Viability of Smart City Applications with LoRa WAN

Tanu Dhusia[1], Faseeh Ahmad[2]

[1]M. Tech Student, Department of Electronics & Communication Engineering, Goel Institute of Technology & Management, Lucknow
[2]Assistant Professor, Department of Electronics & Communication Engineering, Goel Institute of Technology & Management, Lucknow

---

ABSTRACT:- *Recent research on Low Power Wide Area Network (LPWAN) technologies, which provide the capability of serving huge low power devices simultaneously has been very attractive. The LoRa (Long Range) WAN is one of the most successful expansions. Feasible replicas are seen in many countries around the world. However, the probability of largescale deployments, for example, for smart city applications need to be further explored. This project provides a comprehensive case study of LoRa WAN to show the feasibility, scalability, and reliability of LoRa WAN in realistic simulated scenarios, from technical perspectives. In this work use cases of two distinctive cities monitoring applications have been studied. The proposed scheme presents an analysis and develop business models for such networks in order to provide a guideline for commercial network operators, IoT merchants, and city organizers to explore future deployments of LoRa WAN for smart city applications.*

Keywords: ***IoT, Low-Power networks, LoRa WAN, case study, smart city.***

1. INTRODUCTION

In this day and age, there is a lot of efforts on the study, analysis and discovery of new keys related to high density sensor networks which are used as part of the IoT (Internet of Things) concepts. It leads exploration of LoRa (Long Range) which is basically a modulation technique that enables the long-range transfer of information with a low transfer rate. It can be envisaged that LoRa will be an exciting technology area for smart cities for many years to come.

The Internet of Things (IoT) paradigm refers to a network of interrelated things. The network is normally projected as the IP network and the things are devices, such as sensors and/or actuators, furnished with a telecommunication (predominately wireless) interface and with processing and storage units. In particular, the wireless IoT access system should provide improved indoor coverage, support for enormous number of low throughput devices, low delay sensitivity, and ultra-low device power consumption.

1.1. LoRa

"LoRa Technology has revolutionized IoT by enabling data communication over a long range while using very little power. When connected to a non-cellular LoRa WAN TM network, LoRa devices accommodate a massive array of IoT applications by transmitting packets with important information. LoRa WAN fills the technology slit of cellular and Wi-Fi/BLE based networks that need either high bandwidth or high power, or have a limited range or incapability to penetrate deep indoor environments. In fact, LoRa Technology is flexible for rural or indoor use cases in smart cities, smart homes and buildings, smart agriculture, smart metering, and smart supply chain and logistics" [2]. Figure 1 shows clearly that LoRa has a greater power economical than Cellular or WiFi and therefore can attain a greater range or deeper in building coverage, by using a much lower data rate.

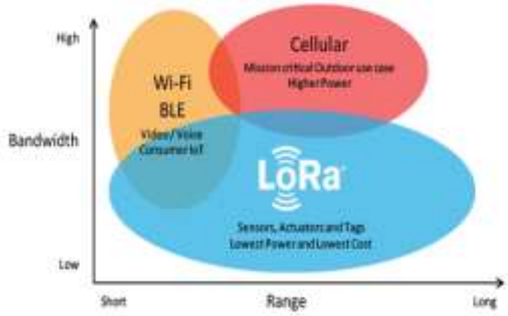

Figure1.WhyLoRa?

LoRa WAN

Many IoT applications, especially in rural regions, need to span considerable range while consuming as little power as possible. LoRa modulation can achieve these goals by spreading the transmission spectrum to, say 125kHz, but limiting the data to a few kilobits per second at most. The relationship between these two variables is called the spreading factor (SF) and it can be varied to suit different needs. A low SF permits higher data while a high SF permits decoding signals even below the receiver's noise floor, thus permitting ranges of dozens of kilometers in unencumbered environments and a few kilometers even in urban areas. LoRa WAN is an open media access control (MAC) layer protocol that provides all the functionalities for a complete solution, based on multiple end-nodes that communicate to one or more LoRa WAN Gateways. Gateways in turn connect to a Network Server (NS) using any kind of IP protocol-based links. For instance, the Gateway might have a cellular modem and SIM card, to connect to the Network server, or it might use a WiFi transceiver and a high gain antenna, or have an Ethernet port to connect to a local wired infrastructure. It can also use a satellite link, by paying the corresponding connection fees. The NS also connects to the Application Servers (APs) using the IP protocol over whatever infrastructure is available as shown in Figure 2. Gateways are transparent bridges relaying messages between end-devices and one or more network servers. Payload is encrypted by the end-node using the 128-bit Advanced Encryption Standard (AES), so each application is isolated from the others. Traffic is bidirectional, but mostly upward, from the end-node to the Gateways with very little in the downlink direction. A significant advantage of LoRaWAN is the fact that it uses unlicensed bands and open protocols so that it can be implemented by any organization independently from any commercial service providers.

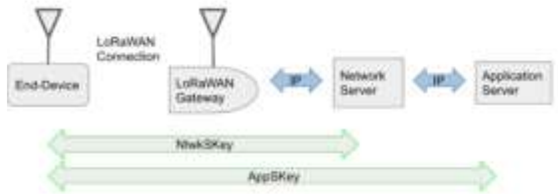

Figure 2. LoRa WAN Secure Architecture.

The LoRa WAN specification defines three device types [3]. All LoRa WAN devices must implement Class A, whereas Class B and Class C are extensions to the specification of Class A devices. A class A device will only listen for possible downlink messages from the Gateway after completing the transmission of its up link messages, and only for two briefs time windows. This will allow the device to sleep most of the time, therefore achieving the maximum battery duration. A class B device will also wake up at certain specified intervals, so its battery will last less. Class C devices will be listening whenever they are not transmitting, so their consumption is the highest, and they are normally meant to be attached to the power grid or a photovoltaic system. All devices and applications have a 64-bit unique identifier (Dev EUI and AppEUI). When a device joins the network, it receives a dynamic (non-unique) 32-bit address (DevAddr). The NwkSKey is used to validate the integrity of each message by its Message Integrity Code (MIC) and the AppSKey is used for encryption of the application payload.

2. APPROACHES

The project presented a comprehensive study on the feasibility of the LoRaWAN deployment for large city monitoring applications. Two realistic network deployments for the Greater London area based on the requirements of air quality and congestion monitoring have been simulated. The simulator is then used to evaluate the technical performance of the network.

The connectivity study showed the capability of Lora WAN in smart home and neighborhood applications. The performance of Lora WAN was studied and investigated in a vehicular scenario in Finland in 2015 [6]. In the experiment, the device in a moving car was used to upload vehicular data every 5 minutes to the base station located at the top of a building. Lora WAN has also attracted significant interest for commercial deployments. In South Korea, a large network covering 99% of the country's population is currently being deployed [7]. The network operator plans to offer LoRa-based IoT services at attractive prices. More large-scale projects are recently proposed or under consideration in France, Sweden, the UK, and many countries around the world. Realizing the increasing popularity and the commercial importance, this work presents a comprehensive study on the use of LoRaWAN from both the technical and economic perspectives. In particular, a realistic LoRaWAN network covering Greater London is designed using Matlab. The system performances in terms of the feasibility, scalability, reliability, and cost-effectiveness are evaluated based on different city monitoring applications. The study provides a reference for future commercial LoRaWAN deployments.

3. RESULTS

At first we examine the feasibility of the designed network in term of power consumption when three different sized packets are uploaded with various upload frequencies. Fig. 5 depicts the relationship of battery life-time and upload frequency.

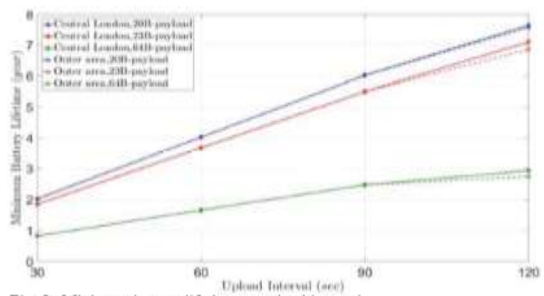

Fig. 5. Minimum battery lifetime vs upload interval.

As observed, when reporting a 20-byte measurement data in every 30 seconds, the end-device can work for around two years, powered only by two industrial AA batteries (2700mAh each). The lifetime increases with the transmission interval, and decreases as the payload size increases. Besides, because the conditions of wireless communication can vary more in the outer cells, a slightly lower battery lifetime is seen comparing with that of central cells. Based on the above experiments, we consider the network is feasible for ITS applications such as near real-time congestion monitoring, where the road-side devices measure and report the vehicle flow rate and average velocity. With the aid of the such data, advanced traffic-light control optimisation algorithms, as proposed in [17], can be apply to reduce the waiting time and gas emission. For air quality monitoring where retransmission is disabled and uploading interval is much longer, power can be saved by switching the LoRa modules to sleep mode for most of the time. An average of 9.03 years of battery life is achieved for the enddevices in outer cells whereas in Central London it is 6.07 years. Comparing with the ideal life time of 10 years as claimed in [18], we consider our results are acceptable in a realistic setting, and LoRaWAN is a capable low-power technology for such applications. For those devices used in the congestion monitoring, battery can drain faster. The devices operating in Central London and outer area will require battery changes after 2.02 years and 4.02 years, respectively. The percentage of the battery life-time spent in each operation mode is depicted in Fig. 6. As seen, most of the time has been spent in sleep mode, as expected. Approximately 0.3% of the time has been spent in transmission mode due to higher data rate, longer messages, and more frequent uploading. Similar amount of time is spent in idle mode for channel sensing.

4. CONCLUSION

We presented a comprehensive study on the feasibility of the LoRaWAN deployment for large city monitoring applications. Two realistic network deployments for the area based on the requirements of air quality and congestion monitoring have been simulated. The simulator is then used to evaluate the technical performance of the network. The results showed the potential of LoRaWAN as a workable low power long range ICT solution for smart cities. We also carried out a brief economic study and developed business models for the designed LoRaWAN considering different investment return plans. We envisage that LoRa will be an exciting technology area for smart cities for many years to come.

REFERENCES

[1]. LoRa AllianceTM. What Is the LoRaWANTM Specification? Available online: https://lora-alliance.org/ about-lorawan (accessed on 3 April 2019).

[2].Semtech. WhyLoRa? Availableonline: https://www.semtech.com/lora/whylora on 3April2019).

[3].LoRaWAN.Availableonline: https://www.thethingsnetwork.org/docs/lorawan/(accessedon3April2019).Future Internet 2019, 11, 93 12 of 12

[4]. TTN. THE THINGS NETWORK. Available online: https://www.thethingsnetwork.org/ (accessed on 3 April 2019).

[5]. ITU. ICT Facts and Figures. 2017. Available online: https://www.itu.int/en/ITU-D/Statistics Documents/ facts/ICTFactsFigures2017.pdf (accessed on 3 April 2019).

[6]. Kiruthika, R.; Umamakeswari, A. Low cost pollution control and air quality monitoring system using Raspberry Pi for Internet-of-Things. In Proceedings of the 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), Chennai, India, 1–2 August 2017; pp. 2319–2326.

[7]. Ahmed, M.M.; Banu, S.; Paul, B. Real-time air quality monitoring system for Bangladesh's perspective based on Internet-of-Things. In Proceedings of the 2017 3rd International Conference on Electrical Information and Communication Technology (EICT), Khulna, Bangladesh, 7–9 December 2017; pp. 1–5.

[8]. Chen, L.J.; Ho, Y.H.; Lee, H.C.; Wu, H.C.; Liu, H.M.; Hsieh, H.H.; Huang, Y.T.; Lung, S.C.C. An Open FrameworkforParticipatoryPM2.5MonitoringinSmartCities. IEEEJ.Mag. 2017,5,14441–14454.

[9]. Desai, N.S.; Alex, J.S.R. IoT based air pollution monitoring and predictor system on Beagle bone black. In Proceedings of the 2017 International Conference on Nextgen Electronic Technologies: Silicon to Software (ICNETS2), Chennai, India, 23–25 March 2017; pp. 367–370.

[10]. Kodali ,R.K.;Mandal,S.;Haider,S.S.Flow based environmental monitoring for smart cities. In Proceedings of the 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI), Udupi, India, 13–16 September 2017; pp. 455–460.

[11]. Kumar, S.; Jasuja, A. Air quality monitoring system based on IoT using Raspberry Pi. In Proceedings of the 2017 International Conference on Computing, Communication and Automation (ICCCA), Greater Noida, India, 5–6 May 2017; pp. 1341–1346.

[12]. Parmar, G.; Lakhani, S.; Chattopadhyay, M.K. An IoT based low cost air pollution monitoring system. In Proceedings of the 2017 International Conference on Recent Innovations in Signal processing and Embedded Systems (RISE), Bhopal, India, 27–29 October 2017; pp. 524–528. [CrossRef]

[13]. Barro, P.A.; Degila, J.; Zennaro, M.; Wamba, S.F. Towards Smart and Sustainable Future Cities Based on Internet-of-Things for Developing Countries: What Approach for Africa? EAI Endorsed Trans. Internet Things 2018,

[14]. THE WORLD BANK. Decline of Global Extreme Poverty Continues but Has Slowed: World Bank. 2018. Available online: https://www.worldbank.org/en/news/press-release/2018/09/19/decline-of-globalextreme-poverty-continues-but-has-slowed-world-bank (accessed on 3 April 2019).

[15]. Oniga, B.; Munteanu, A.; Dadarlat, V. Open-source multi-protocol gateway for Internet-of-Things. In Proceedings of

the 2018 17th RoEduNet Conference: Networking in Education and Research (RoEduNet), Cluj-Napoca, Romania, 6–8 September 2018; pp. 1–6.

[16]. Perera, C.; Qin, Y.; Estrella, J.C.; Reiff-Marganiec, S.; Vasilakos, A.V. Fog Computing for Sustainable Smart Cities: A Survey. ACM Comput. Surv. (CSUR) 2017, 50, 32.

[17]. Pape A. BARRO. A Multi-Services and Multi-Optional Gateway for Communities. 2018. Available online: https://github.com/pape-barro/edge-gateway (accessed on 3 April 2019).

BIOGRAPHIES

I have completed my B.tech in (Electronics and Engineering) from G.L.Bajaj Institute of technology and management in 2015 from Greater Noida, and currently I am working as an assistant professor in Goel Institute of Technology and Management, Lucknow and I have approximately two years of experience. I am pursuing my M. tech in electronics engineering from Goel Institute of Technology and Management.

Mr. Faseeh Ahmad is currently working as Head of Department (Electronics & Communication Engineering) at Goel Institute of Technology & Management, Lucknow. He has approximately 10 years of academic experience in his field. After pursuing his *B.Tech* degree in Electronics & Communication stream, he further enhanced his skills by acquiring PG *Diploma in Embedded Systems Design* from a premier institution C-DAC, Pune. Further he also pursued a PG *Diploma in Wireless Telecommunication* and worked as RF/DT engineer in telecom sector also. Afterwards he pursued his *M.Tech* degree in Electronics & Communication Engineering to serve in academics field in a more skilled & competent way.