Research on the Link Quality Prediction Mechanism Based on ARIMA Model for Multi Person Cooperative Interaction

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Abstract. With the continuous enhancement of the hardware performance, the dynamic high speed sensing network in the small and medium size of the special industry is becoming more and more recognized and valued by the academic circles and enterprises, and in the process of multi - user interaction, the requirements on the quality of the link are also higher, but the high speed communication of the instability of the link quality and difficult to judge critical problem has not been solved. In this paper, we use the ARIMA model to predict the link quality of wireless multimedia sensor network, make the dynamic buffer and link switch in time. Finally through the experiment discovered after post-processing forecast network to meet the real-time dynamic environment average closing package rate, stability and robustness are significantly improved.

Keywords: Wireless multimedia sensor network · Cooperative interaction · Link quality · Trend forecast

1 Introduction

Wireless multimedia sensor network [1–3] is derived from the traditional sensor networks. It is a high speed wireless network which is dynamically self-organizing formed by a group of multi media sensor nodes with sensing, computing and communication capabilities, with the cooperative interaction among nodes, acquisition and processing of multimedia information, Ad hoc network [4–7] is a special kind of wireless mobile network, which can be used to communicate with the nodes outside the coverage area, and has great advantages in the field of military applications. Wireless multimedia sensor networks and Ad hoc networks are not new, with the continuous improvement of the hardware capabilities and application of innovative, in public security, military, anti-terrorism, industrial equipment and environmental monitoring and other fields based on this technology to build a small scale of the interactive work of the network reflects more demand and higher requirements.

1984 MIT Irene Greif and Paul Cashman from DEC, put forward the computer supported cooperative work. The main purpose of this is to establish collaborative work environment, improve information exchange between human beings. It's also can remove the obstacles in the time and space separated, improve the quality and efficiency

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of group work, make the group activities in the network environment become truly digital and agility [8–10]. With the rapid development of pervasive computing, wearable computing, the concept of the form and calculation of the computer is changing, and the extension of cooperation is also expanding.

2 BackGround

In a special environment, the environment is detected, the environment is matched with the real-time information, and the data is collected by the personnel or other equipment. It may happen that the action of high speed, static and slow moving, and the distance between nodes is constantly updated. At this point, the frequency of a single node in a certain range is very high, and the intensity of the sensor is also changed with the change of the distance. The transmission effect of the data packet is bad. Experiments in [11] show that the performance of the AOMDV protocol is declining very fast when the nodes move fast.

At present, the link quality is judged according to the link's remaining life cycle [12], value of RSSI [13–16], LQI [17, 18] or PRR [19]. Although the PRR value can directly reflect the current link state, it is needed to calculate the packet by a large number of samples, and waste a large amount of bandwidth and energy to obtain a large statistical base, and PRR is just a result of a certain time point that can only get the current or previous link quality, but link quality assessment of real-time in the application is very important. While LQI and RSSI can be used to reflect the quality of the link in the open environment without interference [20]. It is not desirable to use this method in our stochastic motion application environment.

In the [19], a average value of RSSI is used as a threshold for the link detection, and then the link is predicted in the future for a period of time. This is a critical point for the link quality of the above mentioned RSSI, which can be regarded as the normal transmission, when the data transmission is considered enough to affect the video quality, the link is switched to improve the transmission quality.

We will find that in the process of communication, data transmission sometimes get slowly when the broken. Although the data is transmitted, the effective transmission rate is very slow, giving a false impression of transmission. But the link is really connected state, routing can not switch because the link is disconnected, the transmission efficiency is very low. In [19] the experiment results show that the average RSSI is lower than 85 DBM, PRR values between 30 % $\sim$ 95 % swings back and forth, link to present a very unstable state, while the average RSSI is greater than 85 DBM, PRR less volatile, link showed good stability. The link stability is poor when the transceiver signal is lower than a certain value, and the data communication is not stable at this time.

In previous studies usually just calculate the link quality after immediately to choose the best links to link to switch, the default link cannot achieve requirements before use. However, the change of the link quality in some application scenarios is a relatively slow process, calculate the quality link immediately after failure or does not meet the requirements of probability is very small. Generally, the two types of links are switched. Firstly, packet loss rate is high, but it is enough to guarantee the video quality is immediately switched; Secondly, packet loss rate has begun to affect the video quality before starting to calculate the link quality to switch, both of them make the high-speed data transmission process is interrupted, the frequent switching will cause the phenomenon of slow transmission of communication, if there are some very urgent interactive processes, it will result in very significant economic and personnel losses.

ARIMA model is a very famous time series forecasting method proposed by Jenkins and Boakes. The non-stationary time series is transformed to stationary time series, and the model is established by regression analysis of the lagged values of the variables and the present value of the random error term and the lag value of the random error term. The data is considered as a random sequence, and a certain mathematical model is used to describe the sequence, and the value of the past and the present value is predicted to be a trend.

In this paper, according to the problems of the above research, the paper puts forward the model based on the time series ARIMA model to analyze the PRR and gets a relatively long time period of the link change trend. According to the forecast trend, the link quality is calculated in advance, the preparatory action is carried out in advance, and some resources are used only in a certain time period.

When the transmission effect reaches a critical point, the transmission link is stable in a small fluctuation range, with a very small price to ensure the quality of data transmission, improve the network performance, solve the problem of the slow transmission of the critical communication phenomenon.

3 Model Construction and Algorithm

3.1 ARIMA Model

ARIMA(p,d,q) model is ARMA(p,q) model after d times difference, AR(p) is the Auto regressive model, p is a self regression, MA(q) is moving average model, q is moving average number; The Xt indicates the T period of the collection rate, and X has the characteristics of MA and AR, For example, the following is a ARMA (1,1) model, Θ is constant term.

$$X_t = \theta + \alpha_1 X_{t-1} + \beta_0 u_t + \beta_1 u_{t-1} \tag{1}$$

Constructing ARIMA(p,d,q) model, firstly should judge whether the time series is stationary sequence, according to the sequence of hash map, the autocorrelation function and partial autocorrelation function, the ADF unit root test variance and so on to carry out the identification of the sequence. As for the non-stationary time series, after d times difference:

$$\Delta X_t = X_t - X_{t-1} = X_t - LX_t = (1 - L)X_t \tag{2}$$

$$\Delta^2 X_t = (1 - L)^d X_t \tag{3}$$

After d times difference, we can get stationary time series $W_t = \Delta^d X_t$, ARMA modeling for W_t, you can get:

$$W_t = \emptyset_1 W_{t-1} + \emptyset_2 W_{t-2} + \cdots + \emptyset_p W_{t-p} + \delta + u_t + \theta_1 u_{t-1} + \theta_2 u_{t-2} + \cdots + \theta_q u_{t-q} \quad (4)$$

The autocorrelation function of ACF ρ_k and the partial autocorrelation function of PACF φ_{kk} with model identification:

$$\rho_k = \frac{\sum_{t=1}^{N-K} X'_{t+k} X'_t}{N} \quad (5)$$

$$\begin{cases} \varphi_{11} = \rho_1 \\ \varphi_{k+1,k+1} = (\rho_{k+1} - \sum_{j=1}^{k} \rho_{k+1} - j\varphi_{kj})(1 - \sum_{j=1}^{k} \rho_j \varphi_{kj})^{-1} \\ \varphi_{k+1,j} = \varphi_{kj} - \varphi_{k+1,k+1}\varphi_{k.k+1-j}, j = 1, 2, \cdots, k \end{cases} \quad (6)$$

According to the above calculation results and according to Table 1 model identification principle, can be determined in accordance with the model.

Table 1. Model identification principle

Model	AR(p)	MA(q)	ARMA(p,q)
AF	exponential decay	finite length, truncation (q)	exponential decay
PAF	truncation (p steps)	exponential decay	exponential decay

In order to test the model satisfy the stationarity and invertibility of and need to estimate the parameters of the model, namely the following formula root meet outside the unit circle:

$$\varphi(B) = 1 - \sum_{j=1}^{p} \varphi_j B^j = 0 \quad \theta(B) = 1 - \sum_{j=1}^{p} \varphi\theta_j B^j = 0 \quad (7)$$

It is also necessary to test the hypothesis of the model, and then the reliability prediction model can be obtained by the white noise test.

3.2 Energy Consumption Model

According to the prediction mechanism, the link quality is changed, and the link quality is calculated. The energy consumption model based on RSSI values is further constructed. Then, the residual energy of nodes is used as a factor to determine the quality of the link.

A node energy consumption model in wireless multimedia sensor networks is proposed in [17].

$$E_{new} = E_{old} - E_{consume} \quad (8)$$

Node energy consumption $E_{consume}$ is mainly composed of data sending, receiving and forwarding of three parts. Nodes send data to consume energy:

$$E_{sent} = P_{sent}T_p = I_sVT_p \tag{9}$$

Forwarding data needs to consume energy:

$$E_{jorw} = (P_{sent} + P_{recv})T_p \tag{10}$$

Receiving data needs to consume energy:

$$E_{recv} = P_{recv}T_p = I_rVT_p \tag{11}$$

So the total energy consumption of the node:

$$E_{consume} = E_{send} + E_{recv} + (N - 1)E_{jorw} \tag{12}$$

Among them, the P_{send} said the node transmit power, P_{recv} for receiving power, T_p for sending and receiving time, I_s for the transmission current, I_r for receiving current. RSSI as a node to receive signal strength indicator, and can be expressed as the node to send and receive power, The RSSI value of the current node is calculated as the energy consumption of the current node, and can be used to calculate the link quality in real time.

When the link quality is detected, the RSSI value of the node is detected as R. At the same time, calculate the node energy consumption as E, both of them as a link quality judgment standard. When the route switch is triggered, the impact of the hop count on the bandwidth is calculated with them. If the current node needs to transmit the video stream number more, increase the bandwidth of the weight, if only one way data need to be transmitted, it can increase the energy consumption and RSSI requirements. T_{max} can be selected when switching route,

$$T_{max} = \frac{1}{1 + I^2} * (E_{min} + R_{max}) + \frac{I^2}{1 + I^2} * \frac{K}{N} \tag{13}$$

K represents bandwidth, and N is the number of hop node and there are I video streams needs to be transmitted.

4 Test and Analysis

In this paper, ZYNQ-7000 is used as an experimental platform to extend the processing platform, using FPGA to combine software and hardware resources to achieve wireless multimedia sensor function. Two kinds of scenes, the building and outside garden, are tested and the data are tested. The nodes are distributed in the indoor and outdoor. In ad hoc networks, the time to complete the whole network interaction between nodes is required at most 7 frames, and the information synchronization is realized. So the data is collected by the 21 frame, and the random selection node is running, walking and waiting for the behavior to simulate a test environment.

After a period of time, the data collected is shown in Fig. 1.

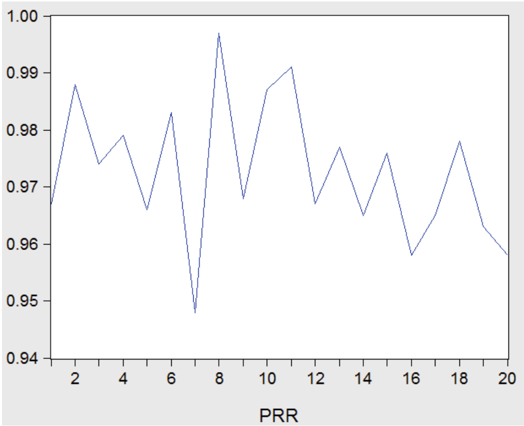

Fig. 1. PRR Time periodic value, the data fluctuate strongly, but still PRR almost 95 % or more

Obviously, the data prove that it's enough to ensure the transmission quality, ARIMA (2,2,1) model was determined by ARIMA model analysis, and the test residual sequence is qualified, we can consider the model can reflect the change trend of the actual collection rate.

Extending predicted space to get the model formula:

$$X_t = 0.960438 + 0.681309X_{t-1} + 0.251076X_{t-2} - 0.997366a_{t-1} \quad (14)$$

Extended space for trend prediction, as shown in Fig. 2.

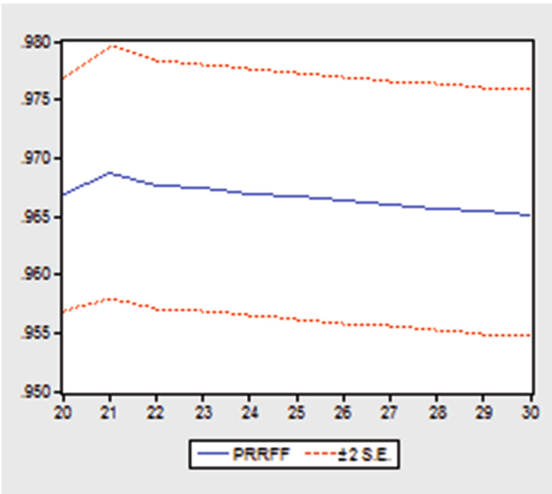

Fig. 2. Trend forecast results, the predicted value and the standard error of the graphics, in the future period of time the packet rate is a slow decline in the form of change.

It can be inferred that in the next period of time, the link transmission effect will gradually become worse. But it can be seen that the rate is still high, still maintained at more than 95 %, can continue to transmit data.

With the prediction of the trend, the PRR value indicates that the link quality will fall to the extent that the link is transmitted in the future.

The link quality can be calculated as the switch link to get the critical point, which indicates that the link transmission effect has been affected by the video quality.

Test the results, and there is a trend to judge and no trend to judge the results of the comparison of the results in Fig. 3;

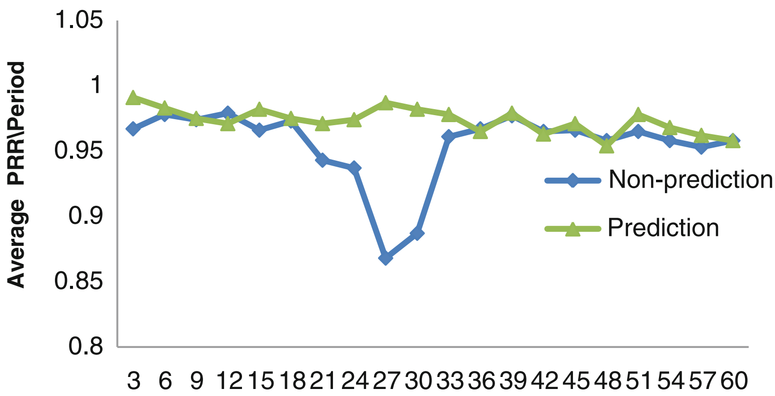

Fig. 3. Average packet rate change contrast, in the network without the use of forecasting mechanisms, the average rate of recovery has been a great decline after recovery

It can be guessed that the link quality is needed to be added after the critical point of the switch, and the link quality is needed to be switched. And the network's packet rate is predicted to have a certain growth trend in that time, which indicates that the time of the handover to the link quality is better.

At the same time, it can be seen in the time period of the test, which has a forecast mechanism of the network's packet rate stability in a very small range of fluctuations, and its transmission efficiency is able to meet the needs.

And for the no prediction mechanism network, the packet reception rate although in a certain period of time can also meet transmission needs, but link switching lead to instability, is likely to accept node suspended phenomenon. Compared the real time performance of data transmission (Fig. 4).

Without the use of predictive mechanisms in the network, it can be seen in the switching of the link time delay is very powerful, but also relatively large fluctuations. From the above evaluation index, the network with prediction mechanism, no matter on the stability, delay or robustness, its data transmission is better than that without the use of prediction mechanism.

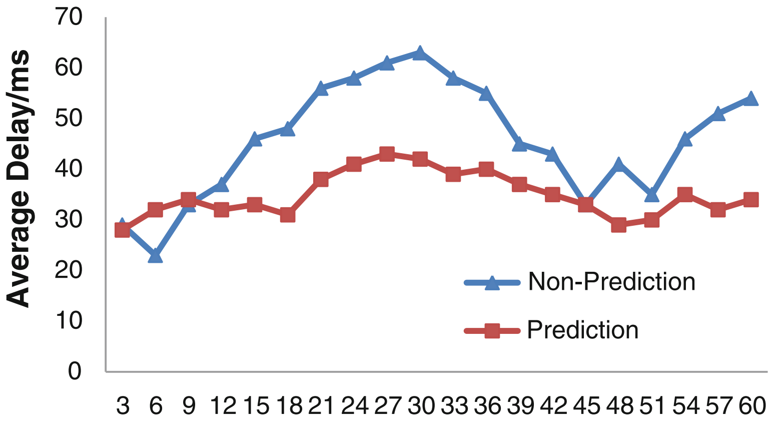

Fig. 4. Average delay contrast, the average delay of the network with a prediction mechanism is maintained in a range, although the link quality can be increased, but the change is not affected.

5 Summary

In this paper, we propose a time series ARIMA model to predict the link quality and select the PRR value as the link quality measure. The link quality prediction results show a downward trend, with the RSSI value, the remaining quality of nodes, the number of hops to the rest of the link to calculate the link quality, when the RSSI value reaches the critical point to switch the best link for data transmission. The results of simulation experiments show that the network packet rate, and the average end delay are stable in a small range, which is obviously superior to the network without using prediction mechanism. In real-time, robustness and stability more than before to meet the requirements of QOS, the basic solution to the data transmission is inefficient, resulting in slow transmission phenomenon.

In this paper, we only use the same link quality calculation method to compare the two networks, in the future testing, we also need to try to join other link calculation method and adding forecasting mechanism of the network to carry on the experiment, and compared with other prediction mechanism. In this paper, the single use of PRR value in the prediction of the link quality, in the follow-up work to increase the accuracy, may also need to refer to other factors, As for the critical point of the judgment is only a reference to the RSSI mean change, the current link quality changes can also be considered to join.

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