Smart Buildings at IITH

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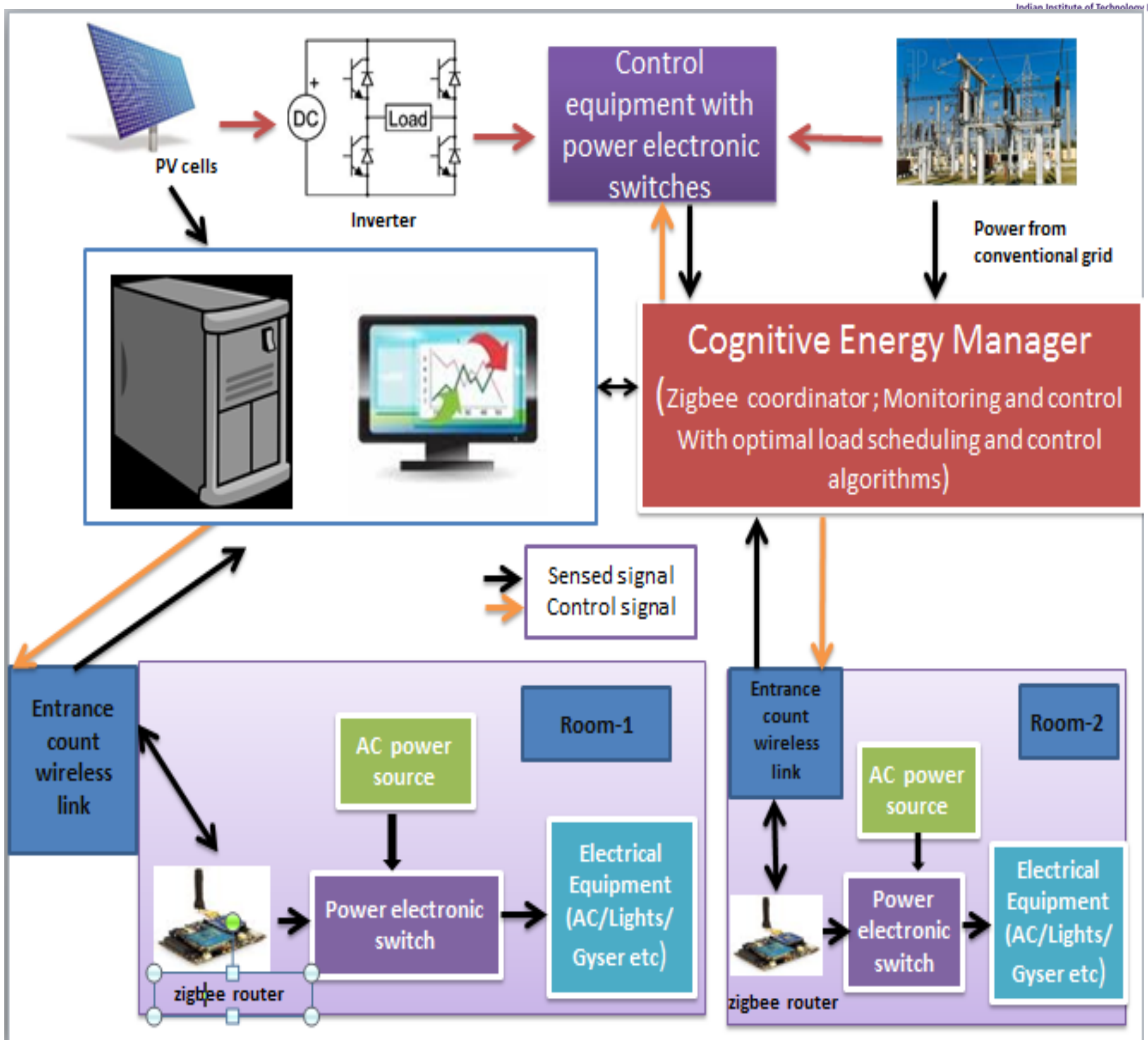
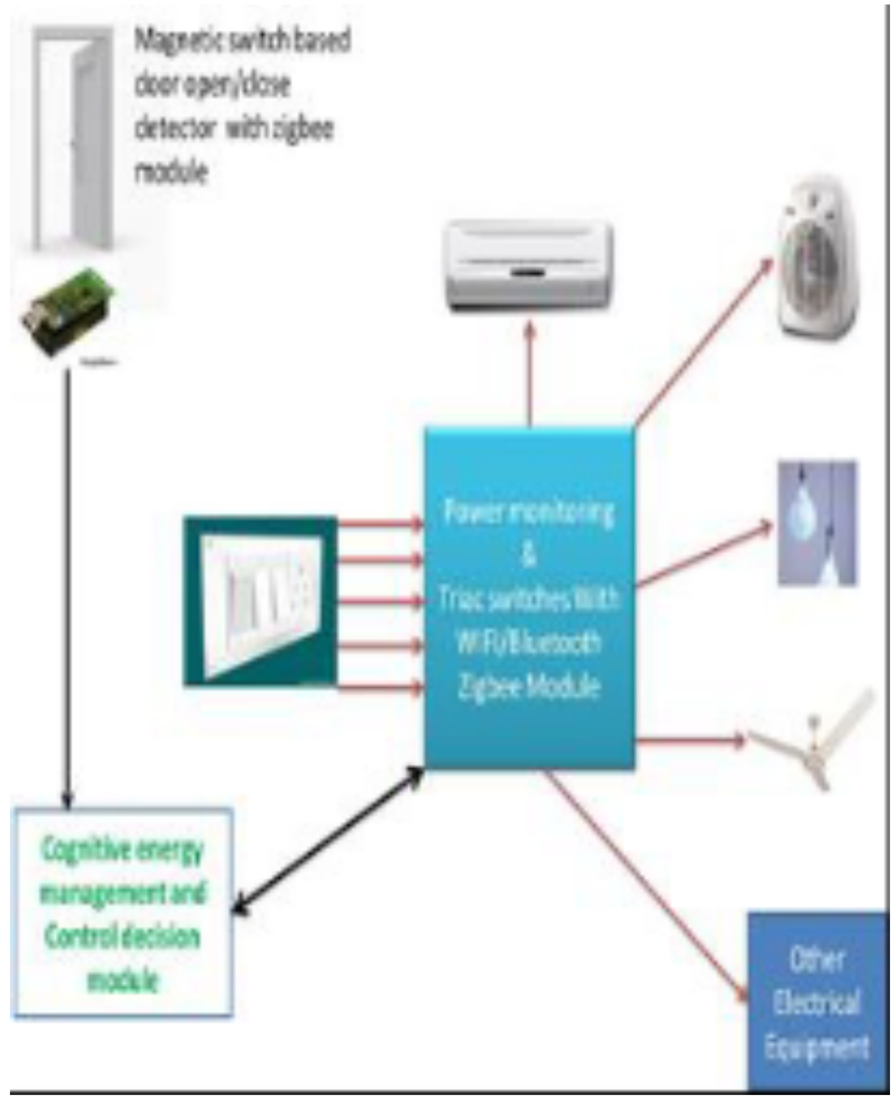
Objectives – Smart Zero Net Energy Buildings

- *ZNEB* - Net energy drawn from the conventional grid should be zero by maximizing the energy drawn from the renewable energy sources in an year
- Ubiquitous Home/Building Networks - Energy management within buildings



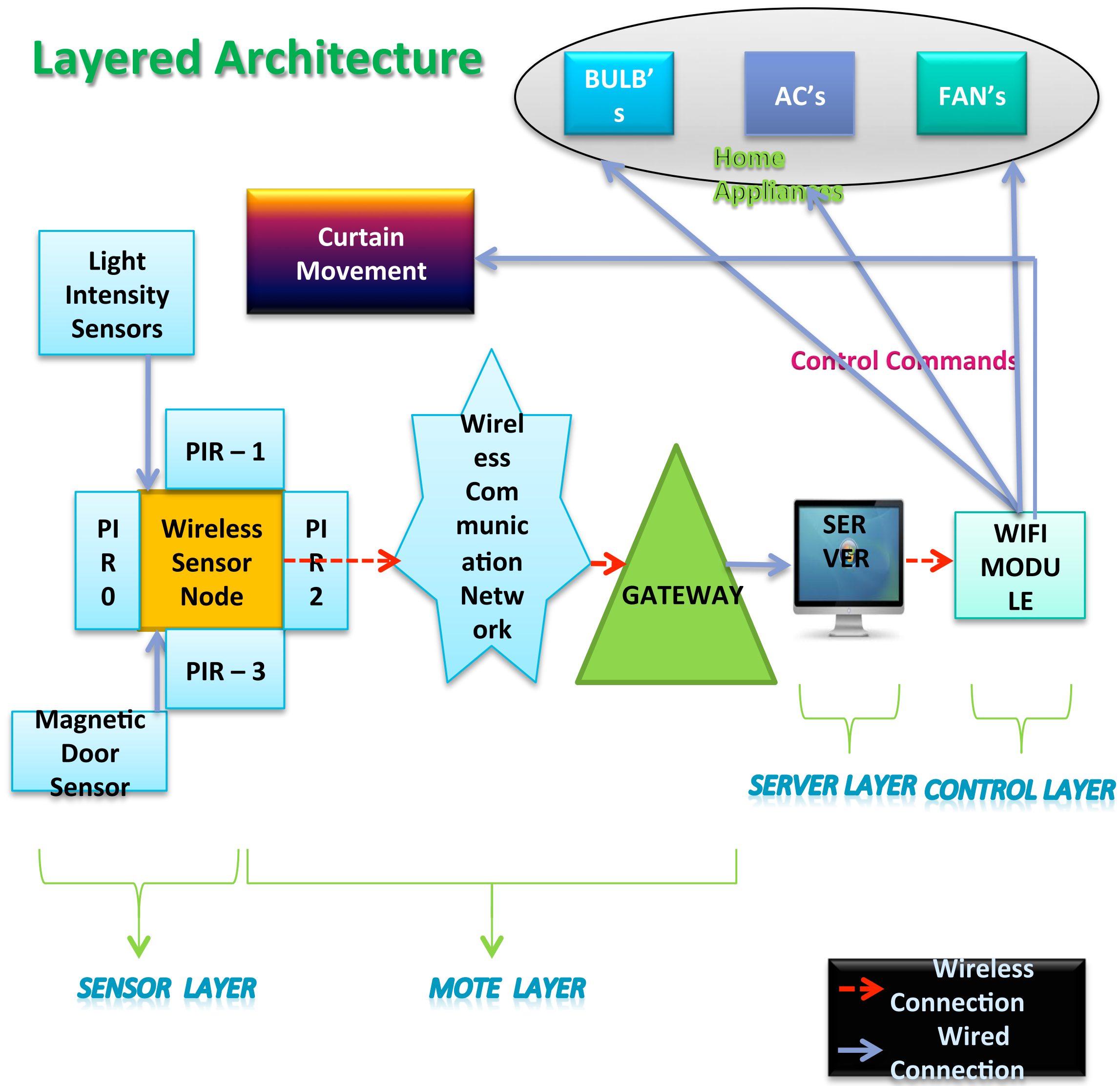
Energy Management within Buildings

- Buildings consume approximately 70% of total electricity produced and lead to approximately 40% of greenhouse gases.
- A smart building with an integrated Wireless Sensor Network, a Cognitive Energy Manager, and an actuation system for controlling electrical appliances in the building.
- Cognitive Energy Manager is the brain



Smart Energy Efficient Building Design

- Layered Architecture: Energy management within the building
  - *Sensing of various physical parameters –*
    - Power monitoring, motion, Location detector, Gas detector, smoke, fire, temperature, hygrometry, CCTV, door/ window status…
  - *Cognitive Base Station –* Intelligent computing with context-awareness
    - Receives sensed data
    - provides relevant services based on the situation/context
    - Sends out commands to the actuators/ control modules
    - Can be centralized or distributed computing
  - *Communication -* Heterogeneous wireless environment
    - Zigbee, Wifi and Bluetooth (services on the phones, web, tabs)
  - *Control module – power electronics*
    - *Wireless signals control the triac switches to drive the load*



IITH mote – 802.15.4 Wireless Communication Node

भारतीय प्रौद्योगिकी संस्थान हैदराबाद
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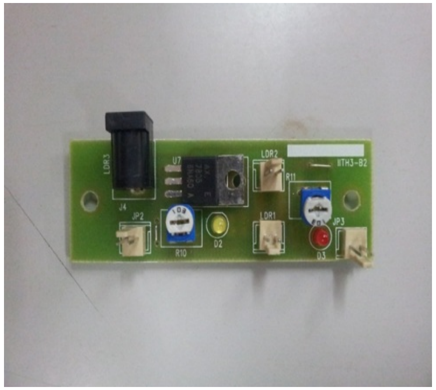
- **ITH mote** Low cost Wireless sensor network platform
- ISM band – 2.4 GHz
- Atmega AT128-1 controller and AT86RF230 radio
- 820.15.4/Zigbee and TinyOS based
- Environment, Agriculture, Smart home applications
- Teaching /R&D to educational institutions

IITH mote

CPS Lab – Field Trials

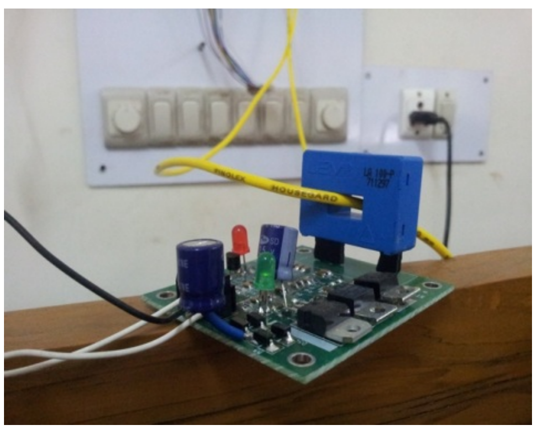
Sensor modules – In-house built based on the commercial sensors



a)Light intensity sensor

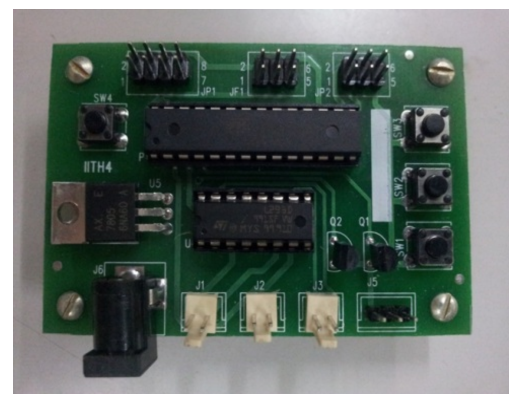
b) RFID Module

c) PIR Sensor



d) Power Monitoring circuit (Hall effect Sensor)

e)Magnetic Sensor

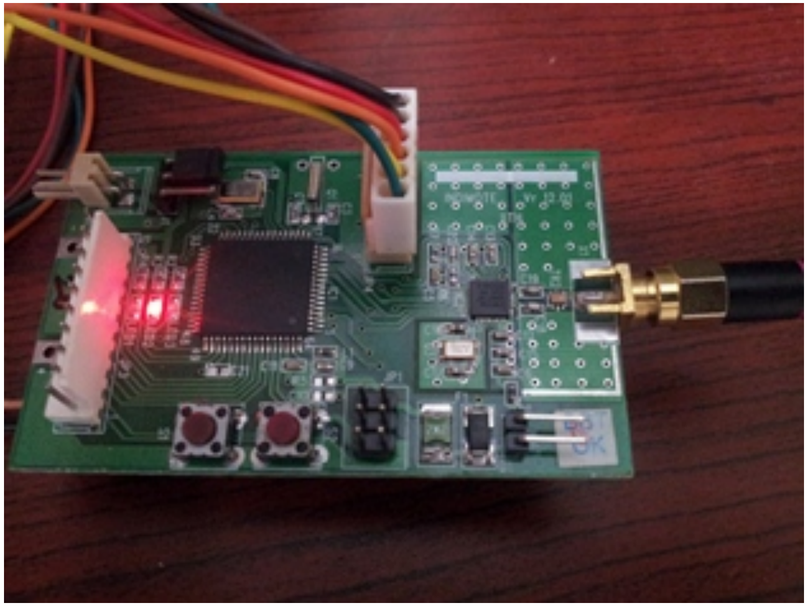


f) Curtain operator control

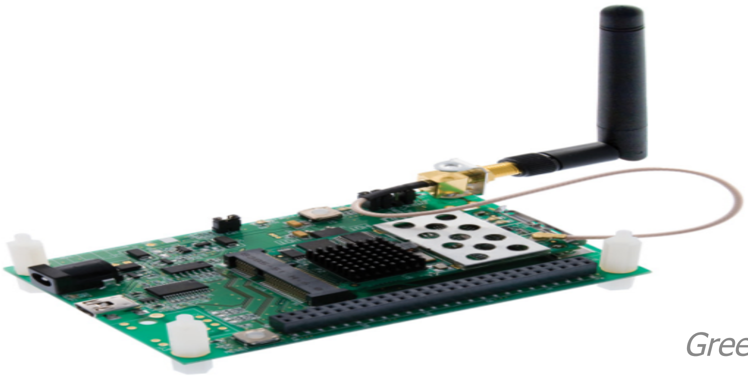
Communication Modules - Heterogeneous wireless network

- To support Variable data rate applications
- Low power, event based applications, low data rate – Zigbee -
- High bandwidth , data rate – WiFi – video, multimedia applications

A) **IITH mote – 802.15.4**



B) **WiFi (Rabbit core)**

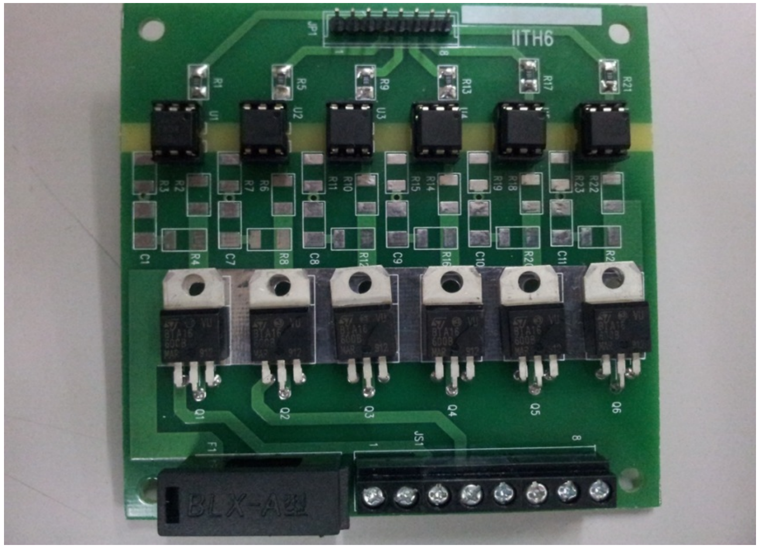


C) **Bluetooth module**

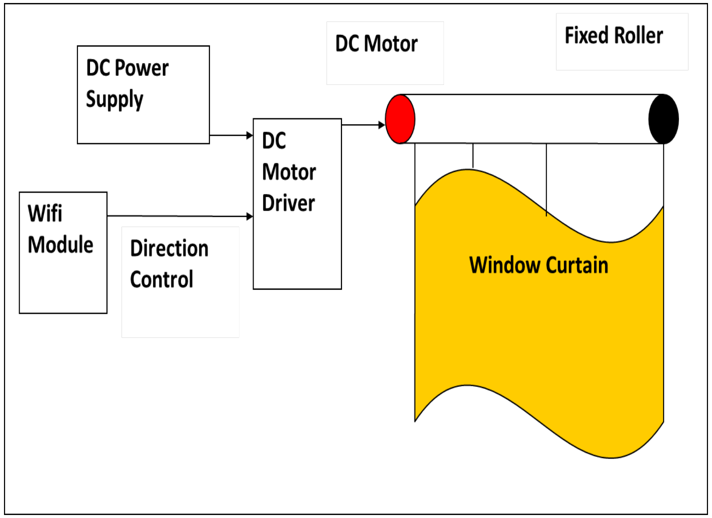
Control Modules

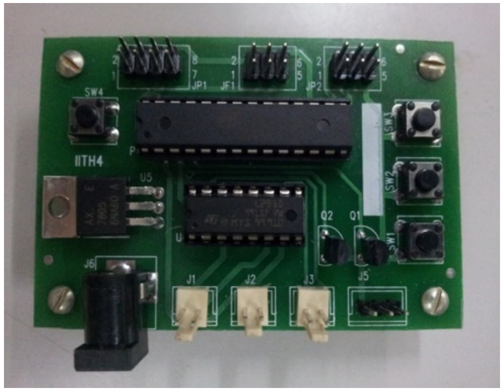
- Actuation with power electronic switches
- Loads with different ratings can be controlled
  - Lights, Fans
  - Acs
  - Curtains
- Manual Override is provided at each control switch.

Power electronics based control modules

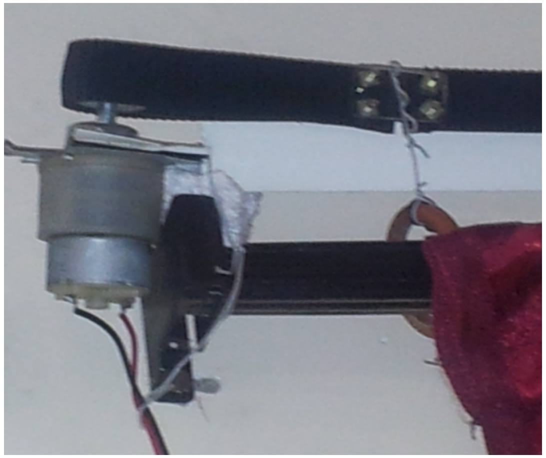


Curtain Operator



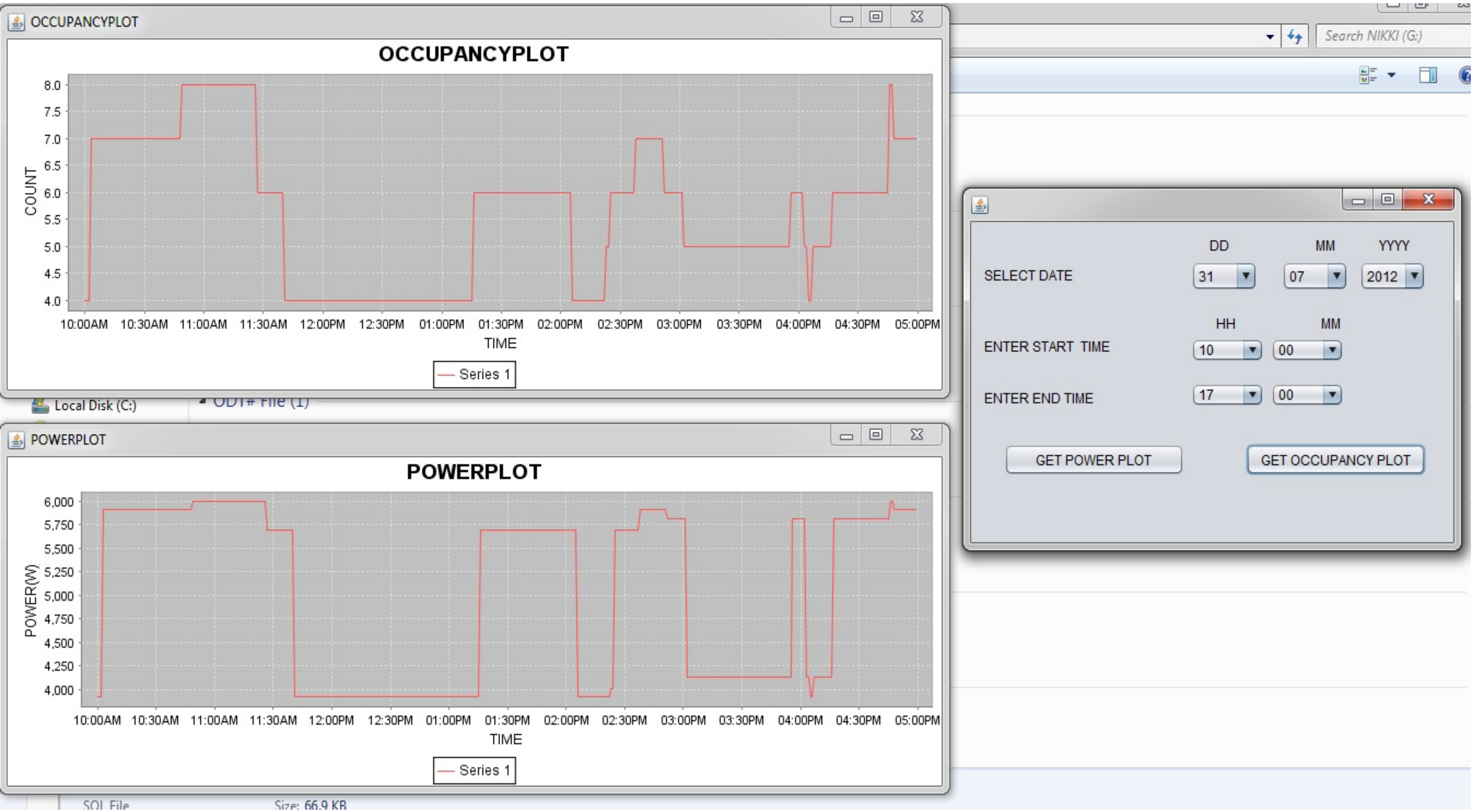


Curtain operator control



Experimentation Results – CPS Lab

Power usage plot for 1 day in Smart lab



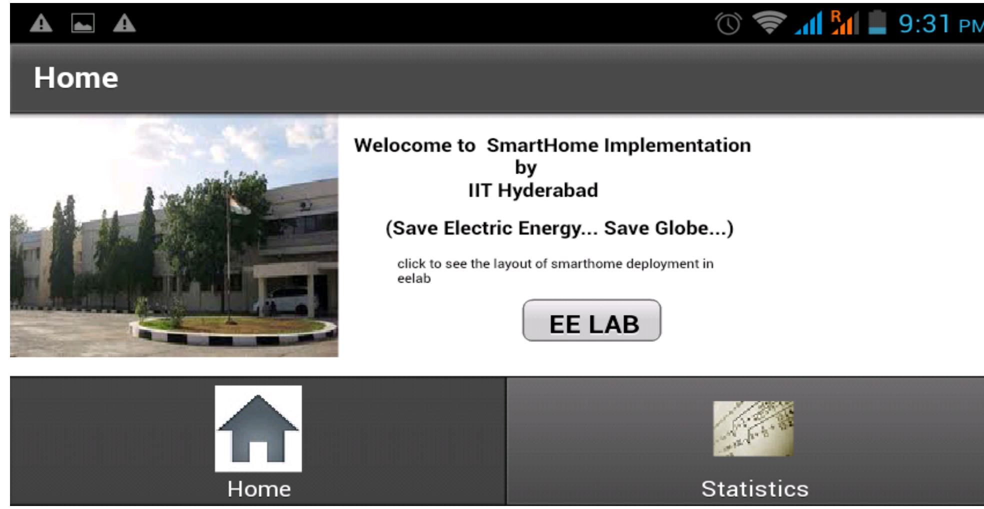
Energy saving in smart Lab is around 30%

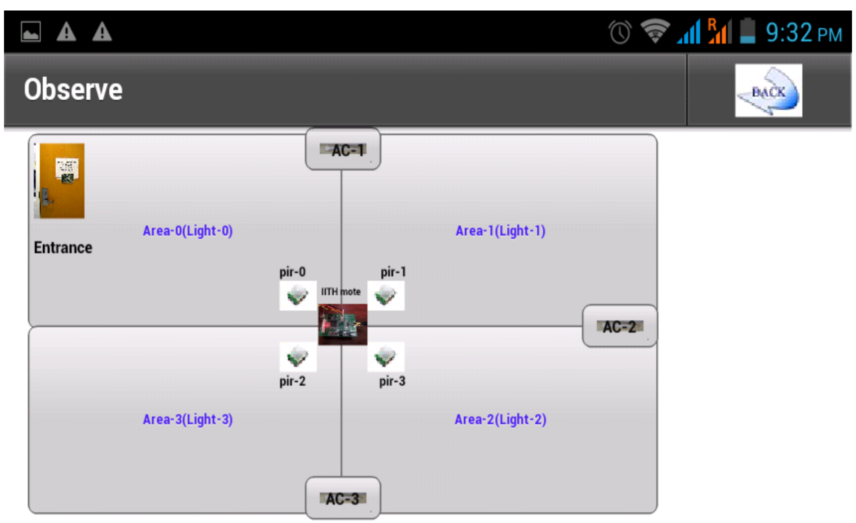
Smartphone based control of smart room

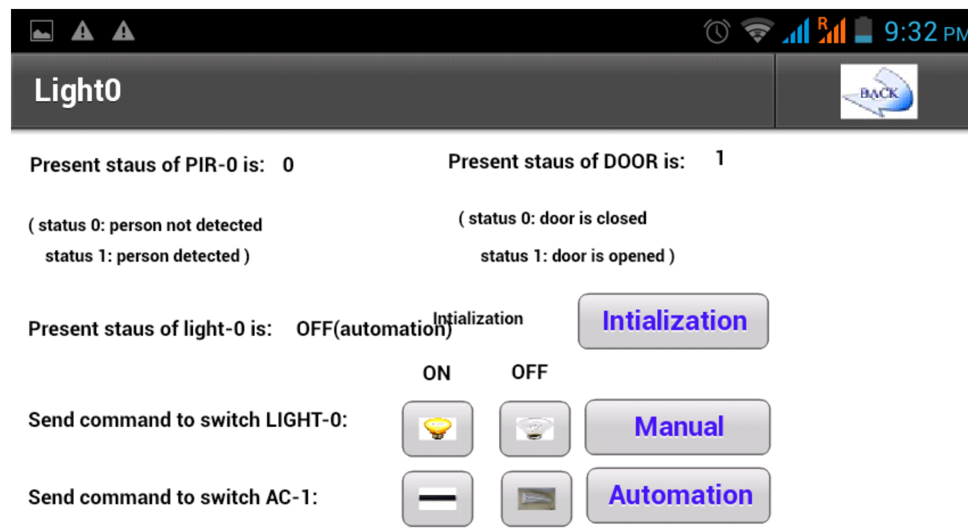
Android based app for smart p hones
and tablet

App → adobe flash builder

- Monitoring and actuation is enabled
- All electrical loads can be monitored from anywhere on the globe
- Manual over ride to stop automation is provided for user comfort
- Scheduling of load from smart phone is under development.







Planned and Ongoing Activities

- Smart Buildings at IITH permanent campus
- Low cost smart monitoring and actuation module development
- Standardization – IEEE 1888 complaint data collection at IITH server, and sensor nodes for smart buildings
- Integration of smart building with renewable sources like solar - ZNEB
- Theoretical models for dense traffic IoT applications
- Scalability with Wireless – ZigBee/Wifi multi-hop networks

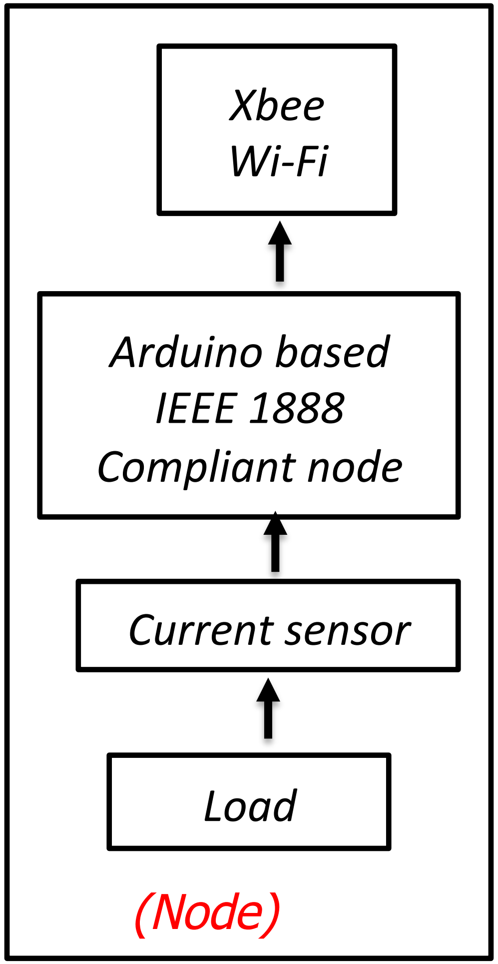
Current based Monitoring at IITH In collaboration with UoT

Objective :

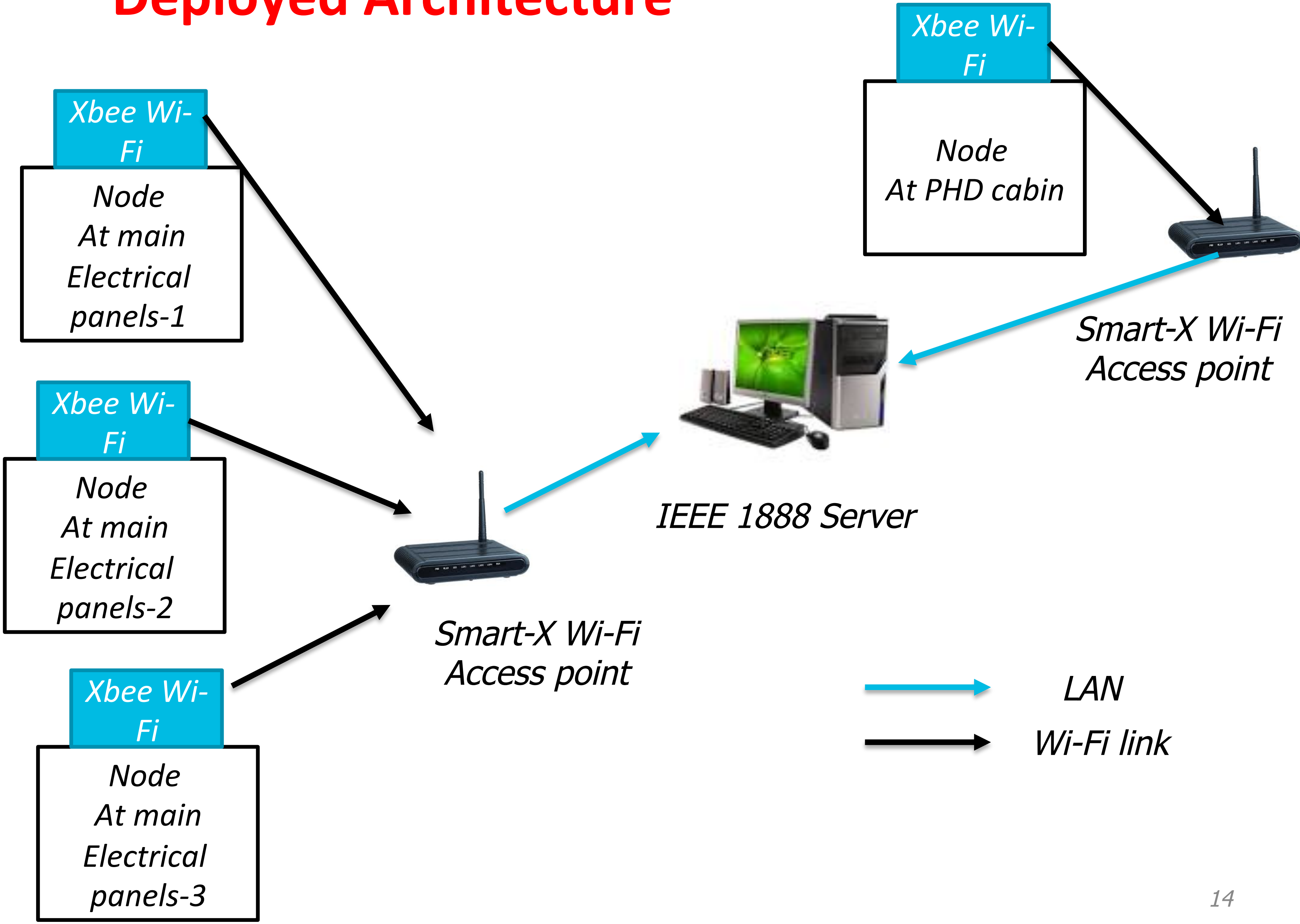
- To tap different electrical networks of IITH building
- monitor and save the current consumption data
- Log to designated IEEE 1888 server.

Architecture of the node deployed in the campus:

- Arduino based embedded platform to sense and
- compute i_{rms} of the load.
- convert data to IEEE 1888 compliant
- Xbee Wi-Fi module to interact with Smart-X Wi-Fi network.
- Log and visualize all monitored load values from anywhere
- using IEEE 1888 server.



Deployed Architecture



Four metres deployed at IITH in collaboration with UoT

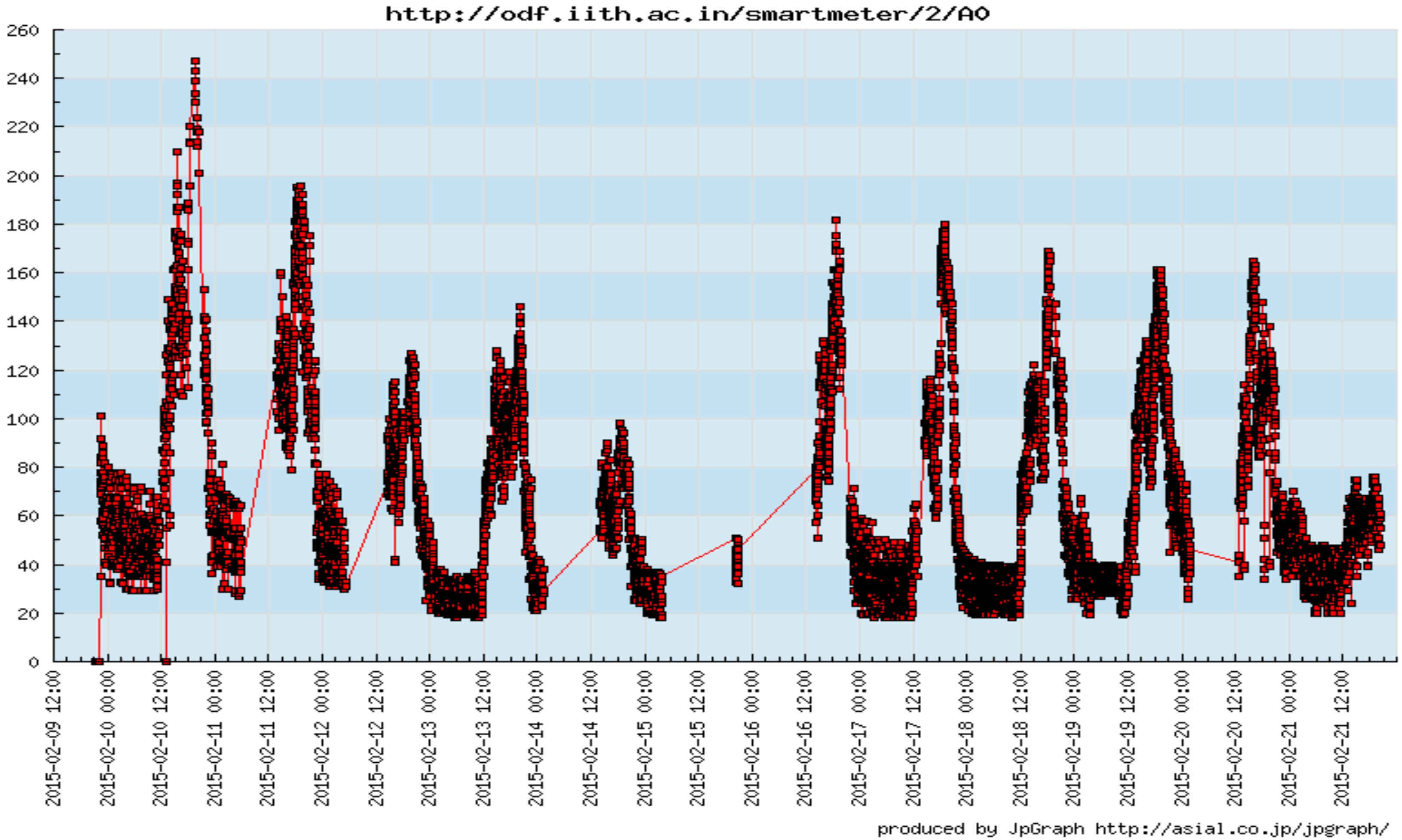
Meter deployment at Electrical Panels-1

Meter deployment at Electrical Panels-2

Meter deployment at Electrical Panels-3

Meter deployment at PHD cabin of IIT Hyderabad

Current consumption of electrical panel-2 at IITH incollaboration with UoT



Low cost smart Modules to monitor and control Edge network in a building for effective BEMS

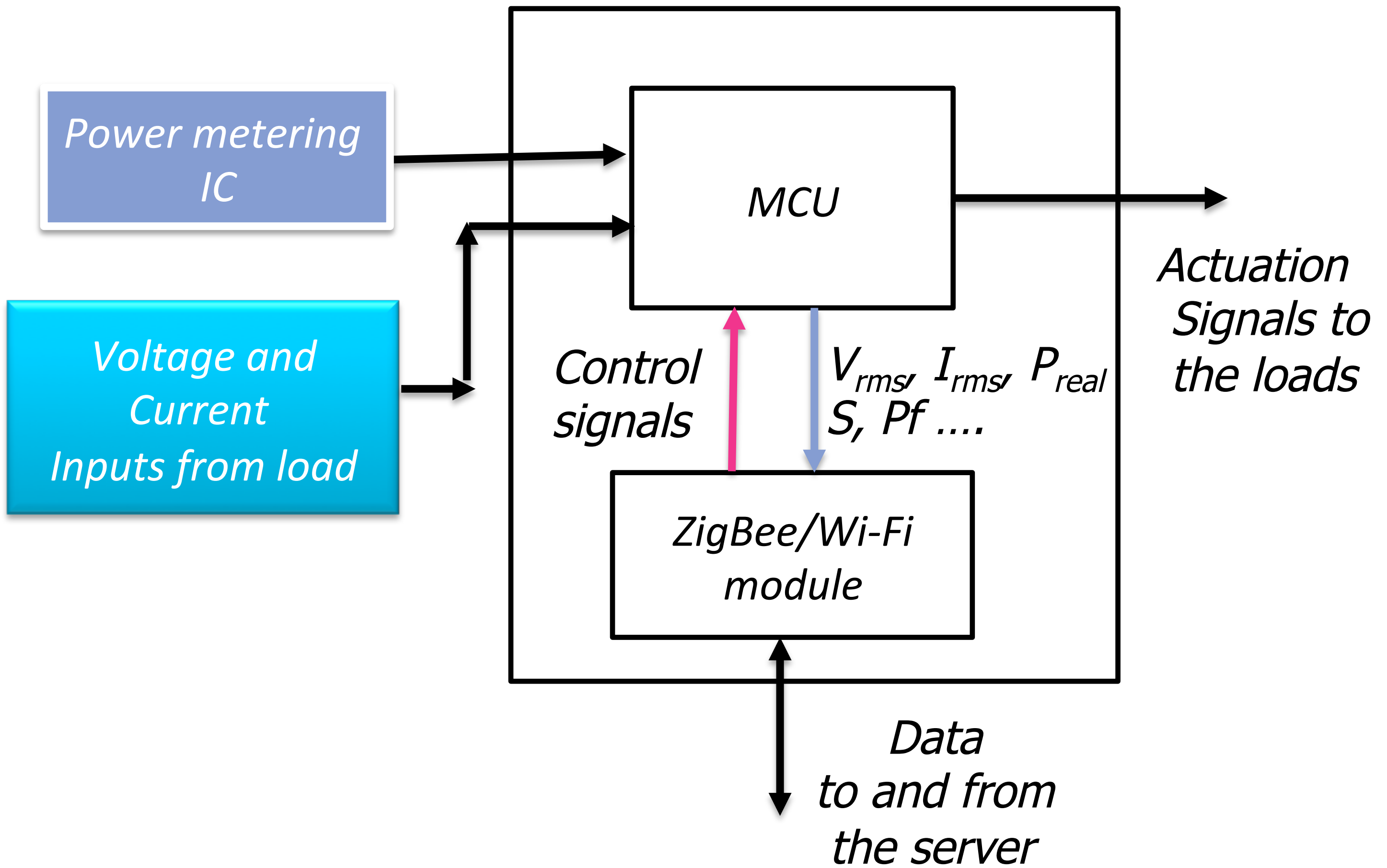
Motivation for Low cost smart Module

- To monitor each individual network in the building contributing to total consumption.
- Improves the efficiency Building Energy manager (BEM) in real time load scheduling of a building.
- Effective peak reduction and flat load profile can be attained with even *edge network monitoring and control*.
- Power quality improvement measures even at individual network level can be planned and implemented.

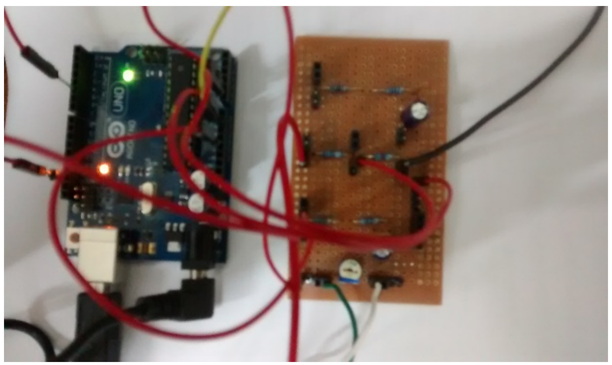
Parameters of consideration :

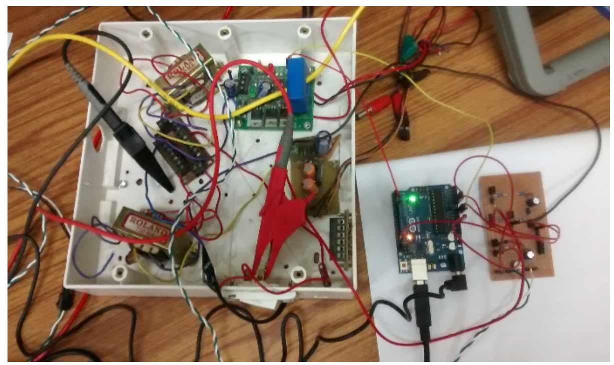
- voltage, current and power factor
- real, reactive and apparent power etc
- Power quality metrics

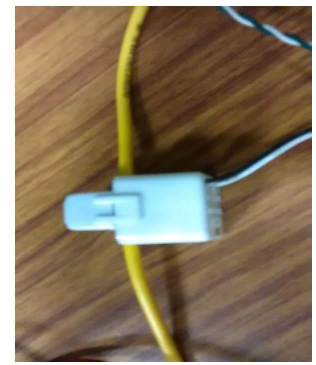
Low cost smart module -- Architecture



Glimpses of smart module development







MCU and signal Conditioning circuit

MCU with Power, Current sensors

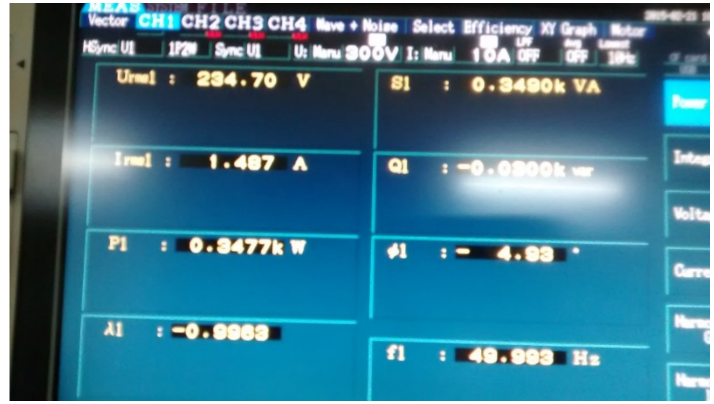
Current sensor for board

Current sens for Hioki-339

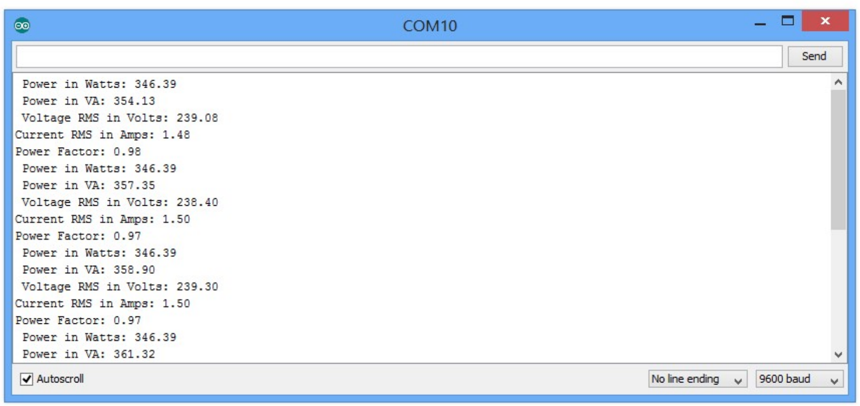
Hioki-3390 power analyzer

Calibration of low cost smart module

Calibration set up for smart module in IITH lab



Load values observed in Hioki-3390 during calibration

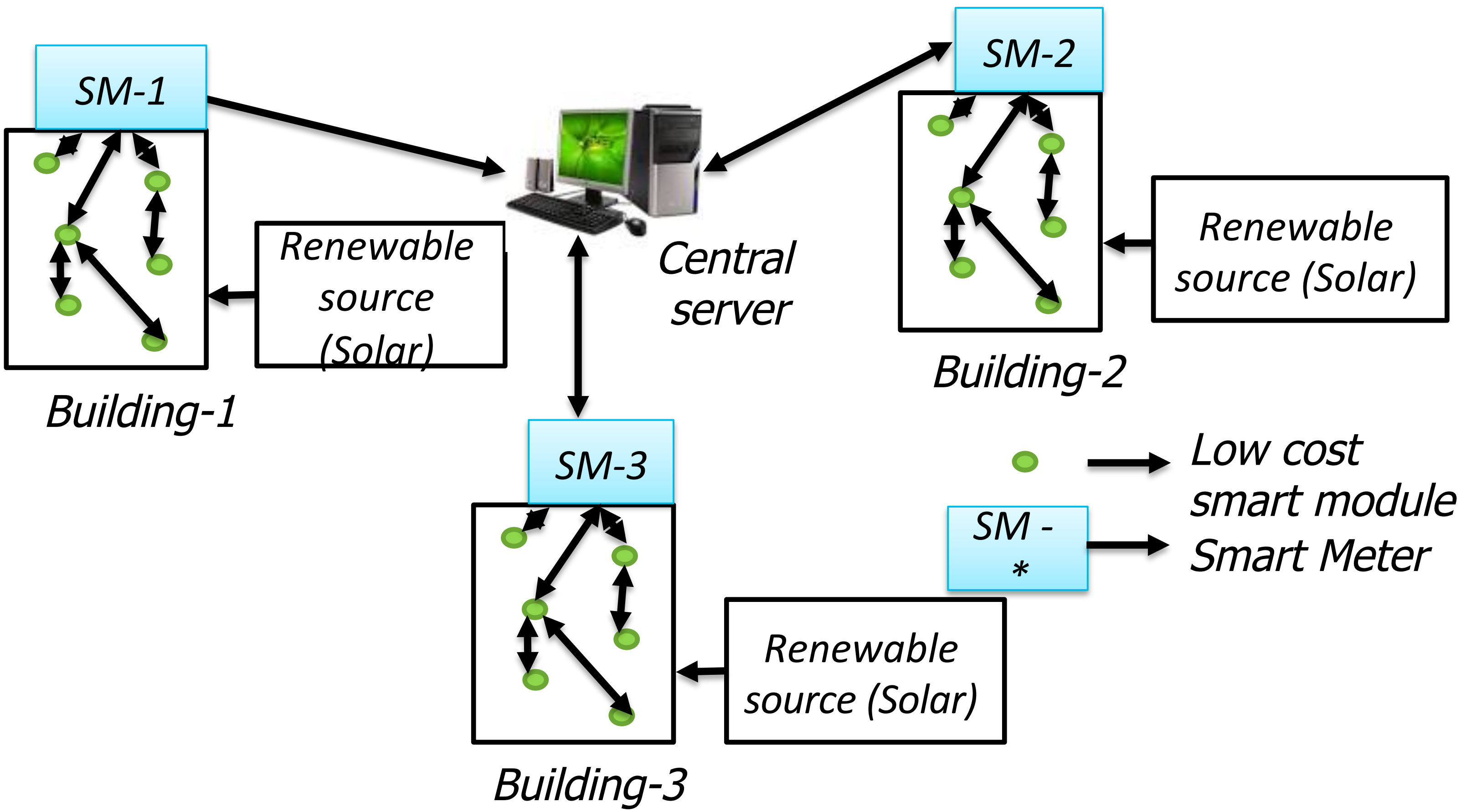


Load values observed for the same load with smart module during calibration

- Developed smart module is calibrated with standard Hioki-3390 module
- V_{rms} , I_{rms} and P_{real} are calibrated with different loads.
- Error observed in most of parameters are less than 3% on an average.
- Power factor obtained from the developed module gives the measure of reactive and apparent power also.
- Smart module can be easily interfaced with Wi-Fi or ZigBee modules finally to forward data to the central server
- Harmonics measure is also under consideration with same smart module

Realizing IITH permanent campus as a collection of Smart Net Zero Energy Building (NZEB)

Architecture for IITH campus



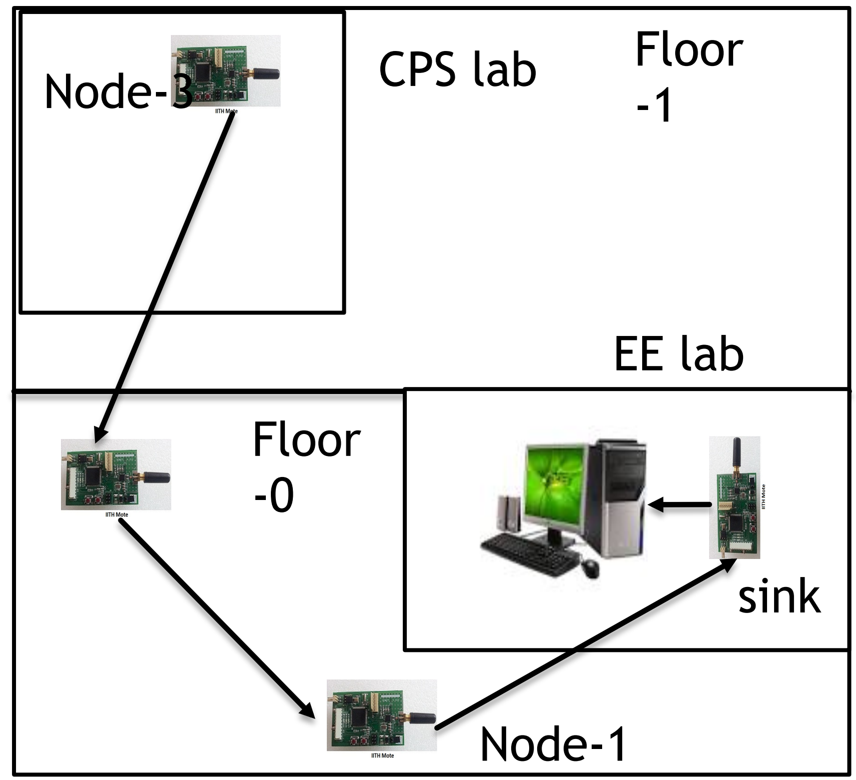
Architectural proposal of smart Net Zero Energy Building (NZEB) for IITH campus

Stage-1:

- Academic building is planned as BEMS with integration of renewable energy source like solar.
- Aggregated consumption of each building is monitored with a sophisticated Smart meter monitoring all possible electrical parameters including power quality.
- Each individual network to be monitored with low cost smart module and controlling with BEMS.
- All monitoring and actuation devices are linked to local and central servers using heterogeneous wireless network architecture
- All smart meters can log data to the central server which controls central power distribution system powering all buildings.
- Central server can also be responsible for switching between local renewable energy resources like solar and utility grid of each building.

Scaling the monitoring network in IITH building with ZigBee multi-hop communication

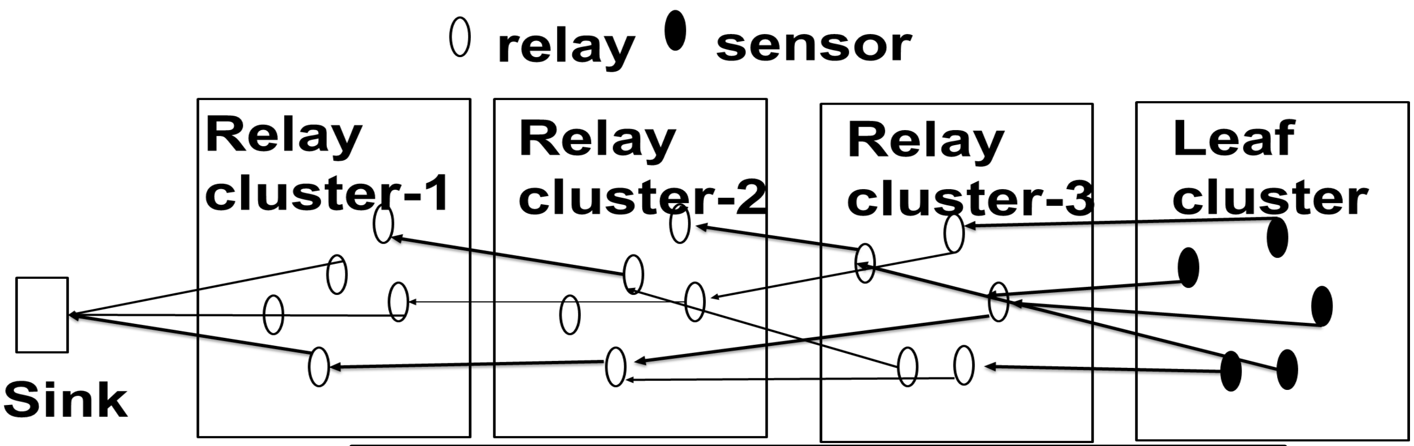
- Multi-hop ZigBee network is essential to scale the network over large area of building.
- IEEE 802.15.4 compliant IITH mote are formed as multi-hop network to forward data from the field to sink node.
- A three node multi-hop network forwarded data from CPS lab to sink node in EE lab with a reliable link.
- Output power of the antenna is set to 3db.
- Distance observed for an indoor single hop ZigBee communication is approximately 30 metres where as outdoors it is around 110 metres in line of sight.
- **Multi-hop wireless network deployment for smart building monitoring and analysing the performances**



Multi-hop Network deployed at IIT Hyderabad

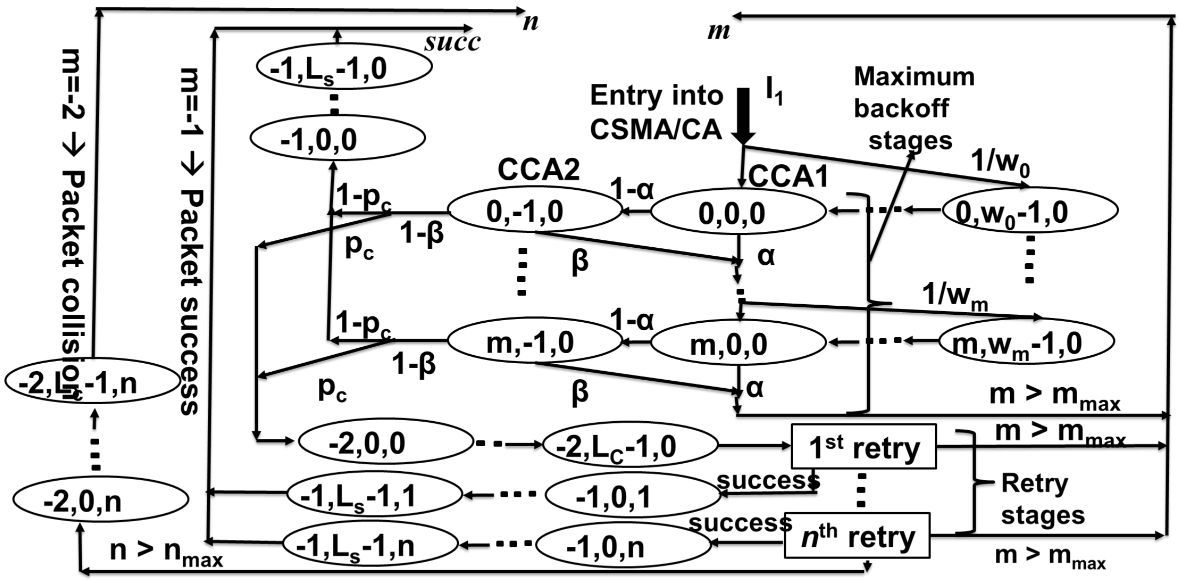
3-Dimentional Markov model for IEEE 802.15.4 MAC targeting dense traffic IoT applications

- Existing multi-hop models lack state wise behaviour of a relay node. Previous models cannot be directly applied to evolving dense traffic applications like IoT.
- Integration of CSMA/CA with state behaviour with Anycast routing is the primary research interest of the proposed model. A 3 dimensional Markov model with state behaviour and Anycast routing is developed and analysed.



Network Architecture

3D Markov model of IEEE 802.15.4 CSMA/CA



3 dimensions :backoff stages (m) , backoff counter (k) and collision retries(n)

→ Using Normalization property of markov chains and state wise models

Channel busy probabilities in CCA1 (α), CCA2 (β), channel sensing probability (T) are required for complete analytical model

$$P_S+P_I+P_A+P_{CSMA} = 1$$

Where P_s , P_I , P_A and P_{CSMA} are Sleep, Idle-Listen, Active-Tx and CSMA/CA state probabilities

Reliabilitv and Delay models

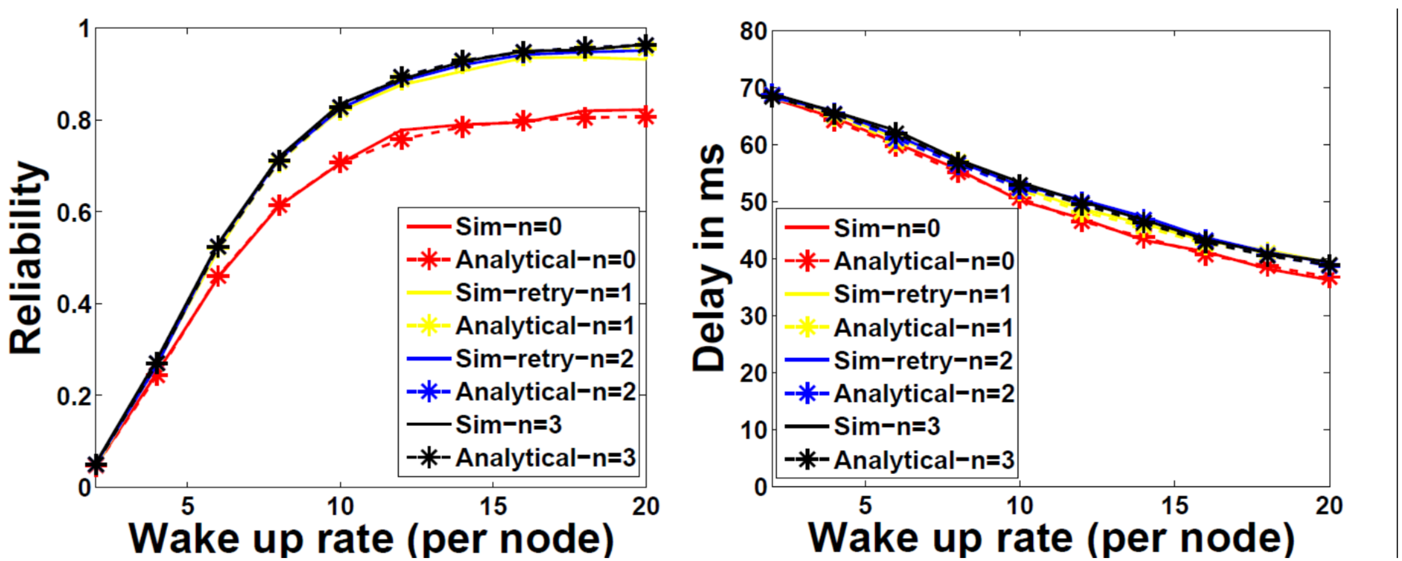
$$R_E = \prod_{k=1}^{h} R_k$$

R_E is the end to end reliability and R_K is the single hop reliability

$$D_{\text{total}} = (D_{\text{csma}} + D_{\text{active}} * S_b) * h$$

D_{total} is the end to end delay, D_{csma} and D_{active} are delay in CSMA state and Active states respectively, h is number of hops, S_b *is the unit backoff time*

Effect of Third dimension – CSMA retries



Thank you!