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Battery signal control model for large-scale IoT medical monitors under multipath interference

Shuhua Yang[1], Shengnan Zhang[1], Ding Chen[1] and Syed Atif Moqurrab[2,*]

[1]School of Traffic and Transportation, Nanchang Jiaotong Institute, No.899, Guanglan Road, Nanchang 330100, China
[2]School of Electronics and Computer Science, University of Southampton, United Kingdom

Abstract

INTRODUCTION: In large-scale IOT medical monitors, the accurate control of battery signals has been facing the problem of multipath interference. Multipath interference causes the receiver to receive multiple signals propagating through different paths and interfering with each other, which results in an imbalance in the battery signal control based on the time delay of the "transmit-receive" signals.
OBJECTIVES: To solve the multipath interference problem of existing battery signal control, this paper designs a battery signal control model for a large-scale IoT medical monitor.
METHODS: Firstly, this paper uses time synchronization to align the time between the receiver and the transmitter to synchronize the communication signals of the acquisition system; Next, a transverse time-domain filter is used for modulation filtering; Then, a judgment feedback equalization algorithm is introduced in combination with a full-feedback filter to suppress the inter-code interference and improve the signal quality; Finally, a fractional interval equalizer is designed to adjust the weight coefficients of the equalizer taps, and implement intelligent battery signal control in multi-hop communication under multipath interference based on fractional interval and bit error rate (BER) feedback modulation.
RESULTS: Experimental results have shown that after using the method described in this paper to control the communication signal of the monitor battery, the output signal is relatively stable, and the BER reaches 1×10^{-4} when the signal-to-noise ratio is equal to 18dB. The BER is low, and the carrier-to-noise ratio of the output signal is 0.73~0.85. The carrier-to-noise ratio always remains above 0.73.
CONCLUSION: The technologies effectively deal with complex network environment and channel condition variation, ensuring balanced system control, and the signal control effect is outstanding.

Keywords: Multipath interference, Internet of Things, Signal control, Impulse response, Intercoder interference.

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1. Introduction

Large-scale networked medical monitors are one of the important IoT devices in the medical field in recent years. The large-scale IoT based medical monitor integrates a variety of sensors (such as electrocardiogram, blood pressure, blood oxygen saturation, respiratory rate, etc.), which monitors and comprehensively analyzes the patient's physiological data real time, providing doctors with a comprehensive assessment. With remote access and control, doctors can view patients' data through mobile devices or computers remotely, achieving cross-regional medical support.

However, intelligent and efficient battery management for them has become an important research issue in this field [1]. Multipath interference refers to the phenomena of reflection, refraction and bypassing of electromagnetic

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[*] Corresponding author. Email: S.A.Moqurrab@soton.ac.uk

waves due to obstacles encountered in the propagation process, resulting in receiving multiple signals propagated through different paths [2-3]. In practice, due to the presence of complex environmental factors such as multipath interference, the low quality of communication transmission in smart batteries can lead to problems such as signal distortion and transmission delay, thus affecting the performance of large-scale monitor work [4]. To ensure the stable operation of the monitor and the safety of patients, it is of great significance to study the signal control strategy of the battery management system of large-scale IoT medical monitors under multipath interference.

Research related to cellular communication has always been a hot spot in the field. Nie R et al [5] proposed a narrow-band interference suppression strategy, which used short-time Fourier transform and Wigner-Ville time-frequency analysis to identify and simulate multi-fixed frequency interference signals. By analyzing the characteristics of signals in different time scales and frequency scales, a narrow-band interference suppression strategy was developed to complete the suppression of fixed frequency interference signals. However, in this method, the short-time Fourier transform process produced a boundary effect at the boundary of the signal, which meant the window can not completely cover the signal at the beginning and end, and the signal was distorted under multi-path interference.

Kumar JT et al [6] used the cyclic stationarity of OFDM/OQAM signals to analyze the cyclic power distribution of transmitted signals, RF interference and additive white Gaussian noise. The power of signal and interference plus noise was isolated in the power domain, and the noise plus ratio of signal interference was calculated to realize the signal control of OFDM/OQAM system under RF interference. However, the RF interference in this method had time-varying characteristics, so it was impossible to accurately understand the change of signal in different channels. The multipath interference can easily distort the signal in different channels.

Recently, to solve the problem of wireless communication systems affected by multi-source interference, Niu et al [7] proposed an anti-interference power control algorithm based on interference observation, which models a wireless communication system affected by multi-source interference as a generalized stability control system, and employs an interference observer to generate an estimate of the system state affected by the interference. This method although the anti-interference power control algorithm can quickly respond to interference changes, but the method may not be able to eliminate the impact of interference.

Bai et al [8] designed a communication system single-carrier frequency-domain equalization algorithm based on deep learning algorithms, joint optimization of channel estimation, noise power estimation and channel equalization of the three modules, to reduce the amount of training data required for the convergence of the network. However, the robustness of this method may be limited when facing new data with large differences from the training data distribution.

To solve the problem that the existing equipment system cannot effectively control the battery signal under multipath interference, this paper proposes a battery signal control model under multipath interference based on synchronized anti-interference and finite impact response. The core route of this paper is as follows:

(a) Signal preprocessing for monitor batteries under multipath interference.

Channel impulse response is a mathematical representation for affected signal propagating by channel characteristics (such as multipath effects, phase shifts, etc.). Study of the channel impulse response accurately understands the change of signal, resulting in small distortion between the received and original signal.

The proposed algorithm calculates the channel impulse response, and combines the positive and negative signal flip methods for output signal reconstruction, and calculates the output data flow in the multipath channel. Then, it uses time synchronization for time alignment between the receiving and the sending end to realize the communication signal preprocessing, which reduces signal distortion and data loss caused by time asynchronism.

(b) Inter-code interference suppression filtering.

Inter-code interference is the interference between adjacent signals. It is required to suppress to decrease the BER, which is generated when the receiver misjudges the interference of adjacent signals as the signal itself during demodulation.

Therefore, the proposed algorithm calculates the impulse response function of the communication module channel after being changed by the multipath effect. The transverse time domain filter is adopted to carry out the modulation filtering of the communication channel; The output code stream of the channel after the inter-code interference filtering is calculated, and the performance of the filter by utilizing the method of the integral value of inter-code interference is evaluated; If the integral value of the inter-code interference is large, then introduces the judgment feedback equalization algorithm, and combines with the full-feeding filter to construct the output code stream matrix of the channel; The inter-code interference filtering suppression is carried out again to eliminate the reverse inter-code interference and realize the suppression filtering according to the signal-to-noise ratio of the signal. This interference suppression for multi-level inter-code flexibly deals with the complex and changeable channels, and significantly improves the communication quality.

(c) Fractional interval-based battery signal control.

Fractional interval equalizers compensate for distortion in channels precisely, including delay and selective fading. A fractional-interval equalizer fully utilizes the advantage of high precision compensation for the channel distortion.

The proposed algorithm designs a fractional interval equalizer based on the finite impulse response (FIR) filtering; The weight coefficient of equalizer taps is adjusted, and the error bit rate feedback modulation technique is combined to get the modulation parameter combination. Then, the transmission state of the intelligent battery signal control node of the monitor is obtained. The proposed algorithm dynamically adjusts the allocation of resources, realizing the intelligent battery signal control of the IoT monitor under the multipath interference through multi-hop communication. The FIR based fractional interval equalizer adjusts the weight coefficient of the equalizer tap more precisely, so as to compensate the channel distortion more accurately and improve the signal communication effect.

2. Intelligent control method of battery signal under multipath interference

Data transmission between IoT devices are affected by network instability, latency, and packet loss, et al., resulting in unreliable data interactions. In this paper, STC89C52RC chip is used to collect battery status, and MQTT protocol is used for information transmission, improving the reliability and orderliness of data interaction. The multipath interference is accurately estimated and compensated to decrease the adverse effect during data transmission, resulting in the signal quality enhancement.

Therefore, the influence of multipath interference on signal is analyzed, and the channel impulse response is estimated accurately by increasing the samples in compensation. The output signal is reconstructed by flipping positive and negative signal, as well as dynamic compensation, to reduce the interference effect. Fractional interval equalization is used to insert additional equalizer taps to process the signal more finely. Resource allocation is dynamically adjusted, such as transmit power and hop count, to decrease the impact of multipath interference. All these technologies effectively deal with complex network environment and channel condition variation, ensuring balanced system control.

2.1. Battery system logic analysis

In IoT monitors, the battery management system contains a control communication module to monitor and manage the battery status of the monitor device. IoT technology rapidly transmits medical data to a central server or cloud platform. It allows multiple medical monitoring devices to connect and exchange data with each other for remote monitoring, collaborative management and maintenance.

The battery management module in this device mainly collects key parameters such as voltage, current, and temperature of the battery in real-time through sensors and monitoring devices to ensure that the battery is in optimal working condition. The collected attribute data will be analyzed and processed by data analysis and processing algorithms to predict and evaluate the battery's health status, remaining life, and so on. Based on the results of analyzing the battery state, the system can automatically adjust the working mode and charging strategy of the device by sending and receiving signals. It prolongs the service life of the battery and improves the reliability of the device [9].

In this paper, the system of intelligent battery management uses the STC89C52RC main control chip as the battery state information processing chip to obtain the use of state information parameters. The chip has high computing speed and can provide an effective monitoring basis. Message queuing telemetry transport protocol (MQTT) is used for the transmission of information between the sensing layer and the transport layer. This protocol is an asynchronous transmission protocol, which is perfectly adapted to the IoT environment with a long connection time. MQTT effectively realizes data interaction and provides an orderly and reliable two-way connection.

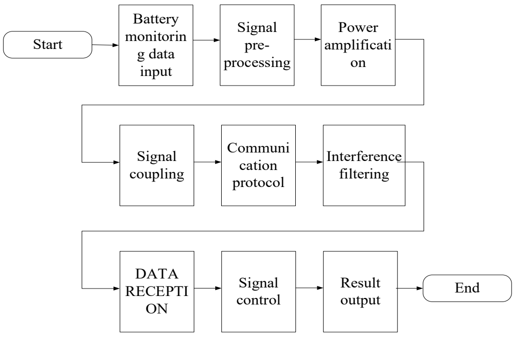


Figure 1. Logic diagram of module design of intelligent battery management system

From the logical analysis can be seen that, By monitoring the battery status real-time and automatically adjusting the working mode, the intelligent battery management system effectively extends the service life of the battery, reduces the frequency of battery replacement, and reduces maintenance costs. The following chapters will introduce the application methods of core modules in battery system logic.

2.2. Signal pre-processing for battery communication module under multipath interference

As the signal passes through multiple paths of different lengths and transmission media during propagation, it leads to superposition and mutual interference at the receiving end of the signal. The quality of the received signal is degraded, and problems such as attenuation, distortion, and delay occur, which is known as multipath interference.

In medical applications, the reliability and stability of equipment is extremely high, and large IoT monitors ensure stable work in complex environments by using anti-interference strategies [10].

In the battery management of large-scale IOT monitoring devices, due to the wide distribution of the devices and the complex communication environment, multipath interference becomes a more common problem. It affects the performance and reliability of the battery management system. Therefore, to realize the effective control and management of smart batteries under multipath interference, it is first necessary to accurately collect and pre-process the battery communication signals under multipath interference.

In this paper, the channel impulse response is used to describe the effect on the signal as it propagates through the channel, mainly reflecting the degree of attenuation of the signal affected by multipath interference. To accurately estimate the channel impulse response, the received signal needs to be sampled and processed at the receiving end. By increasing the number of sampling points, the channel impulse response can be estimated more accurately, thus compensating for multipath interference more effectively [11]. The formula for channel impulse response can be expressed as:

$$h(t) = \sum_{i=1}^{n} a_i(t) e^{\theta_i(t)} \delta(t - T) \tag{1}$$

where, $a_i(t)$ is the signal amplitude at the t moment of the path i, e denotes the communication range parameter, $\theta_i(t)$ refers to the phase offset at the t moment of the i path, δ indicates the number of sampling points, T represents the time interval between pulses.

The random variability of the channel is also an important characteristic of multipath interference. The state of the channel may change over time, including changes in parameters such as gain, phase, and delay of the channel. The multipath interference will lead to superposition and delay of the signal during the transmission of the channel, making the received signal waveform deformed. By reconfiguring the received signal sampling process, the amplitude and phase information of the signal can be obtained at discrete time points, so as to more accurately restore the original signal at the transmitting end.

To adapt to the random variability of the channel, this algorithm employs a dynamic compensation technique to reconstruct the sampling of the signal transmission under multipath interference. It combines positive and negative signal flipping to reconstruct the output signal. The computational formula can be expressed as:

$$x(t) = h(t) \times s(t) \times \frac{x_p(t) a_i(t) e^{\theta_i(t)}}{I(1-L)} \tag{2}$$

$$s(t) = [s_1(t), s_2(t), \ldots, s_I(t)]_{I\times 1}^{L} \tag{3}$$

where $x(t)$ is the reconstructed output signal, $s(t)$ denotes the signal sequence vector. $x_p(t)$ indicates the signal samples at consecutive time points. p represents the signal weights, L is the sequence length, and I is the signal samples.

This algorithm obtains information about the multipath interference data information flow to understand the extent of the impact of multipath interference on system performance. Appropriate measures are taken to eliminate or minimize the impact of multipath interference, and the performance and stability of the communication system are improved. After obtaining the output signal, the output multipath interference data information flow in the multipath channel is calculated using Eq. (2), which is calculated as:

$$x_k = \sum_{n=1}^{N} C_n e(I)^j \times x(t), k = 0,1,\ldots,N \tag{4}$$

where x_k denotes the multipath interference data information flow at the k-th point in the multipath channel. C_n is the time-domain sample of the transmitted signals, and j refers to the imaginary unit, which is used to represent complex numbers.

In the actual communication of monitor battery management, multipath interference causes time delay and phase shift of the received signal, which triggers signal distortion. This distortion can seriously affect the quality and reliability of the signal, leading to an increase in the BER and affecting the stability of the system signal transmission [12]. To ensure the accuracy of the acquired signals so that the receiver can accurately parse the signals sent by the transmitter, this algorithm applies time synchronization to strictly align the time between the receiver and the transmitter. Time synchronization ensures that the timestamps of the signals are accurate at the time of transmission and reception. The receiving end can know exactly when each symbol or bit is supposed to appear, and thus cope with multipath interference more effectively. The time between the receiving end and the sending end is aligned to obtain the battery management signal in the presence of multipath interference by using the time synchronization technique, which is calculated using the following formula:

$$O_k = \sum_{n=1}^{N} x_k \times A\left(a_n \cos\frac{2\pi kn}{N} - b_n \sin\frac{2\pi kn}{N}\right), k = 0,1,\ldots,N \tag{5}$$

where a_n is the signal transmission time interval, b_n is the expected position time deviation. A denotes the synchronization error. This completes the signal acquisition under multipath interference.

2.3. Inter-code interference filtering suppression

In the complex medical environment, multipath interference is one of the main factors affecting the quality of signal transmission. This paper proposes a signal control method under multipath interference to reduce the BER and inter-code interference, and improve the stability and reliability of signal transmission.

In signal transmission, the code element interval refers to the length of time occupied by each code element (i.e., information bit or symbol) that is sent; whereas the fractional interval usually refers to multiple sampling or processing within the code element interval to obtain finer channel information. Under multipath interference, the choice of code-element interval and fractional interval will directly affect the carrier tracking and code-element synchronization of signal forwarding, and an excessively long code-element interval will also reduce the data transmission efficiency of the system.

By reconstructing the received battery management signal at the receiving end with sampling processing, dynamic compensation, and signal flipping, the effect of interference on the signal can be partially reduced to obtain a high-quality communication signal. However, it does not solve the interference in the inter-code interval that can be caused by the transmission of battery management signals under multipath interference. The appearance of inter-code interference will lead to a decrease in the signal-to-noise ratio. The receiving end not correctly extracts useful signals in noisy environment, which reduces the reliability of the battery communication and fails to meet the needs of practical applications [13].

To solve the problem of inter-code interference, the general algorithm employs a transverse time domain filter for modulation filtering of the communication channel. The transverse time domain filter can process the received signal at the receiving end to compensate for channel-induced distortions, thus reducing the effect of inter-code interference. However, lateral time domain filters can cause significant degradation in communication performance due to environmental changes in the battery system caused by the movement of the monitor, which is more evident in the increase in bit error rate. To address the effects such as the increase in BER that occurs due to changes in channel impulse response by multipath effects [14], this algorithm helps to adjust the parameters of the filter by recalculating the impulse response function to restore the system performance. The calculation formula is as follows:

$$U = \sum_{n=1}^{N} a_i(t) \times O_k \beta \, log \left(1 + \gamma \sum_{j=1}^{n} S \frac{R_1}{R_2}\right) \tag{6}$$

Where β is the amplitude of the spread spectrum adjustment, γ denotes the spread spectrum transmission distance, S refers to the spread spectrum adjustment response time. R_1 represents the tap delay correlation data, R_2 indicates the tap delay path.

To further reduce the inter-code interference, this algorithm designs a linear equalizer consisting of a tapped delay line and a weighting network. Among them, the tapped delay line is used to delay the received signals for different times to match the delay characteristics of the channel. The weighting network is used to weigh each delayed signal to adjust the amplitude and phase of the signal to realize the compensation of channel distortion. This algorithm uses an improved transverse time domain filter for modulation filtering of the communication channel. The calculation formula is as follows:

$$H = U \sum_{c=1}^{M} \sum_{d=1}^{Z} q_b w_{cd} P(n) g[t0 + X_s X_c] \, \mu \tag{7}$$

Where H is the completed filtered channel, c denotes the number of nodes, and d refers to the data training sequence. q_b represents the short-term impulse response, w_{cd} denotes the superposition of phase offset components. P denotes the channel output original code stream, g indicates the band match probability, t_0 is the equalizer tap delay time parameter. X_s is the window function parameter, X_c denotes the weighted filtering parameter, μ reports the filtered interference noise function.

To evaluate the effectiveness of the filter, this algorithm calculates the output code stream of the channel after inter-code interference filtering, and obtains the output code stream of the channel after inter-code interference filtering as:

$$\Delta P = \sum F(n, o) + H \tag{8}$$

where ΔP is the channel output stream after inter-code interference filtering, $F(n, o)$ denotes the amount of inter-correlation information of the o network transport layer in the n layer.

The channel output original code stream P with the channel output code stream ΔP after inter-code interference filtering is compared, and the metric of inter-code interference can be calculated directly to evaluate the filter performance. The degree of inter-code interference is quantified by calculating the sum of the interferences of each code element in the received signal. The performance evaluation of transverse time-domain filter is calculated by setting the integral threshold. If the integral interference of inter-symbol is lower than this threshold, the filter effectively reduces the inter-symbol interference and has good performance.

The discrete value of each code element is denoted by $\tau = \{\tau_1, \tau_2, \dots, \tau_n\}$, and the weighted difference between the sampled value of the received signal I_n and the sampled value of its neighboring code elements υ_n is calculated as W with the following formula:

$$W = (I_n - \upsilon_n) \times \frac{x_p(t) a_i(t) e^{\theta_i(t)}}{I(1-L)} x(t) H \tag{9}$$

After obtaining the weighted difference value W, the weighted differences of all code elements are integrated to obtain the integral value of inter-code interference. The larger the integral value of inter-code interference, the more serious the inter-code interference is; On the contrary, the smaller the integral value is, the smaller the interference is. The formula is as follows:

$$D = \frac{[P - \Delta P]}{\sum F(n,o)} \int_0^1 \mathrm{d}W \times H w_{cd} \tag{10}$$

where D indicates the integral value of inter-code interference. In practice, the appropriate method can be selected to choose the appropriate integral value as the judgment standard according to the specific signal form and system requirements.

If the value of the inter-code interference integral is large, then the effectiveness of the filter against inter-code interference could be improved. The main problem is that there may be reverse inter-code interference, i.e., the previous code element interferes with the subsequent code element. Therefore, this algorithm further carries out the equalization process of adaptive interference cancellation, i.e., the judgment feedback equalization algorithm is introduced to eliminate the reverse inter-code interference. The judgment feedback equalization algorithm is an effective technique for eliminating inter-code interference in communication systems, which can utilize the previously adjudicated signals to eliminate the inter-code interference in the current signals, and especially excels in eliminating the reverse inter-code interference. If the signal following the adjudicated signal is also known, the reverse inter-code interference can be further eliminated in the absence of noise. In this process, the calculation of the cancellation processing coefficients is carried out using the following formula in conjunction with the use of a fully-fed filter.

$$\omega(\vartheta) = \frac{\zeta^2}{W\|\xi\|^2+\zeta^2} \tag{11}$$

where ω is the elimination processing coefficient, ϑ denotes the number of fully-fed filtering times. ξ indicates the length of fully-fed filtering, which generally takes the value of infinite length. ζ refers to the path loss index.

In the judgment feedback equalization algorithm, the fully fed filter needs to utilize the adjudicated signals to eliminate the inter-code interference, and the channel output code stream matrix provides an ordered set of these adjudicated signals. The channel output stream matrix contains information about the effect of the channel on the input signal. In the presence of multipath interference, different rows in the channel output stream matrix may represent signals on different paths. By analyzing $\omega(\vartheta)$, it is possible to identify which paths are causing serious interference to the signal and take appropriate measures to suppress or eliminate them. Therefore, the channel output code stream matrix Γ is constructed based on the above content, and the inter-code interference filtering and suppression process is carried out again according to the signal-to-noise ratio of the judgment signal. The calculation formula for the process is as follows:

$$\kappa = \frac{\omega(\vartheta)\|\xi\|^2+\zeta^2}{\Gamma\times\chi^2} \tag{12}$$

Where κ is the de-equalization process, χ denotes the signal-to-noise ratio of the judgment signal.

So far, this algorithm has accomplished the inter-code interference filtering suppression for the battery management communication of the monitor by utilizing the lateral time-domain filter and the full-feed filter.

2.4. Fractional interval-based signal control for battery management

This algorithm adjusts the filter parameters by recalculating the impulse response function in a complex IoT environment to restore the performance of battery system and reduce the effect of inter-code interference. The fractional interval is used to control the signal of the battery management system. It in turn controls the battery management signal by fractional intervals. Fractional interval equalization processes the signal with finer temporal resolution by inserting additional equalizer taps between sampling moments. It allows the equalizer to better adapt to the time-varying characteristics of the channel, especially during high-speed data transmission where channel delay extension becomes more severe. With fractional interval equalization, more information can be obtained in each symbol period [15], which can be more effective in combating inter-code interference and controlling the battery management signals.

Assuming that the number of code elements in the transmission layer of the battery system in the IOT monitor is y and the code element sampling time interval is V_f, the channel bandwidth of the data communication network under multipath interference is obtained based on the principle of finite shock response filtering:

$$G = P(n)y \times V_f \tag{13}$$

After obtaining the channel bandwidth, the received signal is processed through a designed fractional interval equalizer. The design of the fractional interval equalizer for this algorithm takes into account the delay extension of the channel, the noise characteristics, and the required equalization depth condition, which can be expressed as:

$$E = Gr_1(l \times \varphi) + \sum_{c=1}^{M} v(t) \tag{14}$$

where r_1 is the superposition of multiple components with phase shifts, l denotes the channel transmission rate. φ refers to the amplitude of the multipath components, and $v(t)$ indicates the frequency response.

To minimize the system BER and improve the signal quality of the IoT system, this algorithm adjusts and optimizes the parameters of the fractional interval equalizer by adjusting the weight coefficients of the equalizer taps. The calculation formula is as follows:

$$Y = \frac{\Phi}{\varepsilon} \times \eta(\rho_1 + \rho_2) \tag{15}$$

where Y is the adjusted tap weight factor, η denotes the tap factor of the code element, and ε represents the channel deflection under multipath interference, ρ_1 is the sparsity coefficient, ρ_2 denotes the crosstalk coefficient, and Φ reports the frequency domain communication signal spectrum.

Fractional interval equalization focuses on the signal processing level, which optimizes the signal quality by adjusting the equalizer parameters. The BER feedback modulation technique starts from the data transmission level and adjusts the modulation method to reduce the BER. Therefore, the combination of fractional interval equalization and bit error bit feedback can make the system more robust in the face of adverse conditions such as channel variations, noise interference, etc. It can adaptively adjust parameters and strategies to maintain stable performance.

In complex environments such as hospitals, signals experience multiple reflections, refractions, and scattering, resulting in multipath interference that affects quality. This algorithm establishes a feedback mechanism to the transmitter for the error bit rate information after adjusting the weighting coefficients of the equalizer taps. After receiving the BER feedback, the transmitter adjusts the modulation parameters according to the feedback information. The system can gradually find the best combination of modulation parameters to achieve the best balance between BER and data transmission efficiency through many iterations of optimization. The formula for the modulation parameter combination of this algorithm is:

$$B = EY\frac{\sigma\times\varpi_1}{E\times\varpi(\psi)} - N \tag{16}$$

where ϖ_1 is the modulation order, $\varpi(\psi)$ denotes the redundancy of the error correction code and σ refers to the modulation time offset constant.

Diversity battery management system signal control is performed by combining the spectrum of sampled communication signals to obtain the transmission state of the battery management signal control node α under multipath interference:

$$\alpha(m_1,m_2)=\begin{cases}0, m_1=0, & m_2=0\\ 1, \ n-m_2<m_1, & m_1\geq m_2\\ 1, \ n-m_1<m_2, & m_2\geq m_1\end{cases} \tag{17}$$

The referring allows dynamic adjustment of resource allocation to help mitigate the effects of interference. The transmit power of node α is dynamically adjusted based on multipath interference strength z and coverage u. Multipath interference can be resisted and the reception quality of the signal can be improved by increasing the transmit power. The formula for dynamically adjusting

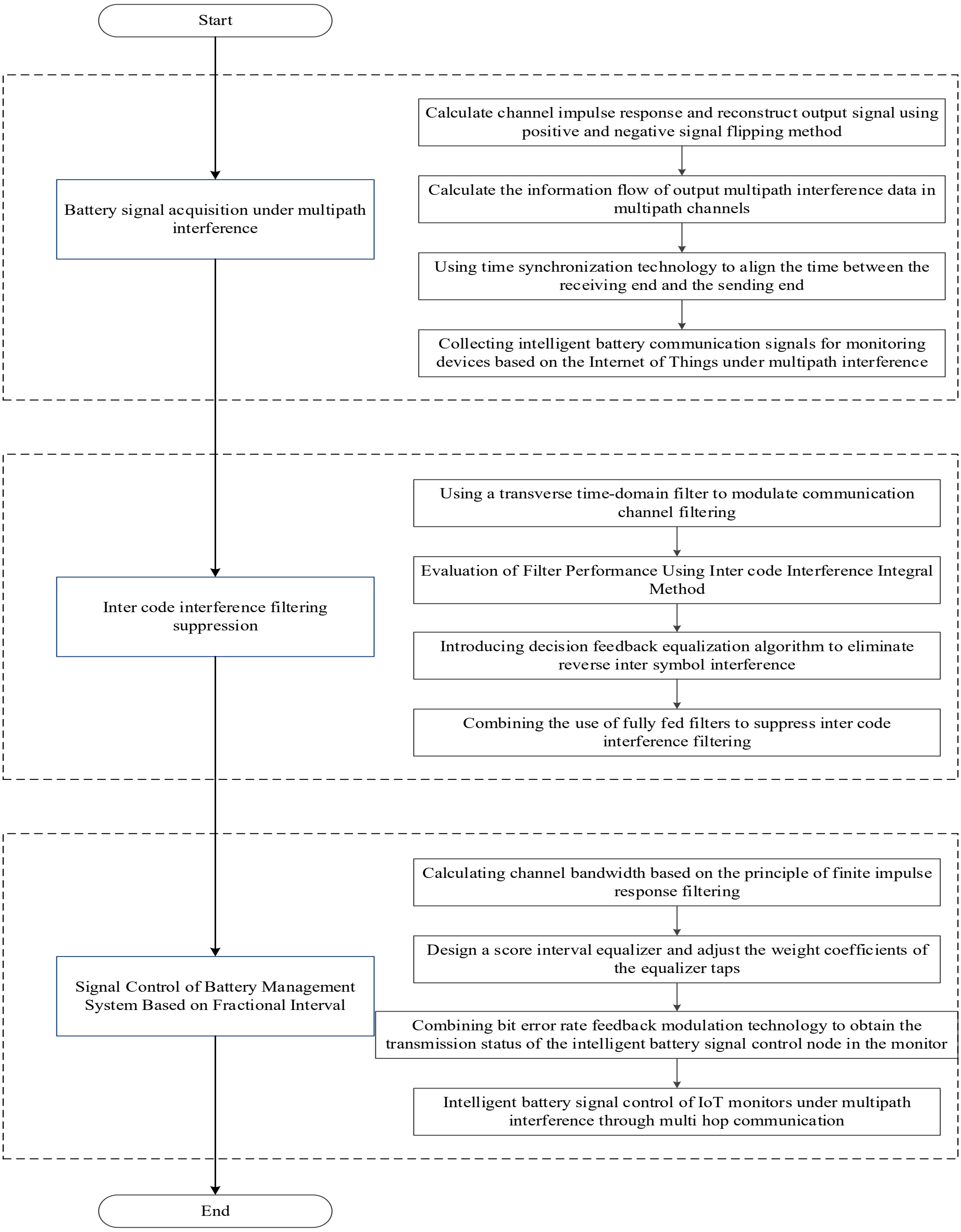


Figure 2. Flowchart of battery signal control of large-scale IoT medical monitor

the resource allocation is given below:

$$Q = Bz \times u\alpha(m_1, m_2) \tag{18}$$

To avoid excessive interference to other nodes caused by increasing the transmission power, the system signal control can be realized by multi-hop communication under the condition of considering the available bandwidth and transmission delay of the battery management system. The calculation formula is as follows:

$$K = Qz + J(\Omega + \Upsilon) \tag{19}$$

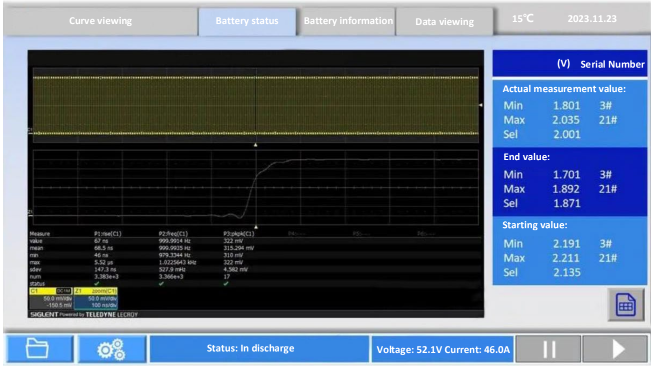
where J is the system operation energy consumption, Ω denotes the transmission delay and Υ refers to the number of hops. With the above, the signal control of intelligent battery management system for IoT monitor is realized by using fractional interval equalization and error bit rate feedback modulation technique.

So far, this paper completes the design of the battery signal control method for large-scale IoT medical monitors under multipath interference. The battery signal control flowchart of the large-scale IoT medical monitor is shown in Figure 2.

3. Experiments and Analysis

3.1. Experimental setup

To verify the effectiveness of the intelligent battery management signal control method for monitors under multipath interference proposed in this paper, a multi-connected monitor in a large public hospital in a city is selected as the test object. The monitor in this hospital is based on the Internet of Things to realize intelligent battery management and has been applied for more than 2 years. The display interface of the intelligent battery management system of the monitor is shown in Figure 3.



Actual measurement value:

Min	1.801	3#
Max	2.035	21#
Sel	2.001	

End value:

Min	1.701	3#
Max	1.892	21#
Sel	1.871	

Starting value:

Min	2.191	3#
Max	2.211	21#
Sel	2.135	

Measure	P1:rise(C1)	P2:freq(C1)	P3:pkpk(C1)
value	67 ns	999.9914 Hz	322 mV
mean	68.5 ns	999.9935 Hz	315.294 mV
min	46 ns	979.3344 Hz	310 mV
max	5.52 µs	1.0225643 kHz	322 mV
sdev	147.3 ns	527.9 mHz	4.582 mV
num	3.383e+3	3.366e+3	17
status	✓	✓	✓

Status: In discharge

Voltage: 52.1V Current: 46.0A

Figure 3. Display interface of monitor intelligent battery management system

The system model is ENS-8006D, 7-inch TFT LCD, resistive touch screen, data communication is RS485 serial communication, voltage measurement accuracy is ±0.5%FS+0.1V, current measurement accuracy is ±1%FS+0.1A, and the emergency shutdown actuator is a high-voltage DC switch 200A or DC air switch. Other technical parameters of the intelligent battery management system of the monitor are shown in Table 1.

Table 1. Patient monitor intelligent battery management system technical parameters

options (as in computer software settings)	Parameters
Discharge voltage range/V	150-800
Electric discharge current/A	60
Power input - AC/V	Single-phase AC 220
Frequency range/Hz	40-60
Battery voltage input - DC/V	10-800
Internal data storage/Mbit	128
Max voltage measurement/V	1000
Max current measurement/A	200
Discharge control accuracy/%FS	±1

After determining the intelligent battery management system of the monitor for the experiment, the test platform of the experiment is built and run in Matlab R2019a software under the development environment of Visual Studio 2010 based on the Windows system, with the help of the virtual machine VMW WORK station8.2, and the application of C++ language.

The experimental environment and parameters are shown in Table 2. In the experiments of this paper, the signal BER and the carrier-to-noise ratio in the battery management communication process are used as evaluation indexes. The lower the BER, the higher the reliability of data transmission and the better the signal quality; The carrier-to-noise ratio is used to assess the relative strength of the carrier and the noise in the communication system, and the higher the carrier-to-noise ratio is. It means that the carrier signal is stronger relative to the noise, and the better the quality of the communication.

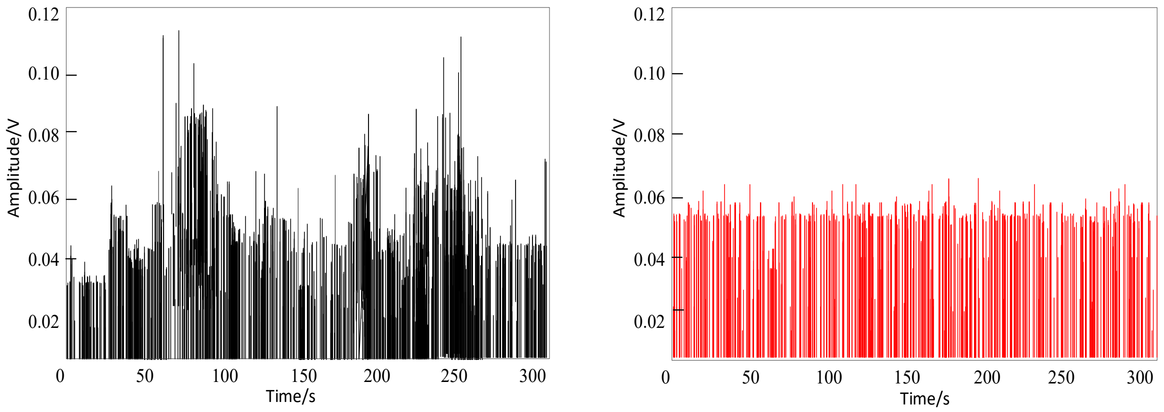
Table 2. Experimental environment and parameters

Environment	Parameter
SQL	SQL2020
virtual machine	VMW WORK station8.2
Memory	256G
Hard disk	20GB
CPU	Intel Pentium Dual-Core 2.4GHZ
Programming	Eclipse SDK

3.2. Experimental results and analysis

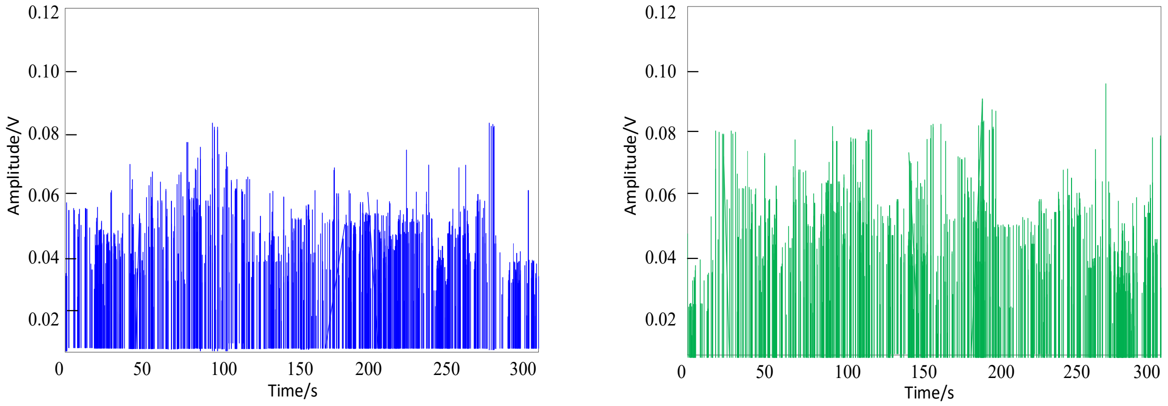
(1) Comparative testing of signal control effects

The intelligent battery management signal control method of the monitor under multipath interference, the method of literature [5] (Narrowband interference suppression method) and literature [6] (Signal control



(a) Raw unprocessed signal

(b) The method of signal control in this article



(c) Reference [5] Method Signal Control

(d) Reference [6] Method Signal Control

Figure 4. Comparison between the original signal and the effect after control by different methods

method under RF interference using OFDM/OQAM system) are compared in this paper. The effect of the intelligent control of the monitor battery is compared and analyzed, and the results are shown in Figure 4.

As can be seen in Figure 4, when multipath interference exists in the current intelligent battery management signal transmission of the monitor, the fluctuation of its communication signal will be larger. The reason is that the signal encounters different obstacles in the transmission process, which leads to the signal arriving at the receiver with different paths and delays, thus triggering fluctuations in the strength of the signal and changes in the phase. Such fluctuations may lead to the degradation of signal quality, increase the BER and affect the communication effectiveness. After the signal control by the method of literature [5] and the method of literature [6], the communication signal of this system is slightly smoother compared to the previous one, but it still shows large fluctuations. It can be seen that the communication signal of the system is smoother after the algorithm control, which indicates that the proposed method can effectively control the multipath interference and improve the smoothness of the signal.

In multipath environment, signal propagates through different paths, and receiver receiving multiple copies of signal with different delays and attenuations. These copies are superimposed on each other, resulting in inter-code interference, which increases the BER. The proposed method effectively suppresses multipath interference for dynamic compensation by using transverse time domain filter to flip positive and negative signals. The filter removes/attenuates those signal copies with inconsistent delay and attenuation due to multipath propagation, thereby reducing their superposition effect at the receiving end. The amplitude and phase of signal are adjusted to compensate the channel distortion and reduce the inter-code interference.

(2) BER Comparison Tests

The BER of the monitor smart battery management system under multipath interference is compared and analyzed using the signal control method proposed in this paper. The method of literature [5] and the method of literature [6], and the comparison results are shown in Figure 5.

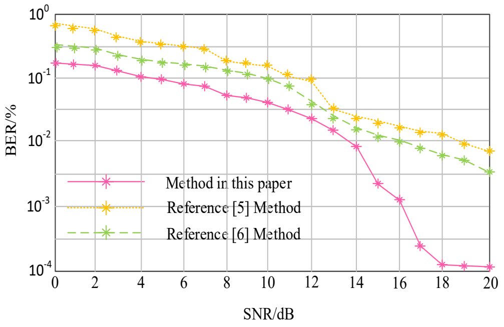


Figure 5. Comparison of Error Rate of IoT Monitor Battery Management System

As can be seen in Figure 5, the BER of the intelligent battery management system for the monitor shows a decreasing trend with the increase of the signal-to-noise ratio. Among them, the BER of the battery management system of the method in literature [5] is equal to 1×10^{-2} at the signal-to-noise ratio equal to 18dB , and the communication quality is poor; The BER of the battery management system of the method in literature [6] is only lower than 1×10^{-2} at the signal-to-noise ratio equal to 18dB , and the communication quality is poor; The BER of the signal control method for the intelligent battery management system of the monitor under the multipath interference presented in this paper is significantly at 15dB lower than the two methods compared in literature [5] and literature [6]. The BER reaches 1×10^{-4} when the signal-to-noise ratio is equal to 18dB, which is a lower BER, a higher reliability of signal transmission, and a better control effect.

This is because the proposed method utilizes fractional interval equalization to process the signal at a finer time resolution by inserting additional equalizer taps between sampling moments [16]. This method can better adapt to the time-varying features of the channel, especially in the high-speed data transmission, and effectively combat inter-code interference. It ensures that the time between the receiving and sending ends is strictly aligned to avoid signal aliasing and misjudgment problems caused by time asynchronism.

(3) Carrier-to-noise ratio comparison test

The method of signal control of the monitor battery under multipath interference proposed, the method of literature [5] and the method of literature [6] is used in this paper. on the basis of the above test environment, the statistics of the carrier-to-noise ratio of the corresponding processed signals under the signal control of the different methods were obtained. The results of the data obtained are shown in Figure 6.

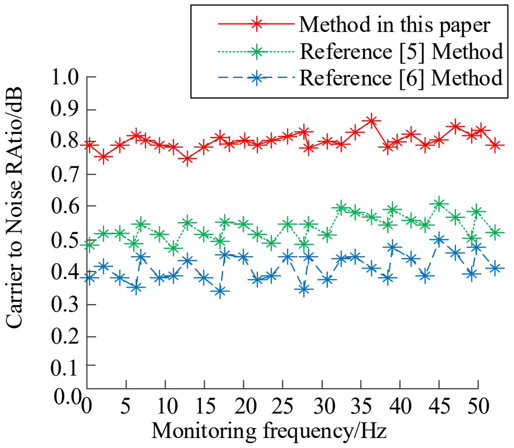


Figure 6. Comparison of download noise ratio of different methods of signal control

According to the data in Fig. 6, it can be seen that the carrier-to-noise ratio of the output signal is 0.47-0.61 dB after the battery signal control using the method of literature [5]. The carrier-to-noise ratio of the output signal is 0.35-0.51 dB after the signal control using the method of literature [6]. The carrier-to-noise ratio of the output signal is 0.73-0.85 dB after the signal control using the method proposed in this paper, and the carrier-to-noise ratio always stays at above 0.73 dB, which is significantly higher than the other two methods. Analyzing the reasons, it can be seen that the reason for the poor denoising effect of literature [5] and literature [6] is the inability to reproduce the peak height of the signal. It makes the estimated bandwidth of the center of the noise signal with a large error, and leads to the poor denoising performance. This method can utilize fractional interval equalization and bit error rate feedback modulation techniques to make IoT systems more robust in the face of adverse conditions such as channel changes and noise interference. It can adaptively adjust the parameters and strategies to maintain stable performance, and the signal control effect is better.

4. Conclusion

With the in-depth development of IoT technology and the growing demand for intelligence in the medical monitoring field, large-scale IoT medical monitors play an increasingly important role in the medical diagnosis and treatment process [17-18]. However, the multipath interference problem has been a key factor restricting its signal control accuracy, especially in the battery signal control. To solve the problem that the existing IoT system cannot realize highly reliable signal control under multipath interference, this paper takes the intelligent battery management system of the monitor as an example to study the signal control problem of the communication system under multipath interference in depth.

(1) First, the impulse response of the picking channel is calculated, and the time between the receiving end and the sending end is aligned using a time synchronization technique to collect the communication signal of the IOT system under the multipath interference; Then, the transverse time-domain filter is used for the modulation and filtering of the communication channel, and the inter-code interference filter is suppressed; Finally, the fractional-interval equalizer is designed, and the weight coefficients of the equalizer taps are adjusted to achieve the efficient signal control through the multi-hop communication by using the fractional-interval and the erroneous bit-rate feedback modulation technique. It realizes efficient signal control under multipath interference through multi-hop communication.

(2) It is proved through experiments that the signal control method proposed in this paper is applied to the communication signal of this system. The output signal is relatively smooth, and the BER reaches 1×10-4 when the signal-to-noise ratio is equal to 18dB. The BER is low, and the carrier-to-noise ratio of the output signal is 0.73~0.85. The carrier-to-noise ratio is always above 0.73, and the signal control effect is superior.

(3) The current research has made some progress for signal control under multipath interference, but there are still many challenges to overcome in the face of increasingly complex medical monitoring needs and variable communication environments. In the future, in-depth research on battery signal control methods for large-scale IoT medical monitors under multipath interference will be continued to further optimize and improve the existing technology. On the one hand, more advanced time synchronization techniques can be explored to improve the time alignment accuracy between the receiving end and the sending end, so as to further reduce the signal interference caused by time deviation. On the other hand, new generation communication technologies such as 5G and 6G can be considered to be introduced into the signal control of the monitor. The low-latency and high-reliability characteristics of 5G, the real-time and accuracy of the signal transmission of medical monitors is used to further improved; While the ultra-high bandwidth and intelligent sensing capability of 6G are expected to provide richer data resources and more accurate signal control means for IoT medical monitors. It provides stronger technical support for the development of intelligence in the field of medical monitoring.

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