An Improved Data Rate Change Algorithm based on Adaptive Frame Length

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Abstract. In order to solve the high bit error rate (BER) caused by rate oscillation in traditional Data Rate Change (DRC) algorithm, an improved DRC algorithm based on Adaptive Frame Length (AFL) was proposed. Firstly, the frame length and transmission rate of the initial transmission were determined by the parameters of the current channel and the information of previous empirical values. Then, if two frames with the same length were successively sent in the transmission process, the frame length would be accordingly increased. If the retransmission failed twice in a row, the frame length would be halved in the next transmission. Finally, the frame error rate was calculated based on the current frame length. The data rate would be updated if the value was less than the present threshold. Compared with RapidM DRC, the average bit error rate of the link decreased by 4.8 percentage points, and the link availability increased by 10 percentage points. The experimental results show that the proposed algorithm can eliminate the rate oscillation and improve the communication capability of the HF communication system.

1. Introduction

Since the 80s that communications on the high frequency (HF) band have undergone a remarkable technologic evolution, short-wave communication [1] has always been an important means of emergency communication and no-blind area communication, as well as a minimum guarantee means of military long-distance communication. However, short-wave channel is in an unstable state affected by weather and other factors. In order to achieve reliable and efficient communication, Automatic Link Quality Analysis (LQA), Automatic Link Establishment (ALE), Data Rate Change (DRC) and other technologies have emerged. Among them, variable-rate communication can select the highest data rate in the current channel state [2] to achieve reliable and efficient communication.

The development and application of variable speed short-wave communication technology is relatively late. In 1999, NATO first proposed DRC idea in its standard STANAG 5066, which opened up space for the development of variable speed technology of short-wave communication. In the same year, S. E. Trinder and D. J. Brown proposed the DRC algorithm based on STANAG 5066 standard [3], which can adjust the data Rate step by step according to the Frame Error Rate (FER). Subsequently, Trinder proposed DRC algorithm based on STANAG 4369 standard in literature [4]. Stephan proposed RapidM DRC algorithm based on the same standard [5], which mainly adapts to the higher rate of Autobaud waveform. In literature [6], a fast DRC algorithm is proposed to collect
statistical information including Bit Error rate and signal-to-noise Ratio, and make unified decision of multiple information based on the current Bit Error Ratio (BER) to adjust the data rate. In literature [7], the above two algorithms were improved by adding bit error rate judgment module before changing data rate, reducing data rate oscillation and improving Link Availability (LA).

In summary, scholars have achieved a lot of excellent results in the transmission rate communication, but at present, DRC algorithm is mainly focused on the modulation mode [8] and waveform [9] to improve, and the adjustment delay due to the high algorithm complexity is also long. Meanwhile, DRC communication technology is adopted in the short-wave radio stations in service [10]. Therefore, the speed rate algorithm based on frame length is a worthy research direction.

The paper is divided into three parts. In the first part, the principle and flow chart of Trinder DRC and RapidM DRC are introduced. In the second part, the improved algorithm of the two algorithms is presented, and the flow chart is given. In the last part, the feasibility of the improvement is obtained by comparing the algorithms before and after the improvement.

2. Traditional rate of change algorithm

At present, Trinder DRC and RapidM DRC are the main DRC algorithms in use.

2.1. Trinder DRC algorithm

Trinder DRC algorithm is mainly proposed to serve STANAG 5066 standard. Regarding the three different channel models proposed by the standard, AWGN(Additive White Gaussian Noise), ITU-R (International Telecommunication Union-Radio Communications Sector) Good, ITU-R Poor, the optimal data rate is selected by referring to the Signal to Noise Ratio (SNR) of the receiver. As shown in table 1:

| Data rate (bit/s) | SNR(dB) | AWGN | Good | Poor |
|------------------|---------|------|------|------|
| 75               | -6.75   | 1.75 | -2.50|
| 150              | -4.00   | 2.00 | -1.00|
| 300              | -1.50   | 5.50 | 1.00 |
| 600              | 2.02    | 12.18| 7.10 |
| 1200             | 5.25    | 14.95| 10.10|
| 3200             | 7.60    | 21.40| 15.00|
| 4800             | 12.29   | 25.21| 19.75|
| 6400             | 14.69   | 30.71| 22.20|
| 8000             | 15.44   | 35.56| 25.50|
| 9600             | 20.48   | 42.02| 29.75|

After the initial transmission rate is obtained through table 1, the transmission is carried out and the Frame Error Rate (FER) is calculated.

\[
FER = 1 - (1 - BER)^L
\]  

(1)

After obtaining the frame error rate, comparison table 2 changes the transmission rate. When the error frame rate reaches the minimum threshold, the data rate will be reduced by one step (the current rate will be reduced to half of the current value at 75 bit/s-2400 bit/s), and the data rate will be increased by one step (the current rate will be increased by one step at 75 bit/s-2400 bit/s).
Table 2. FER thresholder values used for DRC algorithm.

| Data rate (bit/s) | Minimum FER (Decrease Rate) | Maximum FER (Increase Rate) |
|------------------|-------------------------------|-----------------------------|
| 75-2400          | 50                            | 10                          |
| 3200             | 50                            | 10                          |
| 4800             | 35                            | 5                           |
| 6400             | 20                            | 5                           |
| 8000             | 15                            | 2                           |
| 9600             | 5                             | N/A                         |

2.2. RapidM DRC algorithm

RapidM DRC algorithm is implemented in the following three steps:

- Step 1: calculate the SNR after receiving, and select the initial data transmission rate by referring to table 1.
- Step 2: calculate the bit error rate at the current rate. Determine whether the rate needs to be changed according to table 3.
- Step 3: use bit error rate and average bit error rate to calculate the optimal data rate. After obtaining the data rate, only a small change in the data rate is carried out.

Table 3. BER decision thresholder for RapidM DRC algorithm.

| BER    | Data Rate Action                        |
|--------|-----------------------------------------|
| BER≥10^{-4} | Decrease data rate                     |
| 10^{-4}>BER≥10^{-6} | Keep data rate the same    |
| BER<10^{-6}       | Increase data rate                     |

At the same time, the algorithm implements security controls that do not allow the data rate to increase to more than two levels (for example, if the current data rate is 600 bits/second, the new data rate may be up to 3200 bits/second), or reduce the current data rate to more than three levels.

2.3. Algorithm simulation and analysis

The simulation system for realizing and analysing DRC algorithm is shown in figure 1. In order to guarantee the communication quality prize, the SNR threshold is set to 10^{-5}, simulation is carried out under AWGN, ITU-R Good and ITU-R Poor channel quality.

The initial data rate is calculated by comparing the current SNR and SNR threshold requirements. After initialization, BER and FER are calculated by formulas (1), (2) and (3).

\[ \Delta SNR = SNR_{measured} - SNR_{required} \]  
\[ BER = 10^{-5} \times 10^{-\Delta SNR} \]  

\[ SNR_{measured} = SNR_{required} - \Delta SNR \] (2)  

\[ BER = 10^{-5} \times 10^{-\Delta SNR} \] (3)
In this paper, two algorithms are presented in which the SNR time decreases (according to the sinusoidal curve) and the data rate changes with the SNR. The simulation is carried out under AWGN, ITU-R Good and ITU-R Poor channel quality.

In terms of parameter setting, the running time interval after each channel change; Total running time interval; The frame length. The simulation results are as follows:

Table 4. Link quality assessment of traditional DRC algorithm.

| Algorithm   | \( \overline{BER} \) \((10^{-5})\) | \( \overline{FER} \) (%) | LA (%) | \( \overline{Th} \) (bits/s) | \( \overline{Gp} \) (frames/s) |
|-------------|-------------------------------------|--------------------------|--------|----------------------------|-------------------------------|
| Trinder algorithm | 4.82                                | 8.76                     | 66     | 4001.38                    | 1942                          |
| RapidM algorithm | 3.15                                | 5.64                     | 72     | 4189.34                    | 2066                          |

The link evaluation indexes obtained are shown in table 4. It can be seen from table 4 that RapidM algorithm performs better than Trinder algorithm. However, it still has the data rate fluctuation caused by the sudden increase of bit error rate.

3. Data Rate Change Algorithm based on Adaptive Frame Length

This section mainly introduces the adaptive frame length algorithm, and then carries on the simulation of the transmission system based on this algorithm, and finally gives the experimental results and analysis.

3.1. DRC algorithm based on adaptive frame length

There is an optimal value for the frame length of the channel, but it is difficult to get it accurately. So far we can only approximate it with the right algorithm. At the same time, the algorithm should be able to determine the frame length quickly and ensure the stability of the used frame length.

The specific steps of the algorithm are as follows:
1) firstly, the sender and receiver negotiate the initial frame length. The sender can use the prior value method to determine the initial frame length by listening to the successful frame length sent in the current channel or use the original frame length value which has been successfully sent.

2) the sending end records the frame length of each successful sending. When the frame length of two consecutive successful sending is L, the new frame length is twice L. When a predetermined upper limit is reached, the frame length does not increase.

3) when error correction of a frame fails and it needs to be retransmitted, retransmit the original frame twice. If both transfers fail, select half of the frame length of the failed transmission as the new frame length. A link failure is declared when the portion of the data frame is less than one byte.

4) when the frame length jumps continuously between the two values of L and 2L for 3 times, the new frame length is 1.5L (the integer value of the length). Reduce the frame length to L if three consecutive transmission failures occur.

The algorithm is a whole, including not only the fast avoidance when encountering obstacles, but also the full use of channel quality. At the same time, the oscillation of frame length near a certain value is avoided.

3.2. Algorithm simulation and analysis

Trinder algorithm and RapidM algorithm are improved and simulated respectively. The state of short-wave channel changes rapidly and has certain periodicity. The initial frame length is set according to the empirical value of communication L = 240 bytes. To ensure communication quality, the threshold value of FER is set to 10%; Similarly, the running time interval \( T_s = 120 \) s;

| Trinder algorithm   | RapidM algorithm  |
|---------------------|-------------------|
| BER (10^-5)         | BER (10^-5)       |
| FER (%)             | FER (%)           |
| LA (%)              | LA (%)            |
| \( \overline{Th} \) (bits/s) | \( \overline{Gp} \) (frames/s) |
| 1.95                | 1.35              |
| 3.81                | 2.16              |
| 78                  | 83                |
| 3443.38             | 4519.34           |
| 2144                | 2234              |

It can be seen from table 5 that the improved Trinder algorithm and RapidM algorithm have certain improvement in performance. After adopting the improved algorithm, the Trinder algorithm reduces the frame error rate by 4.83 percentage points and the link connectivity rate increases by 12 percentage points. In the improved RapidM algorithm, the frame error rate was reduced by 3.18 percentage points, the link connectivity rate was increased by 10 percentage points, and the average throughput and average frame rate were also improved.

In conclusion, the adaptive frame length DRC algorithm proposed in this paper has a great advantage over the traditional two DRC algorithms. Therefore, the effectiveness of the transmission quality control mechanism by changing the frame length can be seen. As the traditional DRC algorithm is evaluated with the same frame length, when the bit error rate increases, the frame length should be reduced appropriately to keep the same frame error rate, thus improving the communication quality.

4. Conclusions

Short-wave communication has always been used as a basic means of military long-distance communication. Because the quality of short-wave channel changes rapidly, it is important to study the DRC algorithm.

In this paper, Trinder DRC and RapidM DRC are introduced and the traditional short-wave variable-rate algorithms are simulated. At the same time, a solution is proposed to solve the problem
of rate oscillation by adding a new judgment module before updating the data rate of the original algorithm flow, and to reduce the frame error rate and improve the link connectivity rate by introducing the concept of adaptive frame length.

For the follow-up research, it is suggested to extend in two directions: one is to realize more efficient adaptive frame length algorithm; On the other hand, the research is combined with broadband short-wave communication

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