Smart Waste Management Based on Fog and NB-IoT

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Annotation:
The increasing number of people on the planet brings, among other things, increasing waste production. This increase in waste is a major problem, especially in urban areas. IoT, fog computing and cloud computing offer automation to collect and evaluate data from systems that change the way solid waste is managed. Such solutions can also be used in rural areas. Thanks to Narrowband-IoT technology (NB-IoT) there is no need to build or modify existing BTS (base transceiver station). The aim of this article is to provide a different perspective on this issue. Using the possibility of fog computing as a middleware layer to reduce computational demands on a separate cloud.

Anotace:
Rostoucí počet lidí na planetě přináší mimo jiné i zvýšení produkce odpadu. Tento nárůst odpadu je velkým problémem, zejména v městských oblastech. IoT, fog computing a cloud computing nabízejí automatizaci sběru a vyhodnocení dat ze systémů, které mění způsob nakládání s pevným odpadem. Taková řešení lze použít i ve venkovských oblastech. Díky technologii Narrowband-IoT (NB-IoT) není třeba stavět ani upravovat stávající BTS (základní vysílací a přijímací stanici). Cílem tohoto článku je poskytnout jiný pohled na tuto problematiku. Využití možnosti fog výpočtu jako vrstvy middlewaru ke snížení výpočetních požadavků na samostatný cloud.

INTRODUCTION

Nowadays, the term IoT is becoming more and more in the subconscious, cities and other areas where new IoT-based systems and applications are being developed. One of these areas is waste management, which falls under the concept of smart city. According to data published by the United Nations Department of Economic and Social Affairs, by 2050, the proportion of urban population worldwide is expected to be 66%, compared to 52% in 2014, leading to an increase in urban waste generation. This was confirmed by the World Bank Group. Interesting data are in waste production from 2012, when cities around the world generated about 1.3 billion tons of solid waste, which is 1.2 kilograms of waste produced per person per day. In view of the increasing population, urban waste production is projected to rise to 2.2 billion tons by 2025 [1]. Another fact is that urbanization rates are growing more slowly than urban growth. This implies higher waste concentrations.

Nowadays, in 2020, there are several companies and institutions that deal with waste management technologies. With the advent of IoT, communication between devices has been made much easier. These “intelligent” devices could capture, evaluate and communicate without integration into the environment [2].

The expanding network for IoT devices - low-power wide-area network (LPWAN), ensures fast and secure over sensor data theoretically anywhere in the world. This family includes technologies such as ZigBee, Sigfox, Lora, NB-IoT, etc. Each technology has its own specifications, but one feature they have in common is low communication consumption. By 2025, it is expected that more than 90 -100 billion devices will be connected to IoT. This raises additional questions about where and how data sent by devices will be processed. Attention is also focused on computing power, which now takes place in the cloud in the vast majority. This article focuses on the use of "fog computing" as an interface between devices and the cloud. [3,4] Thus, the potential reduction of computing operations in the cloud.

STRATEGIES IN DATA PROCESSING

As mentioned, IoT generates a huge amount of data. Which is a challenge for traditional data processing technologies. There are several architectures that try to solve partial parts of computational performance reduction:

- Grid Computing
- Cloud Computing
- Fog Computing
- Mobile-edge Computing
- Cloudlets
- On-site Processing

Fig. 1 represents the cloud computing design in which the devices are directly connected to the data centric cloud. IoT devices are designed for long-term use without human intervention and have a long battery

life (up to 10 years) [5]. This implies that the device only must measure the values from the sensor and send them. Any other action is undesirable and increases battery consumption. Thus, all computing power takes place in the cloud.
At the beginning of IoT development, the application logic was built into the firmware of the IoT device and processed on the device. Although this allowed real-time processing and immediate response, it was difficult to upgrade and reprogram these devices if any changes in use had to be induced [7]. Also, due to resource constraints, sophisticated algorithms could not be run on IoT devices. Therefore, it was recommended to exclude application logic and processing from data-based devices and delegate to the cloud server [7]. Now all raw data is transported and processed in the cloud instead of the device. Since data processing has been moved from the local network to a remote data center, this concept is called "out-of-network processing" [6].

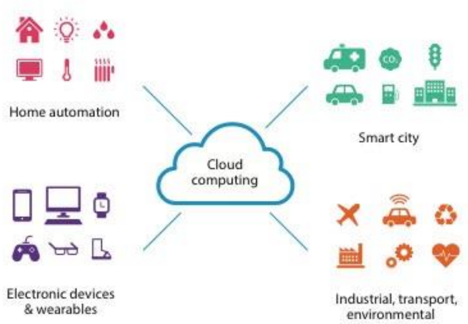

Figure 1. General cloud Computing Model IoT

Cloud Computing

Cloud computing is so far the most used platform for IoT data processing. Its main advantage is the centralized approach. All data and calculations are hosted in the cloud. Users have the option to log in and receive data of their choice or provided to them.
Most devices are operated in real time. For example, building access systems or various equipment controls require real-time access to sensors. This leads to latency when the network is busy. Next is the fact that all data is directly sent to the cloud. It is not solved that some data may not be processed at all. And this leads to the utilization of the basic backbone network. [6]. In the following section we will focus more on Fog computing.

Fog computing

Fog computing is a distributed computing infrastructure where some services are solved at network edge and some in a remote data center - the cloud, improving efficiency and reducing the amount of data sent to the cloud for processing. Basically, you can too to be understood as cloud computing, which is carried closer to the end customer's network. Already in the name of technology there is an effort to reflect the basic difference from cloud computing - fog is actually a cloud that is closer to the earth - illustrating the fact that fog computing brings part of the cloud computing infrastructure closer to the edge of the network services.

The Fog layer consists of highly virtualized and geographically distributed servers that are located on the edge of the network. Each of these servers is basically a simpler and lighter version of a classic cloud server, equipped with a large storage capacity and computing power. The role of these servers is to be an intermediary between the classic cloud and mobile users. On the one hand, they communicate with users using wireless technologies such as Bluetooth or WiFi, and with the help of locally available resources they can provide the required services to end users without the need for cloud support. On the other hand, they can communicate with the cloud and use all the functions and tools that the cloud provides. Fog computing also seeks to take advantage of the power of network-enabled devices already available, such as smartphones, whose performance increases every year, but users only use a fraction of the time. Although the use of these resources would bring many benefits, it cannot be implemented without any problems. The aim of fog computing is to provide a portion of the services in close proximity to the users to which they have immediate access and thus reduce the disadvantage of using the cloud in the form of a high and unpredictable response. Given the large number of heterogeneous devices deployed in a variety of environments, the fog architecture must enable seamless resource management across a diverse range of platforms.

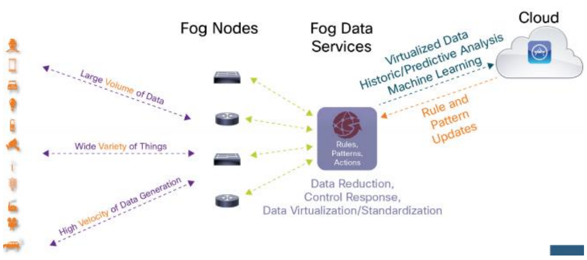

Figure 2. Fog Data Services Coordinate the Movement of Data from Fog to Cloud [8]

Advantages of fog computing

- Data is closer to end users, eliminating transmission delays.
- Delete the weakest links in the network resulting from centralized computing systems.
- Faster development and deployment of new applications.

- Faster data analysis by placing processing nodes closer to their source before getting any valuable business information.
- Reduce operating expenses by significantly reducing the amount of data sent.
- Improved security of encrypted data that stays closer to the user, reducing it possible exposure to attackers.
- Increased privacy control - sensitive data can be analyzed locally and not sent to the cloud, leaving the user with the choice of which devices will be the data collect, analyze and store.
- By creating a dense geographic network that fog computing shifts cloud services on the edge of the network, big data analysis can be greatly accelerated, support can be provided based on site-specific requirements and not across the entire WAN and real-time data analysis is a good way to build a fog infrastructure.

Disadvantages of fog computing

- Security - it is still unclear what is the most convenient type of encryption, so that it is not demanding but at the same time highly secure [9].
- Privacy - Although in the fog environment, most of the data is kept relatively close to users and problems privacy may not seem so serious.
- Monetization and Accountability - A concept in which users share part of their available performance to host fog applications is one of its key aspects [9].
- Programmability - Effectively controlling the application life cycle in the cloud environment.

NAROWBAND IOT

NB-IoT is a narrow band mobile technology and also its classified as 5G technology which described in 3GPP edition 13 (March, 2016) and is designed for IoT communication. It utilizes many LTE physical layer principles and building blocks and higher protocols for rapid standardization and product development. The aim of this technology is to provide connectivity to large number of devices with low throughput, low delay sensitivity, low energy consumption and low-cost communication modules. NB-IoT supports three deployment modes: (a) In-band mode (b) Guard-band mode and (c) Stand-alone mode [6]. The three deployment modes of NB-IoT are shown in Fig. 3.

NB-IoT technology has been designed to provide greater coverage of territory other than GSM networks, namely up to 164 dB MCL (20 dB more than GPRS). It should provide coverage even in inaccessible places such as cellars buildings, which is possible thanks to the single-tone UL broadcast. New physical layer signals and channels such as synchronization and physical random-access channel are designed for extended coverage and reduced complexity. Higher protocols such as a Physical layer processing is simplified to achieve reduced complexity and from that resulting in reduced energy consumption of the equipment [10, 11].

This figure shows that the NB-IoT network can operate completely independently of the LTE standard. As a result, it does not disturb existing broadcasts because it operates at a different frequency [14].

Initially, the technology seemed to be less useable for IoT devices. Over time, however, technology has improved as we know it today. 3GPP Release 14 (June, 2014) has brought many improvements to this technology. Technology got a new name as a standard CAT-NB2. Significantly, the increase in UL and DL up to 2536 bits was compared to the original 1000 for UL and 680 for DL. The method for acquiring the location of a given device using eCID (enhanced cell ID) has been refined. Multicast Single-Cell Point to Multipoint (SC-PTM) has also been added to communicate with multiple devices at the same time. Support for connecting multiple devices per square kilometer from 60,000 devices to 6 million devices has been expanded, and a low-power user class has been introduced with maximum UL power limited to 14 dBm [12].

3GPP Standard Edition 15 (Sept, 2018) focused on reducing device battery consumption. New mechanisms have been developed to reduce power consumption such as Early Data Transmission (EDT), Wake-up Signal (WUS), Time Division Duplexing (TDD) and many other minor enhancements. [13]

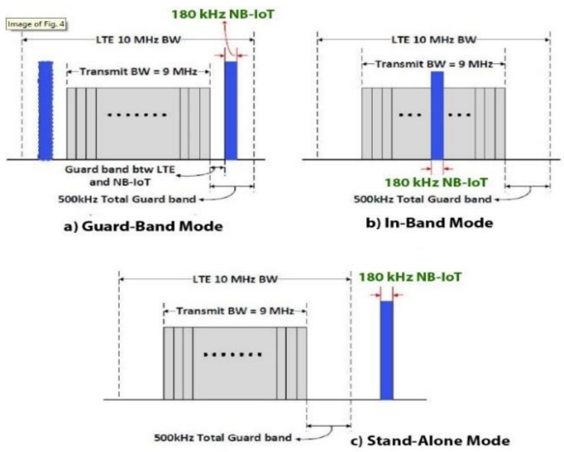

Figure 3. Deployment modes of NB-IoT.

SMART WASTE MANAGEMENT ARCHITECTURE

Today's intelligent waste management with the NB-IoT system based on cloud computing. All data processing and communication based on cloud computing has its own drawbacks and disadvantages, such as slow processing, insufficient storage space and high latency. Design based on the NB-IoT network and on fog computing lead to more efficient, less more energy efficient and smarter system.

Architecture model design

The Smart waste management architecture is shown in Fig. 4. The sensors located in the waste bins are always connected to the nearest BT tower where information is exchanged via NB-IoT network.

EDGE layer

The basis of the waste management system is the Edge layer, which contains sensors of various kinds of detection of the fullness of the waste baskets. In addition to these sensors, temperature or weight sensors can also be placed in waste bins. In the case of multiple sponsors, the waste bin is adapted to lead all sensors to the control unit. They then send data to a fog computing using a NB-IoT network (existing BT towers) at a predefined time. Defined sending time is important for battery consumption, which is given by the following relation:

$$\mathbf{t} = \frac{\boldsymbol{P_B}}{(\sum_{l=1}^{7} \boldsymbol{P_C}(\boldsymbol{l}) + \boldsymbol{P_w}(\boldsymbol{l}))/7} \qquad (1)$$

P_B represents the current state of charge of a battery, Pw(l) is the power consumption for device operation per day, Pc(l) is the power consumption required for communication per day. If we broadcast 7 days a week, the battery life can be calculated. The battery consumption can be calculated by various modifications.

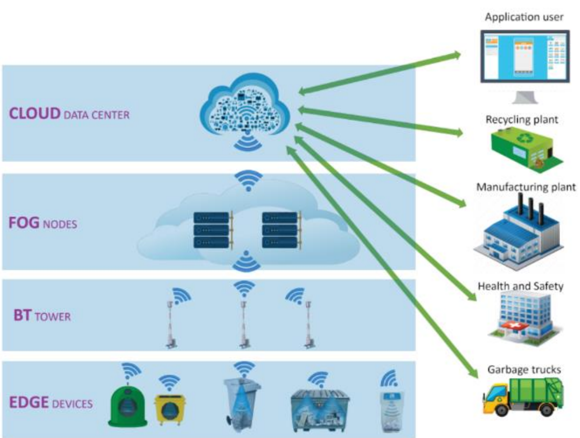

Figure 4. Smart waste management based on NB-IOT and Fog computing.

FOG layer

The fog layer, which is in proximity (max. 100 km) [15], receives data and works with them in realtime. This layer performs various operations on received data. There are also filters in this layer that evaluate the correctness of the received data. If the data is damaged or not formatted correctly, it is discarded. Here, data can be more effectively secured for subsequent sending to the cloud.

CLOUD layer

The last layer is a cloud in which the waste management system is deployed. The cloak layer abstracts the basic services, such as the current status of the waste bin, the location of the bin, the battery consumption and additional information such as temperature and possibly other. The system provides information to third parties by sending messages or provides API services. The Cloud Computing Center performs in-depth processing of transactional data. Previously worked Fog Computing and analyzed massive business data, reducing the burden and power consumption of cloud computing center, increases processing speed and ensures efficient storage capacity and storage speed.

CONCLUSION

According to the current situation the structure model and system architecture of intelligent waste management system are based on NB-IoT and fog computers and their key technologies are analyzed in the application. Thanks to NB-IoT technology, deployment, low power consumption, low cost and wide reach are great advantages over the technologies. Fog computing provides faster data transfer and calculation. Thus, it provides low latency, wide coverage, easy to use, high efficiency, lowenergy and smarter waste manament system. It also enables more efficient management of waste collection, particularly by planning garbage routes. This saves fuel, time and, more recently, the often discussed environment.

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