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DTU

Protocols and standards in IoT

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Contents

1 Introduction

1.1 Abstract

Forecasts say that in 2020 there will be 25 Billion devices connected to the internet. In 2014 it was estimated to be 3.7 Billion devices[1]. This put a big demand on common tehnologies such as wifi, http, relational databases, etc. This project investigate how to deal with these challenges by building a prototype of a system that meets these challenges. The system consist of multiple devices which connect in a local network and are made availerble via the internet. This is a fully realistic example of how to deal with the futura of IoT. The application consist of some battery powered devices that communicate wireless via the ZigBee protocol, a ZigBee/internet gateway and an application server where the backend, a database and a webportal is implemented. This report will focus on the devices, ZigBee protocol, gateway and communication between the gateway and application server. The report will losely touch the design of the application server.

1.2 Overview of this report

In section 1.3 is the bacground for the system described. Section 2 will give a Theoretical background on some of the technologies which will be used to implement the system. Section 3 will give a technical description on the implementation of the system and section 4 contains the conclution. I is sugested to read

1.3 Background

Internet of Things is the term that describes networks of physical devices that are connected to the internet. This can be anything like sensors, whearabels,

fridges, heating systems, lightballs and what ever you else could imagine. As mentioned there is a high growth in the number of these devices. This project is about solving a common problem in lesure harbours. In leisure, harbors there are a limited number of moorings. Therefor each boat owner has his own mooring space. At each mooring space there are a sign which can be set to red or green. When the owner leave the harbor he should set the sign to green indicating that the mooring is free to use for guests. If he is away for less than a day he can set it to red indicating that the mooring is not free to use. When the owner returns home after some days he call the harbor master who then flip the sign to red indicating that the mooring is no longer free. A common problem is that the boat owners often don't set the signs to green when they leave the harbor. The reason is it is easier to let it stay red instead of calling the harbor master when returning home. This often result in many unused moorings has red signs and make it difficult for guests to find free moorings. Another problem is the time the harbor master use on flipping the signs for people returning home to their berth. To solve these problems a system of electronically controlled signs is suggested. For more details about the sugested system refer to section 3.1

1.4 Abbreviations

ACK	Acknowledgement
AIS	Automatic Identification System
APL	Aplication Layer,
	Application Support Layer
	Clear Channel Assement
	Carrier Sense Multiple Access with Collition Avoidance
	Garantied Time Slot
	Internet of Things
	Link Quality Indicator
	Medium Access Layer
	Network Layer Management Entety Service Access Point
	Network Layer,
	Open System Interconnection Reference Model
	Personal Area Network
	Physical Layer
	Physical Layer Management Entity Service Access Point
	Service Access Point
	ZigBee Device Object

2 Theroretical background

2.1 Wireless networks

Their exist many different wireless communication standards today all serving different purpose. There is the IEEE 802.11 specifications which define different protocols used for implementing WLAN which we mostly use for connecting our computers and smartphone to the internet. Then there are the mobile networks such as GSM, EDGE, UMTS, HSPA, etc. Which are used by phones to send voice or internet data. Some less know technollogies include AIS which is used to transfer data between commercial ships over VHF and satelite. They all have different purpose and theirfore also different demands. Eg. When handling voice calls over the mobile network the latency should not be to high and the protocol should suport the devices in using as litle power as posible. Here follow a list of important factors to consider when choosing a wireless tecnology.

- Bandwide
- Latency
- Power consumtion
- Maximum number of nodes in the network
- Range
- Reliability
- Cost
- interoparebility

For the purpose of this project we will later see that the ZigBee Standard is a good solution for communicating with the signs in the harbour.

2.2 ZigBee

2.2.1 Overview

ZigBee is a standard used to connect devices. It is managed by the ZigBee allianze which count mebers such as Texas Instruments, Philips, Silicon Labs, NXP, Samsung and many more. ZigBee aims at being relierble, secure, lowpower and easy for the consumer to use. ZigBee specify all the layers in

the OSI-model. There exist different version of the ZigBee protocol. But this project is bassed on the ZigBee Pro standard. In the rest of the report refering to the ZigBee standard it should be asumed it is the Pro version.

2.2.2 Layers

2.2.2.1 ZigBee layers ZigBee is build on top of the 802.15.4 standard which define the PHY and MAC layer. Therefore these layers are not defined by but implemented by ZigBee. On top of 802.15.4 ZigBee define the layers all the way up to and including the APL. The layers communicate via Service Access Points (SAP). An overview of the ZigBee model and the SAP that makes the services availerble between them are shown in figure from the ZigBee Alliance in fig. 1. below.

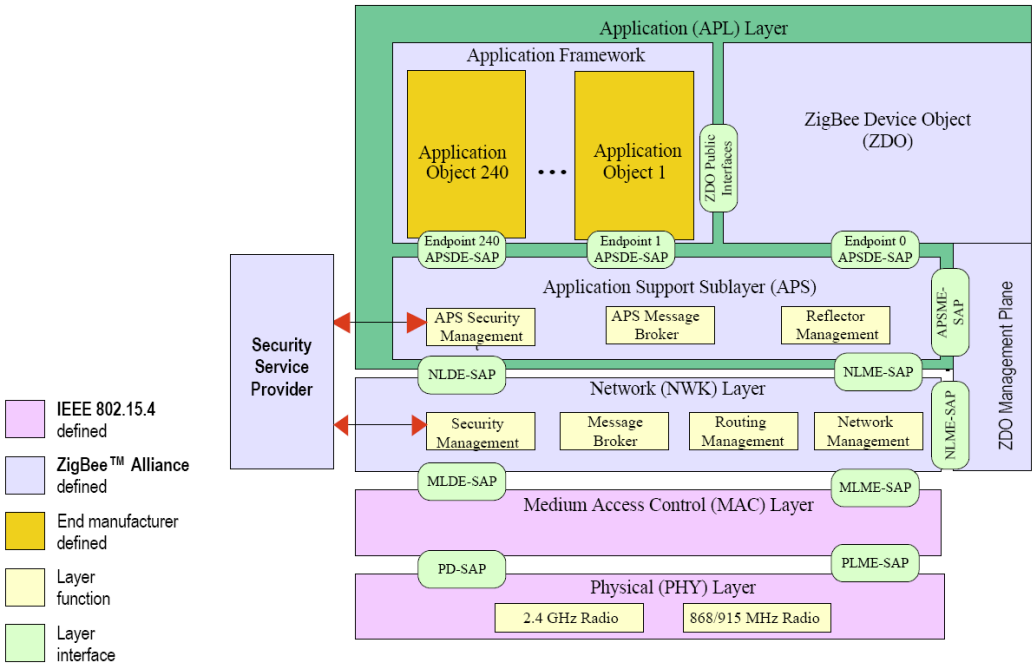

Figure 1: ZigBee Model[2]

2.2.2.2 802.15.4 The 802.15.4 standard specify the 2 lowest layers PHY and MAC. 802.15.4 specify three types of roles. These roles are named a litle different in ZigBee. See fig 2 for a list of the roles in 802.15.4 and their corsponding ZigBee names. In this section (2.2.2.2) we will use the 802.15.4 names

802.15.4 role	ZigBee role
PAN coordinator	Coordinator
Coordinator	Router
Device	End Device

Figure 2: 802.15.4 and ZigBee device roles

There can only be one PAN coordinator in a network. The 802.15.4 Implement star networking where the Devices can be connected to exactly one coordinator and the coordinators can be connected to other coordinators and multiple devices. see fig 3 ——————————————————

Physical (PHY) The PHY is responsible for the physical part of the network. This is harware specific things like frequency, modulation, how to avoid coalition with other devices, receiver sensitivity, output power and other hardware specific parametters. The PHY provide service to the MAC layer via the PLME-SAP .The PHY is also responsible for the following tasks

- Selecting the frequncy
- Turning on or off the transiver
- Perform Energy Detection. This can be used by the coordinator to find the channel with is least bussy to use for the network.
- Generate Link Quality Indication (LQI)
- Performing clear channel assesment (CCA) which is used to detect if there is other transmision happening.

Medium Access Layer (MAC) The mac layer provide service to the NWK layer via the MLME-SAP . The MAC layer has the following responsibilities:

- Generate the becons if the network is becon enabeled.
- Syncronisation of the devises with the becon messages
- Implement CSMA-CA
- Keep control of when the device has its GTS
- Perform relierble transfers between to notes

- Support security if enabeled

To avoid coaltion with other devises ZigBee can use two different mekanismes. The first methode completly relly on a tecnics called CArrier Sense Multiple Access with Collition Avoidance (CSMA-CA) which basicaly means that the device listen for a carrier before transmiting. If a carrier is sensed the device back of for a set time and then try again. In the other method the coordinator assigns a garantied time slot (GTS)to a device. If the device has been assigned a GTS it will transmite doing that time slot. All the time slots that are being assigned are happening doing the Supper Frame. The supper frame is simply a time period where the time slots are assigned. Before/after the supper fram the devices that has not been assigned a GTS can transmit using the CSMA-CA. For this method to work all the devices requires to have the clock syncronised. Therefore this method require that the devices wake up oftent to syncronise the clocks by listening to becons send from the coordinator. This methode is therefore not used so often when there is a high demand for low power consumtion.

Transfers from a device to a coordinator is simple. The device simply sent the data either doing its garantied GTS or with CSMA-CA. The device can specify if it want an Acknowledgement (ACK) from the coordinator but that is optional.

When a coordinator has data for a device it can not just send it imidiatly as the device might be a sleep. So the coordinator keeps the data until the device ask for it. What happens is the following.

- The device Periodicaly or every time it wakes up sends a data request to the coordinator.
- When the coordinator recives the data request it sends an ACK with indication that there is pending data.
- Right after the ACK has been send the coordinator start sending the data.
- The device first receives an ACK with data indication and then know it should expect incomming data. So it waits for the data and if indicated by the coordinator the device sends an ACK.

First the device

If the device sends a data request and there is no pending data the coordinator will send back an ACK with a no data indication and the device can then go back to sleep.

2.2.2.3 Network Layer (NWK) The NVK is specified by ZigBee and therefore the ZigBee names will be used to specify the dive roles. refer to fig. 2. The NVK layer is the heart of the of the ZigBee protocol. It is in this layer the core features which makes ZigBee speciel is implemented. The NWK layer are responsible for the following

- Seting up a device as Coordinator, Router, or End device
- Forming the network and implement tree or mesh topology
- Association and assigning adresses
- Route discovery and maintanense
- Routing messages

Network topology The topology of a ZigBee network can be either tree or mesh. In tree topology there is a hierarchi between the devices. A device can only communicate with its parrents and childs. In contrast to the tree topology is the mesh topology. In a mesh topology any device can contact other devices. eg. if the responsible router of and End device breaks down the device will then try to connect to another router if there is any within its range. Also if a route is broken the devices can then fix the route by goin other ways. This is what makes the ZigBee network self healling. There is some few different ways the ZigBee network can be set up which affect how routing is performed. It will be out of the scope of this report to go true all details. Here gives an overview of how it works using one of common settings.

Routing Coordinator and routers create and maintain routing tables. A routing table does not contain all information about a route, but only which direction (to which device) a router or coordinator should send the package. The endevice does not store any routing table. When an end device wants to send a message it sends it to the router it is connected. Lets asume that routes has been discovered and their by also the routing tables has been populated with the data. Then when a router or coordinator along a route receives a package. It look up the naighbor device to which it should send the package in its routing table. It then forward the package to that device. this happens until the device reach its destination. But before the this can happen the route discovery ofcourse need to take place.

Route discovery Only the coordinator and routers can perform route discovery. When discovering routes the cost of the path are calculated. The route whith has the lowest cost is choosen. When calculating the cost of a path the LQI number and number of hops is used. There are 3 types of route discovery.

- Unicast route discovery
- Multicast route discovery
- Many to one route discovery

Unicast route discovery is initiaded from the source device which sends a broadcast route discovery to the devices in range. When the request is received by a neighbor then this neighbor look in its routing table if it has the route for that device. If not it sends a new route discovery brodcast message. But before the packet is send a routing discovery table is populated with the path cost. In this way a route discovery message can travel true the network until it reach the destination. At the destination the cost of the route can be obtained from the route discovery table whis whas populated when the packet traveled along the route. The destination device will often receive more route discovery packages with different route discoveryu tables. The destination will then choose the route with the lowest cost and send a responce back to the source devices and the routing tables along the way will then be updated.

Multicast route discovery is in many ways similar but instead of the destination is one device it can be a group of devices.

The many to one route discovery also works in similar ways as the unicast route discovery but here the route discovery will discover routes to all devices in the network. This is usefull when there is a central point that need to receive messages from all the other devices.

It is posible for a device to specify the exact route when sending a message. In this way the routing tables in the are not used. But this is not being used in this projekt.

Route maintenence ZigBee is self healing. This means that if a route gets broken a route repair can be initiated. A route repair is not initiated first time a route fails as it is expencive to do route recovery. It can therefore be set hour many time a route should fail before a route repair is initiated. A route repair works similar to the route discovery. Except that the discovery is taking place from where the route is brokken.

Association When a device want to join a network the following interaction happens.

- The device send an association request to the coordinator.
- The coordinator reply with an ACK
- The Device sends a data request to the coordinator
- The Coordinator respond with an ACK followed by an association Response
- The Dvice answer with an ACK

If every thing went well the device in now associated.

Addressing A ZigBee device has a garantied unique 64bit addresses which is assigned from the manufactor. A zigBee network can use this address for addressing. But using 64bit addresses requires more data to be transmittet and more memory use than if fewer bits is used. Therefore a 16bit short address can be used instead. The short address can be assigned in two ways. The ways are Distributed and stochastic addressing. When using distributed addressing the coordinator assigns a pool of addresses to a router which then can divide this pool to the other routers connected to it which then againg can divide the assigned routes. This was also the way addressing was used in the earlier ZigBee versions. But in ZigBee Pro stochastic addressing was introduced. When using stochastic addressing the device choose a random address and if there is an address conflict the device then choose another random address.

2.2.2.4 Application layer

Application Framework

Application Support Layer (APS)

ZigBee Device Object (ZDO)

2.2.3 ZigBee versus other technologies

ZigBee is not a high speed network. The maximum speed that can be achived on the ZigBee PRO standard is 250kbit/s on 2.4Ghz, 40kbit/s on 915Mhz and 20kbit/s on868Mhz which are the 3 bands the ZigBee can use[3]. This is not much compared with the latest public wlan standard 802.11ac which manage a data rate of up to some feew Ghz depending on the configuration [4].other standard which is worth mention in comparsion with ZigBee is bluetooth low energy and Z-wave. A litle more on those tech

2.3 Database system

2.3.1 The traditional SQL database

2.3.2 NoSQL databse

2.3.3 NoSQL versus SQL

3 Design of the harbour system

3.1 Requirements

The functional requerments of the system requirements is as follow

- The signs should automatically turn green when a boat leaves the mooring
- The signs should be operated from a remote plateform. E.g. a web platform
- The signs should be wireless controlled and battery powered as it is complicated and expencive to do cabling in the harbors.
- Each sign should be able to hold power for minimum of 7 years.

There are many possibilities for adding functionality to the system such as setting a predefined time when a sign should flip and let guest see which moorings is free and for how long. But these functionalities should be implemented on the server side and is therefore not considered important for this project as the focus is on the wireless communication between the signs, interconnection with the web platform/application server. The sensor which should sense if there is a boat at the mooring is simulated by a switch and the red green indication is simulated with an led. Again this is do to keeping the focus around the communication between devices and application server.

3.2 Acrhitecture

3.3 Harware

3.3.1 Texas Instruments CC2530 SoC

3.3.2 FlipDots

3.3.3 Raspbarry Pi

3.3.4 Aplication server

3.4 Implementaision

3.4.1 CC2530

3.4.1.1 Z-Stack

3.4.1.2 IAR

3.4.1.3 ZNP

3.4.2 Raspberry Pi

3.4.2.1 Linux

3.4.2.2 BCM2835 Driver

3.4.2.3 REST

3.4.2.4 Gateway implementation

3.4.3 Application Server

3.4.3.1 Amazon EC2

3.4.3.2 Nodejs

3.4.3.3 MongoDB

3.4.3.4 RESTfull API

3.4.3.5 Websocket

4 Conclusion

- unit_test_heap_initialize
  This tests returns **passed**.

5 References

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