIAC Annual Work Program 2010) and on the basis of the national research program “IKT 2020 – Research for Innovation” by the German Federal Ministry of Education and Research (BMBF)
Next Generation Lighting System with

- More than 44% energy savings at similar illumination level and occupancy
- Uniformly distributed illumination with a lighting level according to standards
- End user surveys indicate enhancement in the user comfort

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Thank you