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The Implementation of Civil IoT Architecture

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Abstract. Billions of interconnected Internet-of-Things (IoT) devices collect huge amounts of real-time data. However, this massive stream of data presents technical challenges for processing and analysis and the digital gap between urban and rural areas is also a critical consideration. A powerful platform is crucial to cost-effectively and efficiently process such massive collections of messages. This work introduces the civil IoT architecture in Taiwan including the dedicated B20 spectrum, backbone network facilities, and a scalable data platform. The proposed system operates in Taiwan for IoT applications with real cases. In the experiment, we demonstrate the performance of signal coverage, throughput, real-time query and visualization, and a monitoring mechanism. The results showed that the presented architecture is efficient and effective for dealing with IoT scenarios in a cost-effective approach.

Keywords: IoT, sensor network, cloud computing.

1. Introduction

More than 25 billion Internet-of-Things devices have been connected by the end of 2020 [1]. Industrial-Internet-of-Things (IIoT) devices are especially important in the field of Industry 4.0. Due to the increasing velocity and volume of big data, it is crucial to improve operational efficiency and manufacturing processes [2]. Among the variety of data properties, there has been momentum in recent years to model normal behaviour into an AI model [3]. However, the high cost of mobile networks and the short coverage of Wi-Fi have affected the willingness of many to join. It is also difficult to implement into rural areas because of the digital gap.

Therefore, Taiwan has designated the bands between 816~821, 857~862 MHz (collectively referred to as Band 20) as the "Civil Internet of Things Experimental Band" for science development. In order to effectively use and promote the use of this Band 20 (B20) frequency band, the National Center for High-performance Computing (NCHC) in Taiwan plans to build a Civil IoT Architecture (Fig. 1) and dedicate SIM cards for IoT devices, collectively referred to as the public IoT backbone network. In addition, the platform also evaluates various wireless communication technologies, makes good use of the popular high-speed fixed network construction, and combines the resources of communication operators to solve the network problems of IoT devices in wild environments. It also collects sensor data for back-end analysis application.

The aims of this work are: (1) to reduce the network transmission cost, (2) to develop a high-throughput and low-latency data collection mechanism, and (3) to serve as high availability and high-quality services.

In the architecture design part, this work describes the components of the backbone network of civil IoT, which can be divided into three parts:

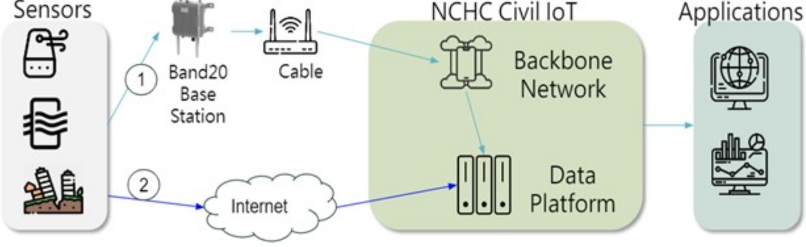

Fig. 1: Civil IoT architecture.

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(A) IoT sensor network equipment: IoT sensors, Band20 base stations, connection mechanism to broadband network.

(B) Civil Backbone Network facilities: the entire system is used to transform 4G telecommunications packets into TCP/IP to Internet.

(C) Civil Data platform: leveraging publish/subscribe mode to collect real-time data and persistent in DB.

In the research results, we also present the service range of the Band20 base station under this work. In the actual environment, the signal is degraded due to blockage from buildings. Distance also affects signal strength. After receiving the data, we used the dashboard interface to present real-time information, and matched it with the monitoring alarm.

In summary, the contributions of this study are as follows:

- Build a cost-effective and secure backbone network through the Band20 spectrum for industry, government, academia and research applications;
- Provide a high-throughput/low-latency data collection mechanism where data is persistent by automatic Extract-Transform-Load;
- Support high availability, fault tolerance, and scale-out to deliver high quality service.

2. Related Work

IOT is a network that allows sensors to constantly detect its environmental condition for related actions based on pre-programmed rules [4][5]. To improve reliability and cost-effectiveness, data generated by sensors directly connected to IoT can be used for condition monitoring to predict abnormal behaviour [6]. Even though edge computing smart devices are becoming increasingly popular, the actual training of the model is still often in the cloud [7].

Especially in the IIoT domain, transferring business-sensitive data to the cloud can also lead to data privacy concerns [8][9], which is why federated learning (FL) approaches are popular in IIoT. Additionally, [10] developed a blockchain-based FL solution for an IIoT approach. [11] presented a big data framework for intrusion detection with multiple grid sensors. [12] used big data and DL algorithms to implement an intrusion detection system. To detect denial of service attacks in IoT networks, 0 came up with a big data framework including ML algorithm.

3. Implementations

3.1 Civil backbone network

Fig. 2 shows the Civil Backbone Network, with details as below.

- B20 spectrum with LTE Cat.M1: The National Communications Commission (NCC) in Taiwan provides authorization to use this frequency band, and built a telecommunications management facility for the backbone network in order to effectively utilize it as a Band20 800 MHz uplink and downlink 5 MHz spectrum (816~821/857~862). In order to balance the trade-off between throughput and cost, we choose the LTE Cat.M1 protocol to transfer data.
- Security Gateway: The Security Gateway built by FortiGate is used to cooperate with small base stations to establish VPN encrypted channels, and also integrates information security protection between base stations and core network equipment.
- EPC (Evolved Packet Core Networks, EPC): Supports LTE and Cat-M1 and can support the evolution of a packet core network (EPC) that can be expanded to 5G. It is the core network architecture of LTE based on the IP network protocol. In addition to being used as data packets for transmitting mobile network IP, different access networks can be built to provide more services.
- EMS (Element Management System): EMS is a system that manages multiple telecommunications network elements (NE, Network Element) of a specific type, and is responsible for management, operation and maintenance, including an HSS/MME/PGW/SGW Server and other network equipment.
- HeMS (HeNB Management System): responsible for operation and maintenance of Band20 base stations and gateways.
- HSS (Home Subscriber System): management for SIM card subscribers connecting to sensors.

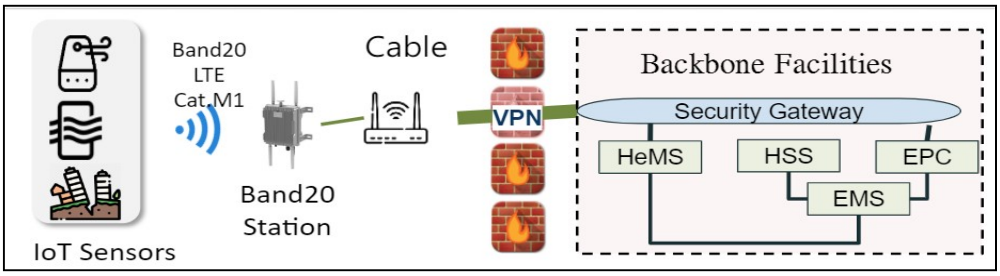

Fig. 2: Civil backbone network.

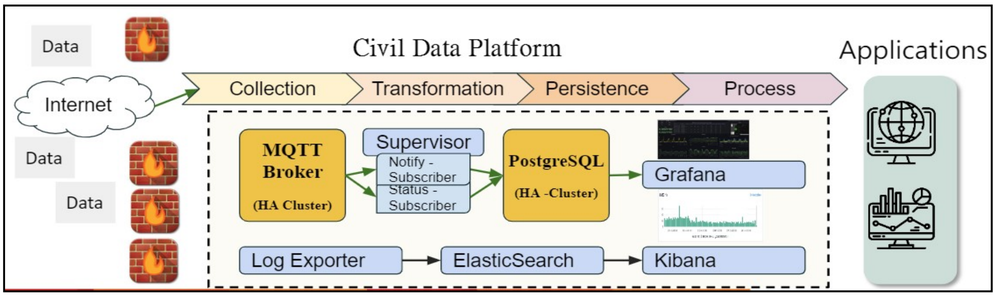

Fig. 3: Civil Data Platform.

3.2 Civil data platform

Fig. 3 presents the Data Platform of the Civil Backbone Network, which is divided into four sections in a data pipeline: Collection, Transformation, Persistence and Analysis.

(1) Collection

MQTT Broker: This is based on RabbitMQ as the bottom layer with a MQTT plugin, and is used to match the role of Publisher and Subscriber, and considering high availability and scalability, it uses 3 nodes cluster to setup, and the frontend is equipped with a load balancer with a round-Robin mechanism. **Fluentd:** This component is used to collect the log information of RabbitMQ on the Broker side, which is used to troubleshoot service status when an abnormal situation occurs.

(2) Transformation

Subscribers of Supervisor: Subscriber uses Python 3 with PAHO library to receive MQTT packets. However, considering the continuity of the program, the Supervisor is introduced to manage the program, and the status can be checked online, and the program can also be restarted due to errors.

(3) Persistence

PostgreSQL: After the data is received by a Subscriber, it will be written into the PostgreSQL DB, and the message format is recorded in jsonb format. **Elasticsearch**: is a sequential database for receiving logs by Fluentd, including the establishment of index and search mechanisms.

(4) Analysis

Grafana: This is the user interface, which is often used for a dashboard display. It can support multiple database formats, display multiple charts, and design alarm mechanisms. Kibana: In order to match the user interface of Elasticsearch, it can perform RabbitMQ Cluster debugging and a specific purpose search.

4. Experiments and Results

4.1 Signal coverage

Fig. 4 presents the service areas of the Band20 small base stations in the three experimental areas where the signal is affected differently due to environmental factors, such as the number and density of buildings, the distance between the equipment and the base station, and so on. The blue triangle is the location of the base station, and the PLMN means catch wrong signal because of too far away from the base station, that can be ignored. In the outdoor environment of the three factories, the longest can reach 916 meters, and the shortest is within 245 meters.

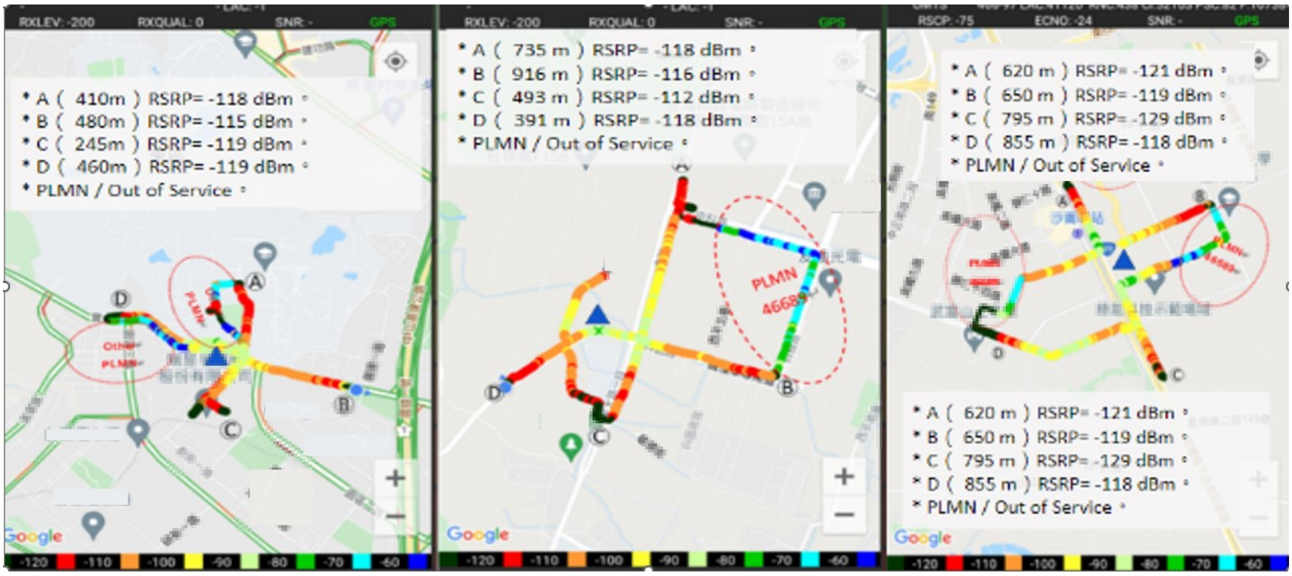

Fig. 4: The Signal Coverage Test.

4.2 Signal Strength and Internet Speed

The strength of the network signal is also a key factor affecting the transmission speed, as shown in Fig. 5, the red line is the download speed, and the blue line is the upload speed. Under the condition of RSRP = -90 dBm, the average upload speed is 31 Mbps, between 28 ~ 34 Mbps, and the upload speed is 7 Mbps, between 7.5 ~ 6 Mbps. Therefore, as the signal decays with distance, the upload and download speeds measured at -100, -105, and -110 dBm are also decreasing, and when it reaches -115 dBm, it is out of service due to an unstable network and cannot provide stable services.

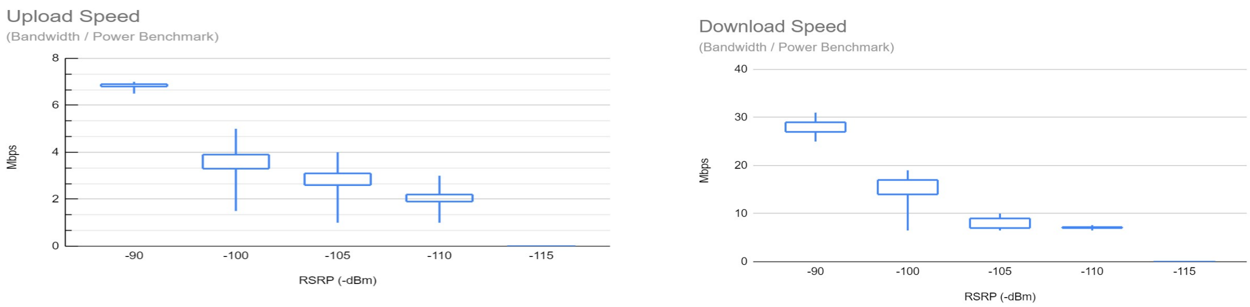

Fig. 5: Upload and download speed.

4.3 Real-time presentation and monitor alarm

Through Grafana + PostgreSQL, various data types transmitted by IoT sensors can be displayed in real time, as shown in Fig. 6. This is the real-time information presented through Grafana from the actual cooperation field (refer to Annex B, C), including the sensor, number of devices, the number of data, the number of sensing data, etc., and various historical graphs. The sensors regularly report Heartbeat to a dedicated MQTT topic, and set an exception notification mechanism on Grafana to monitor whether the device is operating normally.

5. Conclusions

In this work, we establish the practicality and scalability for a civil IoT architecture in terms of both hardware and software. Alternative to telecom 4G network, we built a cost-effective and secure backbone network through the Band20 spectrum established for industry, government, academic and research applications in Taiwan. We also provide a high-throughput/low-latency data collection mechanism that data is persistent thru an automatic Extract-Transform-Load. In the future, after completion of the infrastructure for a civil IoT, we will cooperate with local governments or non-profit organizations to enhance and scale out the application scope. Moreover, we will analyse data to promote increased awareness and knowledge about the platform. We hope this work can achieve the goal of being a win-win scenario with our partners and pave the way for future work that can guarantee IoT convenience.

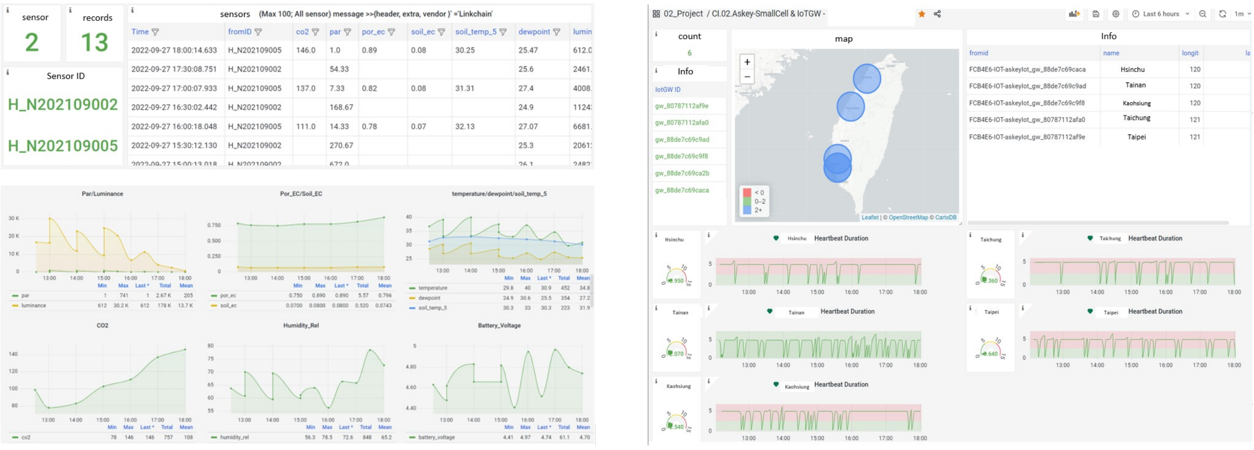

Fig. 6: Data dashboard and monitor interface

6. Acknowledgements

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