Research and Realization on Smart City Applications Based on eMTC wireless communication technology

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Abstract. In response to the call of strengthening the construction of the ubiquitous electric power Internet of Things by the State Grid Corporation, combining the urgent requirement in the construction of smart cities, this paper researched the application of wireless communication technology on smart street lamps based enhanced machine type communication (eMTC) technology. Based on this research, a kind of single-lamp controller PEC6403 based on eMTC wireless communication technology was developed. In order to realize remote control of the lamp, run data sampling in real-time and malfunction alarm, the TCP long connection established by the remote management platform and the eMTC wireless communication module was used to receive and send a message by this single-lamp controller. At last, this paper did some experiments to certificate the high communication rate, low latency, and low power consumption of this eMTC wireless communication module. Finally, this paper analyzed the problems existing in the large-scale promotion in the field of electricity application of the product and put forward the prospect of eMTC technology application in the electric field in the future.

Keywords: eMTC; smart street lamp; wireless communication; Internet of Things

1. Introduction
The State Grid Corporation of China proposed the "Three Types and Two Grids" strategy at the 2019 working conference, which is to build a hub, platform and sharing enterprise, build and operate a strong smart grid and ubiquitous power Internet of Things[1][2]. The Internet of Things [3] [4] is a network system that realizes the identification, perception, interconnection and control of power grid infrastructure, humans and the environment. Its essence is to realize the combination of various information sensing equipment and communication resources (Internet, telecommunication network, electric power communication private network), thereby forming a physical entity with self-identification, perception and intelligent processing. The collaboration and interaction between entities enable related objects to perceive and feedback control each other, forming a more intelligent power production and living system. Thus derives the ubiquitous smart grid-a full-service ubiquitous power Internet of Things based on communication technology.

Smart city [5][6] is an advanced form of urban informatization based on the next-generation innovation (Innovation 2.0) of the knowledge society by fully applying the new generation of information technology in all walks of life in the city, realizing the deep integration of informatization, industrialization and urbanization. As the in-depth expansion and integrated application of information technology, smart city is one of the important directions for the generation of breakthroughs in new
generation information technology and an important part of the development of global strategic emerging industries. The construction of smart cities is based on the application of information technology, and information technology is based on emerging hot technologies such as the Internet of Things, cloud computing, mobile Internet, big data, and artificial intelligence.

eMTC (enhanced Machine Type Communication) [7] [8] as an important branch of the Internet of Things technology, based on LTE[9] [10] protocol evolution, in order to become more suitable for communication between objects and lower costs, eMTC tailored and optimized the LTE protocol. eMTC is deployed based on cellular networks [11] [12], and its user equipment can directly access the existing LTE network by supporting 1.4MHz radio frequency and baseband bandwidth. eMTC supports a maximum peak rate of 1Mbps for uplink and downlink, and can support rich and innovative IoT applications. eMTC has the characteristics of high speed, mobility and positioning ability. Compared with NB-IoT[13][14], eMTC can meet industry applications with relatively high requirements for speed, voice function, mobility and positioning ability[15].

At present, most urban lighting street lamp controllers use PLC(power line carrier) communication module, which means data transmit through cables. The considerable advantage of this method is low construction and operating costs, however, there are also shortages such as poor signal quality, susceptibility to interference, and limited carrying services. In addition, an additional concentrator needs to be configured to centrally upload the information of each controller. Combining the characteristics of eMTC communication technology, this paper designs and implements a single-lamp controller PEC6403 based on eMTC wireless communication technology. The eMTC communication module on the controller communicates with the remote intelligent control platform through the eMTC network built by the operator for remote control. The platform can realize the remote control of street lights (including real-time switching, brightness adjustment, policy issuance, etc.), real-time operation data sampling, fault warning and other functions through message communication with eMTC.

2. Design
The system architecture is roughly divided into three levels: equipment layer, network layer and platform layer (as shown in Fig 1). The equipment layer mainly includes the single lamp controller PEC6403 based on the eMTC communication module, and the LED lamp power distribution cabinet. The power distribution cabinet is responsible for supplying power to the single-lamp controller and street lamps. The single-lamp controller controls the switch and brightness of the LED lamps, the message communication is carried out through the eMTC communication module and the remote control platform. The network layer is mainly an eMTC network built by communication operators, which consists of multiple eMTC base stations. The platform layer mainly includes the PEC6800 intelligent management and control platform, and a series of applications based on this platform, such as data display, intelligent management and control (including switch light control, brightness adjustment, policy issuance, etc.), mobile applications and real-time display of fault alarms, etc.

![System architecture diagram](image)

Fig. 1 System architecture diagram.
2.1. Module Design

The position of the eMTC communication module in the single lamp controller is shown in Fig 2. The red arrow represents the power signal, and the black arrow represents the serial digital signal. The module on the single-lamp controller produced by NARI also refers to this standard, so this module can be directly integrated into the PEC series. On the single lamp controller, namely PEC6403. The single board is mainly responsible for the communication between the terminal device (single light controller) and the remote control platform. After the terminal device is powered on, it will connect to the remote control platform through the eMTC network. After login authentication, the single light controller can receive remote control commands sent by the platform are executed and the real-time operating, besides, voltage and current information of street lights can also be actively uploaded.

![Fig. 2 The position of communication module on the light controller.](image1)

eMTC communication Module uses Quectel BG36 which integrated LTE Cat M1 and Cat NB1 (NB-IoT) solution that supports a maximum uplink and downlink rate of 375Kbps and has ultra-low power consumption. The size of BG36 is only 26.5mm × 22.5mm × 2.3mm. It also has the characteristics of low power consumption, high integration, high mechanical strength, etc., which can maximize the convenience of customers for product development. BG36 embeds rich network protocols, integrates multiple industrial standard interfaces (such as USB/UART/I2C/Status Indicator, etc.), and supports multiple drivers and software functions (such as Windows 7/8/8.1/10, USB driver of Linux and Android systems, etc.); greatly expanded its application in the M2M field.

eMTC communication module is mainly composed of 5 modules, which are power level conversion module, SIM card module, BG36 module, an external communication module, and debug serial communication module. The functional block diagram is shown in Fig 3, and the red arrow indicates the power supply. Signal, the black arrow indicates the serial digital signal.

![Fig. 3 eMTC module overall design diagram.](image2)
Power level conversion module is mainly responsible for supplying power to the BG36 module, external communication module and debug serial port module. SIM card modules are mainly used in GSM networks, W-CDMA networks and TD-SCDMA networks. BG36 module is a global multi-mode dedicated solution that integrates Qualcomm MDM9206 LTE IoT modem, which supports eMTC/Cat-M1, NB-IoT/Cat-NB1 and 2G/E-GPRS and achieves a maximum uplink and downlink rate of 375Kbps with low power consumption. External communication module is the interface between itself and other boards or products (such as NARI single-lamp controller or single-phase electric energy meter). Debugging serial port module is mainly composed of two sets of serial communication modules. One set of serial communication modules is mainly used to output the debugging and diagnostic information of the BG36 module itself to assist in locating communication problems, the other set of serial communication modules is used to debug the information of satellites positioning system.

2.2. Communication Protocol Design

The communication protocol of the eMTC module supports TCP or UDP protocol at the same time, remote management and control platform serves as the server, and the eMTC wireless communication module serves as the client. The protocol uses little-endian mode to transfer message. Each message is composed of package header, message header, message body, CRC check code and terminator. The message structure diagram is shown in Table 1:

| package header | message header | message body | CRC check code | terminator |
|----------------|----------------|--------------|----------------|------------|

**Tab. 1** message structure T

Package header has a total of 4 bytes, consisting of a start character (68H), length identifier field, and a start character (68H). Length identifier field describes the number of the total bytes of the message header and the message body by two bytes. Message header consists of message id, message body attributes, module id, message serial number, message package encapsulation items, and time stamp. Message body is consist of the bytes of specific application.CRC check code is used to check whether the message is broken. Terminator is a fixed type that represents the end of the package.

2.3. Message Interaction

Remote management and control platform (mentioned as platform afterward) adopts a multi-thread response mode. When a connection request from an eMTC communication terminal (mentioned as terminal afterward) is monitored, a TCP long connection thread is created to communicate with the terminal. When platform does not receive the message sent by the communication terminal until the maximum lifetime (default 60 seconds) reaches, the TCP long connection thread established before is automatically terminated. Terminal will resend the message when it does not receive any reply message from platform within 20 seconds after it sends a message to platform. After resends three times without receiving any reply, the terminal automatically restarts.
The communication messages exchanged between platform and terminal are roughly divided into four categories: login messages, heartbeat messages, inquiry messages and control messages. The specific interaction process is shown in Fig. 4, where the red arrow represents the logic flow, and the black arrow represents the data flow.

Login message: After a terminal is powered on with a series of configurations, after successfully connecting with platform, it sends a login message to the platform to inform platform that the module is online immediately. After platform receives the login message, platform updates the states of the terminal to logged in and replies to it with a general response message.

Heartbeat message: Terminal actively sends heartbeat messages to platform at regular intervals (30 seconds by default) to inform platform of the current online status of the terminal, and platform will mark the terminal after receiving the heartbeat message to be online and reply a frame of message to the terminal, if platform does not receive a terminal's heartbeat message for a certain period of time (60 seconds by default), the communication state of the terminal will be set to offline.

Inquiry message: Platform sends this message to specified terminal, requesting the status information of the terminal (including clock, strategy, control mode, operating parameters, etc.). After receiving a request message, the terminal will encapsulate the information inquired by platform into a reply message by protocol and reply it to platform. After receiving the response message from the terminal, platform parses the response message to obtain the status information of the terminal.

Control message: Platform sends this message to specified terminal. After receiving control message, the terminal performs corresponding control operations, and then sends a reply message to platform to inform whether the corresponding operation has been performed. After receiving the response from the terminal, platform parses the response message to update the terminal status information.

3. Experimental verification

3.1. Power-on verification
After the power is turned on, the embedded program of the module will actively pull down the PWRKEY pin of the BG36 chip to turn on the module. As shown in Fig 5, the red light STATUS on the eMTC module lights up to indicate that the module has been powered on normally, and the green light NET Flashing indicates that the eMTC signal is normal.
3.2. Sending and receiving message verification

After booting up and completing the configuration, the eMTC module starts to send a login message to the remote management and control platform, as shown in Fig 6(a). After receiving the login message, the management and control platform sends a login confirmation message to the eMTC module, as shown in Fig 6(b), the eMTC module starts to send heartbeat messages to the management and control platform after receiving the login confirmation message.

3.3. Communication performance verification

The eMTC module currently only supports a maximum baud rate of 115200 while the theoretical maximum rate supported by eMTC technology is about 375Kbps. There is no packet loss under the measured rate of 115.2Kbps.

Time delay refers to the timing from the TCP message sent by eMTC module, the data is sent out through the wireless communication serial port, and reaches the remote control platform via the core network and the Internet. The remote platform parses the TCP message and sends corresponding response message after receiving the TCP message. The remote control platform The total time for the sent response message to reach the eMTC module through the Internet and core network.

Experiment simulates 50 pieces of message data sent by the single lamp controller equipped with eMTC module, and these data were sent to the remote platform through the eMTC network established by operators. The remote platform will reply response message to the eMTC communication module after receiving the message. T 2 records the delay records of these 50 sets of data. Among the 50 sets of data, the maximum delay is 392 milliseconds, the minimum delay is 312 milliseconds, and the average is 351.8 milliseconds, which conforms to the delay requirements of street lamp control for data transmission.

| num | time(ms) | num | time(ms) | num | time(ms) | num | time(ms) | num | time(ms) |
|-----|----------|-----|----------|-----|----------|-----|----------|-----|----------|
| 1   | 322      | 11  | 362      | 21  | 362      | 31  | 362      | 41  | 342      |
Tab.2 experiment data of delay between module send and receive message

3.4. Power consumption verification

In eMTC module power consumption verification, with DC power supply with voltage of 12V and maximum current of 1A provided, and the eMTC is normally turned on. As shown in Fig 7(a), the eMTC communication module operates at a current of about 6mA and a power of about 0.072W in standby state. When sending a message, as shown in Fig 7(b), the operating current is about 35mA and the power is about 0.42W.

Fig.7 verification of power consumption under sleeping and sending message

3.5. Verification summary

Except these test above, more experimental verification has been taken in our laboratory, such as packet loss rate validation, bit error rate validation, max communication distance validation, and so on. According to the requirement in smart lamp control and management system, the comparison between experimental results of eMTC module and PLC module has confirmed the fact that eMTC has better performance than PLC in long-distance data transmission which appears frequently in lamp control and management, while PLC communication technology is used widely at current.

In addition, PEC6403 single-lamp controller prototype equipped with the eMTC module mentioned in this article has been sent to the experimental verification center of State Grid Electric Power Research Institute Co., Ltd. for third-party testing. The controller passed all the experimental tests and met the product registration and filing conditions.

4. Conclusion

This paper studies the feasibility of eMTC communication technology in smart city applications. Based on this research, designs and develops a single-lamp controller PEC6403 based on eMTC wireless communication module. The function and performance of the communication module are verified through experiments. PEC6403 has The pilot project was put into operation at the site of Guodian NARI Guangzhou Street Lighting Project. However, there are still two shortages with this module for the large-scale market:
Firstly, high production cost makes eMTC communication module has no price advantage when compared to the other mainstream wireless communication modules in the industry. 

Besides, the research and development of eMTC communication modules are carried out in the eMTC pilot area. eMTC wireless network coverage is not enough currently.

Further promotion of eMTC in the power field will be paid more attention, in addition more cooperation with operators will be set up to open more eMTC pilot areas, finally more applications of eMTC communication technology in the power system will be explored, such as eMTC smart electric meters and eMTC electric distribution terminals, etc.

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