PERFORMANCE AND ARCHITECTURE OF LORAWAN AS PART OF LPWAN TECHNOLOGY

Abstract

In this project I tried to introduce Low-power wide area network and discuss performance and architecture of LoRaWAN as one of its technology, also discuss one of the challenges in this protocol, using IPV6. Discuss set of solution which have been proposed in order to have IPV6 over LoRaWAN

Somayeh Roshandel
V00942553
Instructor: Dr. Lin Cai

Contents

Introduction

LPWAN

As soon as range of IOT network increased we faced complicated issues, like how to connect all these devices, which spectrum use to send data, how far we can cover. IOT is about bringing different things together by gathering information, process that information and then have intelligent system. And for this connection we faced a challenge to connect all of them in a systematic way along side security and energy and cost saving. Over the years different wireless technology have been developed for IOT like IEEE 802.15.4, and some of them are very low energy like ZigBee and Bluetooth and Wi-Fi which are good for within short rage to middle range and cellular for long range. Fig 1

Fig 1. Different wireless technologies use in IOT, comparison based on cost and range. [5]

But all these technologies have limitation from range of coverage to number of devices possible to connect to them, so new technology has been developed which consider both range and cost, Low power wireless access or LPWAN technology.

Another consideration in this technology is low power usage, which make it possible to use low energy sensors which does not have a lot of bandwidth. So as these devices transmit more, they consume more energy, but with low bandwidth battery can stay much longer. So, this is the advantage of LPWAN. data is low and battery last long time. This technology has two type of classes. One uses unlicensed spectrum, ISM, industrial scientific medical band like LoRaWAN and SigFox.

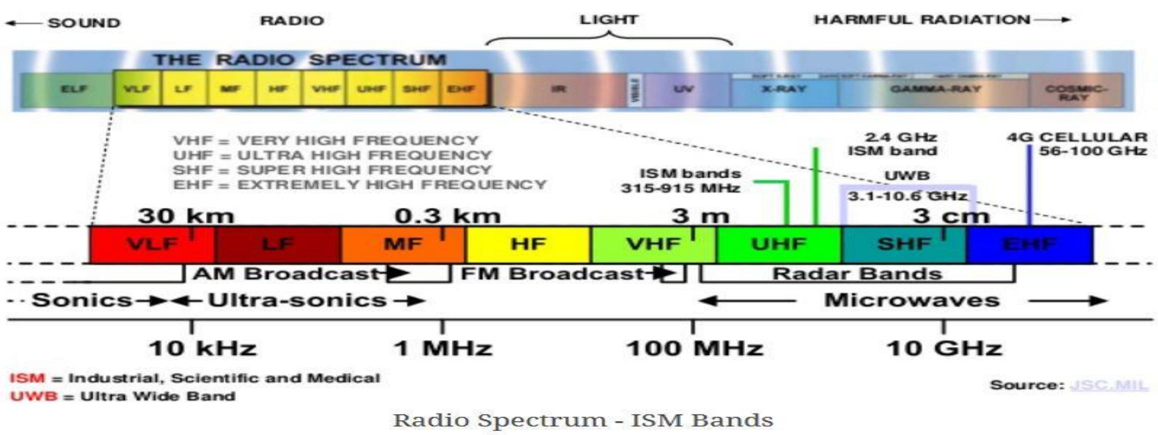

Fig 2. Radio Spectrum. ISM band [5]

Another uses license technologies like narrowband IOT.in this report LoRaWAN has been discussed.

LoRaWAN

LoRa stands for long-range, is a technology developed by Semtech. This company as inventor of LoRa chipset owns the modulation technology. LoRa protocol can support from 125KHz to 500KHz channels. LoRa is low power wireless technology which can transmit only bits or kilobits of data in the long range. With maximum data of 5.4Kbps and minimum 300bps.

LoRaWAN Architecture

Fig3 shows LoRaWAN architecture, in completed system we have end points which are IOT devices/sensors, these sensors transmit signal to gateway, when gateway receive this signal, they pass it through cellular network to LoRa network servers. These servers are transmission point in the architecture which are doing management and communication of end point devices. Since LoRa network servers can not do anything about application, we have application servers which is sitting at the end behind the network servers.

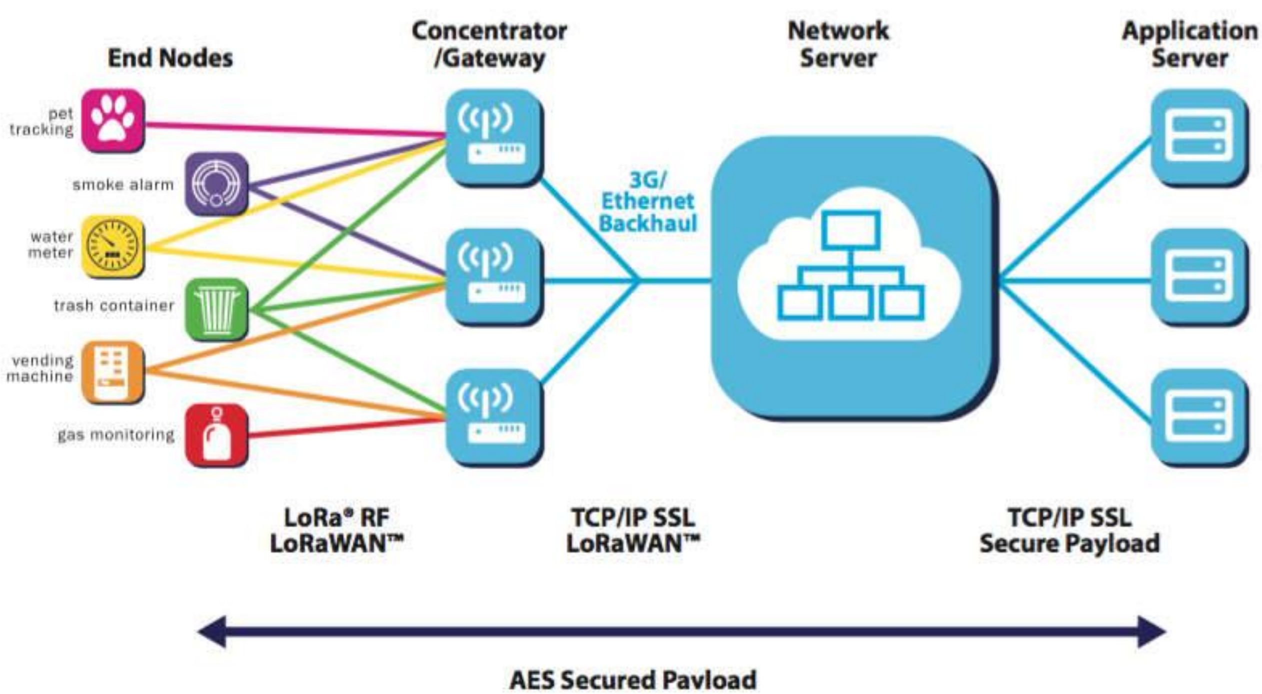

Fig 3 LoRaWAN Architecture [3]

LoRa Protocol Stack

LoRa protocol Stack is differ from other protocol stack.

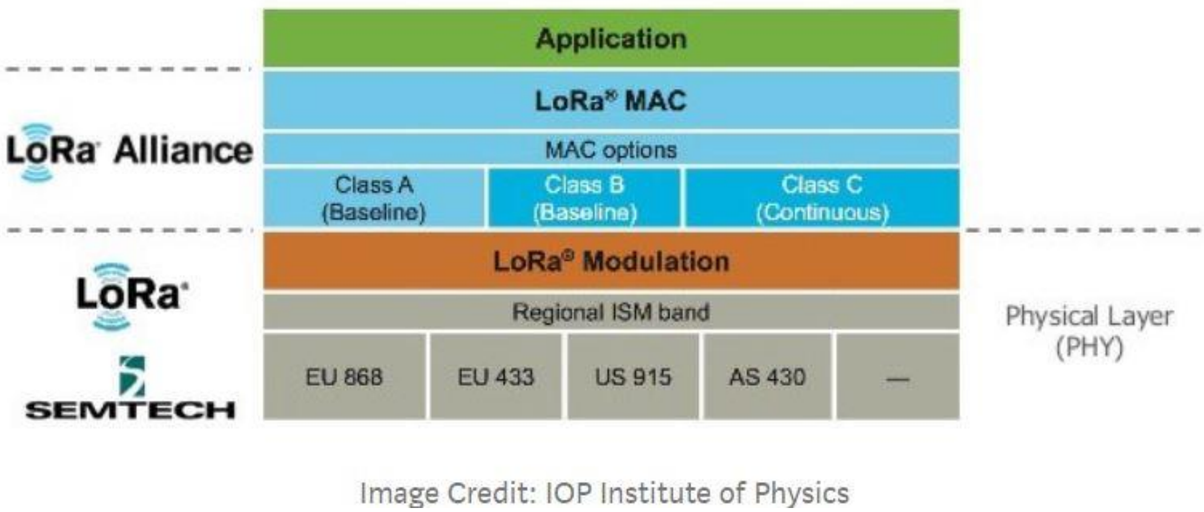

Fig 4. LoRaWAN protocol Stack[3][8]

In this stack as shown in Figure 4, on the bottom we have different regional which LoRa spectrum can use. After that its modulation. This chipset belongs to Semtech as inventor of LoRa and is physical layer. After that we see LoRa Alliance stack and everything above is controlled through alliance of different vendors. Fig 5.

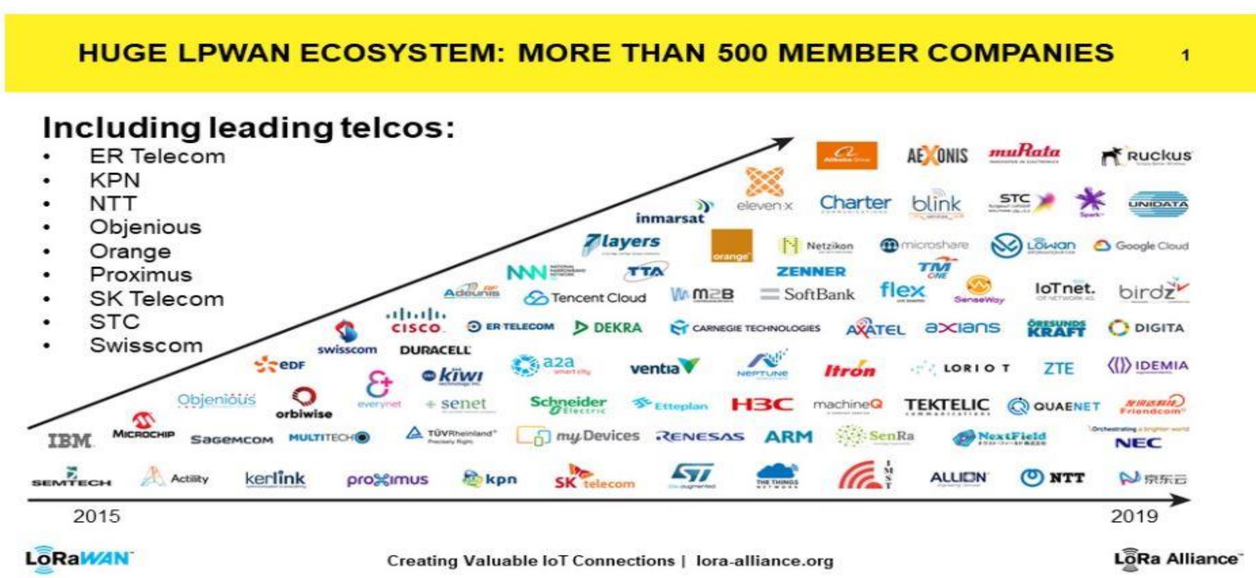

Fig 5. LoRa Alliance [7]

Physical Layer

LoRa modulation is based on spread spectrum means works by spreading signal across a wide band. Called chirp spread spectrum (CSS). this is a very old modulation, but advantage is it takes less power. In CSS based modulation by considering low-end frequency and high-end frequency band, chirping occurs from the low frequency to high and bits have been encoded into signal.

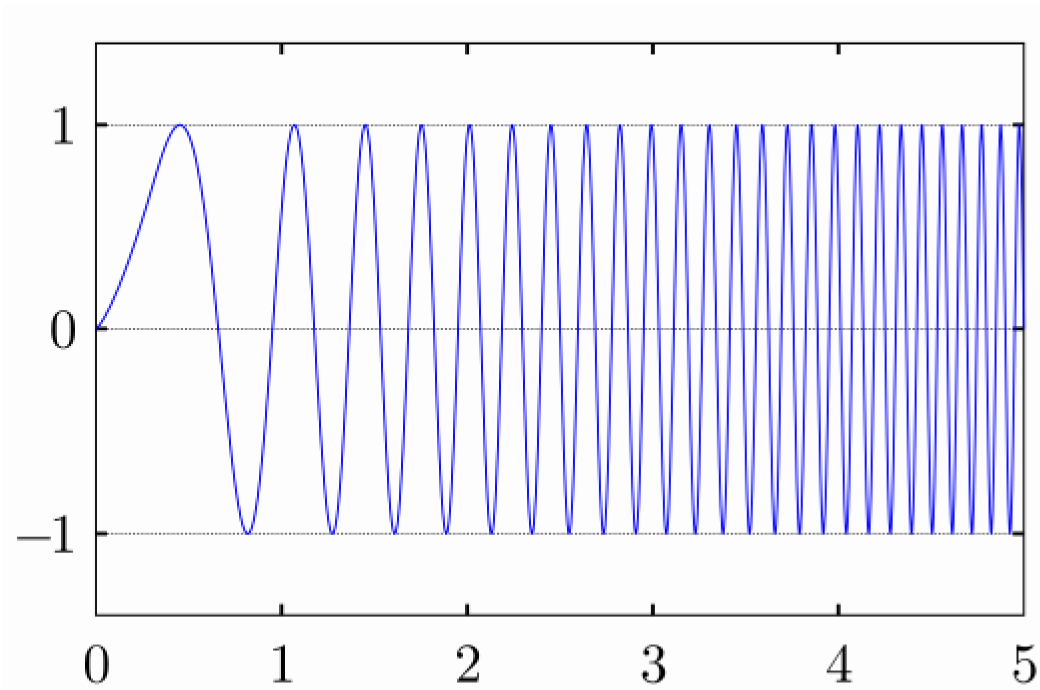

Fig 6. Chirp spread spectrum (CSS) [8]

In LoRa modulation for having spectral efficiency and increase network capacity six different data rates have been defined, spreading factor (SF) codes. SF make is possible to have multiple access on the same channel without degrading the performance.[2]

Based on this equation LoRa data rate is related to SF and the bandwidth.

$$R_b = SF \times \frac{BW}{2^{SF}} \times CR \qquad [8]$$

SF	LoRa BW (KHz)	Coding Rate	Data Rate (bps)	Sensitivity (dBm)
7	125	4/5	5,469	-125
8	125	4/5	3,125	-127.5
9	125	4/5	1,758	-130
10	125	4/5	977	-132.5
11	125	4/5	537	-135
12	125	4/5	293	-137.5
7	500	4/5	21,875	-119
8	500	4/5	12,500	-121.5
9	500	4/5	7,031	-124
10	500	4/5	3,906	-126.5
11	500	4/5	2,148	-129
12	500	4/5	1,172	-131.5

Fig 7. Data rate and sensitivity based on different SF and BW [5]

Above table shows that maximum and minimum data rates are for SF 7 and 12, but with SF12 we have sensitivity about -137.5 which enable system to cover long distance.

MAC Layer

MAC layer of LoRaWAN defined as ALOHA based on pseudo-random media access mechanism. So LoRa devices when they have data to transmit, they need to wait for random of time and then transmit. Because in LoRa we have thousands of sensors connected in long distance and they can not listen to each other and wait for their turn to send data. So, in LoRa performance must be base on all devices do not be activate at the same time and keep device as much as possible quite to avoid radio frequency interference and collision.

To do this another metric is defined as Time on Air (ToA) which define as the time takes for transmitter to put packet into wireless medium. And calculated as following equation. [1]

$$ToA\,(ms) = T_{preamble}\,(ms) + T_{payload}\,(ms)$$ [1]

And

$$T_{preamble}\,(ms) = (n_{preamble} + 4.25) \cdot T_s\,(ms)$$ [1]

$$T_{payload}\,(ms) = n_{payload} \cdot T_s\,(ms)$$ [1]

$$T_s\,(ms) = \frac{2^{SF}}{BW} \cdot 1000$$ [1]

Data Rate (Spreading Factor)	Sensitivity	Time On Air
SF7	-123.0 dBm	41 ms
SF8	-126.0 dBm	72 ms
SF9	-129.0 dBm	144 ms
SF10	-132.0 dBm	288 ms
SF11	-134.5 dBm	577 ms
SF12	-137.0 dBm	991 ms

Fig 8. Different ToA based on SF[5]

MAC layer defines three classes for received window slots for downlink communication, class A, B and C. [1]

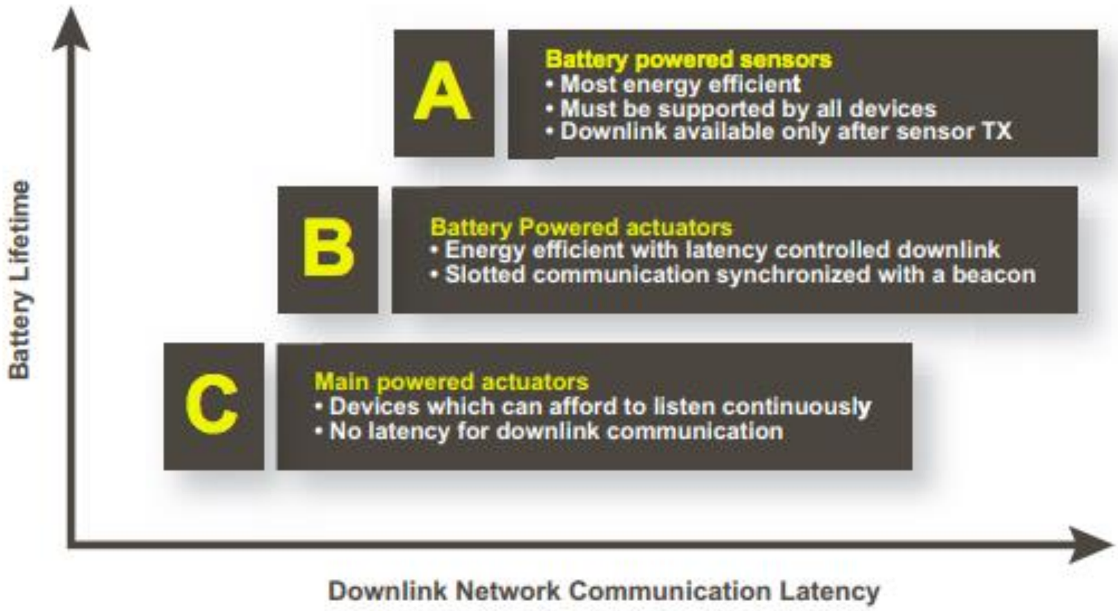

Fig 9. Different MAC layer device classes [5]

In table below we see differences between these three classes. Class A, two receive window are opened after each uplink transmission. In class B, there is extra window and make possible for gateway to periodically transmit beacon packet for time reference and class C which is on all the time. [1]

LoRa Class A	LoRa Class B	LoRa Class C
Battery Powered	Low Latency	No Latency
Bidirectional communications	Bidirectional with scheduled receive slots	Bidirectional communications
Unicast messages	Unicast and Multicast messages	Unicast and Multicast messages
Small payloads, long intervals	Small payloads, long intervals, Periodic beacon from gateway	Small payloads
End-device initiates communication (uplink)	Extra receive window (ping slot)	Server can initiate transmission at any time
Server communicates with end-device (downlink) during predetermined response windows	Server can initiate transmission at fixed intervals	End-device is constantly receiving

Fig 10. LoRa Class A, B, C [5]

IP and LoRaWAN

In LoRaWAN protocol stack as wee see from physical layer we went to application layer without having the usual network layer. Actually, based on small bandwidth technology which LoRa has, there is no enough space for IP header stack. since design in LoRaWAN is based on connecting thousand to millions of sensors in long range, if we want to have internet connectivity we need internet protocol and using IPV6 have advantage for IOT [1] but it is impossible to apply it directly to LPWAN technologies even with the use of fragmentation [1][2]. IPV6 header alone is 40bytes and its address is 128bits on both source and destination. so we would not transmit it across the network.

lots of study have been done to bring IPV6 to LoRaWAN, for using IP we need to use a method of compression on IPV6 header. Starting in summer 2017 IETF, LPWAN working group defined SCHC function as in fig 10 shown, SCHC do compression, fragmentation. So, from an application point of view, there is just IP Stack. [6]

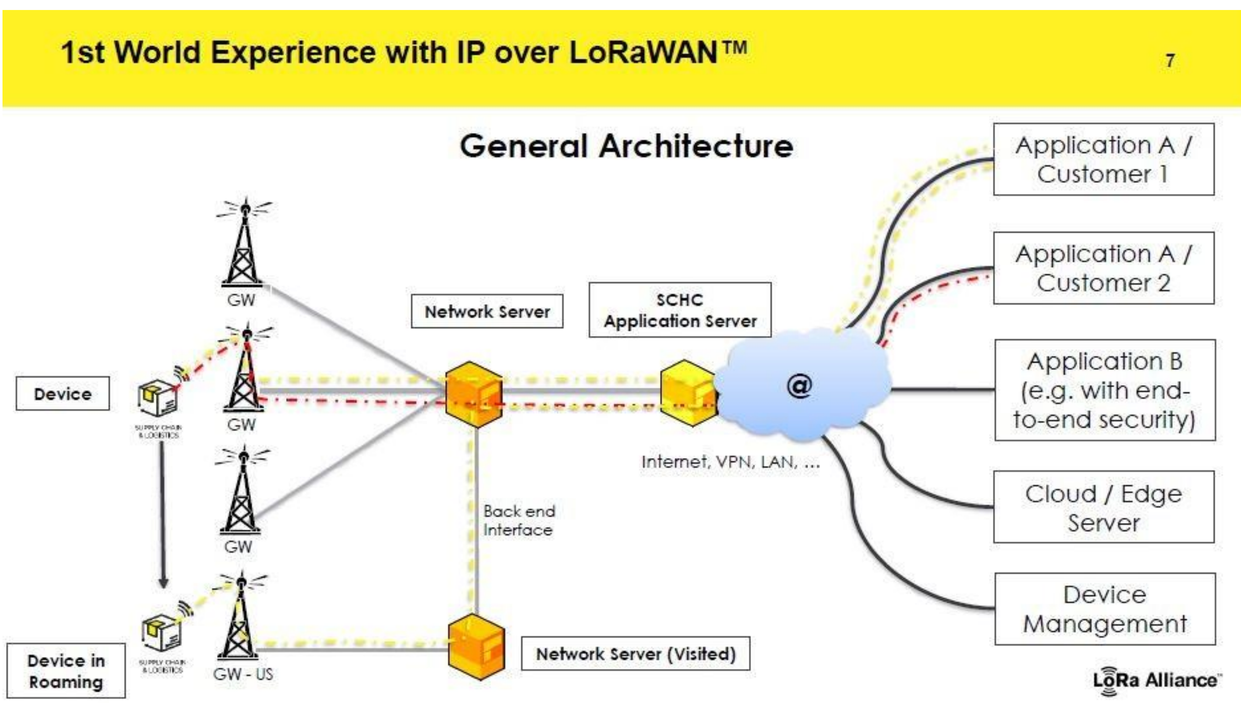

Figure 10. SCHC usage in LoRaWAN Architecture. [6]

SCHC stands for Static Context Header Compression is a header compression scheme that support fragmentation level [1]. SCHC works based on considering common static context on end points without any change [1].

By assuming SCHC as a layer between IPV6 and LPWAN, it has two sublayers for itself as Fig 11 shows, compression and fragmentation.

```
           +----------------+
           |      IPv6      |
        +- +----------------+
        |  |  Compression   |
 SCHC <    +----------------+
        |  | Fragmentation  |
        +- +----------------+
           |LPWAN technology|
           +----------------+
```

Fig 11. SCHC Stack[6]

SCHC packet includes 2 portions, payload which is original packet and compressed part which itself is divided to two part, RuleID and compression Residu.[6], Rule ID and Compression Residu can have different size. Fig 12

SCHC Packet		
Rule ID	Compression Residue	Payload

Fig 12. SCHC Structure [1]

Rule ID, which is a rule, used for compression/ decompression or fragmentation/ defragmentation is a link between device and network gateway. [6] Compression Residue is the bit left to sent after SCHC compression [6]

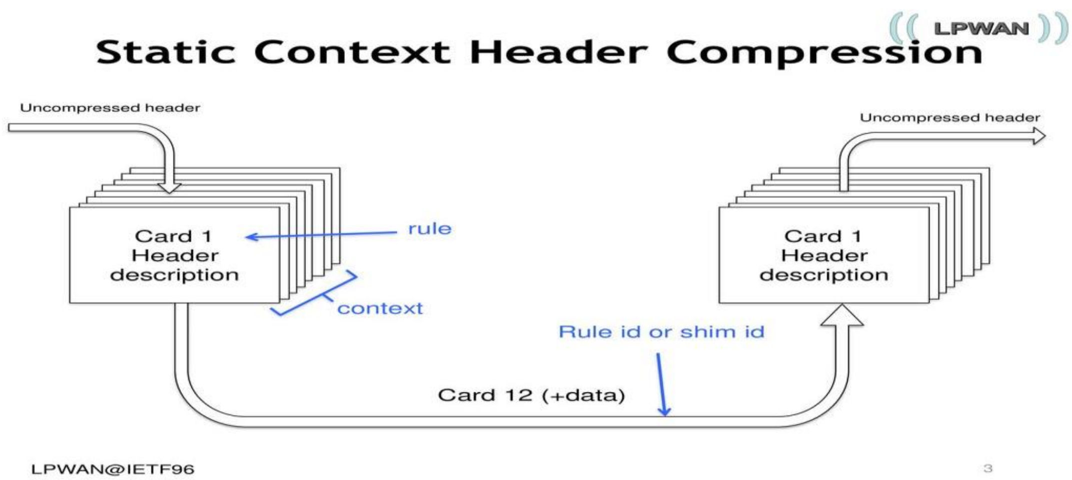

Fig 12 Rule id between devices [6]

In FIG 10 we see architecture based on SCHC. In this architecture each device uses IPV6/UDP protocol, after device send packet first it compresses the header by using SDHC C/D, based on requirement of fragmentation SCHC F/R is performed. Output of this SCHC is going to LoRaWAN radio gateway and from there has been forwarded to network gateway. from this gateway, compressed packet is going to SCHC F/R for reassemble and to SCHC C/D for decompression. From this point packet can go over internet to LoRaWAN applications servers.

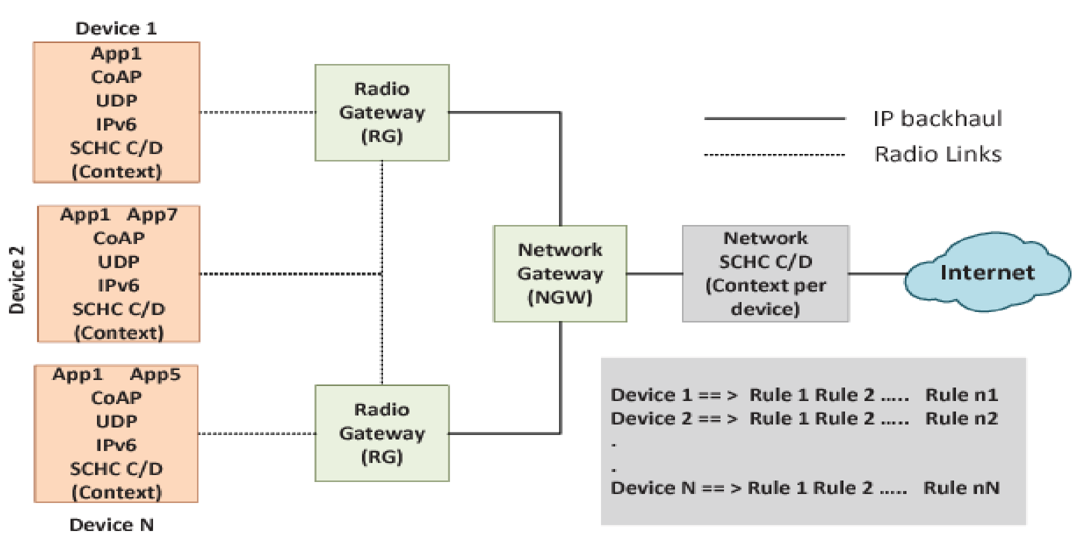

Fig13. SCHC architecture[9]

compression in SCHC have been done based on defined rules which called context and can compress or decompress headers.

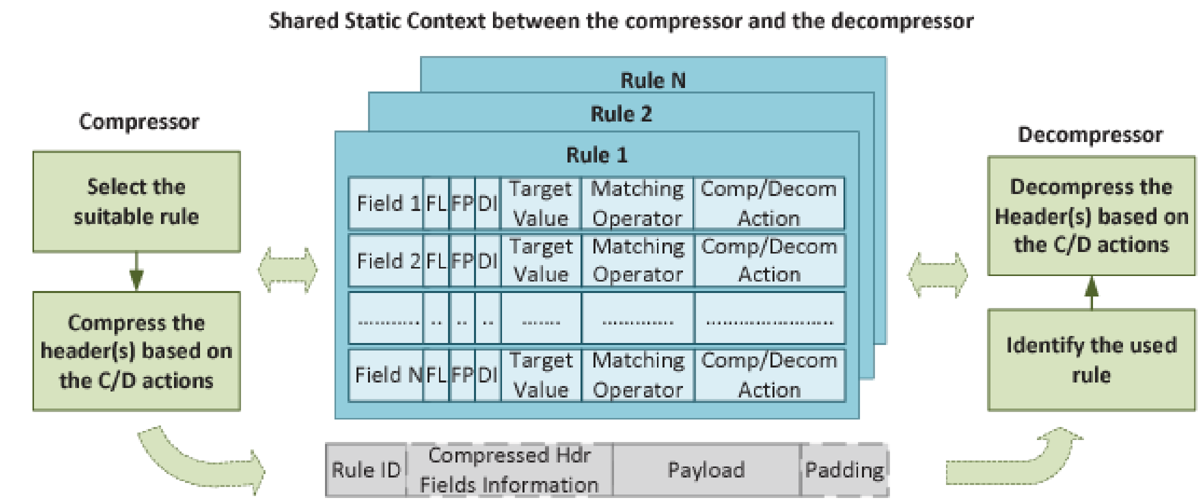

Fig 14 SCHC Framework and SCHC Context [9]

In this figure Field ID indicate the protocol and header eg. UDP and destination port [1].Field length (FL) indicate the length of the header. Field position (FP) defines which header evaluated. Direction Indicator (DI) indicate packet direction eg. Up/ Dw/ bi. Target value is used for comparison in header value. Matching operator use to match value in header with target value. And compression/ decompression (CDA) defines the Comp/Decomp process which has to be done. [1]

Size of SCHC packet is based on sum of bits in the compression Residue, bits in the RuleID and UDPayload calculated as:

$$SCHC_{length} = RuleID + ComRes + UDP_{payload}. \qquad [1]$$

Based on equation introduced for time on air and SCHC and equation and plotting proposed in reference [1] we see TOA and percentage of compression have revers behavior. Small percentage cause larger SCHC packet.so when we want to decide about choosing the Rules for compression we need consider time on air as ToA to study delay. ToA does not have linear behaviour.

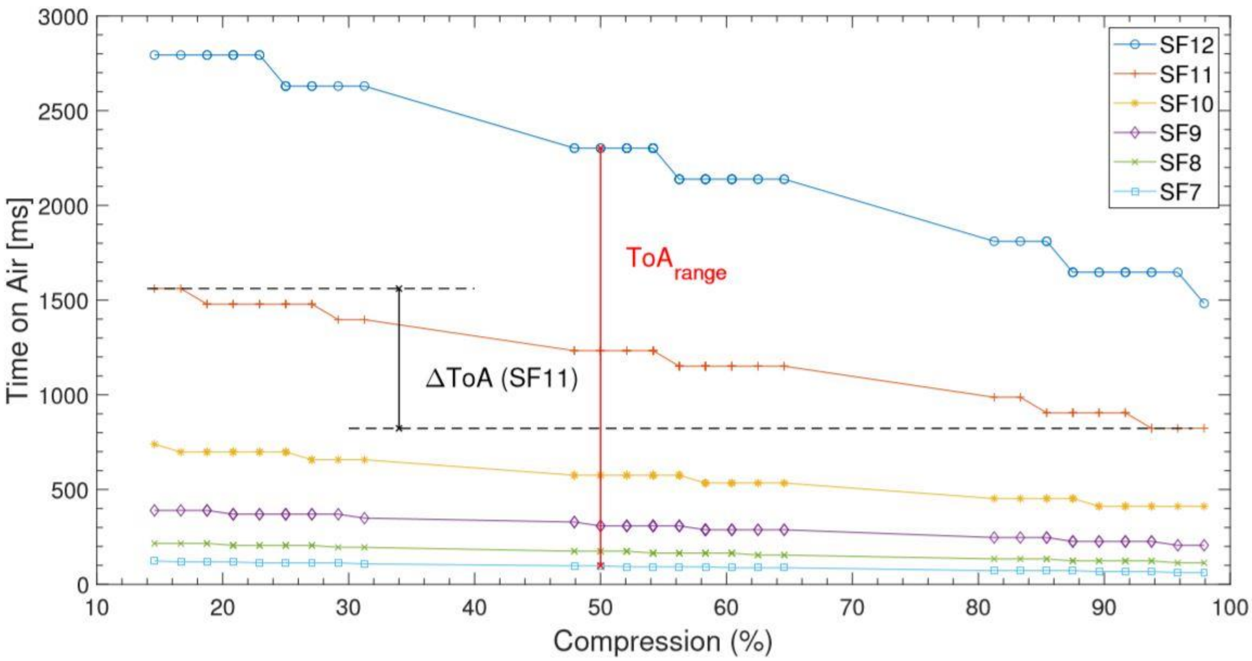

Fig 15. Time on air according to the percentage of compression for different Spreading Factors [1]

However, all this study is based on static context devices in SCHC. But challenge is in IoT when we use IPV6, endpoint can have any IP addresses or can be not fix in one location so data flow can be unknown.

Conclusion

In this project LoRaWAN has been introduced as open source standard for IoT. since there is huge growth in this industry it is important to have technology which can support low power and long range of coverage, LoRa protocol stack, MAC layer and physical layer and bringing IP to LoRa stack SCHC has been presented because IP has lots of benefit for LoRa based networks and devices from application development and security.

Reference

[1] Understanding and Characterizing Transmission Times for Compressed IP packets over LoRaWAN, Rodrigo Muñoz Lara ; Sandra Céspedes ; Abdelhakim Hafid,DOI: 10.1109/LATINCOM48065.2019.8938005

[2] Performance of a low-power wide-area network based on LoRa technology: Doppler robustness, scalability, and coverage, International Journal of Distributed Sensor Networks 2017, Vol. 13(3)

[3] A technical overview of LoRaWAN, LoRa alliance, https://lora-alliance.org

[4] Characterization of LoRa Point-to-Point PathLoss:Measurement Campaigns and Modeling,Considering Censored Data, JIOT.2019.2953804, IEEE

[5] Internet of Things Journal, IEEE

[6] IETF. LPWAN working group .https://www.ietf.org/id/draft-ietf-lpwan-ipv6-static-context-hc-24.txt

[7] loRa alliance conference Jan 2020 . https://lora-alliance.org/about-lorawan

[8] LoRa: A low power wide area network for the internet of things, Seminar report.heim.2019

[9] Dynamic Context for Static Context Header Compression in LPWANs, 2018 14th International Conference on Distributed Computing in Sensor Systems Khaled Q. Abdelfadeel, Victor Cionca, Dirk Pesch Nimbus Centre