# A novel approach towards Building Automation through DALI-WSN Integration

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***Abstract-*** The building automation systems (BAS) include the monitoring and control of building services and networks. Since different manufacturers usually deal with one aspect of building automation such as heating ventilation and air conditioning, lighting control, different kinds of alarms, etc, the Final building automation system has different subsystems which are finally taken to an integrated building management system. The development of a prototype to be used in a wireless sensor network (WSN) which also integrates Digital addressable lighting interface (DALI) protocol can provide a solution for centralization of building automation services. Since DALI is a well-established standard and it has been adopted by major electronic ballasts' suppliers it is very easy to find DALI compliant devices. Despite it is designed for lighting control, DALI has also been adapted to other applications, such as motor or fan controllers, proximity alarms, etc. Adapting the standard to a WSN allows integrating DALI devices as a part of the WSN, expanding the traditional DALI bus and removing wires, which results in a reduction of installation costs. For more efficient energy utilization of wireless sensor network, the IEEE 802.15.4 standard is modified to a deployable energy efficient 802.15.4 MAC protocol (DEEP).

***Index Terms-*** Building Automation System, Wireless Sensor Network, Digital addressable lighting interface, IEEE 802.15.4, Deployable energy efficient 802.15.4 MAC protocol.

## I. INTRODUCTION

The building automation system (BAS) had gained great amount of attention in recent years. BAS are implemented to monitor the parameters defining living and working conditions within a building, and control its electrical equipment. BAS were initially developed to control heating, ventilation and air conditioning (HVAC) systems. Through time we have gone through several kinds of controllers, e.g. pneumatics, analog circuits, microprocessors, etc. Even though other home systems like lighting, security should also use automation, they are usually installed in a different system than HVAC. This division of the two subsystems increases the end consumer cost due to additional investment in communication hardware and software for integrating HVAC and lighting in a single control point.

Different manufacturers are concerned about only one aspect of building automation and hence the final building automation system has different subsystems which are finally taken to an integrated building management system. The need of a centralized monitoring control centre makes necessary the integration of all BA applications. However, the new and exciting opportunities to increase the connectivity of devices within the building for the purpose of building automation remains largely unexploited.The WSN-DALI integration can provide a solution for centralization of building automation services.The digital addressing capability of the DALI is being used for this purpose.

## II. MATERIALS AND METHOD

### 1. DALI

A digitally addressable lighting interface (DALI) network consists of a controller and one or more lighting devices that have DALI interfaces. The controller can monitor and control each light by means of a bi-directional data exchange. The DALI protocol permits devices to be individually addressed and it also incorporates Group and Scene broadcast messages to simultaneously address multiple devices. Each lighting device is assigned a unique static address in the numeric range 0 to 63, making possible up to 64 devices in a standalone system. Alternatively, DALI can be used as a subsystem via DALI gateways to address more than 64 devices. Data is transferred between controller and devices by means of an asynchronous, half-duplex, serial protocol over a two-wire differential bus, with a fixed data transfer rate of 1200 bit/s.

DALI requires a single pair of wires to form the bus for communication to all devices on a single DALI network. The network can be arranged in a bus or star topology, or a combination of these. The DALI System is not classified as separated extra low voltage and therefore may be run next to the mains cables or within a multi-core cable that includes mains power. The DALI data is transmitted using Manchester encoding and has a high signal to noise ratio which enables reliable communications in the presence of a large amount of electrical noise.

Earlier generations of DALI devices stored configuration data in EEPROM, which was problematic due to the limited number of write cycles supported by EEPROMs. In current generations of DALI devices, RAM is used in preference to EEPROM during normal operation, which significantly reduces the number of EEPROM writes and thus extends their lifetimes. This use of RAM, however, is patented and therefore mandates payment of a license fee. DALI is a dedicated lighting control interface. It uses differential pair with fixed baud of 1200bps. Each DALI bus can address up to 64 devices. And when configured as a subsystem of the whole building management system, more devices can be

controlled. DALI is based on Digital Signal Interface (DSI), which is also a lighting control interface.

## 2. WIRELESS SENSOR NETWORK

A wireless sensor network consist of autonomous sensors that are distributed to monitor physical or environmental conditions such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on.

The WSN is built of nodes – from a few to several hundreds or even thousands, where each node is connected to one or sometimes several sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting.

A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.

To reduce communication costs, some algorithms that remove or reduce nodes redundant sensor information and avoiding forwarding data is of no use. As nodes can inspect the data they forward, they can measure averages or directionality of readings from other nodes. For example, in sensing and monitoring applications, it is generally the case that neighboring sensor nodes monitoring an environmental feature typically register similar values. This kind of data redundancy due to the spatial correlation between sensor observations inspires the techniques for network data aggregation and mining.

Several standards are currently either ratified or under development by organizations including WAVE2M for wireless sensor networks. There are a number of standardization bodies in the field of WSNs. The IEEE focuses on the physical and MAC layers; the Internet Engineering Task Force works on layers 3 and above. In addition to these, bodies such as the International Society of Automation provide vertical solutions, covering all protocol layers. Finally, there are also several non-standard, proprietary mechanisms and specifications. Standards are used far less in WSNs than in other computing systems which make most systems incapable of direct communication between different systems. However predominant standards commonly used in WSN communications include wireless HART , IEEE1451, ZigBee / 802.15.4, ZigBee IP and 6LoWPAN. Here we are utilizing 802.15.4 WSN.

## 3. TOOL FOR MODEL-BASED DESIGN AND SIMULATION

Simulink provides a graphical user interface (GUI) for building models as block diagrams, allowing to draw models as would with pencil and paper. Simulink also includes a comprehensive block library of sinks, sources, linear and nonlinear components, and connectors. The interactive graphical environment simplifies the modeling process, eliminating the need to formulate differential and difference equations in a language or program. Models are hierarchical, so can build models using both top-down and bottom-up approaches.

After defining a model, you can simulate its dynamic behavior using a choice of mathematical integration methods, either from the Simulink menus or by entering commands in the MATLAB Command Window. The menus are convenient for interactive work, while the command line is useful for running a batch of simulations. Using scopes and other display blocks, see the simulation results while the simulation runs, then change parameters and see what happens. The simulation results can be put in the MATLAB workspace for post processing and visualization.

## III. SYSTEM MODELLING

Despite being designed for lighting control, DALI can also adapted to other applications, such as motor or fan controllers, proximity alarms, etc. This possibility is being utilized for extending the integration of DALI and wireless sensor network to a centralized building automation system. The systems such as heating ventilation and air-conditioning (HVAC), security systems are hence included along with lighting system to extend the capability of DALI. The lighting control is implemented using human sensors and an led light indicator. The heating ventilation and air conditioning (HVAC) system is simplified and implemented using temperature sensors, AC motor control system and power displays for fan control and a humidity sensor, DC heater and power display for heater control. The efficient usage of WSN is being enhanced with deployable energy efficient MAC protocol (DEEP). DALI is based upon the master-slave principle. The implementation of a DALI master controller is using an IEEE 802.15.4-based wireless sensor network (WSN). The Nodes which compose the wireless sensor network (WSN) have a microcontroller unit (MCU) and an IEEE 802.15.4-compliant transceiver. The DALI address generation takesplace here. The slave section is composed of the DALI address comparison and device control section. The automation of the devices with in our concerned system is being done here. The full system is being modeled with this concept.

The implementation of deployable energy efficient MAC protocol is based on request, acknowledge concept. This concept is implemented in heater system which represents high power devices which are controlled using request and acknowledge

system. The system is mainly implemented in two section, the DALI master control section where digital address generation and transmission takesplace and a slave section where the DALI address comparison and device control section lies.

## 1. DALI-WSN MASTER CONTROL SECTION

The DALI master control section consists of wireless sensor network (WSN). Nodes which compose the wireless sensor network (WSN) have a microcontroller unit (MCU) and an IEEE 802.15.4 compliant transceiver.

For lighting control, we make use of the human sensors in three rooms, when there is human entry indicated in the human sensor of the concerned room, the light in the concerned room is on. For fan control, we make use of temperature sensors in two rooms, when there is indication of high temperature, the fan runs at high speed else at low speed. The security system, we make use of an intrusion sensor, when there is an indication of an intruder, the alarm indicated by an led light is on. The heater system make use of humidity sensor and works upon DEEP protocol, ie, upon the request acknowledgement principle.

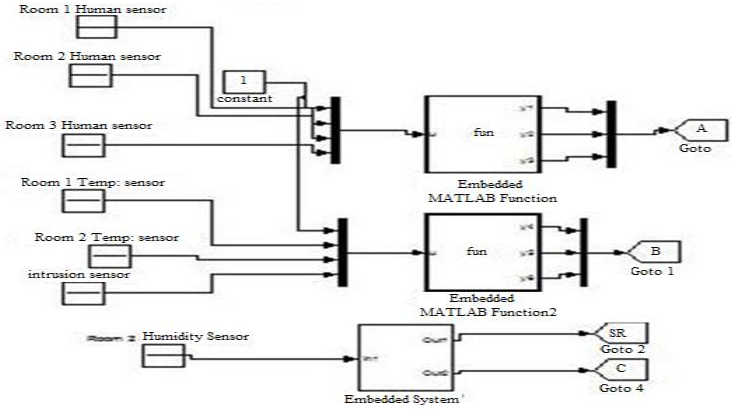


Figure 1: DALI-WSN master control section

## 2. DALI-WSN SLAVE SECTION

The DALI slave section composes of the address comparison and device control mechanisms. The controls of the devices are done according to the digital address being send by the master section. If the correct digital address of the device is being received, the particular device is being activated henceforth.

For the lighting control, if the correct digital address of the lights of any three rooms is being received, then the light for the corresponding rooms are kept on, otherwise the lights are always at the off condition. Hence it works in such a way that whenever the presence of human in room is detected, the digital address of that particular room is send by the wireless transceiver and upon the reception of the digital address by the slave section, the light is kept on. For the alarm system too same procedure is being done. As such upon the indication of an intruder in a room by the intrusion sensor, the alarm in the respective room is on. This is upon the reception of the particular digital address of the alarm device send by the wireless transceiver.

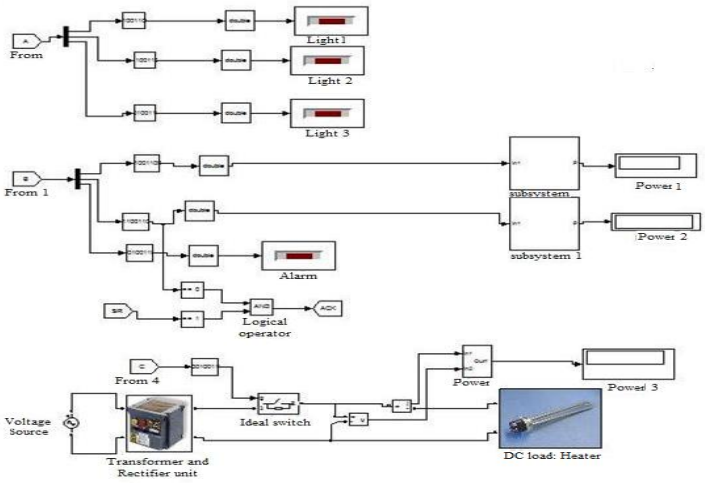


Figure 2: DALI-WSN slave section

For the lighting control, if the correct digital address of the lights of any three rooms is being received, then the light for the corresponding rooms are kept on, otherwise the lights are always at the off condition. Hence it works in such a way that whenever the presence of human in room is detected, the digital address of that particular room is send by the wireless transceiver and upon the reception of the digital address by the slave section, the light is kept on. For the alarm system too same procedure is being done. As such upon the indication of an intruder in a room by the intrusion sensor, the alarm in the respective room is on. This is upon the reception of the particular digital address of the alarm device send by the wireless transceiver.

## IV. RESULTS AND DISCUSSION

DALI, when alone used for lighting control in building automation can be represented as shown in fig.5.1.1. When the input to the human sensor of a particular room is high, then the light in that room will be on, else it will be off. In Fig. 3, the human sensor inputs of room1 and room3 is high and that of room 2 is low, hence the lights in room1 and room3 is on and that of room2 is off. Whenever the human entry in a particular room is detected then the lights in that particular room are kept on.

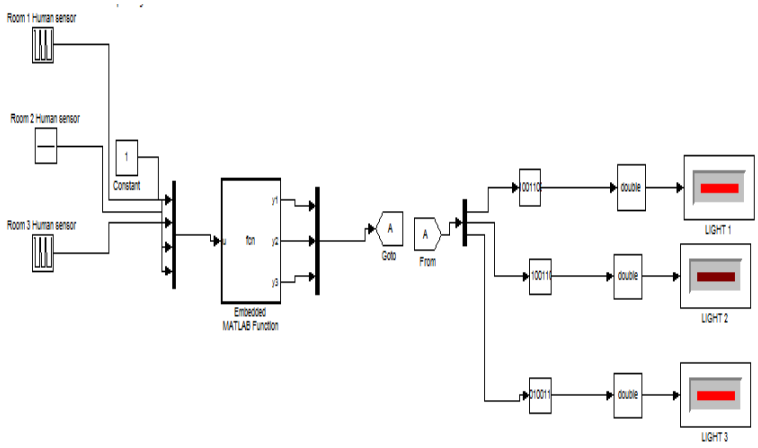


Figure 3: Simulation diagram of building lighting automation

Although DALI was designed for lighting purposes, the up and down commands or direct levels can be also used for setting a fan speed , detection of intruder in a room etc .They can be implemented as shown in Fig. 4. The room1 and room2 is having fan controllers and an intrusion sensor is included to add the features of security system in buildings. The inputs are provided to the sensors so that room1 temperature sensor senses a low temperature, room2 temperature sensor senses a high temperature, and the intrusion sensor senses the presence of an intruder. Hence we obtain the simulation result as for room1 fan runs at low speed consuming less power, room2 fan runs at high speed consuming more power, and intrusion alarm is on.

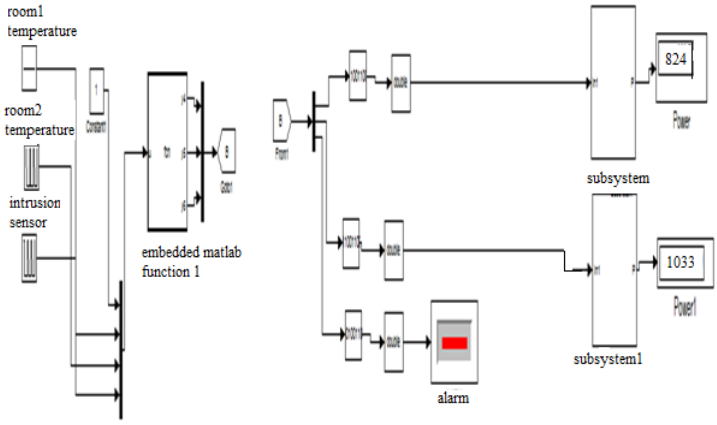


Figure 4: Simulation diagram of fan controller and security system in BAS

For high power consuming devices such as room heater systems, the DEEP protocol can be implemented for the purpose of conformation of the efficiency of the wireless sensors. This is implemented in Fig. 5.

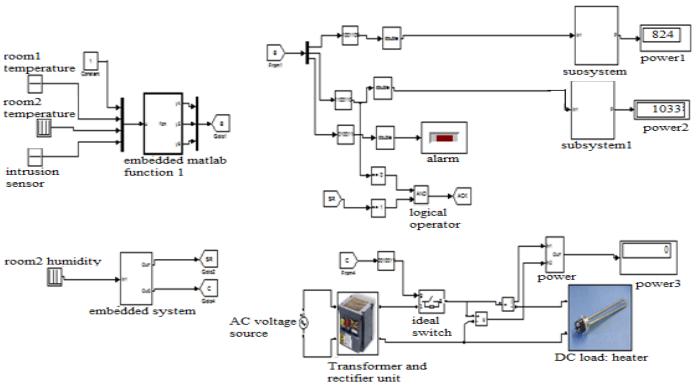


Figure 5: Simulation diagram of BAS implementing DEEP

Even though the room2 humidity sensor senses a high humidity, there is again made a conformation with the room2 temperature sensor. Since the temperature sensor senses high itself, the heater is kept off and room2 fan still runs at high speed consuming high power. The room1 temperature is sensed low; hence it runs at low speed consuming less power. The intrusion sensor senses a low and hence intrusion alarm is off.

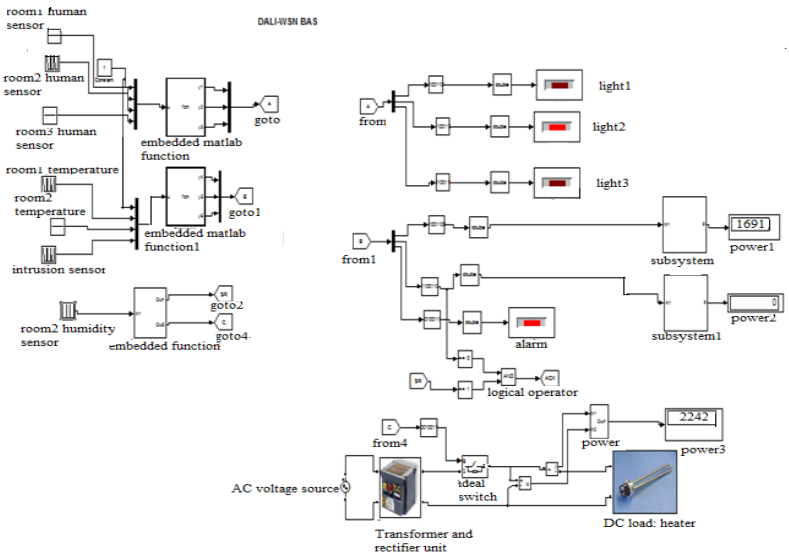


Figure 6: Simulation diagram of final BAS with DALI-WSN integration

The final building automation takes into account all the above systems and integrates them together into a single building automation system. It is implemented as shown in Fig.6. The room1 and room3 human sensors are kept low, and room2 human sensor at high, hence the room2 light is only on. The intrusion sensor senses high and so it is on. The temperature sensor for room1 is high and for room 2 is sensed low. The humidity sensor for room2 senses high. Incorporating them, the room1 fan runs at high speed consuming more power, room2 fan is off and the room2 heater is kept on. Hence the full building automation can be controlled through the integration of DALI with wireless sensor network (WSN).

## V. CONCLUSION

DALI was initially introduced for lighting control alone for the purpose of building automation. But the capability that it can also be adapted to other applications, such as motor or fan controllers, proximity alarms, etc is being utilized here. Beneath that expanding the traditional DALI bus and removing wires, results in a reduction of installation costs. Adapting a standard wireless sensor network allows integrating DALI devices as a part of the WSN .Hence opted the IEEE 802.15.4wireless sensor network.
DALI is based upon the master-slave principle. Implementing a DALI master controller is using an IEEE 802.15.4-based wireless sensor network. Nodes which compose the wireless sensor network have a microcontroller unit (MCU) and IEEE 802.15.4-compliant transceiver. DALI-WSN integration is done through the digital addressing of devices. The analysis of the concept of WSN-DALI integration is done with the powerful simulation modeling capabilities of Matlab /Simulink. The different subsystem functions are connected through dedicated Matlab functional blocks through codings. The utility of digital addressing capability of DALI makes the integration of blocks together and for the purpose of centralized building automation. Direct comparison with digital address of the devices enables the centralized integration of building automation. Besides the

lighting control, the heating ventilation and air-conditioning (HVAC) and security systems are also being included for the purpose of centralized building automation.

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