Title: An intelligent wireless lighting control system using IEEE802.15.4 and WIFI (IEEE802.11) technology

Description:

The present invention relates to a wireless light control system with control and sensor modules and method thereof for controlling light fixtures such as lighting on and off, lighting on and off duration, and brightness of the lighting apparatus. It can also switch fans on or off via the fan relays. The said system also has temperature, gas sensors on its wireless network (IEEE 802.15.4) for providing inputs about the temperature and gas level of the surroundings. Connection to the internet is through WIFI on the local area network and router.

Brief description of drawing

Figure 1 is an electrical block diagram of an exemplary embodiment of the invention with internet access. It comprises:

- dimmer modules **1** with IEEE802.15.4 wireless connectivity **11** to control dimmable light fixtures **5**
- relay modules **2** with IEEE802.15.4 wireless connectivity **11** to control non dimmable light fixtures **6**
- normal wall mounted light switches **3** to control the power to the modules connected to it.
- gateway **4** which is also the coordinator of the IEEE802.15.4 wireless network **11** with WIFI connectivity **13** . WIFI connectivity is provided by an onboard WIFI module at the gateway. There is only one gateway **4** in the same IEEE802.15.4 wireless network **11** .
- internet router **7** with WIFI connectivity **13**
- Remote units **8** like mobile phone or tablet to control or monitor the system via a mobile application or personal computer (PC) to control or monitor the system via the web pages. The remote units uses WIFI **13** or mobile data **14** to access the system.
- remote control **9** with IEEE802.15.4 wireless connectivity **11**
- motion detector **10** with IEEE802.15.4 wireless connectivity **11**
- presence detector **12** with IEEE802.15.4 wireless connectivity **11**
- temperature and humidity sensor **15** with IEEE802.15.4 wireless connectivity **11**
- gas sensor **16** with IEEE802.15.4 wireless connectivity **11** . The gas sensor can be a smoke or carbon monoxide or carbon dioxide sensor
- fan relay **18** with IEEE802.15.4 wireless connectivity **11** to control an electrical fan **19**
- remote server **17** which contains the MQTT broker, database and webserver for web and mobile app control.

Detailed description of the system

The IEEE802.15.4 connectivity is provided by a microcontroller with IEEE802.15.4 transceiver. All the modules of the system with IEEE802.15.4 connectivity will have this microcontroller. The IEEE802.15.4 wireless network is also known as wireless personal area network (WPAN) **11.** It operates on 2.4 Ghz carrier. The dimmer modules **1** and relay modules **2** are normally sited above the ceiling board. The dimmer modules **1** are connected to light fixtures **5** which are dimmable light sources and the relay modules **2** are connected to light fixture **6** which are non dimmable light sources. The gateway **4** which is also the coordinator of the WPAN network is connected to the WIFI router **7** via WIFI **13.** Communication between all the modules is through software commands sent and received by the microcontrollers in each module, via WPAN 11 . The modules can function as routers or end devices. Routers are repeaters of wireless information between routers,

end devices and coordinator. End devices are generally sleeping devices and are battery operated. They can only send or receive information from itself to its parent which can be a router.

The software protocol that runs on the WPAN modules is proprietarial. The gateway **4** and the rest of the WPAN modules which are also called nodes are identified by their unique MACID , node ID and device ID. Devices with the same device ID will have the same characteristics. Example: all devices which are motion detectors will have the same characteristics but are different from other devices like presence detectors, remote control, dimmers, etc. This enables the creation of many types of devices on the system. Any control action from the nodes to other nodes are direct. Eg. The motion detector **10** which is programmed to control the dimmer **1** will send the command directly to the dimmer **1** and at the same time inform the gateway **4** of the action so that the gateway **4** can update the light status on its database and compare with the subsequent light status reported by the dimmer **1.** This data is also sent to the webserver so that the mobile application and the webpages can be updated. It will also allow the gateway **4** to take remedial action to set the light status on the dimmer **1** correct in the event the wireless command from the motion detector **10** is missed by the dimmer **1.** This method allows for faster response of control commands from the nodes and also prevent overloading of tasks on the gateway **4.** Control actions from the gateway **4** to the nodes only come from the remote units **8.**

The following is a more detailed description of the modules and the software system running on the modules. All the modules

1. Gateway **4** : The gateway's primary function is to start the WPAN **11** as a gateway 4 with its unique security key called the network security key. Once the network is started, other WPAN modules which can be dimmer, relay, remote control or sensor modules on the network with the same network application ID , PAN ID (personal area network ID) and network security key will be able to join the network by sending requests to the gateway **4.** A feature is incorporated in the gateway **4** which will allow new modules not having any network security key to join the network. The messages from the new modules are initially encrypted by a commission key which is generated by a formula which is present in both the gateway **4** and the nodes. The commission key is different for every node but the gateway **4** using the same formula is able to generate the node's commission key and decrypt the incoming message. If the incoming message contains the same network application ID, then the node is put up for acceptance by the end user via mobile app or via a webpage. The end user will then decide whether to admit the modules to the network. If the module is admitted, the MAC ID of the modules will be saved in the non volatile memory of the gateway 4. The PANID of the gateway **4** will also be saved on the nodes. The gateway **4** will also transfer its network security key to the accepted node. This network security key is used for encrypting messages between the gateway **4** and all the other nodes. The network security key is generated using the MAC ID of the gateway **4** and the time at which the first node is accepted as a member of the network. This will introduce an element of randomness to the network security key. The network security key will be stored in the non volatile memory of the gateway **4** and in the non volatile memory of all the modules in the network. Whenever there is a reset of the modules or gateway **4**, the modules having the same network security key, network application ID and PAN ID (which are the joining requirements) will be allowed to rejoin the WPAN and be marked online. Commands from the gateway **4** to the modules will only be sent if the modules are online. All WPAN modules have similar network joining exercise: On power up, they will try to join the network with similar joining requirements. If it cannot find any network that it can join, it will scan all the network channels indefinitely until a WPAN network that it can join can be found. In this way, we can have a few WPANs operating on the same channel frequency because they have different network security key and will not interfere with each other's operations.

   The gateway **4** will periodically collect data of the other modules on the WPAN. This is to enable it to have an updated information of all the modules on the network. An onboard WIFI module with TCP/IP stack allows the gateway **4** to be connected to a WIFI router **7**

and onwards to the remote server **17**. The gateway **4** will provide updated information of the WPAN modules to the remote server **17** whenever there are changes in the WPAN module data. The information provided is for both online and offline modules. Modules which are offline are those modules which were previously online but are no longer detected in the network. The protocol for sending data to the remote server is MQTT. The architecture of using the gateway 4 with IEEE802.15.4 connectivity connected to a WIFI module with TCP/IP stack allows a low cost WPAN system to be scaled to a much larger system without the limitation of the different WPANs having to be sited close to each other. Each gateway only has to be sited closed to the WPAN modules in its own WPAN. The reach of WIFI in a building is quite pervasive so it is possible for gateways which are not adjacent to be connected and centrally controlled. It is also possible for the WPAN system to function in the absence of WIFI.

Control requests sent by remote units **8** to the WPAN modules via the remote server are checked and managed by the gateway **4** to prevent too many similar events from happening to the same affected modules. In so doing, it will prevent crowding the wireless bandwidth of WPAN with unnecessary requests.

2. Dimmer **1** : The dimmer module **1** is a router node which means it is able to relay messages from its parent node to its child nodes .Its primary function to provide dimming ability to the dimmable light fixture **5** base on the commands it receive from the remote control modules **9**, presence detector **12**, motion detector **10** or the gateway **4** via the WPAN **11** . The dimmer module is powered by the mains cable.

3. Relay **2** : The relay module **2** provides relay switching of mains power to the light fixture which can be dimmable or non dimmable. Non dimmable light fixture **6** can only use this module to switch the lights on or off. The relay module 2 receives its commands to switch the lights from the remote control modules **9**, presence detector **12**, motion detector **10** or the gateway **4** via the WPAN **11**. When the module is powered up, it will try to join the network with similar joining requirements. Once it has joined the network, it will report its status to the gateway whenever there are changes. This is to enable the gateway to be aware that the module is still active. Like the dimmer module **1** , if the relay module were to lose connection to the gateway 4, it will automatically scan all the network channels to see if it can rejoin the network with the same IDs. This exercise will go on indefinitely. The relay module is also a router. It act as a message repeater, i.e. it will relay any message to and fro any modules. The relay module is powered by the mains cable.

4. Wall mounted mains light switches **3** : The mains light switches is used for providing electrical isolation of the mains supply to the dimmer or relay modules or mains powered sensor modules. It is not part of the WPAN **11**. It does not have a IEEE802.15.4 wireless microcontroller on it.

5. Remote control **9** : The remote control **9** is an end device. This means that it can only respond to its parent module in the network and cannot relay messages to other modules. When not in use, it is put to sleep mode. It is battery operated. There are 4 to 10 buttons on the remote control allowing it to control different lights or groups of lights in the WPAN network. The function of the buttons are programmable via mobile app or webpages. It can be configured as a ON button, OFF button, TOGGLE button or SCENE button. ON mode is to switch the associated lights or fan to on, OFF mode is to switch lights or fan to off, TOGGLE mode will switch the lights or fan on or off with repeated press. SCENE mode is to switch the lights only on at defined brightness setting associated with the button. One button can be assigned to one group only or numerous individual lights or fan.

6. Motion detector **10** : The motion detector **10** is a sensor module. It provides detection of infra red movement. When motion is detected, the resulting switching actions can be programmed using mobile app or web pages to switch the lights or fans to ON or OFF.

Brightness preset can also be programmed on the module via mobile app or web pages such that the lights can be switched on at a defined brightness level. The motion detector can be programmed as a router or end device. If it is a router, it has parent and child nodes and will be mains powered. If it is a end device, it only has parent node and no child node and will be battery powered. When it is an end device, it will sleep at regular intervals.

7. Presence detector **12** : The presence detector **12** is a sensor module. It has a thermal sensor on it. The thermal sensor will detect human presence, not by motion of infra red but by presence of infra red heat emitted. The infra red temperature detected will be used to decide whether there is human presence or not. The switching function of the presence detector **12** is the same as the motion detector **10**. The sensor module can be pre-programmed as router or end device.

8. Temperature and humidity sensor **15** : The temperature and humidity sensor is used for providing information to the gateway **4** about the temperature and humidity of the area it is located. The temperature and humidity information can then be used to control the air conditioner or heater using another software system via an api provided by the remote server **17.**

9. Gas sensor **16** : The gas sensor can be a smoke, carbon dioxide (CO2) or carbon monoxide (CO) sensor module. It provides information to the gateway **4** about the smoke / CO2 /CO level of the location where the module is sited. The sensor module can be pre-programmed as router or end device. The gas information can then be used to control the air conditioner or heater using another software system via an api provided by the remote server **17.**

10. Fan relay **18** : The fan relay **18** provides relay switching of mains power to the electrical fan **19**. It receives its commands to switch the fan from the remote control **9**, presence detector **12**, motion detector **10** or the gateway **4** via the WPAN **11**.

11. Remote unit 8 : The remote unit **8** can be a mobile phone or tablet personal computer (PC) or desktop PC. The remote unit communicates with the gateway **4** via the mobile network **13** or WIFI **14** . The application running on the remote unit is a mobile application software when it is a mobile phone or tablet PC. When it is a desktop PC, the application running on it is a web application software. The mobile and web application will communicate with the remote server **17** to perform the following functions:
    - to update the latest information of the network on the applications .
    - to approve the joining of all the modules to the gateway **4**
    - to switch the lights and fans
    - to form groups of lights or sensors or fans to be used by the sensors **10** and **12**, remote control **9** , and events to control the switching of lights and fans.
    - to create and amend events on the gateway **4** to time the switching of lights and fans.
    - to set the gateway timing
    - to set the channel used by the WPAN
    - to set the SSID which the gateway **4** WIFI module must be connected to and the remote server **17** URL to which the mqtt client on the gateway must subscribe or publish the gateway's data

12. Remote server **17** : The remote server **17** can be a remote personal computer (PC) or cloud server. The remote server **17** contains a MQTT broker, a database and a webserver. The MQTT broker is used for hosting topics published and subscribed by the MQTT client residing on the gateway , remote units and web server. Encryption and user authentication is implemented for internet message transfer between the gateway and remote server and between android and remote server. The database on the remote server is regularly updated by data sent by the gateways to the MQTT broker. The presence of the remote server **17** serve as a buffer between a huge number of remote units **8** and a single gateway **4**. This makes for a scaleable architecture in that the remote server can handle numerous requests for information and control from remote units.

Claims:

1. A wireless light control system comprising a gateway, a remote server and at least one remote unit and having some or all of the following WPAN modules: dimmer, relay, remote control, motion detector, presence detector, temperature and humidity sensor, gas (smoke or carbon monoxide or carbon dioxide) sensor and fan relay. The gateway uses IEEE802.15.4 connectivity or WPAN to control and monitor the WPAN modules.. The gateway uses WIFI to connect to the remote server and remote units. Application software running on remote units like mobile phone or tablet personal computer (PC) or desktop PC, is used for configuring and controlling the entire WPAN system.
2. The system in claim 1 can be configured such that neighbouring similar systems cannot control or join the system unless they have the same network application ID, PAN ID and network security key. The network security key is created using combination of the gateway MACID and the time the first non gateway node becomes a member of the network. It is used for encrypting and decrypting messages between all the nodes. The gateway will first start the WPAN. Other modules which are powered up will then try to join the WPAN if their network application ID, PAN ID and network security key is the same. New modules which are routers or end devices and has no network security key but has the same network application ID and whose encrypted wireless messages can be decrypted by the gateway, can join the network if approval is given via the mobile application or web pages software.
3. The remote server in claim 1contains a MQTT broker and database and webserver. The remote server serves to buffer huge number of users from the gateway in claim 1 as all information of the WPAN resides on the server and are updated when changed. This allows a scaleable system to be built.
4. The dimmer in claim 1 is used for controlling the brightness of dimmable light fixturbues.
5. The relay in claim 1 is used for switching mains power to the non dimmable light fixtures using a relay or other electronics switching method.
6. The remote control in claim 1 is programmable by the mobile application software or web pages software. It can be used to switch the lights or fans to on or off and the dimmable lights can be switched on at user defined brightness. Commands by the remote control is sent directly to the dimmers and relays and the gateway is also notified of the action. This allows distributed control and faster switching of the affected nodes.
7. The motion detector in claim 1 is used to send switching information to the dimmer, relay or fan relay and the gateway when motion is detected. Commands by the motion detector is sent directly to the dimmers and relays and the gateway is also notified of the action. This allows distributed control and faster switching of the affected nodes
8. The presence detector in claim 1 is used to send switching information to the dimmer, relay and fan relay and the gateway when human presence via thermal heat is detected. Commands by the presence detector is sent directly to the dimmers and relays and the gateway is also notified of the action. This allows distributed control and faster switching of the affected nodes
9. The temperature and humidity sensor in claim 1 is used to provide the temperature and humidity of the area it is located. It sends its information regularly to the gateway which is further sent to the remote server for use by other control systems via a software api, example air con controller or heater controller.
10. The gas sensor module in claim 1 is used to collect information of the smoke/carbon monoxide/carbon dioxide of the the environment it is located in. It then sends the information to the gateway and remote server for use by other controller systems via software api. Example of other controller system is exhaust fan system.
11. The fan relay in claim 1 is used for switching mains power to the electrical fan.