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An Algorithm for Network Fluctuation Hopping Signal Suppression Based on Disturbance Characteristics Decomposition and Feed-Forward Modulation

Chen Weijun and Sui Dan

School of Software, Anyang Normal University, Anyang 455000, Henan, China
Weijun221@163.com

Abstract

In the data communication, a time-frequency hopping resonance signal will be created, and this network fluctuation hopping signal must be suppressed in order to improve the network stability. An algorithm for network fluctuation hopping signal suppression based on disturbance characteristics decomposition and feed-forward modulation is proposed, and the disturbance characteristics decomposition for a network fluctuation hopping signal is done in a Hilbert space. A feed-forward modulation filter is created to get the feed-forward modulation suppression of the network fluctuation hopping signal. The simulation results indicate that this algorithm has good real-time data transmission, which can effectively suppress the resonance signal in the network fluctuation hopping, low loss of information, and has the obvious function to resolve the startup hysteresis, server load, tremble and other problems in the large-scale hybrid networking.

Keywords: *Resonance signal, disturbance characteristics decomposition, feed-forward modulation*

1. Introduction

Today, the network user terminals aren't only the traditional computer users yet, but also include the on-vehicle, ship-bone, airborne terminals and hand-held and other network users, these users of which jointly constitute a hybrid network. The hybrid network has become the trend of network distribution and design, in the hybrid network, since the phase-group character between networks is different, a network fluctuation hopping resonance signal is generated in the network switcher and data communication, and this resonance signal exists in the network communication system in the form of noise, which is represented with a hopping pulse and brings the network fluctuation and signal instability, and thus results in the startup hysteresis, server load, tremble and other phenomena. With the increase of network safety and network stability development and application demands, the research on the suppression algorithm of network fluctuation hopping signal generated during the network switching is very important to provide the safety stability of information communication and network system.

In the traditional method, the fluctuation hopping resonance signal from the hybrid network is mainly suppressed using the fractional interval balanced modulation algorithm and enveloped instantaneous value statistical method. By using the statistical signal processing method, with the signal detection theory, the focusing of useful signal is realized to suppress the harmonic oscillation signal [1, 2]. The algorithm has a certain achievements and results both in theory and practice, which the literature [3] presents a network resonance signal suppression algorithm based on the enveloped instantaneous value estimation and shuffled frog leaping baud interval balanced modulation, which the methods including the envelope detection modulation method are used to fulfill the detection and estimation of the network fluctuation hopping signal, pick up the useful information characteristics, and thus realize the purpose of wave absorbing and

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suppression. However, these algorithms require to carry out the pre-treatment of energy detection, and are relatively complex for fulfillment. Literature [4] presents a stabilization and equanimity method after fluctuation of unstable network intrusion based on the tracking differential time-delay error compensation, which the time-delay error compensation control method is used to carry out the suppression of the unstable signal during the network switching, but this algorithm fails to fully consider the noise influence after the network intrusion, and its accuracy is low. For this purpose, the literature [5] improves the algorithm, and presents a front balance designed network switching fluctuation control algorithm based on the energy management and baud interval, but it has the short network connection time, high data package transmission interruption rate and other problems; the literature [6] presents a network fluctuation hopping signal suppression algorithm based on unbalanced time-varying signal analysis, which is used to inhibit the cross term of the signal frequency hopping, and increase suppression of the noise and fluctuation interference signal, but this algorithm needs to time-frequency decomposition and phase space rearrangement of the signal, with large calculation quantity. In addition, the literature [7] presents a network self-networking hopping signal suppression algorithm based on Gabor wavelet transformation; and the literature [8] employs a hopping signal anti-fluctuation detection algorithm based on fractional order Fourier transformation, which is used to carry out the suppression and noise-reduction treatment of network fluctuation hopping signal. However, after the traditional algorithms were comprehensively analyzed, we found that all these algorithms can't effectively real-time implement the inhabitation of network fluctuation hopping signal, in particular, they have poor processing ability for the fluctuation hopping resonance signals which are generated due to the network switching of a large-scale hybrid combination network, with poor robustness and real-time[9, 10].

Focusing on the above problems, an algorithm for network fluctuation hopping signal suppression based on disturbance characteristics decomposition and feed-forward modulation was proposed in this paper, which was used to increase the hopping signal suppression performance of large-scale hybrid combination network, carry out the improvement of algorithm based on the disturbance characteristics decomposition and modulation processing according to the creation of signal model, improve the wave-absorbing inhibition ability of network resonance and hopping, and thus increase the balance of network communication, reduce the packet loss probability, ensure the stability of network system, and improve the robustness. The simulation experiment verified the effectiveness and feasibility of the algorithm.

2. Resonance Mathematical Model and Analysis of Network Fluctuation Hopping Signal

3. Problem Description and Mathematical Model of Network Fluctuation Hopping Signal Resonance

This paper investigated the suppression algorithms of fluctuation hopping resonance signal in the data communication and switching of large-scale complicated hybrid combination network, and the resonance mathematical model of the network signal was given first. It provides the model foundation for the generation of signal. The large-scale combination network normally creates the corresponding network model according to the topological structure of node, and changes with the expansion of network scale and the difference of protocols between networks, and since this difference characteristics during the networking of the hybrid network will generate the signal fluctuation, which may result in the instability of network communication transmission channel, and even leave the loophole and backdoor for the network attacker, and thus affects the stability and safety of the network system. Therefore, it is required to carry out the wave absorbing and inhibition of the fluctuation signals, the equation used to create the network resonance signal model is:

$$z(t) = s(t) + js(t) \otimes h(t) = s(t) + j\int_{-\infty}^{+\infty} \frac{s(u)}{t-u} du = s(t) + jH[s(t)] \tag{1}$$

where, $a(t)$ is the transient amplitude of complex signal $z(t)$, sometimes also called envelope; $\phi(t)$ is the instantaneous phase, $Z(f)$ can be obtained from $S(f)$ according to Fourier transform, and $H(f)$ is the step type transmission (transfer) function of the network resonance signal. It is seen from analysis of equation (1) that the resonance signals of network fluctuation hopping are a group of unstable random signals, which have time-varying characteristics and nonlinearity. It is assumed that the signal hopping node of the network during the network switching is defined as $v_m, m \in [1, n]$. The network resonance signal is the complex envelope form of the time-domain and frequency-domain composed narrow-band echo wave, and can be written as:

$$\tilde{y}(t) = \iint_{\tau\phi} b(\tau,\phi) \exp[\ j2\pi\phi t] \tilde{f}(t-\tau) dtd\ \phi \tag{2}$$

where, $b(\tau,\phi)$ is the narrow-band spread function, $\tilde{f}(t)$ is the complex envelope of various frequency component signal, τ is the transmission time delay, and ϕ is the frequency shift characteristics of multi-frequency modulated signal with the change of time. Assume that the linear change of resonance signal as the change of time is the linear transformation during the fluctuation hopping process of the network, which is represented as a frequency modulated signal, and it can be obtained that the narrow-band spread function of the network fluctuation hopping signal is the Fourier transform of a time-varying impulse function or time-varying Green's function, and the transformation process is:

$$y(t) = \iint_{a,b} \rho(a,b) \frac{1}{\sqrt{|a|}} f(\frac{t-b}{a}) \frac{dadb}{a^2} \tag{3}$$

where, $f(t)$ is the non-stationary transient frequency estimation value of the signal, $\rho(a,b)$ is the wide-band spread function, a is the scale parameter, and b is the time-delay parameter. Assume that b_k is the difference of phase value to control the network resonance signal of two different phase hopping nodes, the weight coefficient is $b_0 = 0$, c_k is the phase sampling interval parameter, the wide-band spread function is used to describe the resonance mathematical model of the network fluctuation hopping signal, and it is obtained that the echo signal evolution process of the network fluctuation hopping signal is:

$$y(t) = \frac{1}{c_f} \iint W_f y(a,b) \frac{1}{\sqrt{|a|}} f(\frac{t-b}{a}) \frac{dadb}{a^2} \tag{4}$$

During the network fluctuation hopping process, the continuous Fourier transformation processing method is used to get the admissibility function of the signal fluctuation characteristics, *i.e.*, the square integrable function meets the following admissibility conditions:

$$c_f = \int_{-\infty}^{+\infty} \frac{|F(\omega)|^2}{\omega} d\omega < \infty \tag{5}$$

where, $F(\omega)$ is the Fourier transformation of $f(t)$, and the constant c_f is the admissibility constant of $f(t)$. For this, the resonance mathematical model of the network fluctuation hopping signal is obtained, which provides the signal source for the implementation of the characteristics analysis and feed-forward modulation of network fluctuation hopping signal.

3.1 Pre-Processing Method and Drawback Analysis of Traditional Signal Envelope Characteristics Decomposition

On the basis of the above created resonance mathematical model of network fluctuation hopping signal, it is required to conduct the characteristics pick-up algorithm design in order to implement the suppression processing of network fluctuation hopping signal, in the traditional methods, the envelope pre-pick characteristics pick-up algorithm is used to carry out the envelope characteristics decomposition of the unstable network hopping single-frequency pulse signal, and its specific description is as follows:

The radiation ray model is used to conduct the estimation of transmission loss of the fluctuation signal in the network hopping single-frequency pulse as follows:

$$TL = n \cdot 10\lg r + \alpha r \tag{6}$$

where, *TL* is the transmission loss of unstable network hopping single-frequency pulse signal (dB), n is the transmission factor, r is the carrier frequency attenuation during the data receiving and dispatching and network switching, and the resulted time scale of the network fluctuation hopping signal and complex envelopes of the band pass signal of the time-delay are respectively as follows:

$$s(v) = \int_0^v \sin(\frac{\pi}{2} x^2) dx \tag{7}$$

$$y(t) = u(s(t-\tau)) \exp(j\omega_C s(t-\tau)) \tag{8}$$

Where, v represents the directivity of signal envelope, $u(t)$ is the complex envelope, and ω_C is the carrier frequency (in rad/s). For the wide-band fluctuation signal, the directivity gain is:

$$c(v) = \int_0^v \cos(\frac{\pi}{2} x^2) dx \tag{9}$$

From the equation, it is obtained that the envelope characteristics decomposition result for the unstable network hopping single-frequency pulse signal is:

$$|s(f)| = A\sqrt{\frac{1}{2k}}\{[c(v_1)+c(v_2)]^2 + [s(v_1)+s(v_2)]^2\} \tag{10}$$

The unstable network hopping single-frequency pulse signal is obtained, and thus the scattering property function at t moment is:

$$P_i(t) = \sum_{n=1}^{N} \frac{A}{r} e^{-jkr} R_{in} \frac{1}{r} e^{-ikr} \tag{11}$$

Simplify it to get:

$$P_i(t) = \frac{A}{r^2} \sum_{n=1}^{N} e^{-j2kr} a_{in} e^{j\psi_{in}} \tag{12}$$

Where, $A(t)$ is the reverberation amplitude of a pulse signal, f_0 is the initial frequency, $k = B/T$ is the transient amplitude of the hopping signal transmission, *B* is the band width of the frequency modulated signal. With the above method, the characteristics decomposition and suppression of the unstable network hopping single-frequency pulse signal based on the envelope pre-pick characteristics pick-up is realized, and it is seen combining with the equation (10) that using the traditional algorithms, the real part of complex signal $z(t)$ is the same as the given real signal $s(t) = a(t)\cos\phi(t)$, it is difficult to effectively remove the load part of the network fluctuation hopping signal, which results in a large amount of loss of network frequency hopping pulse signal information, with poor inhibition effect, bad improvement effect of network stability, and results in plenty of communication channel redundancy and information loss, and improves the packet loss probability of network communication, therefore the improvement design of algorithm should be done.

4. Improved Design and Implementation of Algorithm

4.1 Proposal of Signal Disturbance Characteristics Decomposition Algorithm

The algorithm should be improved according to the disadvantages of the traditional methods, in order to effectively implement the signal noise reduction and purification in the fluctuation hopping resonance signal in the data communication and during switching of the large-scale complicated combination network, an algorithm for network fluctuation hopping signal suppression based on disturbance characteristics decomposition and feed-forward modulation is proposed. The key technology to carry out the signal disturbance characteristics decomposition algorithm is given as follows.

In the previously-given resonance model of the network fluctuation hopping signal, the area of the network hopping signal radiation circular loop is:

$$S = \pi(r^2 - MB^2) \tag{13}$$

Assume the unit area is ΔS, and then the number of scatters contributed by i this circular loop is $N = [S / \Delta S]$. The reverberation instantaneous value for the network hopping single-frequency pulse signal is subject to Gaussian distribution, and its probability density function is:

$$f(V) = \frac{1}{\sqrt{2\pi}\sigma_V}\exp(-\frac{V^2}{2\sigma_V^2}) \tag{14}$$

Where: σ_V is the mean square deviation of the instantaneous value V. For the input unstable network hopping single-frequency pulse signal, a lot of resonance signals contain the disturbance characteristics, this paper uses the Doppler frequency shift algorithm to pick up the disturbance characteristics, adopts the reverberated slowly-varied envelope slice to gather the energy of the fluctuation hopping signal in the disturbance direction, and the Doppler frequency shift of disturbance characteristics is considered as ω_d, which is the Taylor series expansion of signal s, and we get:

$$s = \frac{c-v}{c+v} = (1-\frac{v}{c})(1-\frac{v}{c}+(\frac{v}{c})^2 - \cdots) = 1 - \frac{2v}{c} + 2(\frac{v}{c})^2 + \cdots \tag{15}$$

In the Hilbert space the disturbance characteristics decomposition is done, for the random signal in the Gaussian noise, the maximum likelihood autocorrelation estimation algorithm is available, and for the signal s, the irreducible value of the group G in H in Hilbert space is expressed as U, and if some a $g \in H$ exists, get:

$$\int \left|\langle g, U(x)g \rangle\right|^2 d\mu(x) < \infty \tag{16}$$

Then, the result of the disturbance characteristics decomposition of the network fluctuation hopping signal in Hilbert space is obtained as follows:

$$S_T(x,x') = S_n(x,x') *_G \cdots *_G S_2(x,x') *_G S_1(x,x') \quad (17)$$

Where, $*_G$ represents the group convolution in the affine group, this process is similar to the transmission case of the coherence function passing through the random medium, and with the above processing, the resonance characteristics and independent scattering disturbance characteristics of the network fluctuation hopping signal are accurately mapped onto the Hilbert space, which avoids the problem of loss of information occurred in traditional algorithms, the rear energy gathering is done in the Fourier domain to increase the characteristics accumulation of the signal.

3.2 Implementationo of Characteristics Feed-Forward Modulation and Signal Suppression Algorithm

The above pick-up signal disturbance characteristics decomposition result is the input variable, and a feed-forward modulation filter is designed to get the feed-forward modulation suppression of the network fluctuation hopping signal. Figure 1 shows the functional block diagram of signal suppression processing based on feed-forward filter.

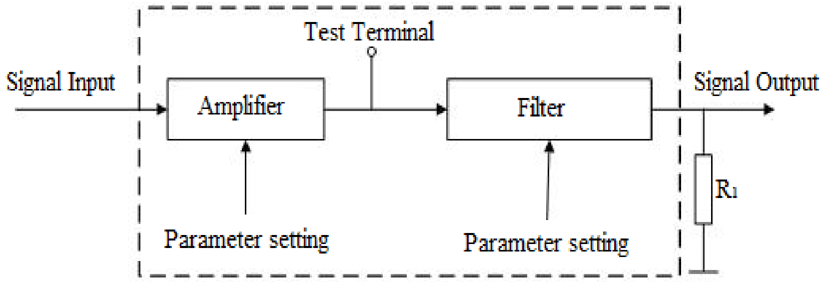

Figure 1. Principle of Signal Suppression Processing Based on Feed-Forward Filter

Combining with Figure 1, the above-calculated signal disturbance characteristics decomposition result is considered as the signal input, the adaptive filter method is used to determine the frequency of signal, and a simple filter form is considered:

$$H(z) = \frac{N(z)}{D(z)} \quad (18)$$

where, $N(z)$ is the numerator polynomial, its zero point is located at $z = e^{\pm j\omega_0}$, $D(z)$ is the denominator polynomial, the amplitude-frequency response is determined according to the frequency parameter a and band-width parameter r of the filter, and on the basis of the feed-forward modulation method, the adaptive adjustment of the tapping coefficient of filter is done and then the frequency of feed-forward filter is obtained:

$$\omega_0 = arc\cos(-a/2) \quad (19)$$

In Hilbert space, since the increase of the hopping signal noise will make the feed-forward modulation filter difficult to get the balanced gain, this paper used the depth zero-point signal channel compensation frequency response estimation algorithm to carry out the adaptive adjustment of the filter tapping coefficient, and the resulted feed-forward filter has high-gain frequency response, as follows:

$$e^{j\pi} = V(e^{j\omega_0}) = \frac{\sin\theta_2 + \sin\theta_1(1+\sin\theta_2)e^{j\omega_0} + e^{j2\omega_0}}{1+\sin\theta_1(1+\sin\theta_2)e^{j\omega_0} + \sin\theta_2 e^{j2\omega_0}} \quad (20)$$

From it, we get the designed transmission function of feed-forward modulation filter as follows:

$$H(z) = \frac{1}{2}\left[1 + V(z)\right]V(e^{j\omega}) + e^{j\Phi(\omega)} \tag{21}$$

Select different wave trapper's frequency parameters θ_1 and band-width parameters θ_2, and calculate the feed-forward modulation band width, and design the feed-forward modulation filter having high-gain frequency response, and the product of the time width by the band width meets the constraint conditions as follows:

$$TW << \frac{c}{2\left|v\right|}, \quad \left|\frac{2v}{c}\right| << 1 \tag{22}$$

Where, $\left|v\right|$ is the time scale expansion of a complex envelope, assume that ω_{ij} is the adaptive adjustment coefficient of transmitted data and node connection in the signal channel e, the disturbance characteristics of the network resonance signal after decomposition fulfills the signal energy suppression filtering in the depth zero-point compensation channel, and the filtering suppression output of the network fluctuation hopping signal after the feed-forward modulated is obtained as follows:

$$y(t) = u(s(t-\tau))\exp(j\omega_C s(t-\tau)) \tag{23}$$

On the basis of the above designed feed-forward filter, the fluctuation hopping resonance signal of the large-scale combination (hybrid) network is subject to the rear resonance suppression processing, with the disturbance characteristics decomposition, it improves the suppression performance of the hopping signal, in particular, the method proposed in this paper makes the signals gather in the Hilbert space and implement the linear overlapping and focusing, reserve the negative-frequency part of the network fluctuation hopping signal and prevent the loss of information, and thus is useful to improvement of accuracy and effectiveness of network communication. With the signal suppression processing, it can avoid the occurrence of startup hysteresis, server load, message consumption, tremble and other symptoms in the network.

5. Results and Discussion

To verify the performance of the algorithm proposed in this paper, the simulation test is conducted, the test platform is a common PC computer, which its CPU is Intel® Core™ i7-2600@3.40 GHz, its RAM memory is 4*4 GB DDR3@1600 9-9-9-24, its operating system is Windows7, and the development tool is VS2008, the parallel processing is done with OpenMP 2.0 and MPICH NT 1.2.5m, and the algorithm design is implemented using Matlab for programming.

The network fluctuation reporting signal center frequency tested is $f_0 = 1000$ Hz, the discrete sampling rate is $f_s = 10 * f_0\text{Hz} = 10\text{KHz}$, and the band width is $B = 1000$ Hz. The time delay of the resonance signal of the network fluctuation hopping is valued as 20 ms, the weight distribution of this predicted result is expressed by using the integration parameters ϕ and φ, with the selection of parameters is: $\phi=\varphi=0.5$, the order of feed-forward modulation filter is 24, all the tapping intervals of feed-forward filter are 1/2 code-element interval, the order of feedback equalizer is 3, its tapping interval is the code element interval, the size of iteration step is 0.01, and the feedback coefficient of order $r = 20$ and length $N = 1048575$ is 4000011. With the acquisition of signal, Figure2 shows the resulted time-domain wave form of the network fluctuation hopping signal of one group of test specimens.

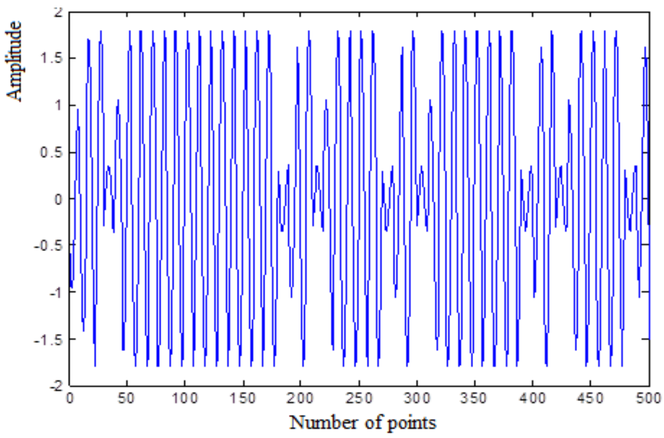

Figure 2. Resonance Waveform of Network Fluctuation Hopping Signal

Under the condition which the code rate is 1kBaud, the carrier frequency is 3kHz, and the sampling frequency is 10 times of carrier frequency, the network fluctuation hopping signal is subject to the disturbance characteristics decomposition, and the resulted decomposition results of the disturbance characteristics is shown in Figure 3, in this figure, the disturbance characteristics of the signal is divided into base-band signal, local carrier wave and modulated wave.

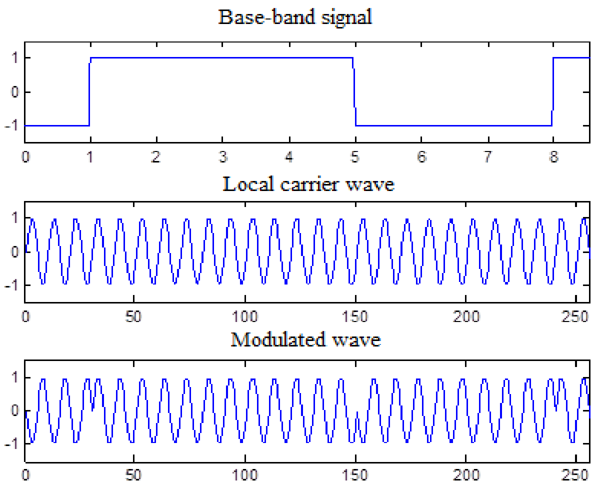

Figure 3. Decomposition Results of Disturbance Characteristics

The resulted decomposed disturbance characteristics is taken as the input variables, in the feed-forward modulation filter designed in this paper, the suppression processing of the network fluctuation hopping signal is done, and the resulted modulated signal output results after feed-forward modulation suppression are shown in Figure 4. It is seen from the figure that the algorithm described in this paper can be used to effectively inhibit the resonance signal during the network fluctuation hopping, prevent the network fluctuation and signal instability, and effectively overcome various startup hysteresis, server load, tremble and other problems which occur in the hybrid network during the network switching and data communication.

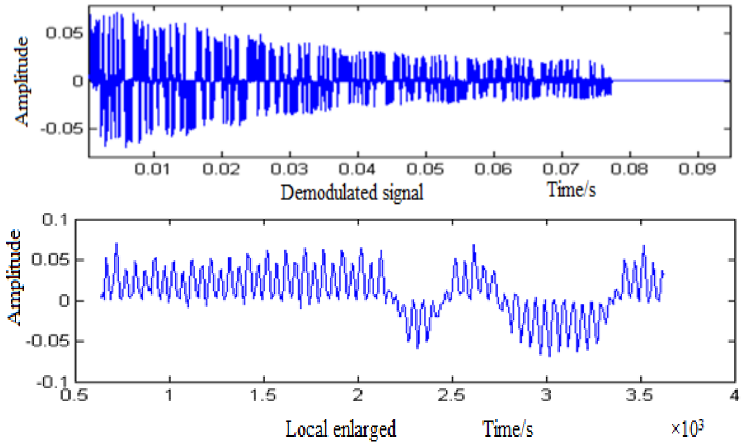

Figure 4. Resonance Signal Suppression Output Result and Local Enlarged Waveform

In order to compare the performance of various algorithms, taking the packet loss probability of the data transmission as the test index, the algorithm proposed in this paper and the traditional algorithms are used to conduct the resonance suppression of the network fluctuation hopping signal and then compare its performance, and the comparison of resulted data transmission pocket loss probability of both methods with different network transmission capacity is shown in Figure 5. It can be seen from Figure 5 that using this algorithm proposed in this paper, the pocket loss probability of network data transmission is lower than that of the traditional algorithms, and it exhibits its superiority of this algorithm in ensuring the stability and safety of the network communication system.

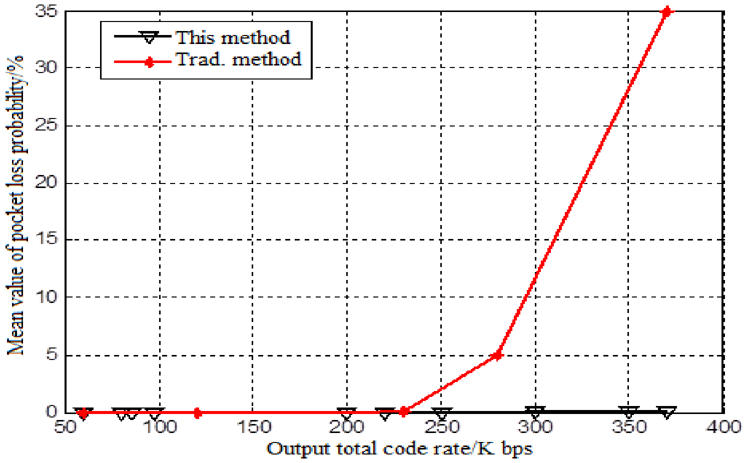

Figure 5. Comparison of Network Performance

The running time of the system is tested, with the same CPU load, this algorithm is used to implement the suppression of network fluctuation hopping signal, the mean running time interval of data transmission is 15s while that of the traditional method is about 35s, it indicates that using this algorithm proposed in this paper, the network transmission adjustment rate is high, with good convergence, which ensures the real-time and stability of the network switching.

6. Conclusion

In large-scale hybrid network, since the phase-group character between networks is different, a network fluctuation hopping resonance signal is generated in the network switcher and data communication, and this resonance signal exists in the network communication system in the form of noise, which is represented with a hopping pulse and brings the network fluctuation and signal instability. The research on the suppression algorithm of network fluctuation hopping signal generated during the network switching is very important to provide the safety stability of information communication and network system. An algorithm for network fluctuation hopping signal suppression based on disturbance characteristics decomposition and feed-forward modulation is proposed in this paper in order to improve the hopping signal suppression performance of a large-scale hybrid network. The resonance mathematical model of the network fluctuation hopping signal is created, and a disturbance characteristics decomposition algorithm of a signal is proposed, and a feed-forward filter is designed to implement the disturbance decomposition characteristics feed-forward modulation and signal resonance suppression. It is found through analysis that the algorithm proposed in this paper can be used to effectively inhibit the resonance signal of the network fluctuation hopping, prevent the network fluctuation and signal instability, and reduce the data transmission pocket loss probability, and this algorithm is superior to the traditional methods in the real-time and stability of the network switching.

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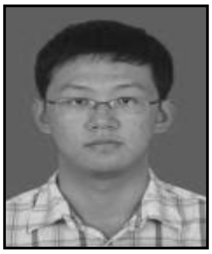

Chen Weijun (1984), School of Software, Anyang Normal University, Anyang 455000, Henan, China.

