Getting Started with Connected Lighting

Set up your own zigbee 3.0 network

For many years the promise of a future where all the objects in our homes will communicate with each other has been reiterated again and again, and yet the consumer is still waiting. Who hasn't seen a demonstration or a video of a smart lightbulb installed somewhere controlled by a switch without wires that could be magically reconfigured to control another lightbulb in another room? But how many people own a home that is actually equipped with this technology?

By **Clemens Valens** (Elektor Labs)

True, kits for connected lights and power outlets are commercially available today. But due to a multitude of networking and communications standards, the devices from one manufacturer cannot, in general, talk to devices from another. Bluetooth, Wi-Fi, custom ISM-band-based, and Zigbee are all mutually incompatible technologies that are actively being pushed into home automation applications. No wonder home automation still remains a "thing of the future" for most consumers.

Then there is cost. An average home in the US has 40 sockets, meaning that with a price of say $25 per connected lamp/switch pair, hooking up each socket would amount to some $1,000; quite a budget just to replace a wired system that is working fine already.

But there is hope. At the beginning of 2017 Swedish furniture giant Ikea has introduced a line of connected lamps and dimmers under the name of Trådfri (**Figure 1**) reportedly based on the brand-new standard zigbee 3.0[*]. This will undoubtedly give home automation a big push forward.

From ZigBee to zigbee

ZigBee, conceived in 1998 and first standardized in 2003, is a wireless networking technology aimed at Personal Area Networks (PANs). It is low-power, has low data rates, and was designed for small-scale projects like home automation and data collection. Some 10 years ago the term ZigBee was on everyone's lips, but then slowly faded away, almost into oblivion it seemed. In reality ZigBee never went away, it got rid of its capital 'Z' and 'B' and discreetly found its way into many products. Chances are that the wirelessly connected lightbulb/dimmer kit you just bought at your local hardware store is using zigbee technology. The popular Philips Hue (**Figure 2**) connected lights do too.

Figure 1. According to zigbee network sniffers (see footnote) Ikea's Trådfri connected lamps are zigbee 3.0 compatible although officially they use ZigBee Light Link (ZLL) and ZigBee Home Automation (ZHA).

Figure 2. Philips Hue personal wireless lighting system uses the ZLL protocol.

Zigbee 3.0

An inconvenience of zigbee is the number of sub-protocols that have come into existence over the past few years, all addressing particular needs and applications. Zigbee 3.0 tries to remedy for that by providing backwards compatibility with Zigbee PRO, ZigBee Light Link (ZLL) 1.0 and Home Automation (ZHA) 1.2. Zigbee 3.0 also provides support for over-the-air (OTA) firmware upgrades and facilitates adding devices to the network (node commissioning). Touchlink commissioning using Near-Field Communication (NFC), for example, is supported.

Future proof

Zigbee is one way of doing things, but other standards are trying to get into home automation and smart lighting too. For instance, Bluetooth and Wi-Fi both have low-energy derivatives intended for just that. Smartphones and tablets, and portable computers to a lesser extent, make for perfect remote controls for smart lights, and they all come equipped with Bluetooth and Wi-Fi. And if there is one thing that we should have learned from the past by now, it is that a new technology may emerge and be adopted at any time, meaning that a truly universal system must be future proof.

A future-proof platform intended for home automation will have to support several wireless communication protocols and should be field-programmable to allow adding new protocols to already installed systems. But a socket built on such a multiprotocol platform can do much more than just dim a light, it could also capture and transmit sensor data and function as a beacon, for instance. It can be part of the Internet of Things (IoT). This implies that the platform must be capable of running several protocols simultaneously. And, of course, all of this has to be done at a minimum cost while consuming as little energy as possible.

Make connected lighting tangible

A good way to start experimenting with connected lighting is an evaluation or demonstration kit as provided by silicon vendors that are into zigbee. In this article we will use a setup from Silicon Labs comprising a Raspberry-Pi-based zigbee gateway and a zigbee node with a sophisticated LED. The latter is actually a controllable LED baseboard together with a radio module built around the ultra-low-power yet powerful EFR32 Mighty Gecko System-on-Chip (SoC).

The gateway consists of a Raspberry Pi (RPi) 2 model B and a MeshConnect USB stick from CEL. Silicon Labs has packed all the required parts—RPi built in a nice enclosure, SD card, Wi-Fi dongle, MeshConnect stick, power adapter—in a nice box with reference RD-0001-0201 (**Figure 3**). The MeshConnect stick can also be purchased alone (ref. RD-0002-0201) in case you prefer to set up a computer as a gateway or if you have an RPi lying around.

The connected lighting node, a reference design as a matter of fact, is available under reference RD-0085-0401 (**Figure 4**). A gateway and a node is the absolute minimum you will need to get started. Extending your setup is possible, of course, with for instance a capacitive sense dimmable-light switch (RD-0039-0201) or with more lights.

Setting up the kit

It all starts by setting up the gateway. You might expect that the people at Silicon Labs prepared the gateway for you, but

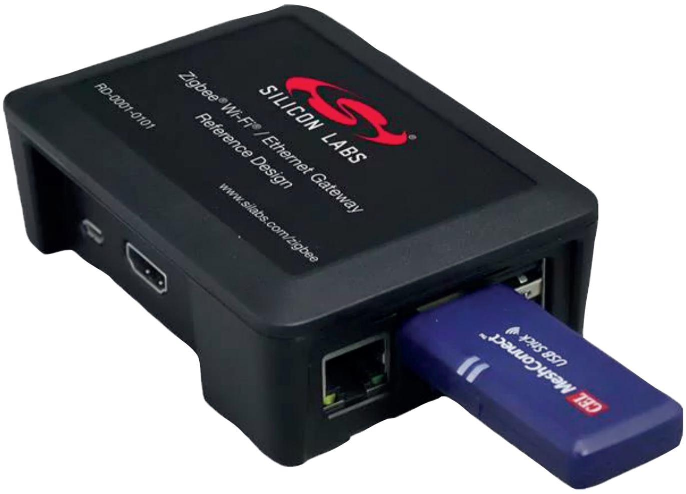


Figure 3. This zigbee gateway (Silicon Labs ref. RD-0001-0201) is built on a Raspberry Pi.

* See https://faire-ca-soi-meme.fr/test/2017/06/06/ikea-tradfri-zigbee-3-0-compatibilite-zigate/

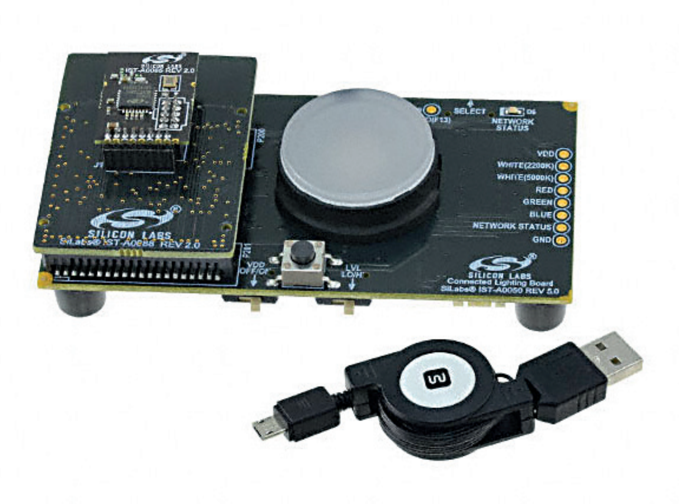
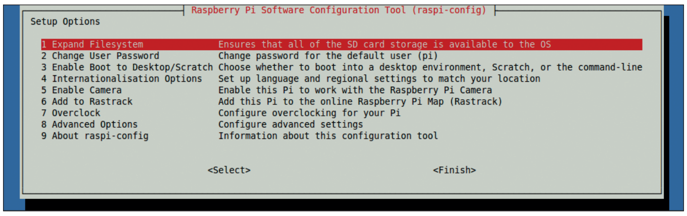


Figure 4. The connected lighting node reference design RD-0085-0401 from Silicon Labs combines a user-programmable EFR32-Mighty-Gecko-based radio module with a sophisticated LED.

they didn't, and it is up to you to install the required software first. This way you will get the latest version when starting, although it seems like an additional step. The procedure to do this follows and is also applicable for those who b(r)ought their own RPi. Note that the Wi-Fi dongle is not needed when using an RPi 3.

Setting up a zigbee gateway on a computer running Ubuntu 16.04 (by itself or in a virtual machine) is described in application note UG129 (see [1]).

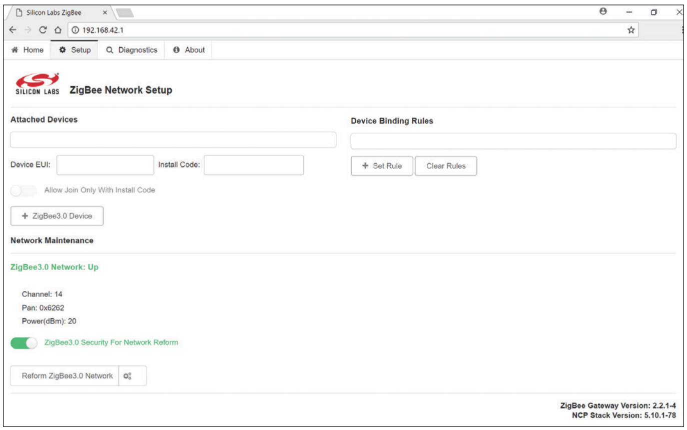


```
                 Raspberry Pi Software Configuration Tool (raspi-config)
Setup Options

  1 Expand Filesystem              Ensures that all of the SD card storage is available to the OS
  2 Change User Password           Change password for the default user (pi)
  3 Enable Boot to Desktop/Scratch Choose whether to boot into a desktop environment, Scratch, or the command-line
  4 Internationalisation Options   Set up language and regional settings to match your location
  5 Enable Camera                  Enable this Pi to work with the Raspberry Pi Camera
  6 Add to Rastrack                Add this Pi to the online Raspberry Pi Map (Rastrack)
  7 Overclock                      Configure overclocking for your Pi
  8 Advanced Options               Configure advanced settings
  9 About raspi-config             Information about this configuration tool

                    <Select>                                 <Finish>
```

Figure 5. The Raspberry Pi must be configured with the raspi-config utility before it can be used. This utility can also be used to change its default password.



ZigBee Network Setup

Attached Devices

Device Binding Rules

Device EUI:

Install Code:

○ Allow Join Only With Install Code

Network Maintenance

ZigBee3.0 Network: Up

Channel: 14
Pan: 0x6262
Power(dBm): 20

● ZigBee3.0 Security For Network Reform

ZigBee Gateway Version: 2.2.1-4
NCP Stack Version: 5.10.1-78

Figure 6. Connected to the zigbee gateway. All lights are green, we are ready to go. Click '+ ZigBee3.0 Device' to add zigbee nodes.

Prepare the SD card for the Raspberry Pi

1. Using a computer, download the official Raspbian operating system http://downloads.raspberrypi.org/raspbian_lite/images/raspbian_lite-2016-05-31/2016-05-27-raspbian-jessie-lite.zip. Due to some driver issues, it is important that the version 2016-05-27 is used and not the current;
2. Stick the SD card into the computer;
3. As recommended by the Raspberry Pi Foundation, use Etcher (https://etcher.io/) to install the image on the SD card;
4. Remove the SD card from the computer in a safe way;

Prepare the Raspberry Pi

5. Install the previously prepared SD card in the RPi;
6. Connect the RPi Ethernet port to a network router with an Ethernet cable;
7. Connect the CEL MeshConnect stick to a USB port on the RPi;
8. Stick the Wi-Fi dongle in another USB port of the RPi;
9. Optional: connect a keyboard and monitor to the RPi. This is not required for what follows;
10. Power on the RPi;

Finalize software installation

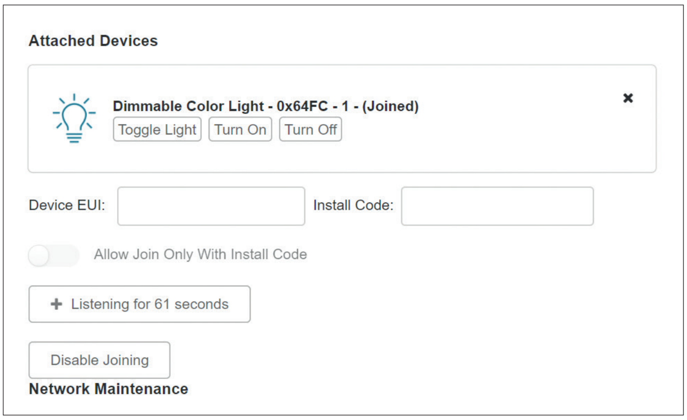
11. Find the RPi's IP address on the network (e.g. get it from the router's connected devices list);
12. With PuTTY or a similar tool on your computer open an SSH session to the RPi's IP address. If you connected a keyboard and monitor to the RPi than the typing that follows is done in the RPi's Command Line Interface (CLI), if not the typing is done on the computer in the SSH client;
13. Login with username 'pi' and password 'raspberry';
14. Enter the command '`sudo raspi-config`' (followed by <Enter>, of course);
    - Select option 1 'Expand Filesystem', wait for it to finish and reboot the RPi (**Figure 5**);
15. Reconnect with your SSH client (e.g. PuTTY) and execute the following list of commands (beware of typos, every command must be followed by <Enter>):

```
- sudo chmod 666 /etc/apt/sources.list
- sudo echo deb http://devtools.silabs.com/solu-
  tions/apt jessie main >> /etc/apt/sources.list
- sudo apt-key adv --keyserver keyserver.ubuntu.com
  --recv-keys 90CE4F77
- sudo apt-get update
- sudo apt-get install silabs-zigbee-gateway
- sudo apt-get install silabs-networking
- sudo reboot
```

Almost there

At this point the Raspberry Pi should act as a Wi-Fi access point (AP) and should be visible by your computer:

16. Connect to the Wi-Fi network 'Silicon Labs xxxx' with 'xxxx' a 4-digit hexadecimal number;
17. Point a browser to IP address 192.168.42.1 (**Figure 6**);



Attached Devices

Dimmable Color Light - 0x64FC - 1 - (Joined)

Device EUI:

Install Code:

○ Allow Join Only With Install Code

Network Maintenance

Figure 7. The connected lighting node RD-0085-0401 has been added to the zigbee 3.0 network.

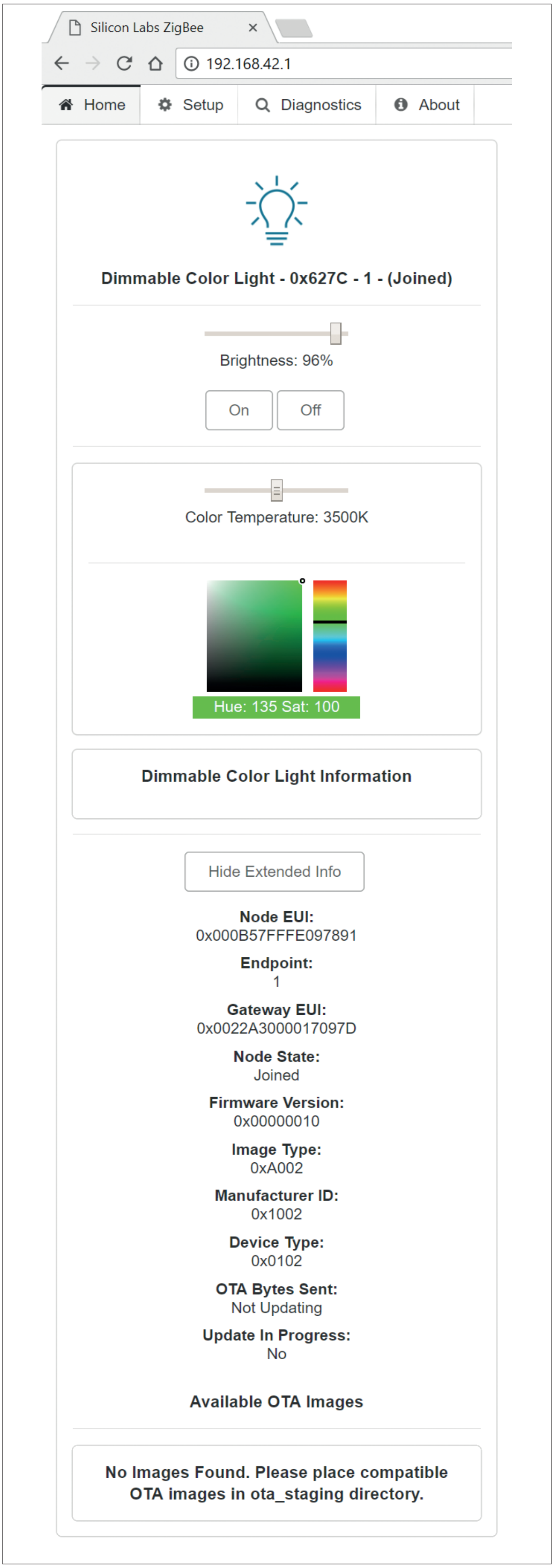
18. If you see (in green) 'ZigBee 3.0 Network: Up' continue at section 'Run the Gateway';
19. Connect PuTTY or another SSH client to 192.168.42.1 and log on to the Raspberry Pi as before (see steps 12 and 13), and then execute the following commands. Make sure the MeshConnect stick is connected to the RPi. Also make sure that the serial port (/dev/ttyUSB0 in the command below) corresponds to the stick:

```
- sudo service siliconlabsgateway stop
- cd /opt/siliconlabs/zigbeegateway/
- sudo python tools/ncp-updater/ncp.py scan
- sudo python tools/ncp-updater/ncp.py flash -p /
  dev/ttyUSB0 -f firmware/ncp-uart/em3588/*.ebl
- sudo reboot
```

Run the Gateway

Now it is time to build the connected lighting network by adding nodes to it:

20. Connect a computer, smartphone or tablet to the gateway as described above (steps 17 and 18);
21. Connect the EFR32MG zigbee node RD-0085-0401 to a USB power source;
22. Set the 'Select' switch to the right (this will activate the network status LED);
23. Set the VDD Off/On switch to the right position;
24. Set the LVL Lo/H switch to the right position;
25. In the browser click/tap button '+ ZigBee3.0 Device'. Listening lasts for 120 seconds but this period can be extended by clicking the '+ Listening for xx seconds' button (**Figure 6**);
26. On the zigbee node RD-0085-0401 press S1 10 times rapidly to enter "join mode". The board should show up as 'Dimmable Color Light - 0xXXXX - 1 - (Joined)' with XXXX a 4-digit hexadecimal number.



Dimmable Color Light - 0x627C - 1 - (Joined)

Brightness: 96%

Color Temperature: 3500K

Hue: 135 Sat: 100

Dimmable Color Light Information

Node EUI:
0x000B57FFFE097891

Endpoint:
1

Gateway EUI:
0x0022A3000017097D

Node State:
Joined

Firmware Version:
0x00000010

Image Type:
0xA002

Manufacturer ID:
0x1002

Device Type:
0x0102

OTA Bytes Sent:
Not Updating

Update In Progress:
No

Available OTA Images

No Images Found. Please place compatible OTA images in ota_staging directory.

Figure 8. The complete webpage to control the connected light with. The "No Images Found" message at the bottom refers to firmware images that should be placed in a special folder so that the device can be programed over-the-air (OTA).

And now?

That’s it. You now have a zigbee network running that you can experiment with. From this point on you can go in several directions. Customizing the gateway is one option, designing your own nodes is another. Whichever direction you choose, know that the future of connected lighting is now partly in your hands too. ⏮

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Shutting Down the Gateway

It is bad practice to switch off a Raspberry Pi simply by pulling its power. An RPi is like any other modern computer running a complex operating system and it must be shut down properly to avoid damaging files. Unfortunately the RPi does not have a power button, but it can be done from a terminal (directly or through an SSH client) with the command:

```
sudo poweroff
```

Wait until the green LED stops blinking (the red LED remains on), then unplug the power supply.

More information

[1] Everything about the gateway, its options, capabilities and possibilities can be found in the Silicon Labs document ‘UG129: Zigbee Gateway Reference Design User’s Guide (RD-0001-0201, RD-0002-0201)’.

[2] Full details for the Zigbee node can be found in the document ‘UG252:
ZigBee Lighting Reference Design Demo Board Kit User’s Guide (RD-0085-0401, RD-0035-0601)’. Schematics and other design files can be downloaded as well.

FROM MOUSER

- **634-RD-0001-0201:** Silicon Labs Zigbee/Wi-Fi Gateway
- **634-RD-0085-0401:** Silicon Labs Zigbee Lighting Kit