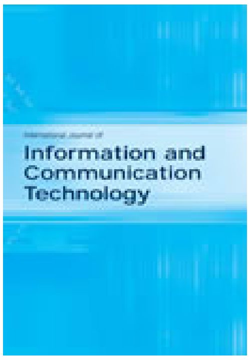

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Optimisation and security fuzzy control of power wireless private networks in internet of things and 5G environments

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Abstract: In order to improve the operating efficiency of PWPNs, this paper proposes an improved genetic algorithm to realise the location planning of 5G base stations in PWPNs. Aiming at the unreliable adaptability of fuzzy control (FC) system to communication channel, this paper proposes an enhanced multi-sampling time fuzzy switching control system. This paper combines experimental research to verify that the power wireless private network (PWPN) optimisation and security FC method proposed in the internet of things (IOT) and 5G environments has certain effects. The communication channel level with a health quality of 85% shows that the proposed solution is effective and the update mode response is good. Therefore, under the same system parameters, this study can afford poor communication channel health quality. It improves the communication transmission quality adaptability of the control system to unreliable communication channels (UCC) and provides a reference method for subsequent optimisation and construction of 5G PWPNs.

Keywords: internet of things; IoT; 5G; power wireless private network; PWPN; fuzzy control system.

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1 Introduction

In the development process, it basically follows the development of public telecommunication network. In the past, because of the particularity of the power services it carries, the construction and development of the power communication network has its inherent characteristics, such as power carrier communication, high-frequency protection communication, etc. However, with the continuous development of communication technology, public network technology has gradually occupied a dominant position in terms of network scale and technical level.

Energy is the material basis of human activities. Human utilisation of energy has gone through three stages: from primitive fire to fossil energy and now to electric energy. It can be said that human progress is inseparable from the change of energy technology. Since the second industrial revolution, electric energy has become the main form of energy used by human beings because of its easy transmission, easy conversion and easy use (Dai et al., 2021). However, the increasingly serious environmental pollution and the exhaustion of traditional energy have attracted people's attention. All walks of life have done a lot of research on developing new renewable energy and further improving the utilisation rate of existing energy. At present, the three concepts of smart grid, energy integrated system and energy Internet that have emerged in the energy field all aim to achieve the goals of environmental friendliness and sustainable energy supply through these two ways. The next generation power grid will become a network for large-scale new energy transmission and distribution, and widely integrate information technology and Internet technology to become more intelligent and stronger (Zhao et al., 2022).

Information and communication technology is the foundation for building the next generation power grid. IOT technology interconnects hundreds of millions of devices in energy production, transmission, and consumption to form an energy Internet and realise comprehensive utilisation of energy. The Energy Internet is a large system with high integration of energy technology and information technology. Its complex communication structure requires strict information interaction. Therefore, it requires a communication network with high reliability, high security and two-way transmission capabilities (Wang et al., 2021).

The distribution network has complex structure, different business needs, many power users and wide geographical distribution. Therefore, power enterprises and operators tend to set up wireless communication networks to realise the communication between power equipment. At present, there are two main application modes of power wireless networks: public network application mode and private network application mode. The public network model mainly refers to power companies renting a large number of public communication channels and mobile terminals from mobile operators. This model has the advantages of fast early deployment and small investment. However, public network communication cannot effectively guarantee the security of power communication and prevent illegal terminal access, while the delay and communication reliability cannot meet the demand.

The ubiquitous power internet of things (IoT) requires an efficient transmission power communication network to achieve the above goals. The power communication network mainly consists of a backbone communication network and a terminal communication access network. At present, the collection frequency is relatively low, which makes it impossible to achieve real-time perception of the power grid. This not only causes resource waste, but also poses a huge challenge to user behaviour analysis;

The communication network has not fully achieved the coverage of emerging businesses in the ubiquitous power IoT, such as electric vehicles and distributed power sources. With the continuous advancement of ubiquitous power IoT construction, researching wireless power private network systems is of great significance and application value. Due to the limited bandwidth, capacity, and latency of TD-LTE based power wireless private networks (PWPNs), they are unable to adapt to the explosive growth of ubiquitous power IoT business types and quantities. Taking into account both economic and forward-looking principles, it is proposed to deploy 5G base stations for the PWPN simultaneously to solve the communication performance issues of the PWPN; In response to the adverse impact of packet loss caused by unreliable communication channels (UCC) in PWPNs on remote control of grid access equipment, an enhanced multi sampling time fuzzy switching controller is designed to improve the adaptability of the control system to the communication transmission quality of UCC. Fuzzy control systems might not always guarantee the real. time responsiveness needed in such environments due to computational overhead or communication delays. So, how to overcome this. In order to improve the operating efficiency of PWPNs, this paper proposes an improved genetic algorithm to realise the location planning of 5G base stations in PWPNs. In addition, aiming at the unreliable adaptability of FC system to communication channel, this paper proposes an enhanced multi-sampling time fuzzy switching control system.

The main contributions of this article are as follows:

1. A model that considers the connection between 4G/5G communication technology and the planning problem of PWPN base stations. A planning method for PWPN base stations based on improved genetic algorithm was proposed; optimise the coding and population initialisation operations in genetic algorithms by combining the location selection of PWPN base stations; The simulation results show that the improved genetic algorithm has good performance and can achieve excellent 4G/5G base station planning for PWPNs in the ubiquitous power IoT environment.
2. Propose an enhanced multi sampling time fuzzy switching controller to solve the adaptability problem of control systems to UCC. Compared with the methods reported in recent literature, more switching modes have been designed based on the updated information at each sampling moment, thus creating more freedom by introducing and allocating additional variables for all possible switching modes.

2 Related works

In recent years, the requirements for communication in power system management and production have been continuously increasing. The construction of ubiquitous power has been considered as a major construction goal for modern power supply enterprises, which is equally important as the construction of smart grids. Fibre optic communication has replaced microwave communication and power line carrier communication as the main technical system of power communication network, and most communication services are gradually developing towards IP direction. Intelligent optical network and soft switching technology are also widely used in power communication network (Yan et al., 2020).

Ethernet passive optical network technology, commonly known as Epon technology, is widely used in fibre to the home broadband in the public network field. It has the advantages of low terminal cost, flexible deployment, and flexible integration with SDH backbone networks (Aijaz, 2020). This technology is widely used in the construction of communication bearer networks for distribution automation. Based on passive optical multiplexing technology, this technology can achieve information transmission from multiple terminals on a single line with fewer fibre cores, effectively saving fibre core resources; On the other hand, optical cables can be installed along distribution lines, pipelines, and poles, which has the inherent advantage of laying Epon network optical cables and reduces the difficulty and cost of optical cable construction. According to the specific requirements for communication quality and security in power distribution automation, State Grid Corporation of China has clearly stipulated that wireless public networks are prohibited from carrying power grid control related services. At present, terminals without remote control function in distribution automation generally use Epon or wireless public network communication methods, while terminals with remote control function in distribution automation generally use Epon communication methods. For businesses with relatively low reliability and safety requirements, such as low-voltage electricity collection, distribution transformer monitoring, and various mobile office, intelligent inspection, video surveillance, etc. Due to economic considerations, the communication method of renting wireless public networks from operators has been widely adopted. The deployment of various business master station systems is relatively scattered, without unified interface specifications, and data exchange between systems is difficult, resulting in professional barriers (Liu and Simeone, 2020). With the uneven development of various communication technology systems in the access layer power communication business, there is an increasing demand for the integration and consolidation of terminal communication services (Shen et al., 2021).

For the development of network planning, there have been some cases of using intelligent algorithms to study base station planning. Wen et al. (2021) proposed using greedy algorithms to solve base station planning problems, focusing on coverage range during planning. By gradually traversing all base stations, the problem scale is reduced until the terminal coverage meets the requirements. This method does not consider time costs and is prone to system crashes when the number of terminal points increases dramatically; Jiang et al. (2020a) introduced an immune algorithm to optimise the planning of TD-SCDMA network base stations, in order to increase the construction cost of base stations and reduce the radiation impact of base stations to meet the coverage requirements of the base station planning scheme; Ashraf et al. (2021) used genetic algorithm to solve the base station planning problem, and improved the algorithm operation to obtain a better base station distribution scheme. However, this method requires controlling multiple variables and has complex operations, resulting in slow solving speed

Scholars both domestically and internationally have conducted extensive research on the interference localisation problem in power wireless communication. Serôdio et al. (2023) proposed a positioning algorithm based on azimuth and network topology. This method introduces azimuth error weights to eliminate and correct azimuth, and uses Brownian least squares triangulation to determine the estimated coordinates of the signal transmission source. Chen et al. (2020) adopted the commonly used arrival time method and arrival angle method based on three base stations, and finally located the signal source by calculating the intersection points of multiple time difference curves; Jiang et al. (2020b) adopts the AOA-RT positioning algorithm based on ray tracing, and uses mirror stations to locate the target interference source in the micro cell AOA positioning model.

Anajemba et al. (2021) divides the detection area uniformly into a grid shape, and the observation stations on known nodes estimate the distance between the target and the observation station based on the transmission power and their own received power to signal strength.

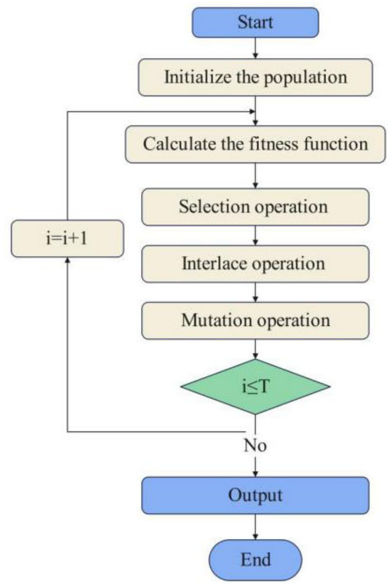
Network selection algorithm is an important part of wireless resource management technology, and previous researchers have conducted extensive exploration. There are three classic network selection algorithms: received signal strength (RSS) based network selection algorithm, multiple attribute decision making (MADM) based network selection algorithm, and artificial intelligence based network selection algorithm. The selection criteria for network selection algorithms based on RSS are mainly based on the size of the RSS value of the coverage network measured by the user equipment to determine whether to access the network and whether to switch (Guo et al., 2022). Only considering RSS for network selection can easily lead to ping-pong effect, while network algorithms based on multi-attribute decision strategies comprehensively analyse and compare multiple network parameters to determine the optimal network access. However, MADM also has the problem of inaccurate description of attribute parameters (Chilamkurthy et al., 2022). Artificial intelligence based network selection algorithms can generally be divided into neural network-based network selection algorithms, game theory based network selection algorithms, and Markov decision process based network selection algorithms. The main purpose is to apply intelligent algorithms to achieve intelligent autonomous network selection, which can select networks more accurately (Buurman et al., 2020). The existing algorithms have their own advantages, but each has its own problems. Here are some examples to illustrate. Arachchige et al. (2023) proposed an access selection algorithm that prioritises high available bandwidth access, while considering the impact of signal-to-noise ratio on access. However, it did not take into account the real-time changes in network resources and the impact on security, which may result in resource waste. Cheimaras et al. (2023) proposed an access control algorithm based on game theory, but the existence and uniqueness of the Nash equilibrium point in this algorithm cannot be guaranteed. Gupta and Sinha (2021) considered various performance parameters in the network selection process, including RSS, available bandwidth, security, network cost, and power consumption. However, this algorithm only considers the current network state and ignores changes in network conditions after accessing the network.

3 Algorithm model

3.1 Genetic algorithm

From the perspective of optimisation, genetic algorithm determines the direction of population development to a certain extent by imposing operations on individuals in the population, and finally finds the global optimal solution. The implementation flow of basic genetic algorithm is shown in Figure 1.

Figure 1 Flowchart of basic genetic algorithm (see online version for colours)



Genetic algorithm mainly refers to the fitness function in the algorithm when solving optimisation problems. Genetic algorithm is not limited to the specific field of optimisation problems, but is suitable for solving optimisation problems in various fields, such as adaptive control, planning and design, function optimisation, image processing and so on. If the basic genetic algorithm is directly applied to the base station optimisation problem of PWPN, it may have low efficiency and fall into the local optimal solution. Therefore, the initial population generation, coding and other operations in genetic algorithms need to be designed in combination with the actual background of PWPNs in the ubiquitous powerIOT environment. Figure 2 is a flowchart of base station location based on improved genetic algorithm.

1 Coding:

N_{5g}, and N_{4g} represent the number of 5G and 4G candidate base station positions respectively, and their values can be calculated by equation (1). The larger the encoding dimension, the longer the running time, and it is difficult to find the global optimum (Yin et al., 2024).

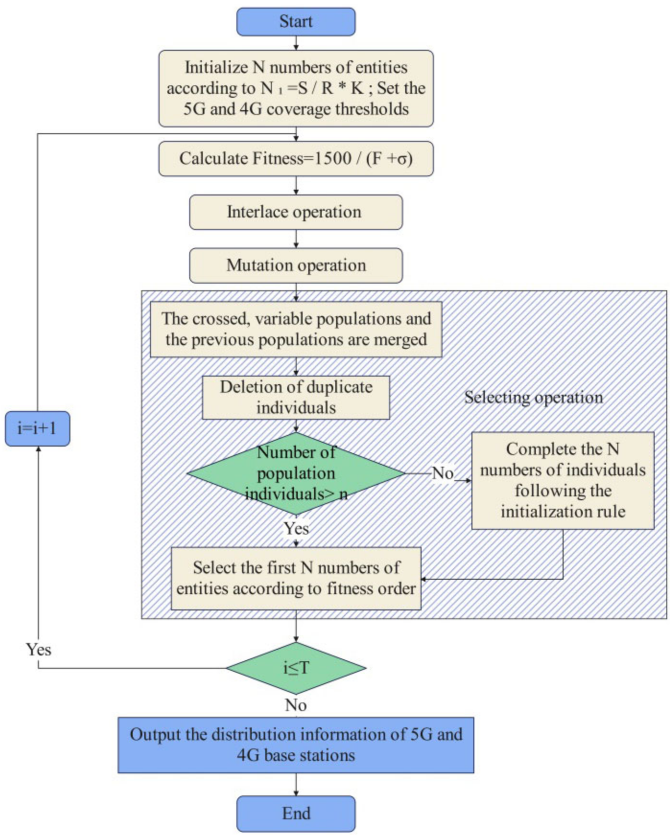
$$L = N_{5g} + N_{4g} \tag{1}$$

2 Initial population

The initial population generation flow chart in the genetic algorithm of this paper is shown in Figure 3. The number of ‘1’ generated by individuals in the population is according to equation (2), N1 represents the number of selected 5G or 4G candidate base stations in the population individuals, S represents the approximate distribution area of 5G or 4G test points in the base station planning area, R represents the coverage area of power wireless 4G/5G base stations, and K is the redundancy coefficient, which generally takes 1.5–2 (Laghari et al., 2023a).

$$N^1 = \frac{S}{R} \times K \tag{2}$$

Figure 2 Flowchart of base station location based on improved genetic algorithm (see online version for colours)

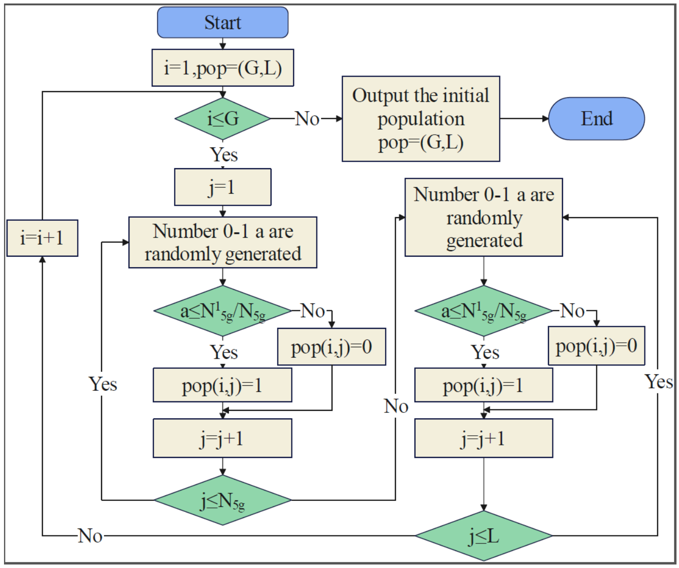


3 Fitness function

The purpose of this paper is to ensure the coverage rate while realising the deployment cost of PWPN base stations as low as possible. In equation (3), F represents the objective function and σ represents the penalty function. If the coverage rate of 4G and 5G test points is met, the penalty value is 0 (Waqas et al., 2022).

$$Fitness = 1{,}500/(F + \sigma) \tag{3}$$

Figure 3 Initial population generation method of base station (see online version for colours)



4 Select operation

The genetic algorithm adopts the selection strategy of considering the contemporary population and the previous generation population at the same time. The previous generation population after crossover and mutation operation is merged with the previous generation population, and the duplicate individuals in the merged population are deleted. The first n individuals are selected as the contemporary population according to the fitness value from high to low. This operation can ensure that the population develops in the optimal direction.

5 Crossover operation

In this paper, the genetic algorithm adopts single point crossover. Firstly, the number between 0–1 is randomly generated, and the number between 0–1 is compared with the current crossover probability to judge whether the individual population crossover or not. Then, the crossover position of the individual is determined by random number, and the base station distribution information is exchanged (Gao et al., 2023a).

$$Pc = 0.9 - (i / T) \times (0.9 - 0.5) \tag{4}$$

6 Variation operation

In this paper, the genetic algorithm adopts gene locus mutation. When the number between 0–1 randomly generated is less than the current mutation probability, the position that needs to be mutated in the individual is determined by random integer, and the binary code ‘1’ becomes ‘0’, indicating that the base station is built at the candidate location at the present time, and the base station is not built at the next generation. ‘0’ to ‘1’ is the opposite. The mutation probability of traditional genetic algorithm is a fixed value, and the crossover probability adopts equation (5) (Gao et al., 2023b).

$$Pm = 0.2 - (i / T) \times (0.2 - 0.02) \tag{5}$$

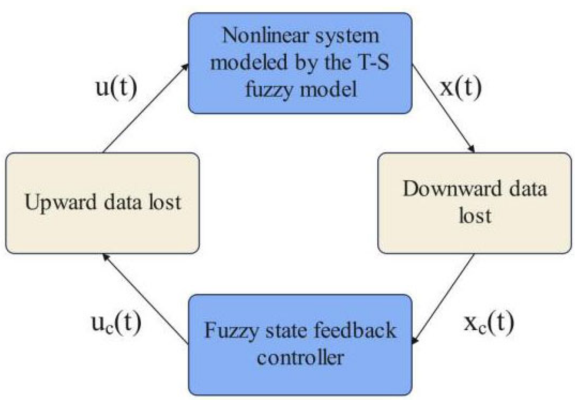
Its main characteristics include the following aspects:

1. When encoding, the algorithm first analyses and preprocesses the location information of the 4G/5G test points and candidate base stations to reduce the individual encoding dimension in the population as much as possible and reduce the population search space. This operation can improve the search efficiency of the algorithm to a certain extent.
2. The randomly generated population is too random, so the number of 0 and 1 of each individual in the binary coded population is usually not much different. This paper proposes an initial population formation method.
3. The crossover and mutation probability are related to the number of iterations. The algorithm has high mutation probability in the early stage, enriches population diversity. Moreover, the mutation probability decreases gradually, which is beneficial to the convergence of genetic algorithm.

3.2 FC system

This paper proposes an enhanced multi-sampling time-time fuzzy switching controller with more flexible switching modes (2r is the possible switching modes, and r is the number of fuzzy rules), so as to solve the adaptability of fuzzy nonlinear control systems with UCC to UCC in wireless transmission environments.

Figure 4 FC system (see online version for colours)



FC system is shown in Figure 4. The packet loss phenomenon of wireless communication is becoming more and more serious, and even network attacks are becoming more and more serious. The timing relationship provided is as follows (Fatima et al., 2023):

$$\begin{aligned} &\chi(t) \Rightarrow \chi_c(t) \Rightarrow \gamma_1(t)\chi(t) \Rightarrow u_c(t) = \gamma_1(t)K\left(\varsigma(t)\right)\chi(t) \Rightarrow u(t) = \\ &\gamma_2(t)u_c(t) \Rightarrow \gamma_1(t)\gamma_2(t)K\left(\varsigma(t)\right)\chi(t) = \chi(t+1) \end{aligned} \tag{6}$$

Among them, $K(\varsigma(t))$ is the time-varying control gain matrix, the FC system can be written as (Laghari et al., 2024):

$$\begin{aligned}\chi(t+1) &= \sum_{j=1}^{r} h_j\left(\varsigma(t)\right)\left(A_j\chi(t)+e(t)B_ju(t)\right) \\ &= \sum_{j=1}^{r} h_j\left(\varsigma(t)\right)\left(A_j\chi(t)+\left((\bar{e})+\tilde{e}(t)\right)B_ju(t)\right)\end{aligned} \tag{7}$$

Among them, $\chi(t)\in\mathbb{R}^{n1}$ represents the system state vector, $u(t)\in\mathbb{R}^{n1}$ represents the control input vector, $\varsigma(t) = (\varsigma_1(t), \ldots, \varsigma_n(t))$ represents the fuzzy premise vector, and $h_j(\varsigma(t))$ represents the fuzzy weighting function with normalisation.

4 PWPN combining theIOT and 5G environment

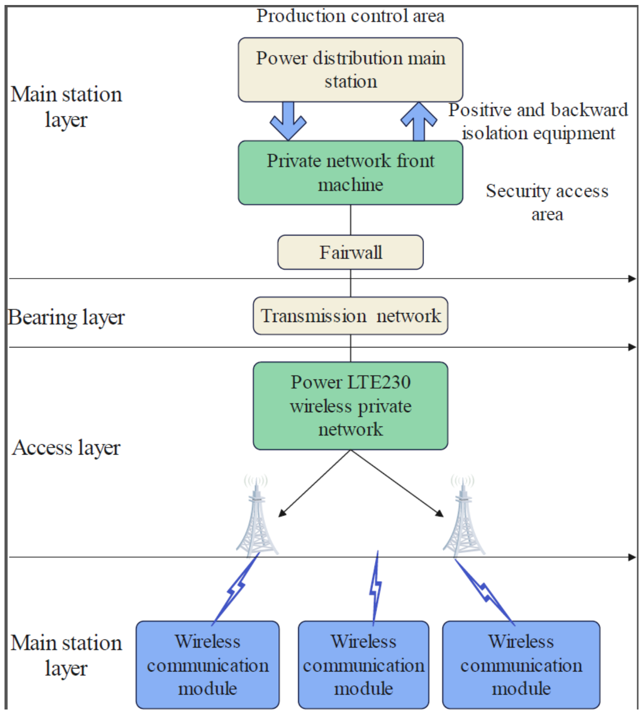
This article adopts the wireless private network form to construct the communication architecture of the power system. This method not only improves the flexibility of the wireless private network networking mode, but also saves the related laying costs of wired communication cables. It is not restricted by a single grid structure and can carry out large-scale coverage. Therefore, it can effectively reduce system communication latency. Adopting the LTE230 PWPN system for electrical information collection and communication terminals, corresponding communication terminal modules can be provided for various terminal devices owned by the power information collection system for different businesses. The various forms, interfaces, and protocol specifications inside the communication module comply with international standards, and various power business terminals can be directly used, fully compatible, safe, and reliable.

4.1 System model

Distribution network automation can be understood as adopting many advanced science and technology such as modern electronic technology, communication, computer and network technology, etc. to integrate the real-time state, off-line information, user data, power grid equipment structure technical parameters, geographical conditions. It can carry out its own monitoring, protection, control and distribution operation and maintenance management during the normal operation of the distribution system and under accident situations, and can carry out intelligent monitoring and management regardless of whether the distribution network is offline or online. Therefore, the distribution network will always be in the optimal operation state, including safety, economy, reliability and high efficiency. The power grid establishes a transmission channel based on 230 MHZ PWPN and adopts the carrier aggregation implementation scheme based on NC-OFDM and the dynamic spectrum access scheme based on hidden Markov model. The safety and stability of related data information transmission are improved, the power loss of AC sampling is reduced, and the fault current error is reduced (Laghari et al., 2023b).

Wireless access solution in this section is: The power terminal communication access network based on the LTE230 wireless communication system adopts a star structure and cellular networking to achieve regional planar coverage, which is very convenient for centrally distributed or discretely distributed distribution terminal communication access. The implementation method is shown in Figure 5.

Figure 5 Wireless access scheme of distribution automation terminal (see online version for colours)



Private protocols are adopted to avoid the risk of illegal theft of power data. The wireless private network system adopts 'terminal-base station-core network' two-way authentication and three-layer encryption mechanism to ensure the security of service information and control information. The data channel is connected to the power distribution master station system through a uniformly constructed safe access area.

Distribution automation consists of three hierarchical structures: master station layer, communication system layer and terminal system layer. Its hierarchical structure diagram is shown in Figure 6. Three layers are discussed below:

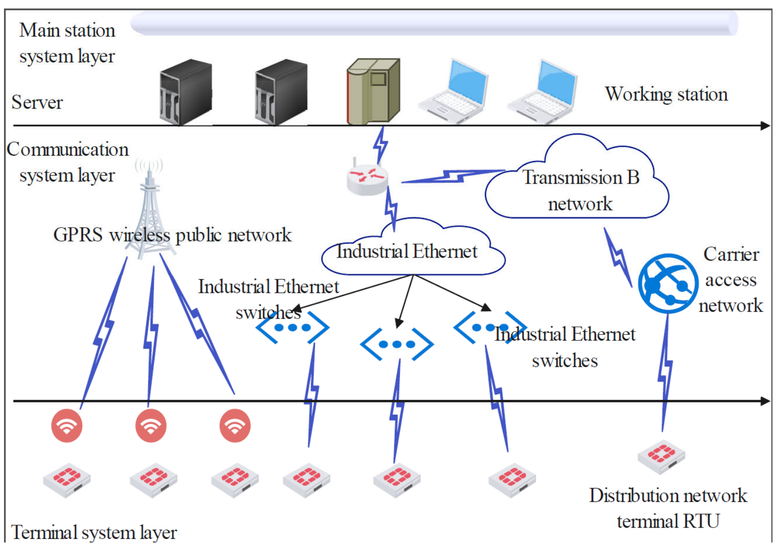
1 Master station layer: this layer is the core part of the entire distribution automation system. It collects digital information transmitted by terminal equipment, calculates, processes and stores the numbers, and then sends out fault alarms and remote control, isolates faults, restores power supply in fault-free areas and other functions. Distribution automation takes UNIX as the platform and adopts TPC/IP transmission protocol.

2 Communication system layer: the communication system layer plays a connecting role in the system, and it transmits the commands of the master station layer to the terminal layer, and at the same time sends the data of the terminal layer to the master

station layer, so that all systems of the distribution network keep close contact. According to the overall design of the system, the functions of the communication system layer can be divided into two types, one is centralised system feeder automation, and the other is distributed feeder automation.

3 Terminal system layer: the terminal layer belongs to the lowest layer of the distribution automation system. Terminal equipment includes many devices, mainly including: FTU, TTU, and DTU. The applications of these terminal equipment are different. FTU cooperates with the switch on the same column, TTU is applied to the distribution transformer monitoring unit, and DTU is the terminal unit in the ring main unit of the switching station. These devices undertake corresponding tasks respectively, and their main role is to control load switches, switching stations, distribution transformers and equipment, etc. In addition to this, they adjust how the system operates.

Figure 6 Schematic diagram of distribution network automation system (see online version for colours)



Damage to power facilities is often accompanied by large-scale power outages in the power grid, and the base station systems and optical cable communications of nearby operators cannot work. The communication means of on-site emergency repair work is the guarantee of emergency repair efficiency. At present, there is a lack of communication means in emergency repair, and communication systems with different technical systems are mixed with each other, so there is no unified platform. The power emergency repair communication diagram is shown in Figure 7. The PWPN is used to undertake the power emergency repair task, and it has the advantages of combining flat stations, high capital utilisation rate, convenient deployment, flexibility and speed, and large coverage area.

Firstly, the interface between LTE230MHz wireless broadband communication system and Beidou positioning system is developed, the interaction protocol is redefined, and the data service is debugged to ensure reliable and safe data transmission. The power terminal user accesses the PWPN through the LTE230 base station, completes the interactive comparison and correction of data with the Beidou system data center, Beidou system receiver and Beidou system reference station through the LTE230 core network, and has the function of timely data collection and accuracy. The mobile terminal can interact the accurate location of the power fault point to the background system, and call the post-event data to realise comprehensive and detailed information data analysis, query and timely update of the power equipment. Figure 8 is an interactive topology schematic diagram:

Figure 7 Power emergency repair communication diagram (see online version for colours)

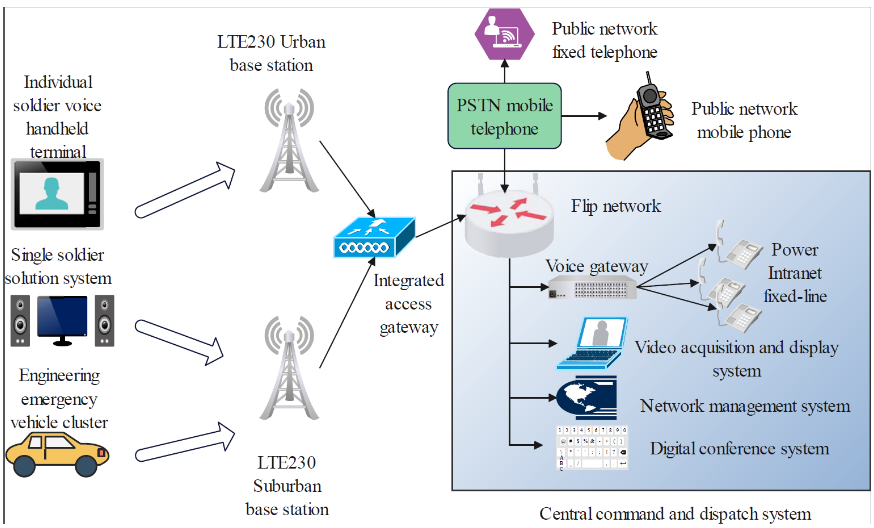
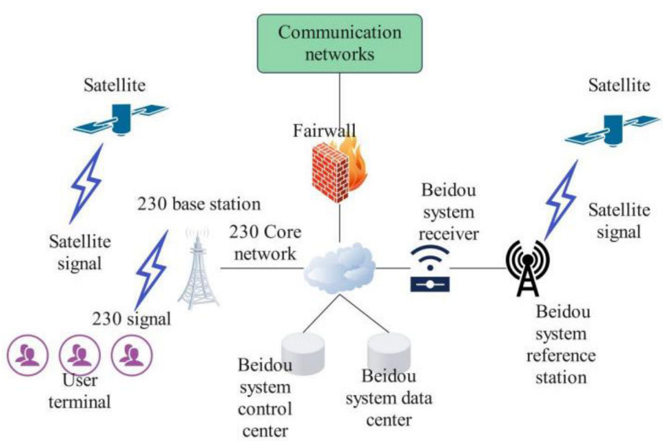


Figure 8 Interactive topology schematic diagram of wireless private network and Beidou positioning system (see online version for colours)



Key negotiation requires data exchange between the key server and the client. In order to facilitate the transmission of message structures defined in memory over the network, Google's open-source protobuf is chosen as the data exchange format. For a structure, simply define the .proto file in the corresponding format, and then use protoc.exe to interpret and compile it to generate the corresponding C++header and source files Serialise and deserialise our structure through API functions. During the key negotiation process, the key client sends a keyreqmsg message to the key server, and the server responds with a keyRessg message to the client. The definitions of these message structures are as follows:

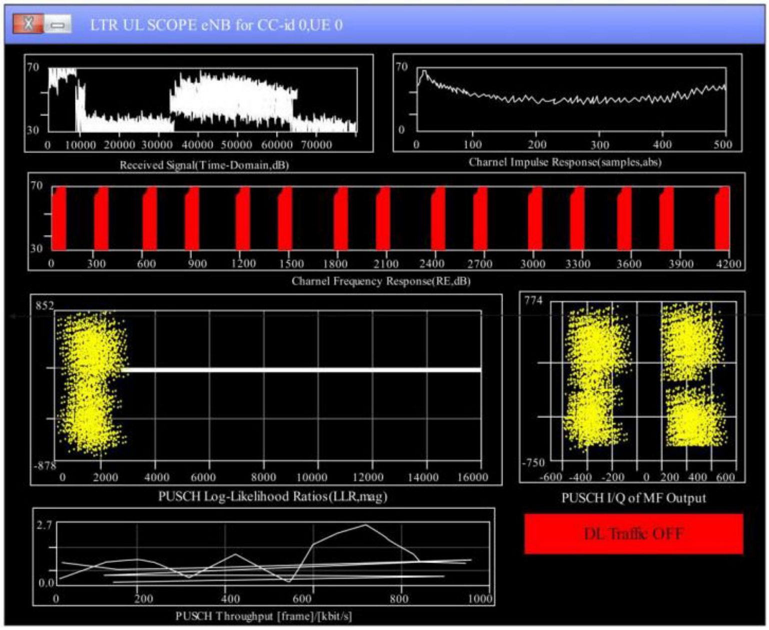
```
struct KeyReqMsg
{
int         cmdType;
string      clientNodeld;
string      authcode;
string      server id:
string      keyFromClient;
};
struct KeyReqMsg
{
int         resV:
string      clientNodeld;
string      serverNodeld;
string      keyFromServer;
int         seqOfkey;
};
struct KeySynMsg
{
int         keyID;
string      clientNodeIP;
string      serverNodeIP;
string      createTime
};
```

4.2 Experimental study

Firstly, this paper builds a complete LTE simulation system, and builds a test environment in two local area networks. The reason is that the security gateway uses dual hosts, and the intranet host and the core network host are in the same LAN. At the same time, the addresses are mapped, so Host 2 can access Host 3. Using the relatively simple network isolation products provided by others, the program developed by this paper is deployed to the internal and external network hosts of network isolation, and some adjustments are made to the software.

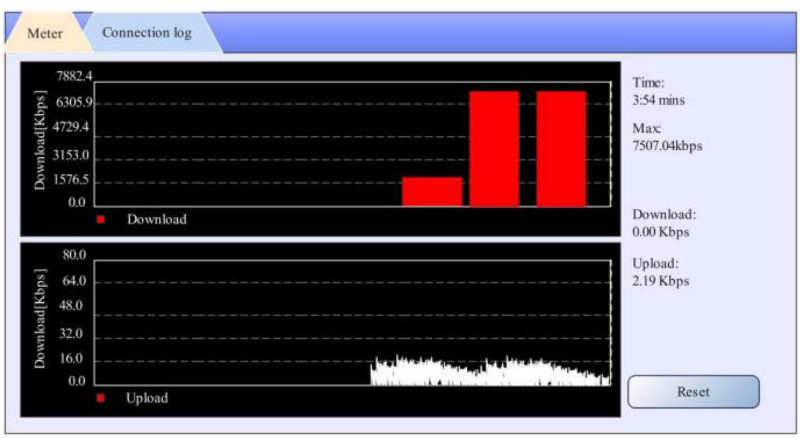
When the system is successfully connected, eNB (Enhanced Node B) will receive the connection reconfiguration complete (CRC) message, and the UE successfully connects to the eNB oscilloscope display is shown in Figure 9.

Figure 9 Oscilloscope (see online version for colours)



When all components of the system run successfully, the data throughput of the system is tested using the tools provided by OAI, as shown in Figure 10.

Figure 10 Data throughput test results (see online version for colours)



For example, there is e = 85% in this case study, and Figure 11 shows the results of the application.

Figure 11 Communication channel with health quality of 85% (see online version for colours)

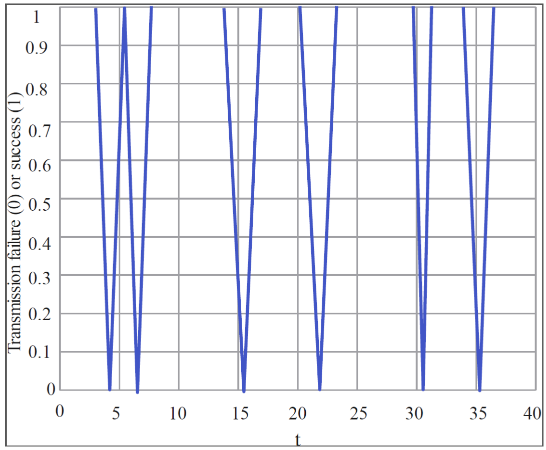
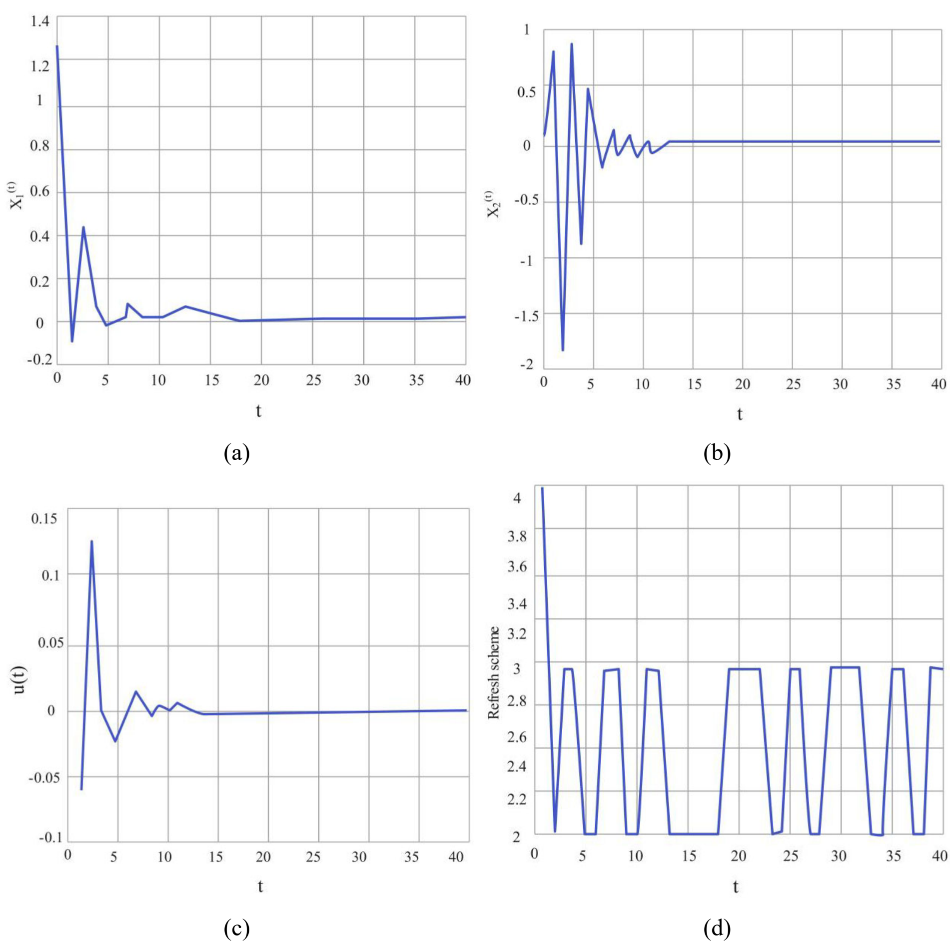


Figure 12 Response diagram, (a) $x_1(t)$ (b) $x_2(t)$ (c) $u(t)$ (d) update mode (see online version for colours)



When the initial value $x(0) = (\delta \text{ max}, 0.75)^T$ is selected as the health quality of the communication channel, the fuzzy handover control method proposed in this paper is used for testing. Figures 12(a) and 12(b) respectively provide two response curves of $x_1(t)$ and $x_2(t)$, and Figures 12(c) and 12(d) show the two responses of $u(t)$.

4.3 Analysis and discussion

Figure 9 shows a case of a downlink channel, and mainly includes information of a physical broadcast channel (PBCH), a physical downlink control channel (PDCCH), and a physical downlink shared channel (PDSCH). The overall quality of the downlink channel is good. The generation of the QAM constellation diagram in the lower right corner shows that the channel decoding and demodulation are good, and the channel signal-to-noise ratio is high, and the PDSCH throughput in the lower left corner displays the transmission rate of user data in real time. Better uplink and downlink channel quality indicates that data can be transmitted.

As shown in Figure 9, this figure shows the display interface of the eNB soft oscilloscope after the eNB is connected to the UE terminal, and shows the situation of the uplink channel. It can be seen from the figure that the communication channel has good transmission performance, and the points with good channel demodulation are evenly gathered around four points, the signal-to-noise is relatively good, and all parameters are basically up to standard. The eNB and UE are connected normally, and subsequent communication can be carried out

When the universal software radio peripheral (USRP) is used as the radio frequency front-end, the uplink and downlink synchronisation of openair-interface user equipment (OAIUE) has not been completed at present, and there are still defects. When the signal fluctuates, the signal fails to completely demodulate and the UE goes offline. At the same time, USRP radio frequency units have poor anti-interference and noise suppression capabilities. In order to ensure system stability and improve data transmission performance, a dielectric duplexer is installed at the antenna end of USRP to realise the isolation of the function of low-pass filter and the antenna transceiver end, which can greatly reduce out-of-band interference and improve system stability.

Therefore, under the same system parameters, this study can afford poor communication channel health quality.

It can be seen from Figure 10 that each dedicated information update has been successfully integrated into the fuzzy system proposed in this chapter to improve the control system performance.

With the continuous advancement of ubiquitous power IoT construction, researching wireless power private network systems is of great significance and application value. Due to the limited bandwidth, capacity, and latency of TD-LTE based PWPNs, they are unable to adapt to the explosive growth of ubiquitous power IoT business types and quantities. Taking into account both economic and forward-looking principles, it is proposed to deploy 5G base stations for the PWPN simultaneously to solve the communication performance issues of the PWPN; In response to the adverse impact of packet loss caused by UCC in PWPNs on remote control of grid access equipment, an enhanced multi sampling time fuzzy switching controller is designed to improve the adaptability of the control system to the communication transmission quality of UCC.

5 Conclusions

Successful data transmission at the network layer is the foundation. PWPN is a part of the network layer. Moreover, the rapid increase in communication demand for ubiquitous power IoT services contradicts the current network performance limitations such as UCC, insufficient bandwidth and capacity and delay that are common in power wireless 5G private networks, so it cannot better carry the existing and future emerging services of the ubiquitous power IOT. Therefore, it is of great research significance and application value to study the optimisation and security control of PWPNs in the ubiquitous power IOT environment. In this paper, an improved genetic algorithm is proposed to realise the location planning of 5G base stations in PWPNs. Aiming at the unreliable adaptability of FC system to communication channel, this paper proposes an enhanced multi-sampling time fuzzy switching controller, and the simulation verifies the correctness of the proposed method.

In this paper, an enhanced multi-sampling time FC system is proposed to improve the adaptability of FC system to UCC. How to enhance the adaptability of FC system under network attack is also a key research direction in the future.

Fuzzy logic systems traditionally focus on decision-making and not on securing the underlying communication protocols. Therefore, the follow-up research direction of this article is to further expand the model framework based on the research in this article, add underlying communication protocol modules, further improve the security and confidentiality of the model, and promote the practicality of the model in this article.

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