UCC
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

Optimised Embedded Distributed Controller for Automated Lighting Systems

Alie El-Din Mady, Menouer Boubekeur and Gregory Provan

Prof. Gregory Provan

Cork Complex Systems Lab

Computer Science Department, University College Cork,

Cork, Ireland.

Cork Complex Systems Lab

Outline…

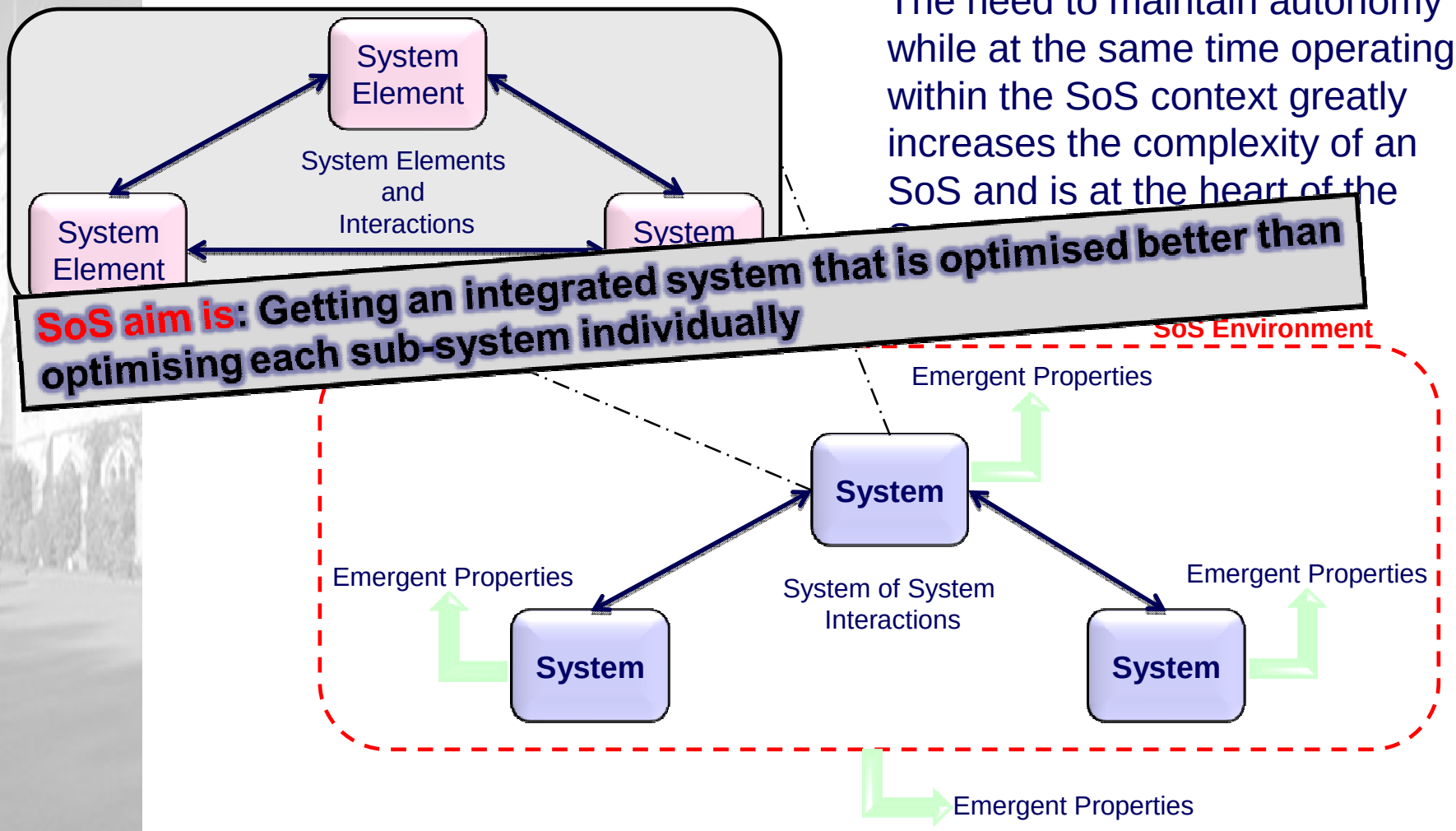
- System of Systems (SoS)
- Integrated Modelling for Building Management Systems (BMS)
- Lighting Scenario
- Parameterizable/Predictable Distributed (PPD) Controller
- Simulation Results
- Design Improvements
- Summary and Future Trends

Outline…

- **System of Systems (SoS)**
- Integrated Modelling for Building Management Systems (BMS)
- Lighting Scenario
- Parameterizable/Predictable Distributed (PPD) Controller
- Simulation Results
- Design Improvements
- Summary and Future Trends

System of Systems (SoS)

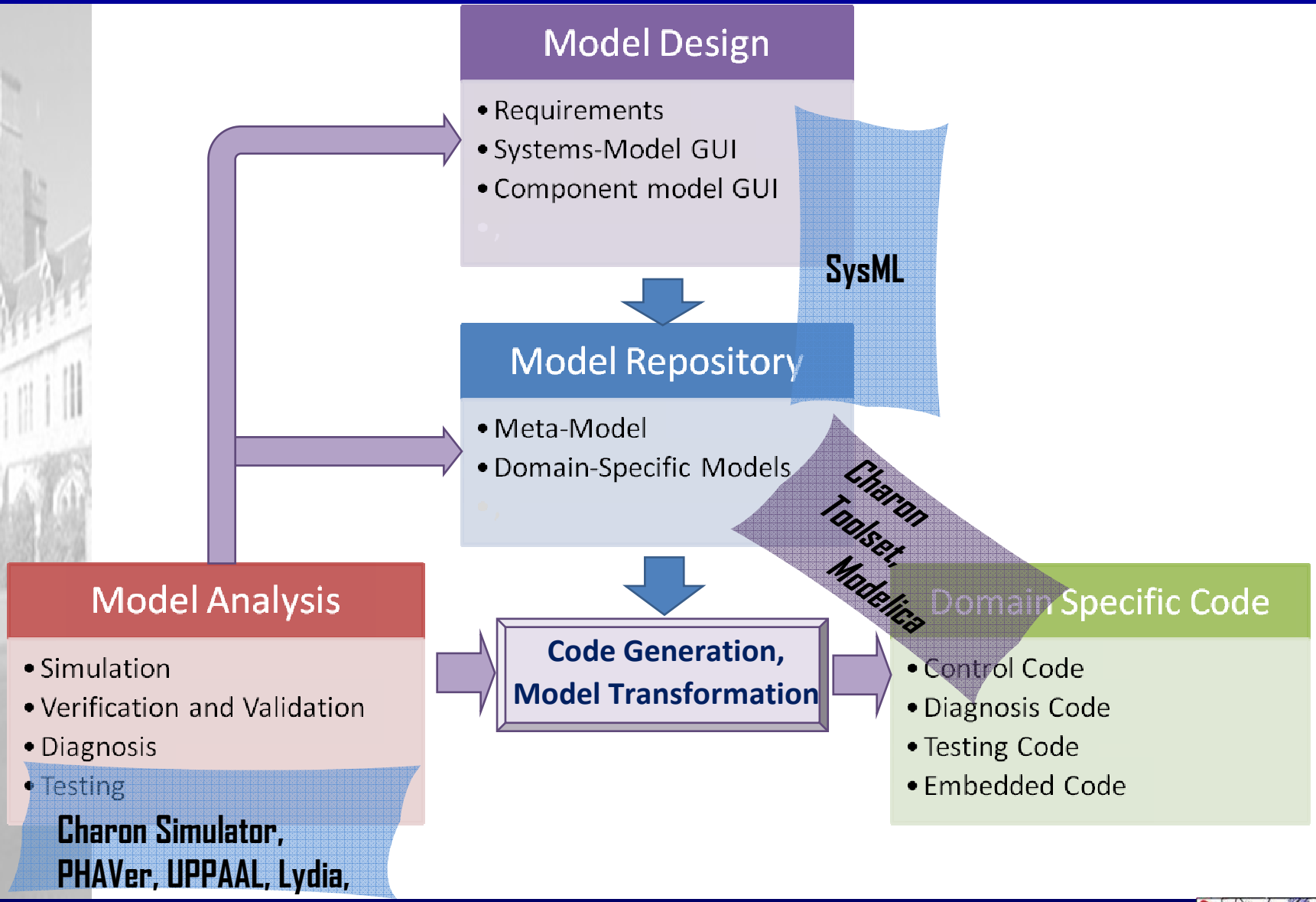
The need to maintain autonomy while at the same time operating within the SoS context greatly increases the complexity of an SoS and is at the heart of the



Outline…

- System of Systems (SoS)
- **Integrated Modelling for Building Management Systems (BMS)**
- Lighting Scenario
- Parameterizable/Predictable Distributed (PPD) Controller
- Simulation Results
- Design Improvements
- Summary and Future Trends

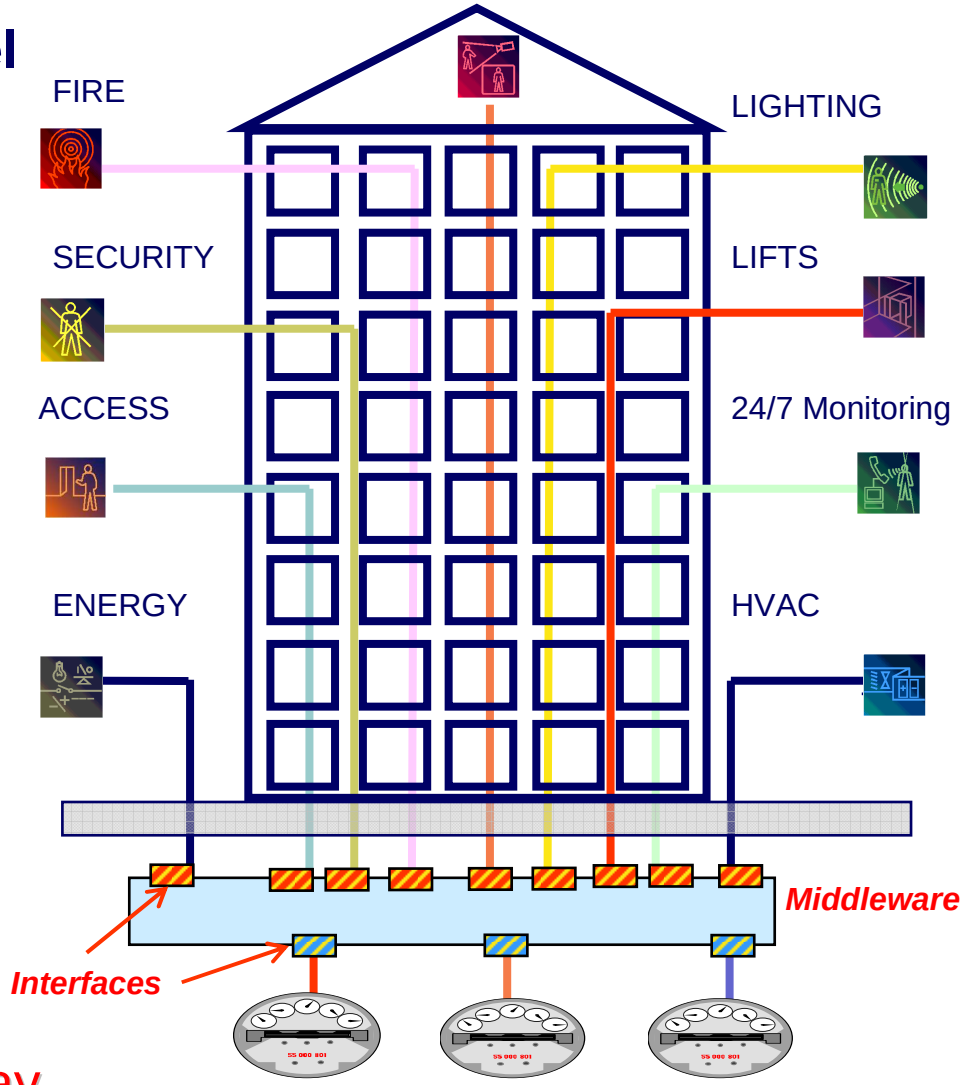
Modelling Methodology



Model Integration for BMS

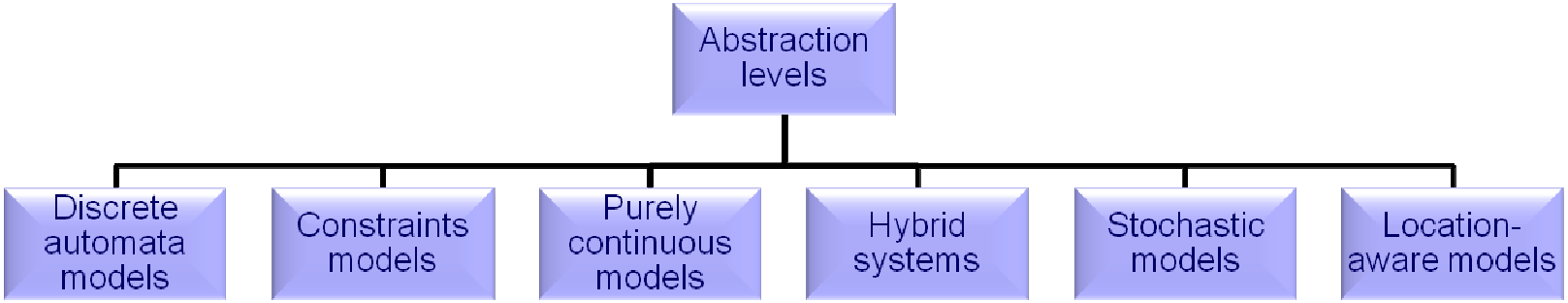
- **Common System–Level Information Model**
  - Data sharing
- **Integration Mechanism**
  - Middleware
- **Benefits**
  - Sub-systems are integrated, yet
  - Retain their own
    - standards
    - protocols
    - networks
    - Separate control environments

No such system exists today

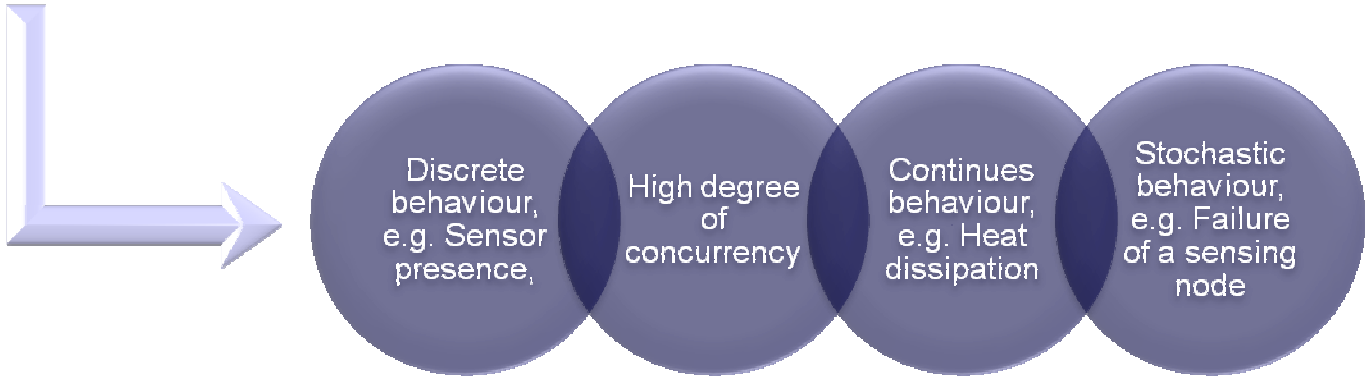


Integrated **Control Environment**

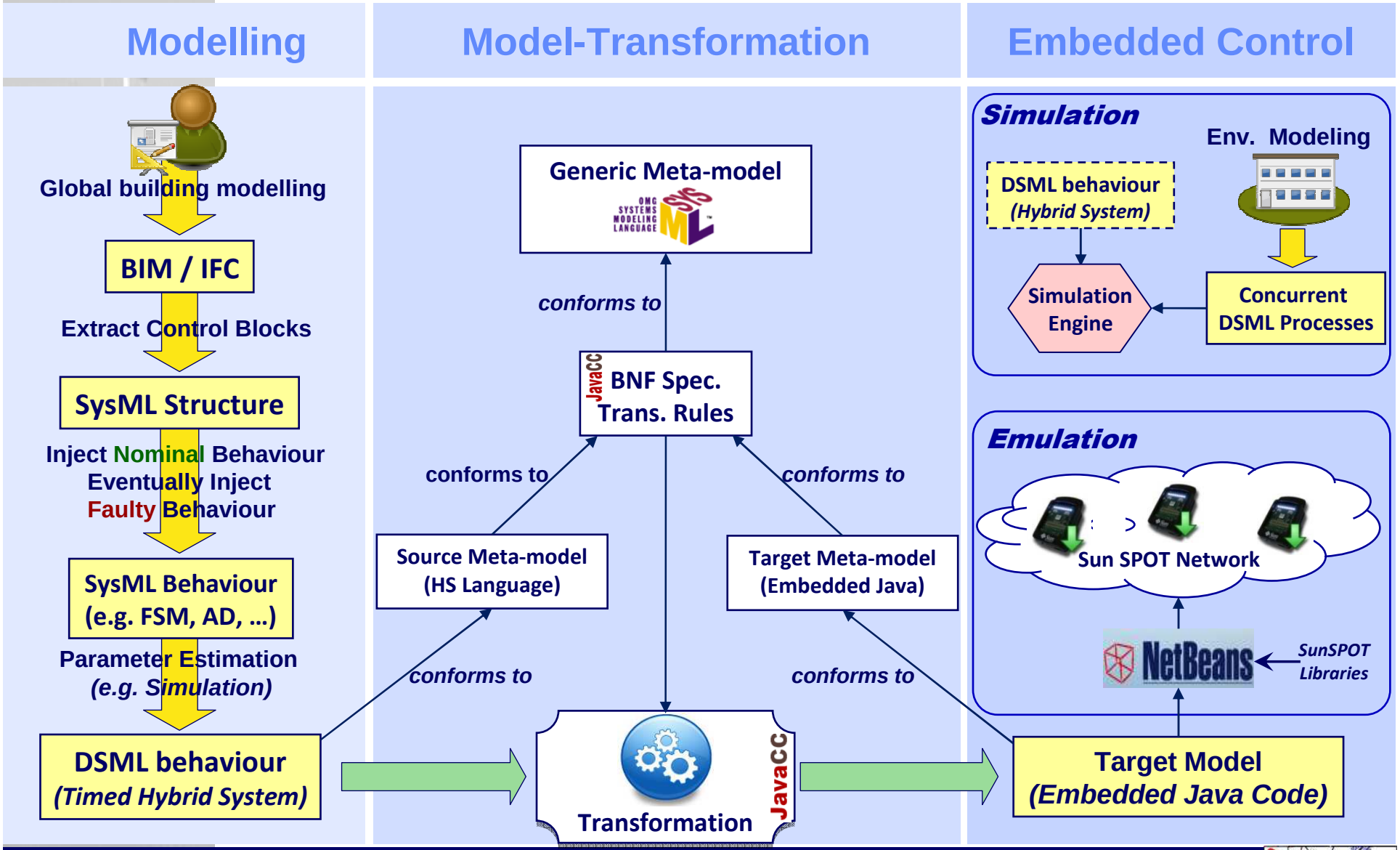
What to Model ?



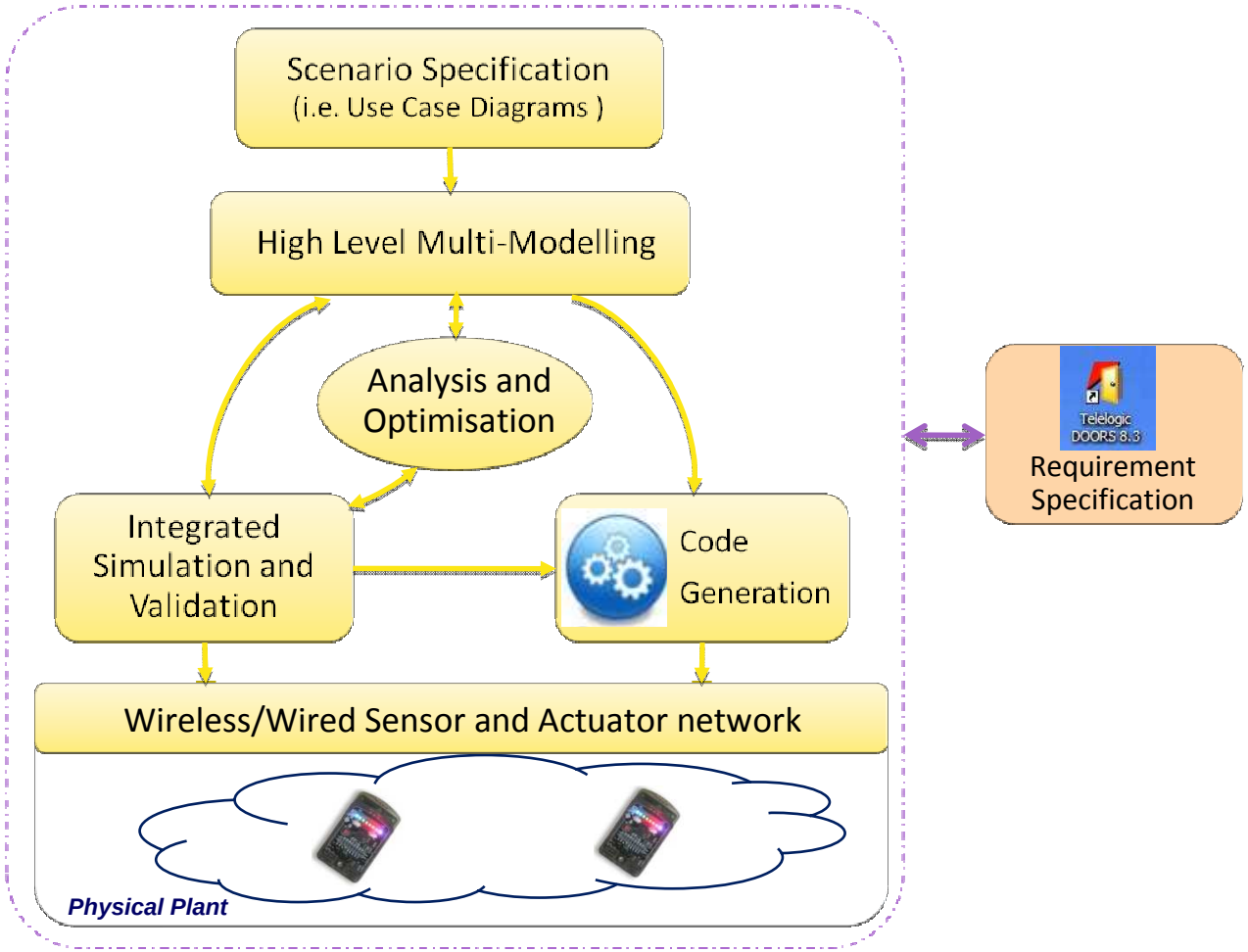
Example: Building Management System (BMS)



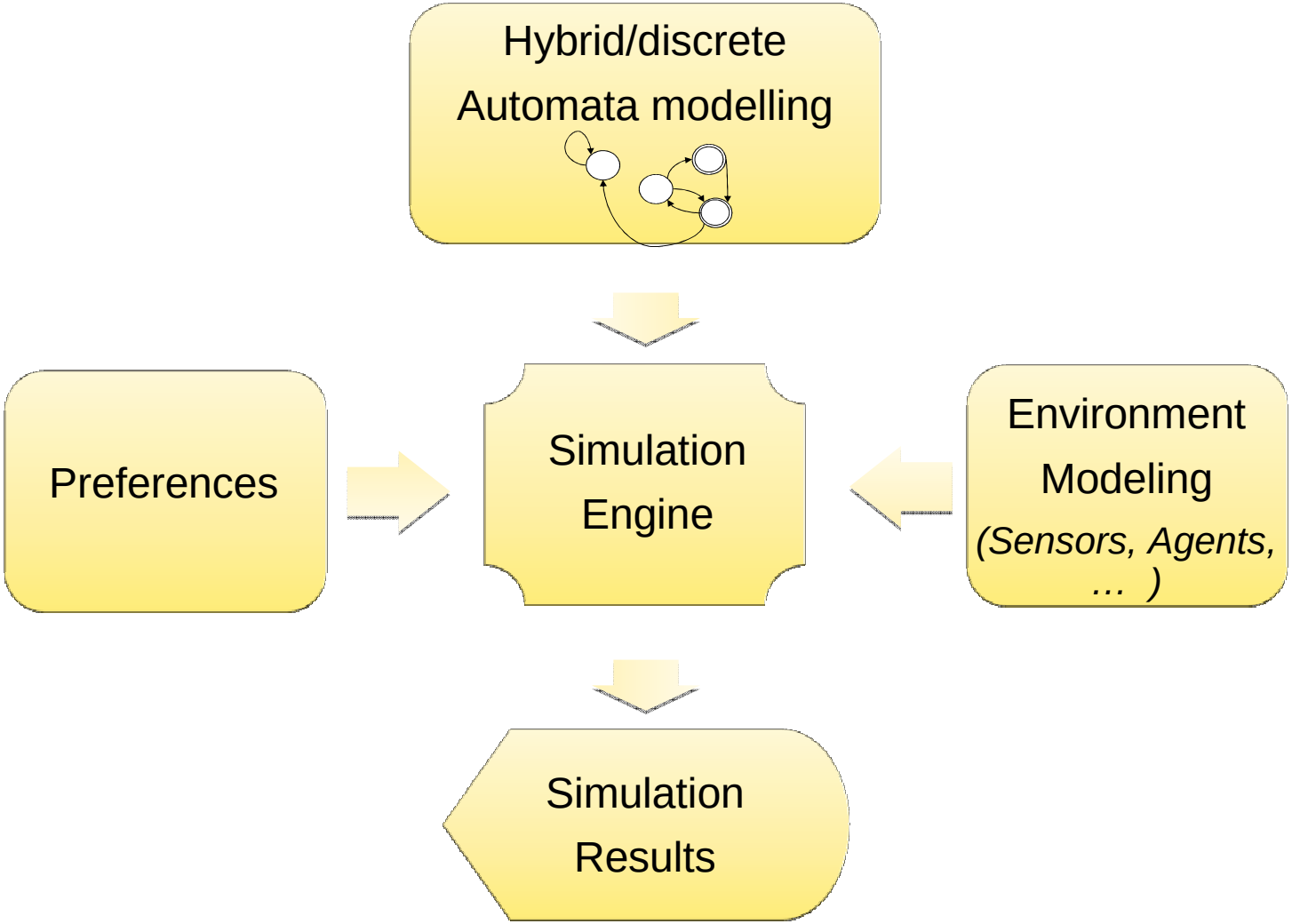
Methodology for Automatic Control Code Generation



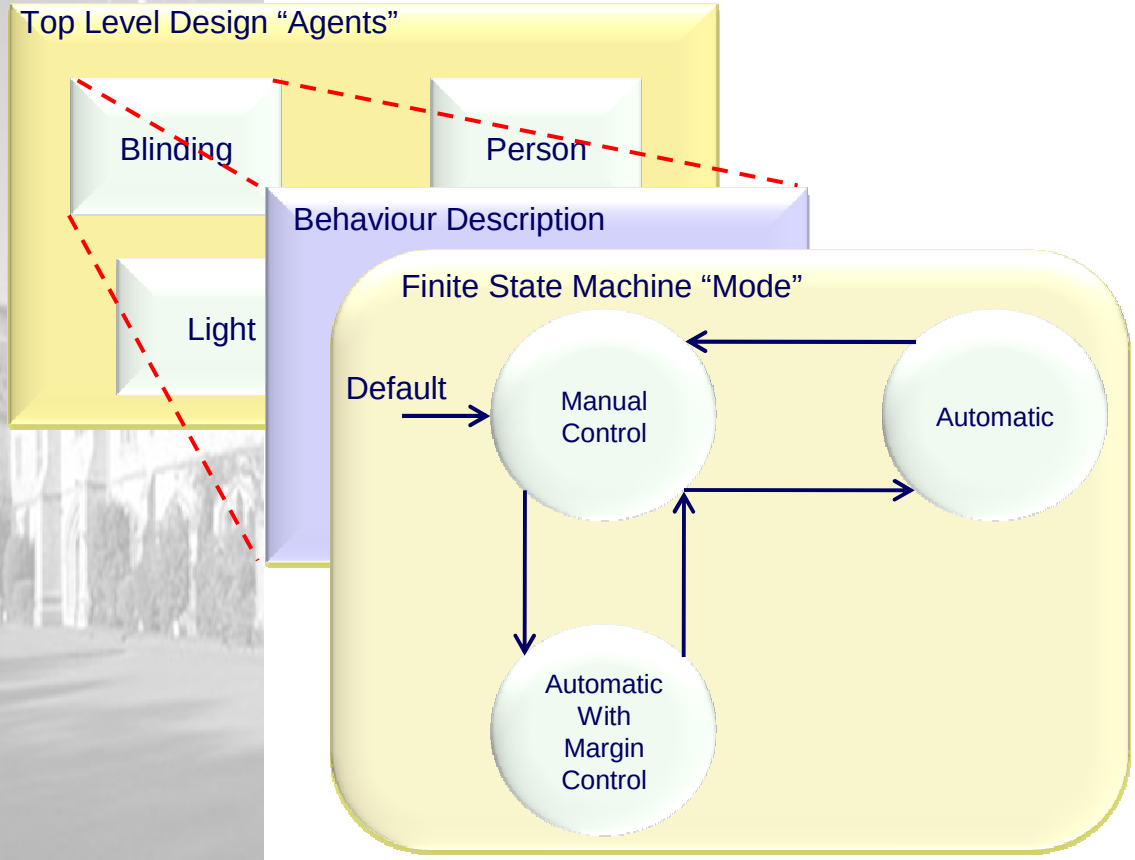
Methodology

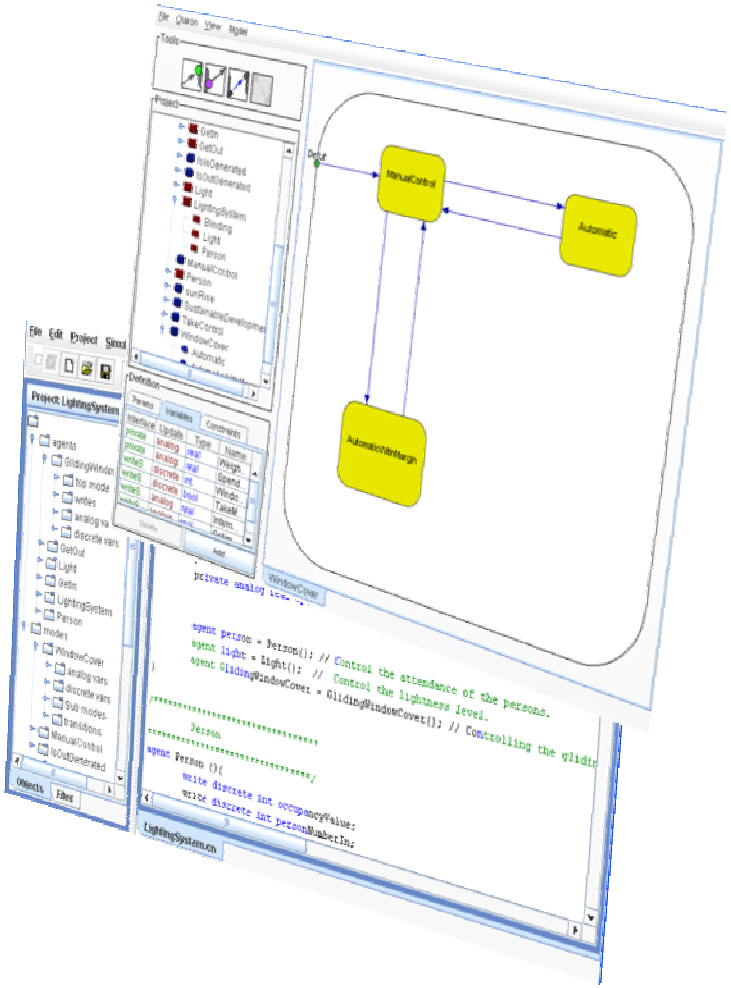


Integrated Simulation Platform



Hierarchical Modelling Using Charon



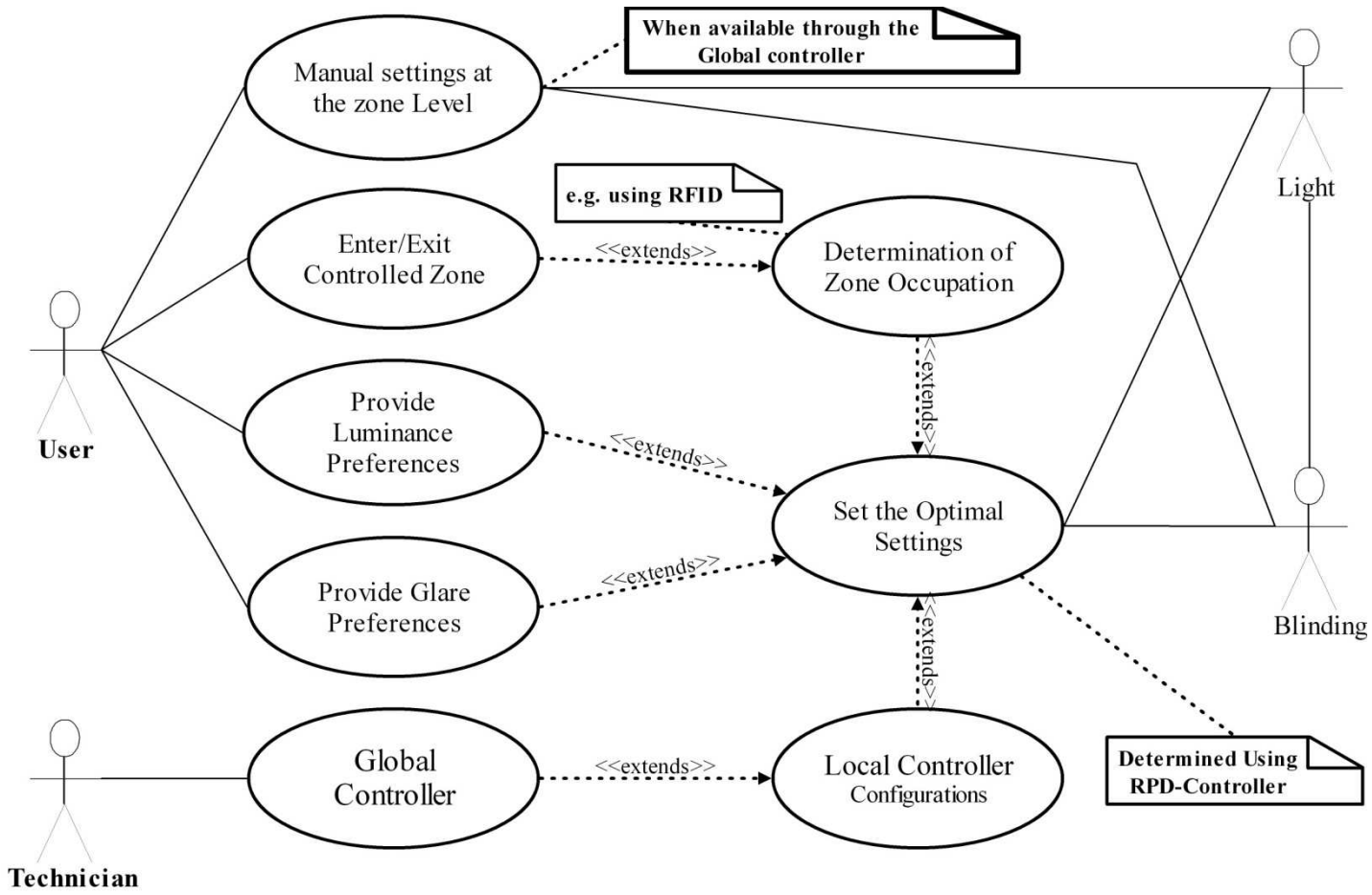


Outline…

- System of Systems (SoS)
- Integrated Modelling for Building Management Systems (BMS)
- **Lighting Scenario**
- Parameterizable/Predictable Distributed (PPD) Controller
- Simulation Results
- Design Improvements
- Summary and Future Trends

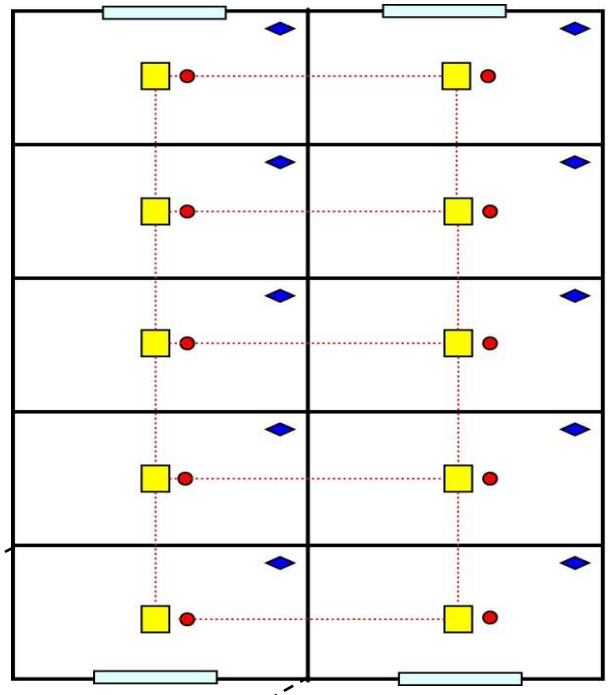
System Description and Requirement Specification

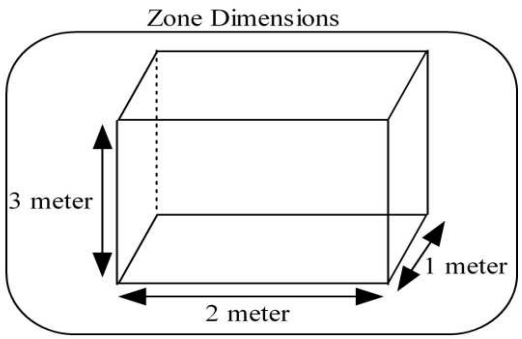
Use-case Diagram : Requirements specification



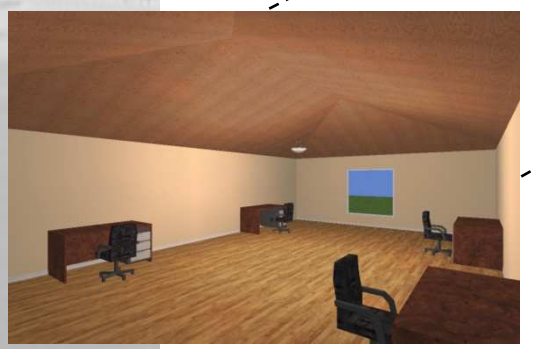
Model Specifications

One open area, 10 controlled zones.





Window/Blinding
Bulb
Light Sensor
RFID Detector
Controller Communication



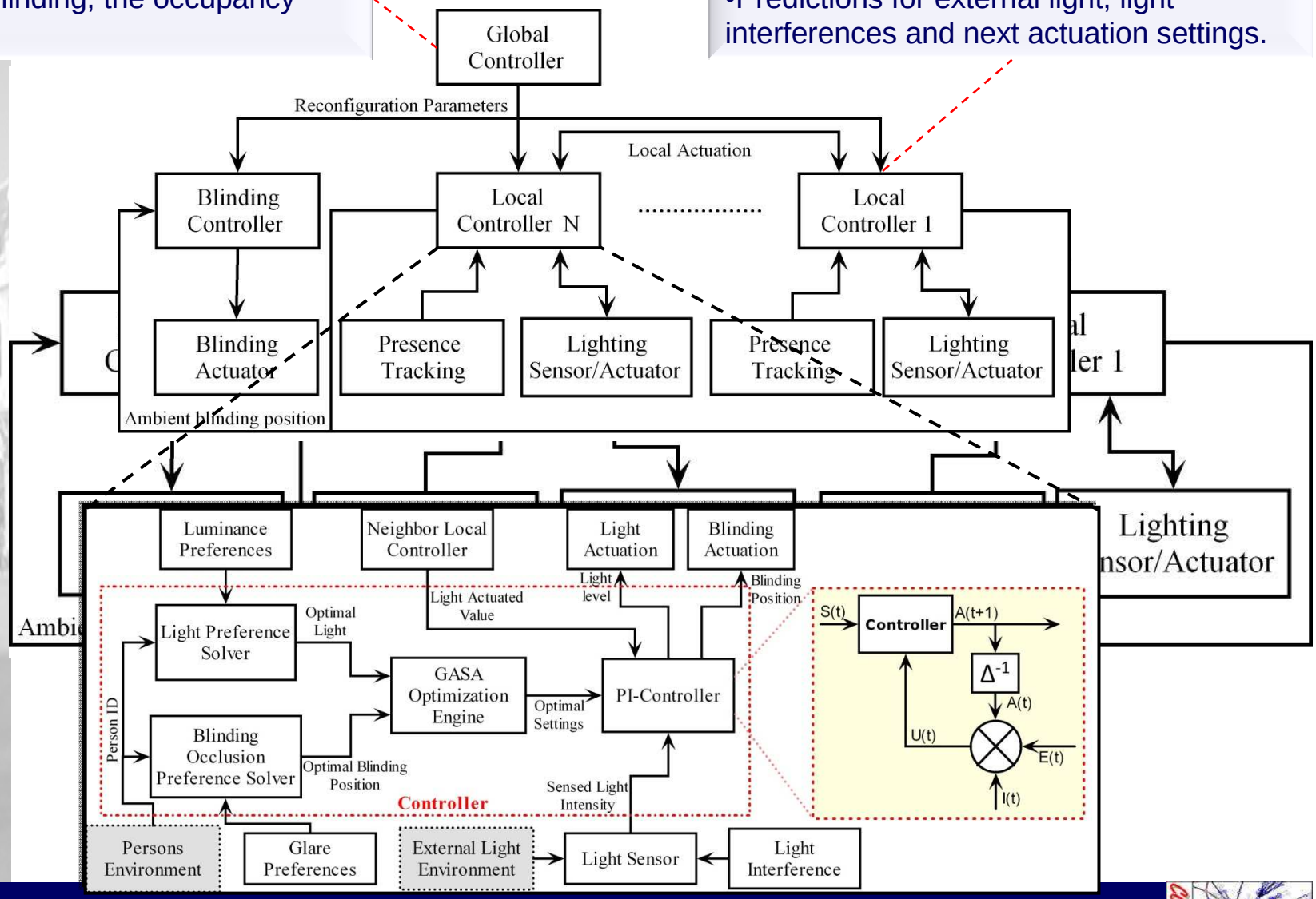
Outline…

- System of Systems (SoS)
- Integrated Modelling for Building Management Systems (BMS)
- Lighting Scenario
- **Parameterizable/Predictable Distributed (PPD) Controller**
- Simulation Results
- Design Improvements
- Summary and Future Trends

Parameterizable/Predictable Distributed Controller

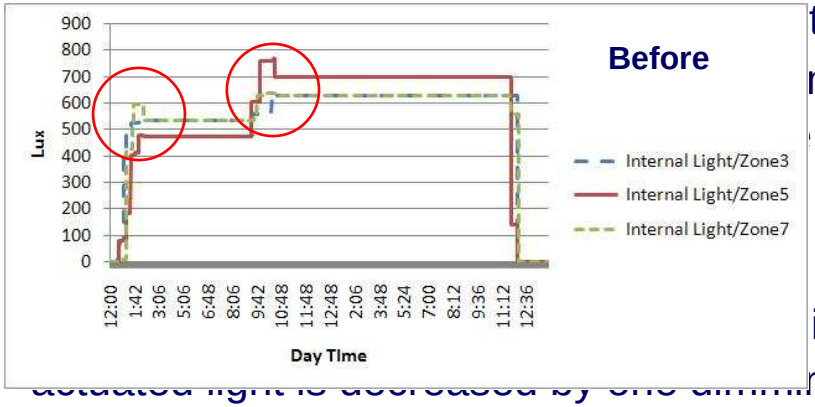
Parameterization for local controllers
(e.g. consider blinding, the occupancy priority).

•Local Optimization
•Predictions for external light, light interferences and next actuation settings.



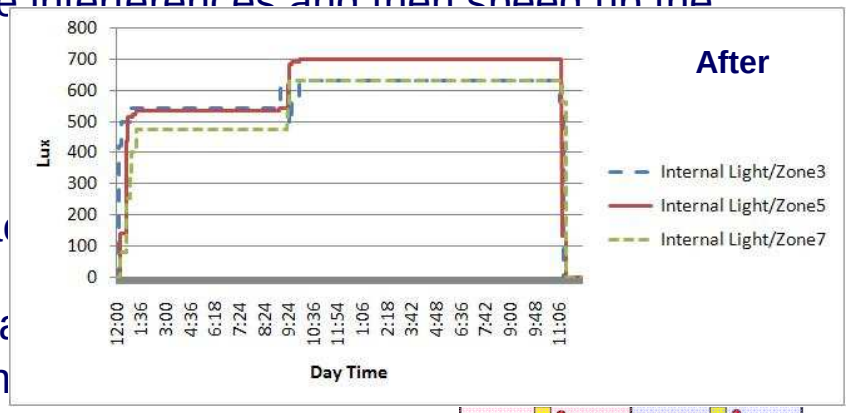
Distributed Optimisation Techniques

- **Luminance Boundaries:**



tion over all the controlled zones,
mit the user's preferences of
interferences between zones.

- ifferent than the optimal one, the
ng level (70 Lux) instead of the exact
Lux difference. This will diminish the interferences and then speed up the
stabilization process.

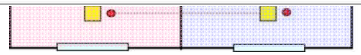


- **Scheduling:**

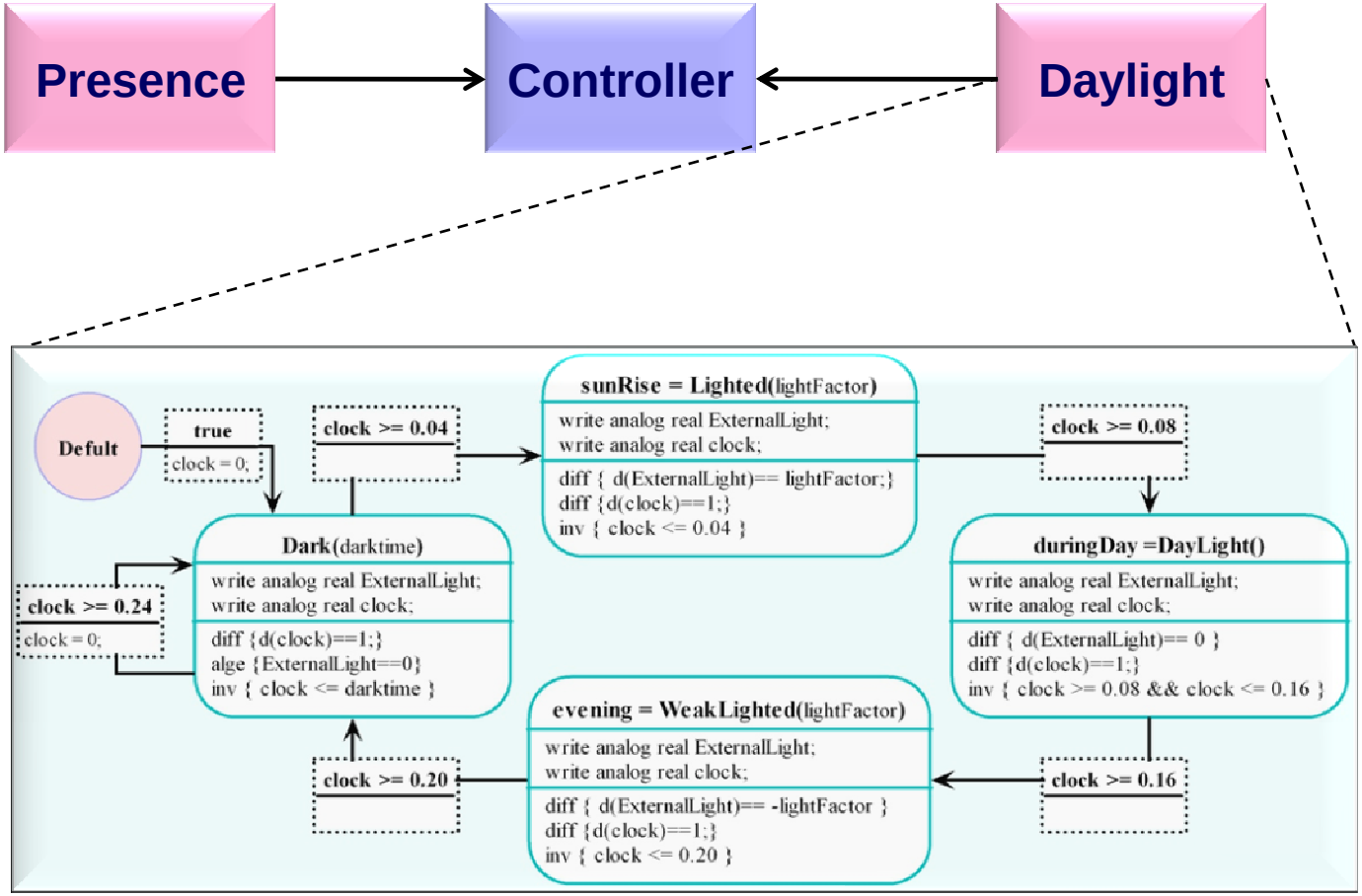
Identify the independent zones to be a

- **Expected Interference :** To a

initial instability, an expected interferen
is introduced using a Linear Prediction Coding (LPC)
algorithm.



Environment Modeling

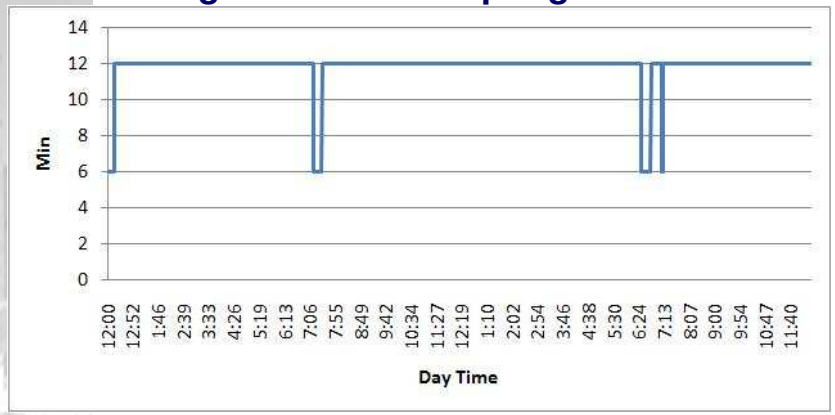


Outline…

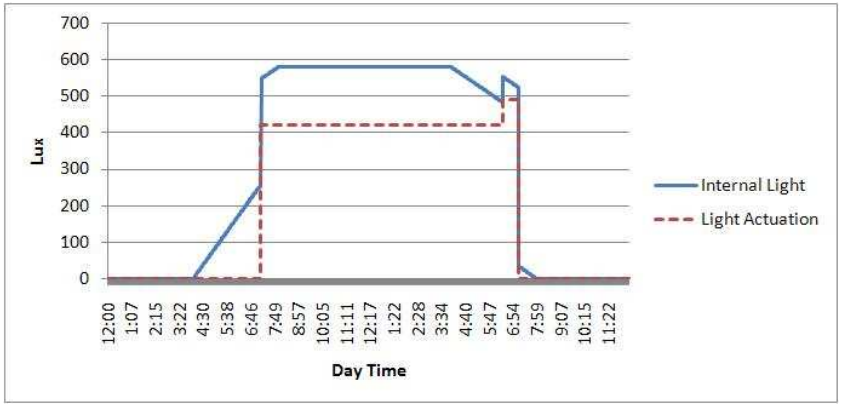
- System of Systems (SoS)
- Integrated Modelling for Building Management Systems (BMS)
- Lighting Scenario
- Parameterizable/Predictable Distributed (PPD) Controller
- **Simulation Results**
- Design Improvements
- Summary and Future Trends

Simulation Results (Single Zone)

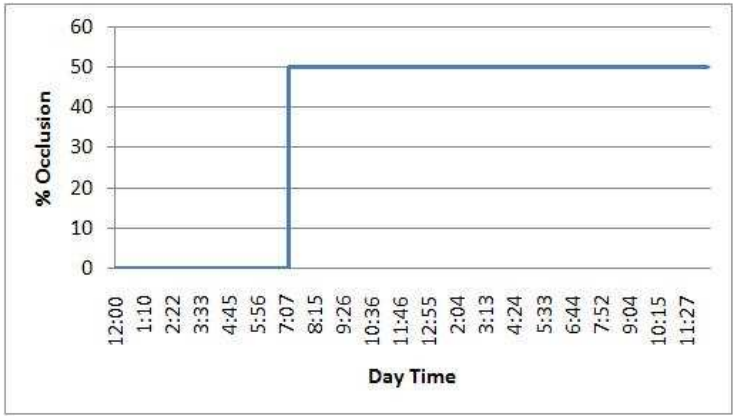
Light Sensor Sampling Rate



Internal Light/Actuation



Blinding Actuation

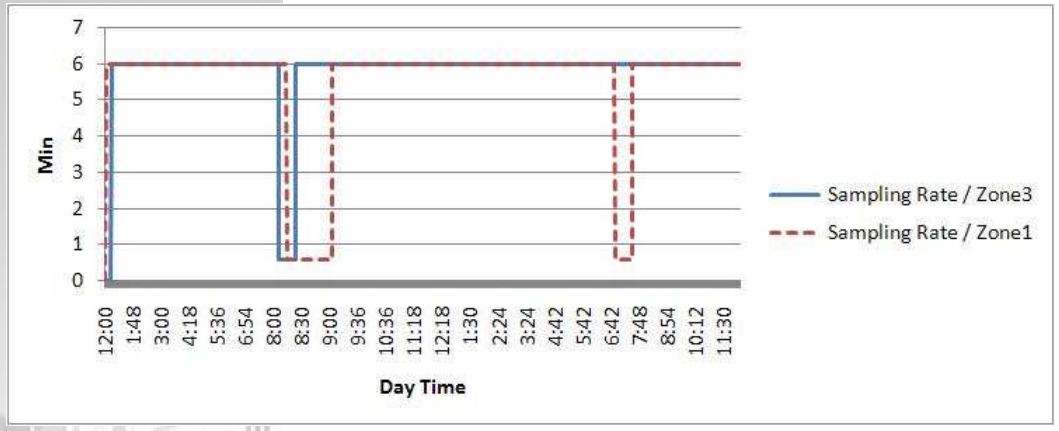


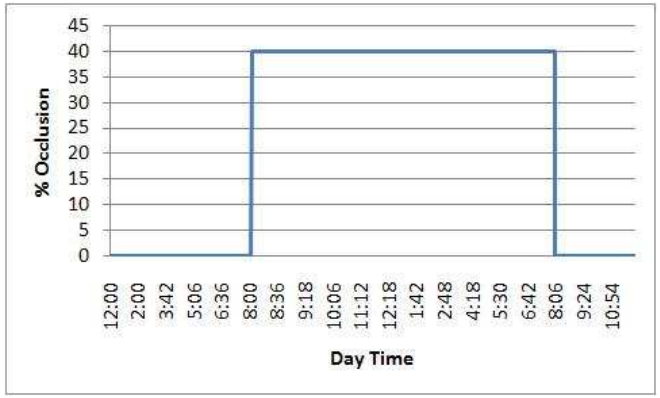
External Light

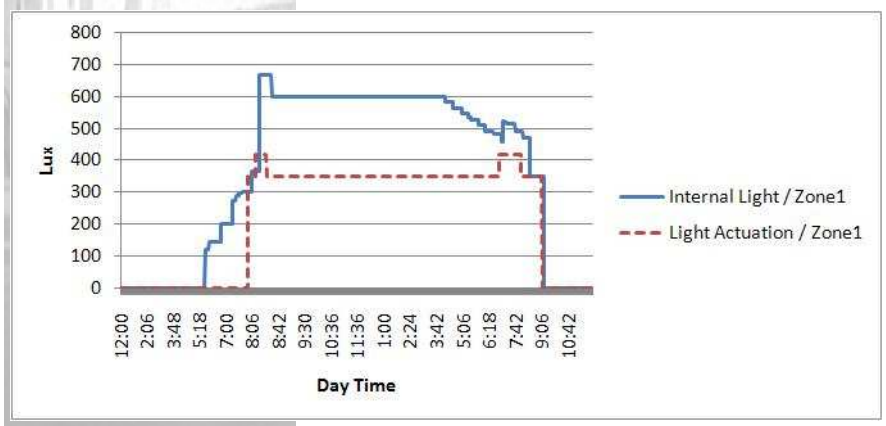
The internal light controller considers the external light and light/blinding preferences

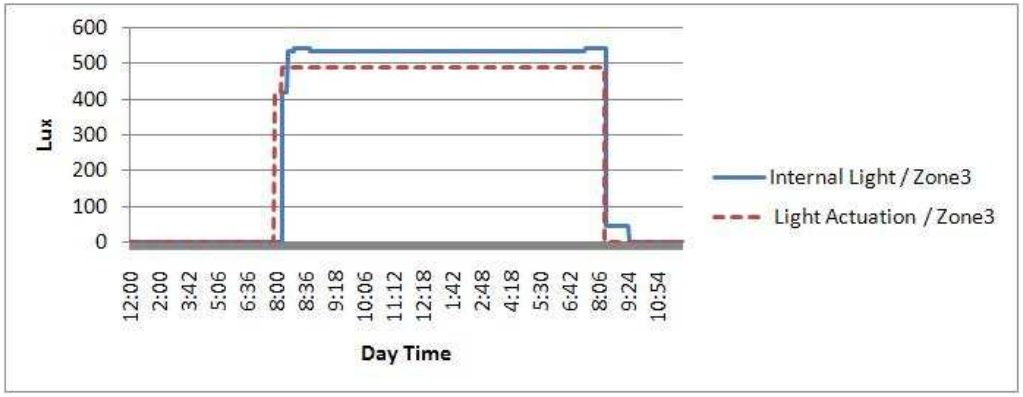
Preferences =560 Lux, 50% Blinding

Simulation Results (Multiple Zones)









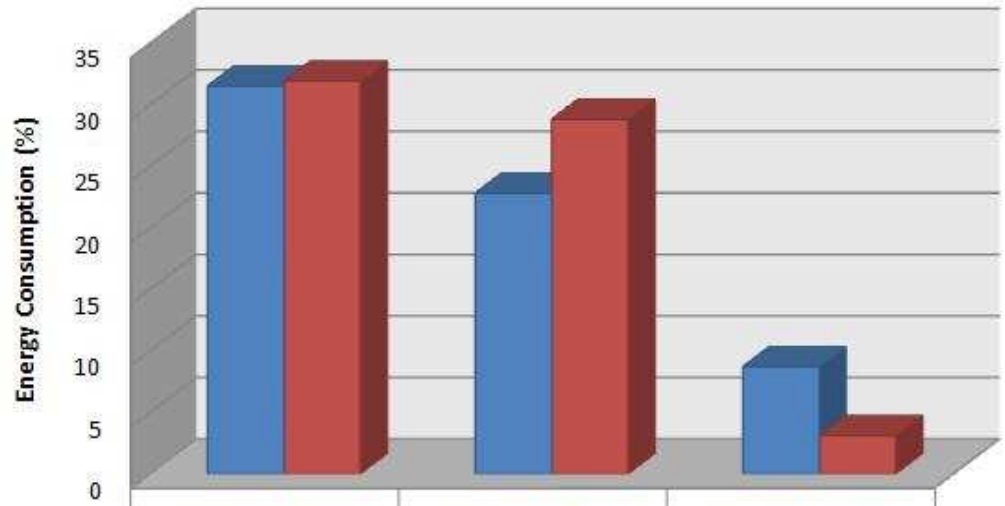
The internal light controller considers the external light, light/blinding preferences and the light interference

Outline…

- System of Systems (SoS)
- Integrated Modelling for Building Management Systems (BMS)
- Lighting Scenario
- Parameterizable/Predictable Distributed (PPD) Controller
- Simulation Results
- **Design Improvements**
- Summary and Future Trends

PPD Energy Usage Improvement

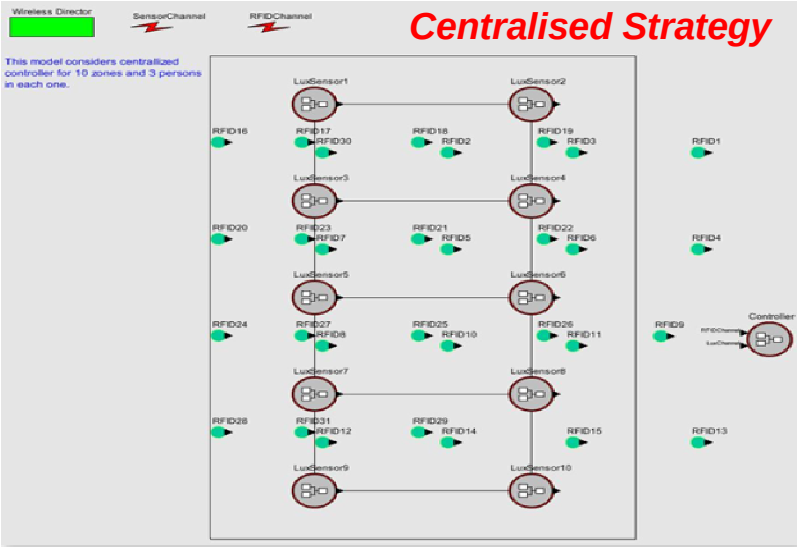
PPD improves ~ 30% comparing to Presence detection strategy
~ 9% comparing to PI Controller

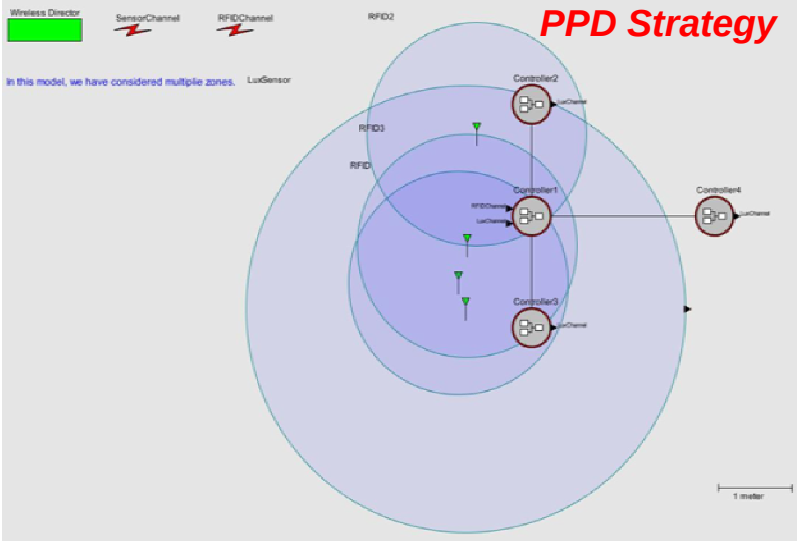


	PPD Controller	PI Controller	Improvement
3 User Preference Changes	31.5	22.8	8.7
Fixed User Preference	31.9	28.8	3.1

PPD WSAN Improvement

QoS to the WSAN for the PPD strategy versus a centralised strategy





WSAN QoS	Improvement
Packet Loss	~ 53-100%
Buffer Size	~ 98%
Controller Duty Cycle	~ 34-65%
Response Time	~ 98-99%
Channel Throughput	~ 82-91%

Outline…

- System of Systems (SoS)
- Integrated Modelling for Building Management Systems (BMS)
- Lighting Scenario
- Parameterizable/Predictable Distributed (PPD) Controller
- Simulation Results
- Design Improvements
- **Summary and Future Trends**

Summary and Future Trends

- **This article has described PPPD-Controller for lighting.**

Parameterization has been implemented through a global controller capable of parameter-reconfiguration of the local controllers.

Predictability is guaranteed through the prediction of light actuation (PI-Controller), interferences (LPC technique) and the external light (GASA engine).

- **Next releases of the controller will integrate fault-tolerant control reconfiguration, allowing the controller to operate when faults occur.**

- **We intend to implement a demonstration of the developed system in the Environmental Research Institute (ERI) building, which is the ITOBO 'Living Laboratory'.**

Thank you