Smart Pole Connectivity via the Fusion of IoT, AI, and 5G

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ABSTRACT

A 5G-based smart pole is an IoT-based streetlight pole that consists of streetlights as its hardware, IoT devices with different functions, and an intelligent network interface with 5G communications protocol. This device can directly link to the Internet independently without a computer and has a built-in gateway and a sensor server to access the digital information from IoT devices, and also to control and to set up them. Digital output of the 5G-based smart pole enables the hardware pole to easily integrate multi-application, including digital illumination, digital monitoring system, push notifications, emergency reporting, and long-distance environmental monitoring. A 5G-based smart pole is usually stationed by the street in the LAN environment to perform the said applications. The 5G-based pole collects IoT data dynamically and provides various services. However, without a suitable scheduling algorithm, accessing various built-in services from a 5G pole will be a difficult job. For an administrator/user of remote access services, to have a full concept of the services and available time is impossible, especially the random access of the 5G pole network will complicate these procedures more. The main objective of this article is to develop an optimized QoS (Quality of Service) / QoE (Quality of Experience) management system that suits the 5G-based smart pole environment in order to utilize the restricted bandwidth more effectively. The QoS/QoE optimized rules that this article intends to develop can actively choose the best QoS resources of 5G communication based on current network status and aim at providing various services to transmit signals among 5G smart electric pole devices and 5G gNB/5GC to satisfy the needs in different scenarios.

Keywords: 5G, Smart Pole, IoT, QoS, QoE, QoL, Queue, Petri Net

INTRODUCTION

In recent years, the Internet of Things has been developing in full swing all over the world, and its influence can be found in the expansion of the Smart Internet of Things (SIoT). Taking QoS/QoE as an example explains the design considerations for Smart and IoT data communication (Fig. 1). Some people say that the Internet of Things will set off a new wave of Industry 4.0 revolution. Why? Technically, it is mainly because SIoT is an enhanced low-power wide area network (LPWAN) IoT application in specific areas. For example, there're requirements of SIoT for accessing services such as supporting a large amount of small data, low power consumption and remote transmission, especially applied to specific industrial fields. What can we do under this diverse and low-power wide-area industrial Internet of Things? In the world of IoT systems, IoT is widely expanded and its various communication protocols are flourishing, which also worsen the problems in IoT interoperability. People may complain about the torments of interworking with numerous IoT protocols, but little can be done to control it. Even so, corresponding measures should be actively taken to reduce such problems. However, it still could trigger false alarms. Therefore, for SIoT, it is different from the old narrow-band communication system where IoT is mainly based on sensing. In the transmission process of data communication, the quality of service (QoS) of various factories or user experience must be considered. Quality of Experience (QoE) requirements to ensure that data can be delivered correctly during transmission [1][2][3].

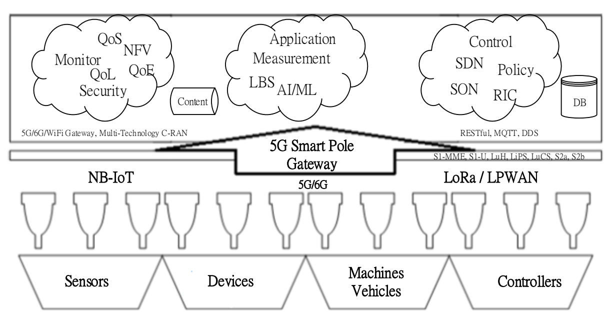

Fig. 1 Architecture of 5G Smart Pole

Obviously, the Smart Internet of Things will take service and user-end experience-oriented data communication as the primary goal, starting from the front-end data collection, accessing through the network, intermediary gateways, database support, and the use of back-end applications. The whole system is ultimately set to provide customers with various services. With the accumulation of time, these data can be analyzed, and even put with intelligent algorithms to form various mathematical models, which are then fed back to the control module to provide data-driven corresponding actions, including normal feedback, abnormal returns and future forecasts, etc. Similar to the

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application process of this service, the sensors of the front-end products will identify customers, continuously collect various behaviors and statuses, access them through various networks, and transmit them to the back-end database. This network may be a private/non-public network or public cloud server. It can meet the future needs of IoT or SIoT users, if it can be combined with advanced artificial intelligence (AI) calculations, and proactively provide service suggestions, these may happen in the foreseeable future [3][4][5].

The demands for capacity, performance and reliability for telecom services are increasing more and more nowadays. Telecom operators are facing increasing demands for the network traffic. Thus, new solutions to accommodate the growth in their networks must be found. One of the solutions could be using 5G Fixed Wireless Access (FWA) to offer their customers a fast and affordable broadband service with higher performance, larger capacity and faster download speeds for its data traffic and lower latency. The article [6] provides an overview for this kind of 5G smart pole solution with the key advantages, technical characteristics, used spectrum, and high-level description of the system. For the past few years, with the popularity of Wi-Fi networks and 5G technologies, many affiliated applications of IoV gradually came true [7]. However, the excessive delay of its control and switch from end to end and insufficient transmission range causes the difficulties of practical use.

METHODOLOGY

How can these service-oriented algorithms be applied? For example, the difference between the code-based algorithm and the data-driven algorithm shows that the former is traditional logical thinking and judgment, with only TRUE or FALSE judgments, and requires less data, while the latter is based on the simulation of modern data science. Starting from the human mind, the amount of data required is large and numerous. Further, in order to provide multi-faceted functions such as SIoT factory instrument monitoring, the size and style of data will also increase and become more complex, and the design thinking of data communication also needs to keep pace with the times. In response to these needs, 3GPP is developing the 5G mMTC communication protocol to support the Internet of Things [8].

3GPP's 5G mMTC communication protocol in the Internet of Things has the original 5G feature of supporting OFDMA in the physical layer (PHY). Due to the sensitivity of the PHY layer of the wireless network to bit error and the extensive and special modulation and coding methods, special emphasis is placed on the linkage of radio resource allocation between the PHY layer and the MAC layer. Compared with the resource scheduling of the PHY, the resource scheduling methods of the MAC layer are more diverse and general. In order to cope with the sudden data traffic, the channel status changes at different time points, and the specific scheduling criteria, the MAC scheduler, must efficiently allocate available wireless network resources. For example, the MAC layer of the gNB must provide the UEs with a media layer that can access the shared media layer without contention, and it is also the most important and must prevent the interference problem caused by simultaneous transmission from multiple UEs. More specifically, 5G mMTC provides support for multiple service-oriented QoS types in terms of specifications, especially on the air interface, so as to meet the various needs of mobile users. Next, it is divided into three types of data communication schedules to explain:

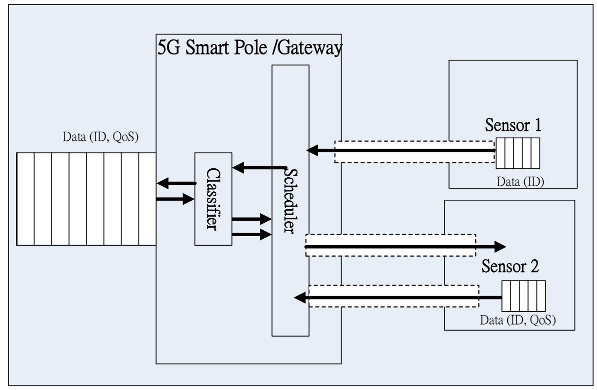

Fig. 2 Queue Petri Net (QPN)

A. Traditionally, considering the transmission capability of wireless sensors, maximize CINR and RSSI scheduling: arrange each service data stream in descending order based on the CINR and RSSI in each Sensor resource allocation area. This approach will have the primary goal of maximizing throughput, but may be unfair to all service streams. A similar method also directly maximizes the C/I (Carrier Interference ratio) allocation of resources, so that users with better channel quality can get more resource allocation, and the user's throughput will also be limited by SINR. That is, for users with poor channel quality, the relative SINR is also poor.

B. Consideration of dynamic resource allocation supplemented by gateway (5G smart pole) in the middle of transmission: Each signal frame of gateway includes the allocation of downlink and uplink frequency domain or time domain resources, and the scheduling service must provide both downlink and uplink traffic. In order for gateway scheduling to efficiently allocate resources and provide the desired QoS service quality between the downstream and upstream sections, the upstream must report accurate and timely information on traffic status and QoS requirements. The result of resource allocation is transmitted through broadcast messages at the beginning of each frame, so that the resource allocation of each frame can be changed according to traffic and channel status. The total number of resources allocated each time can be expanded from a single RB (Resource Block) to the entire signal frame, so that fast and precise resource allocation for data traffic can meet the planned QoS service quality.

C. Taking into account both sensor and gateway access and QoS/QoE-oriented algorithm: gateway connectivity schedules data transmission according to each connection. Each connection is associated with a single stream of data services, which in turn can utilize a set of QoS parameters to quantify various aspects of demand and behavior. With the ability to dynamically allocate resources, scheduling can provide better QoS performance for both downstream and upstream traffic. Especially in the uplink scheduling of SIoT, uplink resources can be allocated more efficiently. The performance can be accurately predicted and QoS can be more flexible and optimized.

Combining the above advantages of 5G mMTC, we can further avoid unnecessary false positives of SIoT. Data-driven supplemented by automatic or manual confirmation can reduce the number of false positives and false positives under normal conditions, and help alleviate the shortage of available resources in specific areas of the SIoT. Second, we can make good use of the physical layer characteristics of 5G mMTC to avoid competition in low-frequency communication. Many users of private networks in SIoT systems think that they only want to transmit data to the destination as soon as possible, not even take safety and convenience for other protocol users into consideration, this will exacerbate the problem of mutual interference. Self-centered attitude is a specific area of SIoT, the hardest avoidance factor at work. If every user can comply with the process of data transmission, including uploading link information and emergency notification, the effect of notification will be safer and more reliable. Using 5G mMTC and adding artificial intelligence algorithms can greatly reduce such false positives [9]. By sensing the surrounding traditional sensing networks and SIoT specific areas, the biggest problem of Smart IoT specific areas can be solved.

CONCLUSIONS

The main objective of this article is to develop an optimized QoS (Quality of Service) / QoE (Quality of Experience) management system that suits the 5G-based smart pole environment in order to utilize the restricted bandwidth more effectively. The QoS/QoE optimized rules that this article intends to develop can choose the best QoS resources of 5G communication based on current network status and aim at providing various services to transmit signals among 5G smart electric pole devices and 5G gNB/5GC to satisfy the needs in different scenarios. This article intends to implement two QoS/QoE management methods. First, after packet classification was completed, execute quantitative and qualitative model analysis and performance setting on packets through QPN (Queueing Petri Net) in accordance with superior order in different classes to choose the best 5G network scheduling (Fig. 2). Second, use artificial intelligence (AI) techniques along with users' experiences to determine the best QoS/QoE mapping in accordance with artificial neural network rules [9]. These two methods all have the advantages of low complexity of computing and fast responding. In the future, after further combining with 5G slicing network technology [2][3][4], the rules of QoS/QoE can be adaptively developed into bandwidth management mechanisms for 5G Smart Pole in accordance with users' needs for QoL (Quality of Living).

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