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Research Document Matter

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Version Control

Version	Date	Who?	Changes
1.0	24-03-2022	Sara + Mart	Wrote the project proposal
		Sara	Started writing the research on Thread
2.0	28-03-2022	Sara	Writing the research Thread and the comparison with other networks.
		Mart	Dot-Framework + research
3.0	04-04-2022	Sara	Research FTD and MTD
4.0	06-04-2022	Mart	Research MTD and other Types and start documenting POC thread network
4.1	06-04-2022	Sara	Further with the documenting the research on FTD. And start researching WIFI. Also did a spelling correction.
5.0	25-04-2022	Sara & Mart	
6.0	28-04-2022	Sara	Made changes to the research.
7.0	2-6-2022	Sara	Made the long-range project proposal clearer and started on documenting the process of the second fase of the project.
8.0	9-6-2022	Sara	Information on what we have discovered and accomplished today.
9.0	13-06-2022	Sara	Added what we accomplished today with pictures.
10.0	15-06-2022	Sara & Mart	Finishing document

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  How does matter communicate with IoT devices? .... **Fout! Bladwijzer niet gedefinieerd.**

    Library .... **Fout! Bladwijzer niet gedefinieerd.**

    Workshop .... **Fout! Bladwijzer niet gedefinieerd.**

  How does matter communicate with the cloud? .... **Fout! Bladwijzer niet gedefinieerd.**

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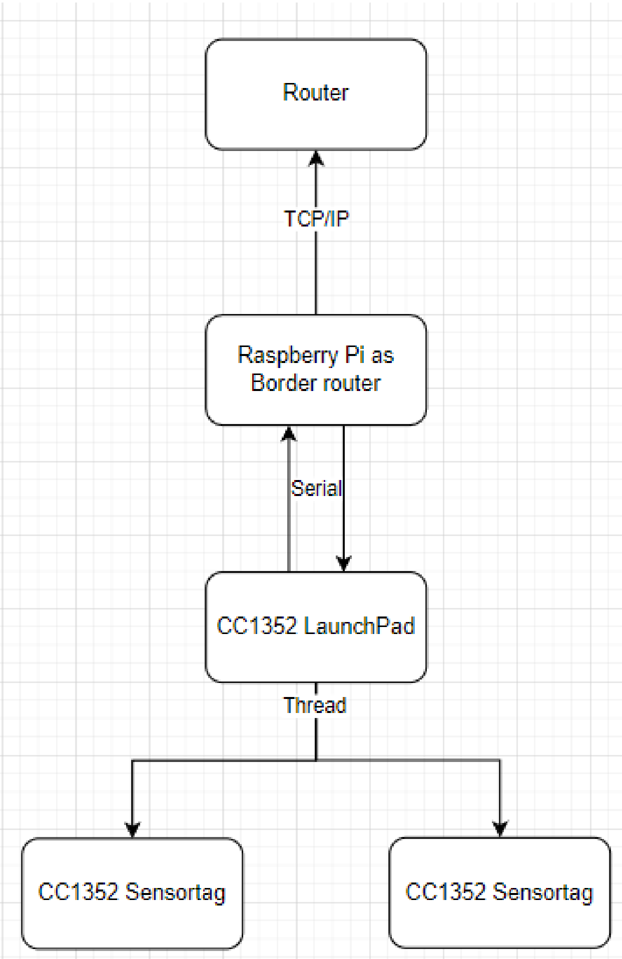
Introduction

Matter is a standard created in 2019 by Google, Apple, Samsung and Amazon. Matter started as Project CHIP (Project Connected Home over IP). The goal of matter is to simplify development and increase compatibility for consumers. The goal of this document is to give a clear view of what matter is, how it communicates with devices, also the goal is to see how Thread works and what it does.. (Wikipedia contributors, 2022) (csa, sd).

Project proposal

Short distance

For our IoT project we want to research the Thread protocol and make a POC with it. We want to create a Thread network with at least 2 nodes using OpenThread. For this we are going to use the Texas Instruments SensorTag kit with SimpleLink Wireless MCU and a RaspberryPi for the border router.



Long distance

For the long distance project, we want to go further with Thread. We want to create our own Thread device so we can read the sensor data from the Sensortags. This means we are going to write code to read the sensor data and then send this sensor data with Tread to the border router. When we have the devices working, we want to collect the data and put it in the cloud. So, the border router will send the received data to the cloud.

The plan is to start with seeing if we can press one of the buttons and then put the light on. Then we are going to send an event over Thread and put the light on. After that we are going to try to read the sensor data and send this over thread. And if we have time left, we are going to see if we can use the Matter application and connect the devices to the cloud.

Dot-Framework

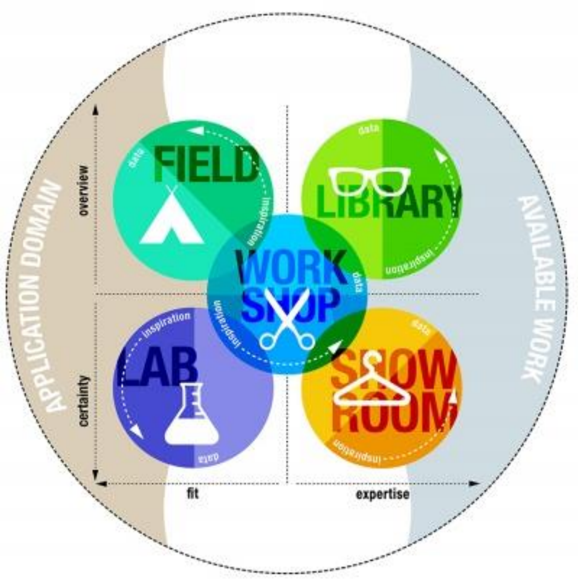


Figure 1 Dot-Framework

Library

With the Library strategy you're looking at research that is already been done. You can do this for example by interviewing an expert or do literature research. With the information you found your gone look how you can improve your idea.

Field

With the Field strategy your researching the end-users. By using the field strategy you learning the needs of the targeted audience. You can work out this strategy by observing and interviewing the users.

Lab

You can use the Lab strategy when you need to test you solution or part of your solution. With Testing you can check if you solution gives the desired outcomes. You also use the Lab strategy when you need to test in different environments. You can work out this strategy by system tests, security tests and user tests.

Showroom

With the showroom strategy you're going to compare your solution with the competition. You can work out the showroom strategy by showing your product to experts and using benchmarks. You can also make a pitch in which you show all the unique points of your product.

Workshop

You use the workshop strategy to get a clear picture of what the possibilities are and how you can improve your product. You can work out this strategy by brainstorming and making prototypes and compare them with each other..

Research question

How to create a Thread POC ?

1.1 Requirements

- Multiple devices
- Communication with cloud
- Devices with different kind of sensors
- Input and output devices.

2 Sub questions

2.1 What is matter?

Library

In 2019 Google, Amazon, Samsung SMART Things, Apple and the Zigbee Alliance announced matter under the name Project CHIP (Connected Home over IP). The goal of matter is to be secure, reliable and seamless to use across smarthome devices, mobile apps and cloud services. Matter is build upon the Internet Protocol (IP). (csa, sd) (Wikipedia contributors, 2022) (matter-smarthome.de, 2022)

Matter is created because a lot of IoT devices have their own bridge. This means that when you have different brands of devices you have multiple IoT networks at home. The goal of matter is connecting the different IoT brands together in one network.

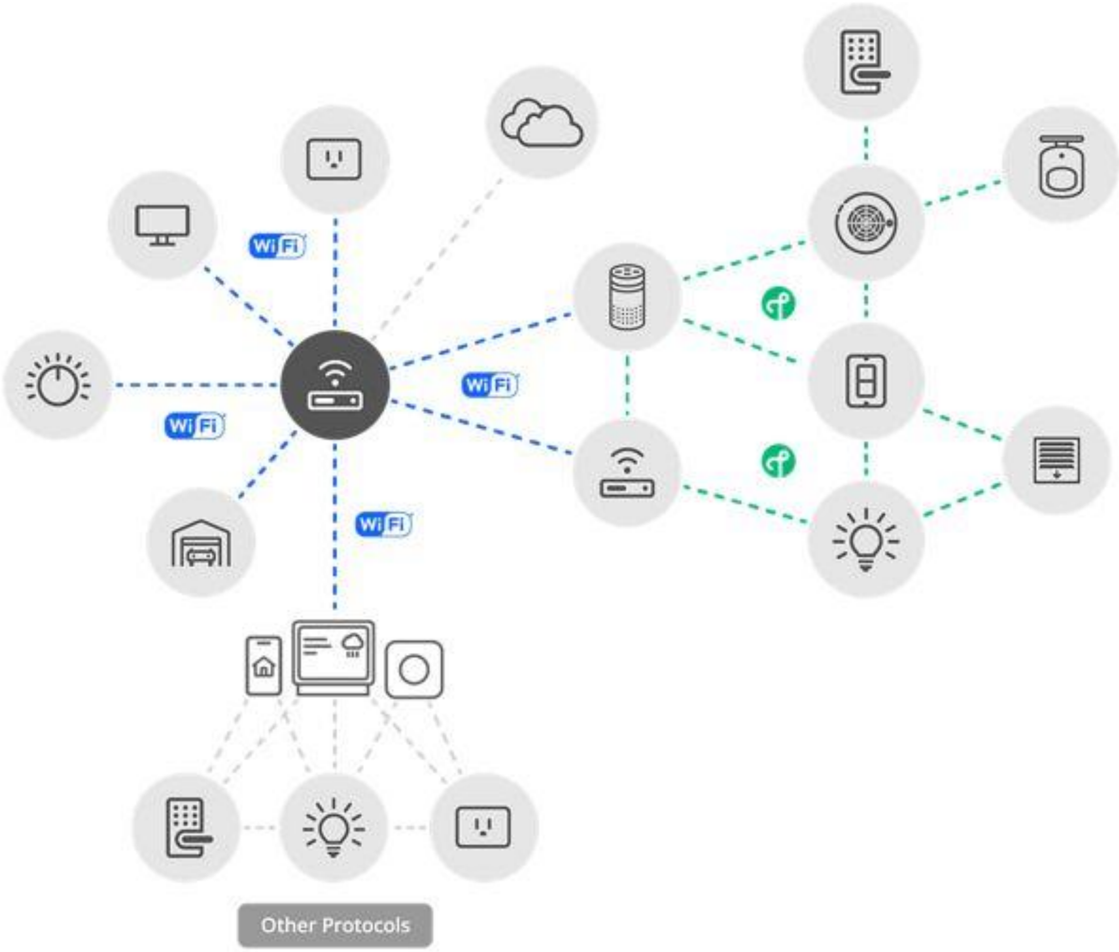


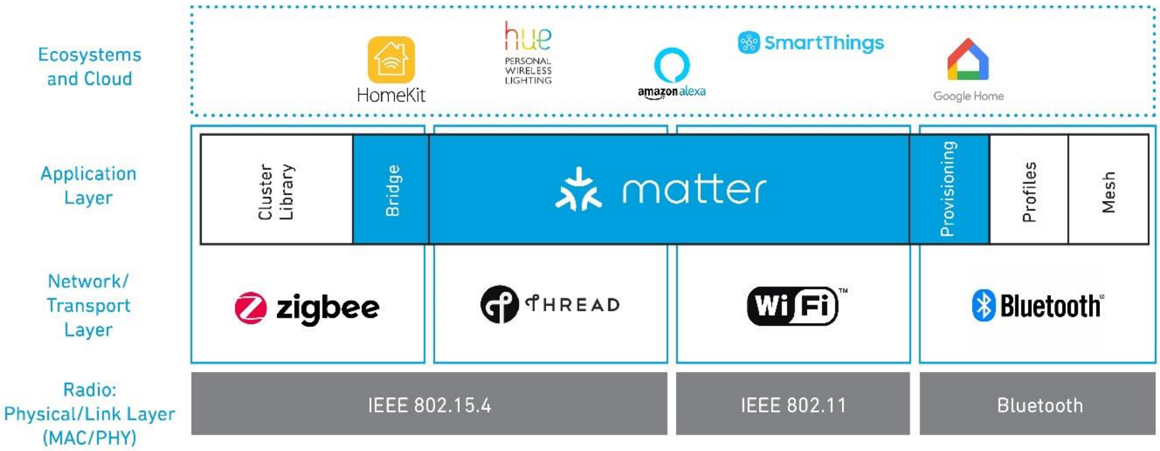
Figure 2 Matter system overview

(silicon labs, sd)

2.2 Which protocols can communicate with matter?

Library

Matter can communicate with a few different protocols. In the next section we are gone explain which protocols and how they work.



(StackPath, sd)

2.2.1.1 Thread

2.2.1.1.1 What is thread?

Thread is based on the 802.15.4 protocol, which is the same protocol as ZigBee uses. Like ZigBee thread is a self-healing mesh network. But unlike ZigBee, Thread devices are IPv6 addressable. This means they can talk to the internet and to each other via native IP protocol and it is a 6LoWPAN technology. What this means is that all Thread devices can talk to each other regardless of who makes them. Thread is a low power protocol, and it can connect up to 250 devices in its network according to the Thread Group. A Thread network needs at least one "border router". This is the connection/bridge between the IP data from the Tread devices and the internet.

Role	Limit
Leader	1
Router	32
End Device	511 per Router

Figure 3 Limits Thread network

Normally a Thread network exist out of one partition but when a group of devices can't communicate with another group the network creates a new partition. Both partition have it's own Leader, Router ID assignments, and network data. When both partition can communicate with each other the partition will be merged. (Thread Group, 2020) (OpenThread, sd)

2.2.1.1.2 Full Thread Device (FTD)

There are different options for the full Thread devices. One is Routing FTD and the other one is Non-routing FTD. When looked at the Routing FTD devices there are two sorts. The router and the leader. The router is a device that provides routing services to the network. A leader is an additional role of the router in a network, which takes certain decisions in the network. For example, allowing Router-Eligible End Devices to upgrade to routers. If the leader of a network fails another router will be dynamically selected to resume the leader role. (Thread Group, 2020) (OpenThread, sd)

When we are looking at the non-routing devices, we also have two types, Router-Eligible End Device (REED) and Full End Device (FED). REEDs have, as mentioned before, the capability to become router but are not acting like routers due to network topology or conditions. FEDs are the end devices and are like REEDs, but they are not capable to be a router. (Thread Group, 2020)

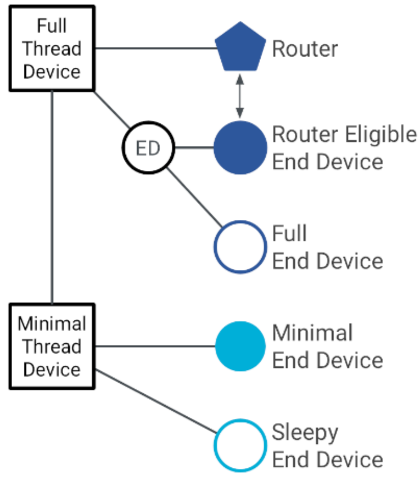


Figure 4 Thread Device Types

2.2.1.1.3 Minimal Thread Device (MTD)

A minimal Thread device connects to one router it can only operate as End Device. There are two types of MTD a Minimal End Device (MED) and a Sleepy End Device (SED). A MED is a transceiver that is always on that means that it doesn't need to poll for new messages. A SED is normally disabled and wake up from time to time to poll for new messages. (Thread Group, 2020) (OpenThread, sd)

2.2.1.1.4 Thread Leader

A Leader is responsible for managing the routers in a Thread network. The leader is dynamically selected when the leader fails another router becomes leader. (Thread Group, 2020) (OpenThread, sd)

2.2.1.1.5 Border Router

A Border Router provides connectivity from the Thread Network to other Networks on the physical layer for example Wi-Fi or Ethernet. There can be multiple Border Routers in one network. Any FTD can provide Border Router services. (Thread Group, 2020) (OpenThread, sd)

2.2.1.1.6 The benefits in your smart home

I already mentioned some major advantages. One of it is that it is a low power protocol, and it means that it doesn't use a lot of battery power. Another one is that it is a self-healing mesh network, which means that all the nodes in the network know each other. Outside that it can connect a lot of devices in its network. But the biggest advantage is that the latency is very low if you compared it to devices with Bluetooth, Zigbee, or Z-Wave, which are the main protocols in smart homes at this time.

//SiLabs has good tables about latency. I will look into that later.

2.2.1.2 Wi-Fi

Wi-Fi is something we all use every day, and all know, but not many people know how it exactly works and that there are different protocols that are called Wi-Fi. With every iteration being better that the one before on point as capability and speed. The most recent version of the 802.11 is 802.11ax, also known as Wi-Fi 6. It accommodates a growing number of devices and applications by increasing network efficiency to meet mobile and IoT devices. 802.11ax delivers greater efficiency and security than previous versions of the protocol. Its theoretical maximum transfer speed is about 10 Gbps—30 percent faster than Wi-Fi 5 (Wireless Networking Protocols Explained, 2021).

How does Wi-Fi work? Now it uses radio frequencies to communicate between devices. There are two frequency bands, 2.4GHz and 5 GHz. The 2.4Ghz band provides more coverage but with slower speeds, while the 5GHz has a faster speed to send data but less coverage. Every band has multiple channels within so our devices can send and receive data, the purpose of these channels is to decrease the changes of interference. (What is WiFi and How Does It Work?)

2.2.1.3 Zigbee

Zigbee is a wireless technology standard that was designed specifically for short-range wireless communications. It is an open-source standard that was developed by a company known as Zigbee Alliance formed back in 2002 and now known as the Connectivity Standards Alliance. There are three different network topologies, Star topology, mesh topology and tree topology. (Colwill, How Does Zigbee Work? Everything You Need to Know, 2021)

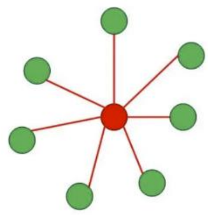


Figure 5 Star topology Zigbee network

The star topology is the simplest and the lowest in cost because this topology does not use any routers. The biggest problem is that when the coordinator fails the whole networks breaks down and the end devices will not do their work anymore because there is no one to give instructions. Another thing is that you are limited to the range of the coordinator for the network.

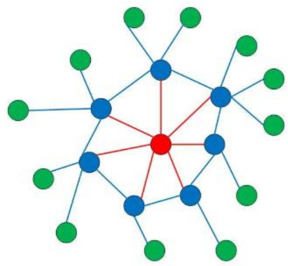


Figure 6 Mesh topology Zigbee network

In a mesh topology every node is connected with a neighbouring node, except for the end devices they are only connect to their parent/ router. The coordinator connects to nearby routers who then connect to the other routers closest to them. This is the topology that is well suited for smart homes as they will usually have a lot more devices than the star topology can handle. In this topology we have a self-healing process, which means that when one node fails the network will re-route the message.

Last, we have the tree topology. This is a topology very similar to the one from mesh. The only thing is that the routers in this network are not connected were as they were connected in the mesh network.

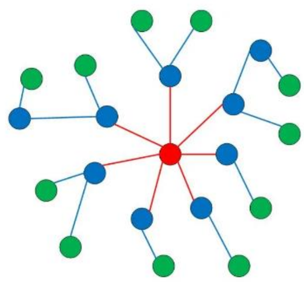


Figure 7 tree topology Zigbee network

Bluetooth

Bluetooth is a protocol that works at a 2.4GHz frequency. It allows wireless short-range communication between devices. As long as two devices are in the range of 50 metres or in mobile devices between a range of 10 to 100 metres. Understanding how the Bluetooth network works or more commonly known as Piconets. Piconets uses a point-to-point and point-to-link system. Point to point is master to slave and point-to-link system is more like a network all the slaves connect to the master. The master in this network can contain up to 7 devices/slaves. A Bluetooth network can contain up to 8 devices.

Comparison

The numbers you see in the next table are mostly theoretical. This means that most of the times it will not get to that number of nodes in the network.

		Z-wave	Zigbee	Thread	Wi-Fi 6	Bluetooth
Speed range	Min Average max	10 Kbps 40 Kbps 100 Kbps	20 Kbps 250 Kbps 250 Kbps	20 Kbps 250 Kbps 250 Kbps	… 1000 Mbps 9600 Mbps	125 Kbps 2 Mbps 3 Mbps
Distance		100 ft	40 ft	100 ft	5 GHz 50 ft 2.4 GHz 150 ft	350 ft
Size	Size Hops Total Mesh	232 4 232 x hubs Repeaters	65 000 10 65 000 Repeaters	511 23 (at least) 11 753 border router	255 (most) ? ? Access points	32 767 ? 32 767 Mesh nodes

When the thread leader fails a border router takes over the leader part unless there are no other border routes available. When this happens with Zigbee the network fails.

Workshop

POC Create Thread Network

In this POC we created a thread network. First, we researched how we can make a border router because this is the main device, we need to create a network. After some research we found the site openthread.io. OpenThread is an opensource way to create a thread network made by google. On this side we found the documentation we needed to create a border router. We created the border router with a raspberry pi 3B and the NRF52840. When the border router was created we created thread devices. We did this with the texas instruments 1352R1 sensortag and launchpad. When the device were ready we connected them to the border router. (OpenThread, sd). For this POC we used the mtd cli and ftd cli examples from texas instruments. To send

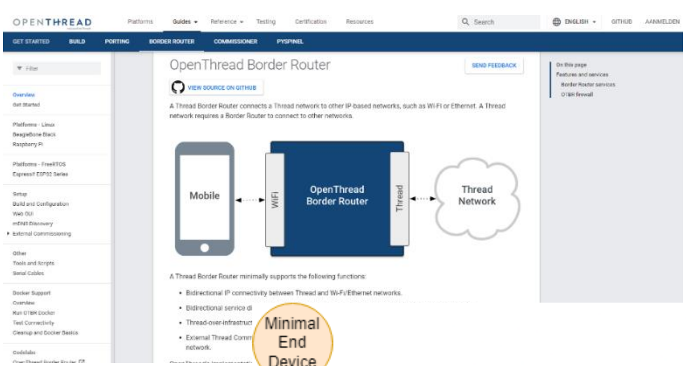


Figure 6 Screen-shot ope

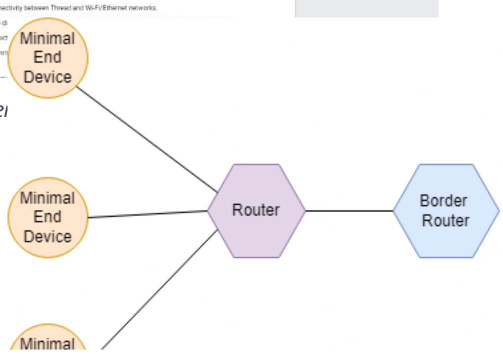


Figure 7 POC Design

messages from on device to another we connected a serial cable to the tx and rx pins and started sending message via the console.

Problems

While making this POC we encounter some problems. First problem we had was that we tried making the border router with the Texas instruments 1352R1 launchpad. According to some documentation it must be possible, but we couldn’t find what was wrong and the official documentation from Texas instruments uses the Beagle Bone Black not the Raspberry Pi. We fixed it by using the NRF52840 about this bord was a lot more documentation on the openthread site, so it was a lot easier.

The Second problem was that we needed to get access to the multiple Texas instruments SDK’s so we could create the thread devices. We fixed it by requesting the access to Texas instruments but did took quite some time. (SIMPLELINK-CC13XX-CC26XX-SDK, sd)

The Third problem was that we couldn’t flash the 1352R1 Sensortag with OAD (Over the Air Download) anymore. We uploaded a thread program with OAD that meant that the Bluetooth was disable so we couldn’t connect to it anymore. We fixed it by connecting the Sensortag with the launchpad and first erase the memory with uniflash, then upload the BIM off-chip (Hackster.io, 2021) project for the Texas instruments SDK and then upload the BLE 5 stack multi sensor project also from the SDK.

Conclusion

After we made this POC we had a thread mesh network which can send messages to each node in the network. The POC is not yet perfect because we need to send the message via the console because the temperature and door lock example didn’t work. For a next POC we want to create our own example so that sensor data from the nodes is send.

POC thread network with own code

We started the POC by seeing if we could turn the light on with the press of a button. When we got that working, we started researching how we could send this over thread. We did that by looking at the example code we already had.

We found out that we needed a CoAP server. We use it to send messages between two nodes of the thread network. When we got it working, we were finally able to send message from the terminal to the self-programmed node.

We wanted this to happen though the router instead of via a cable. We did this by adding the node to the network and after that finding the ip-address of the node. When we got the ip address, we were able to send a message to the node with the following command for the doorlock: ***coap get <<IP-address>> doorlock/lockstate***. When we send this command, we get a hex number back. With a hex ascii converter we found out that the door was unlocked.

We can also enter a command to lock or unlock the door. We lock the door by entering the following command: ***coap post <<IP-address>> doorlock/lockstate con lock.*** We can unlock the door by entering the following message: ***coap post <<IP-address>> doorlock/lockstate con unlock.***

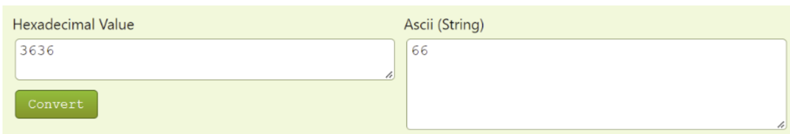
```
Device Info: [EUI64] 0x00124b001cbc4592  [PSKD] DRRLCK1
   Nwk Info: [Network Name] OpenThread  [ExtPanID] 0xdead00beef00cafe
   Nwk Info: [Masterkey] 0x00112233445566778899aabbccddeeff
   Nwk Info: [PAN ID] 0xffff  [Channel] 14  [Short Addr] 0xfffe
  Role Info: [Device Role] Disabled
  Conn Info: [Status] Disabled
   APP Info: [Doorlock State] unlock
```

```
Device Info: [EUI64] 0x00124b001cbc334a  [PSKD] TMPSENS1
   Nwk Info: [Network Name] OpenThread  [ExtPanID] 0xdead00beef00cafe
   Nwk Info: [Masterkey] 0x00112233445566778899aabbccddeeff
   Nwk Info: [PAN ID] 0xffff  [Channel] 14  [Short Addr] 0xfffe
  Role Info: [Device Role] Disabled
  Conn Info: [Status] Disabled
   APP Info: [Temperature] 70 [Poll Period] 2000
```

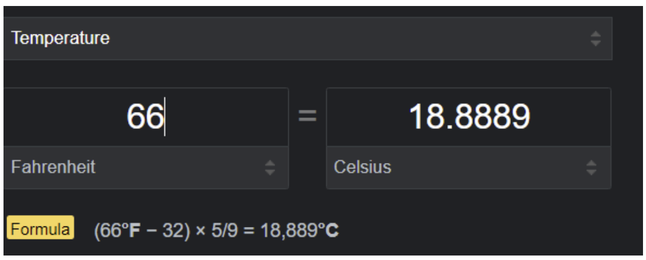
For the temperature: ***coap get <<IP address>> tempsensor/temperature***. When we send this command, we get the temperature back in hex numbers.

```
> coap get ff33:40:fdde:ad00:beef:0:0:1 tempsensor/temperature
Done
> coap response from fdde:ad00:beef:0:f85b:34c:9801:f23c with payload: 3636
```

With a hex to ascii converter we can get the temperature in Fahrenheit back.



With a converter from Fahrenheit to Celsius we see that it is 18 °C.



Problems

We had some problems with understanding the example thread code. There was no proper documentation about the libraries that were used, also we couldn’t find how to send message from a device.

We had a problem with connecting the border router. We don’t know what happened, but the border router wasn’t working anymore. We decided to flash the border router again. But that didn’t work so we decided to flash the SD card of the raspberry pi again. We kept getting problem with connecting to the Wi-Fi, but we did not know what was causing it. We tried flashing it again with a different program and it worked again after chancing some settings.

We had also some troubles with sending the messages between two thread devices. We found out that we needed a CoAP server. For using the CoAP server we needed the ip adress from the nodes. To get these ip addresses we pinged the node via the thread router.

3 Conclusion

Thread is a really interesting protocol, but there is not a lot of documentation. When you have problems you to do a lot of research before you find the solution. Because of the lack of documentation making a thread POC wasn't that easy. It takes a lot of time to find the right sites but when you find them making a thread network is not that hard. We think that thread is a protocol with a lot of potential. It has for example better self-healing qualities then zigbee, It has zero points of failure when you use multiple border routers and you can easily add new devices to your network. Overall thread is a really nice protocol, and we think it will be used a lot in the future.

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