A Study of Enhancing TCP Performance over Heterogeneous Networks

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Abstract

With the development of the communication technology, computer network hasn't limited to wired,simplex and homogeneous network any more,but presents trend of heterogeneous highly. Next generation network can shied the characteristic of heterogeneous of low-level transmission equipment, and provide an open, steady and high-powed service platform to sustain quick exploitation, integration, customization and network distributed application. So far, the communication technology of adapting to heterogeneous networks would be TCP/IP which is the most successful technology in the Internet. This was largely attributed to the core design philosophy of end-to-end transparent. This paper will focus on TCP congestion control technology over heterogeneous networks; with hopefully could provide valuable reference to improve the TCP performance over heterogeneous networks. The main works are as follows: A: The factors which affect the TCP performance and the problems of traditional TCP used in heterogeneous networks are discussed to further study laid a foundation. B: Some representation results of TCP technology which suit for heterogenesous networks are analyzed and simulations over the heterogeneous environment are completed. Then, the problems which exist are presented. C: An alternative scenario-TCP-selective, which may choose different TCP algorithms according to the different link types is proposed to solve the problems which the sole TCP enhancement plan can not solve. Through simulation results, the new TCP technology is available and feasible. D: Relevant modified TCP mechanisms based on different current TCP algorithms are proposed and simulation results show that these algorithms also have good performance.

Keywords

TCP, heterogeneous network, congestion control, enhancing TCP performance.

1. Research Background

Traditional TCP congestion control is mainly for the bandwidth delay product is small (the bottleneck link buffer capacity is far greater than the bandwidth delay product) and channel bit error rate is very low in wired network, and design, it according to the characteristics of wired network generally assumed that packet losses are due to network congestion, this assumption enables TCP works well in wired networks. But when multiple heterogeneous network interconnection together, due to changes in the transmission bandwidth and quality differences of physical link, channel non symmetry, terminal mobility, round-trip delay fluctuation and energy consumption and other factors, often unpredictable interaction, this across heterogeneous media data often leads to a sharp decline in the performance of traditional TCP. In heterogeneous networks, the design of TCP must consider the characteristics and needs of different networks. Therefore, the heterogeneous network TCP performance enhancement technology research has become an urgent research topic in the field of communication.

At present, many researchers at home and abroad has worked in heterogeneous network TCP performance enhancing research, put forward various improvement mechanism. However, with the development of network, the communication environment is constantly changing. Has the most improvement is to solve different performance decline, the result is for a special network environment were optimized, has not yet been accepted solutions. Is the research situation at this stage, for TCP for a variety of heterogeneous network performance enhancing techniques, to be further exploration and research.

In the heterogeneous network environment, which mainly has the following factors: the deterioration of performance of TCP transmission bandwidth strong difference. The difference of physical link quality. Asymmetry of channel. The terminal mobility. The longer the delay time. The fluctuation of time delay. The energy consumption.

In the heterogeneous network environment, due to differences in changes in the transmission bandwidth, a physical link quality, channel of non symmetry, terminal mobility, a longer delay time and large fluctuation of time delay and energy consumption factors, which caused the a series of problems: data lost because of diversification. The "slow start" phase appears unable to make effective use of network bandwidth, resulting in a sharp decline in the performance of TCP. False timeout. The vertical handoff.

In this paper, the heterogeneous network TCP performance enhancing techniques are discussed. Firstly, it analyzes the heterogeneous network under the influence of TCP performance factors and problems, and to solve these problems put forward a macroscopic solution. According to different link types choose different TCP congestion control algorithm, so as to achieve the overall performance of the improved. At the same time, the TCP congestion control algorithm were improved, simulation results show that, algorithm is proposed in this paper can improve network performance to expected target.

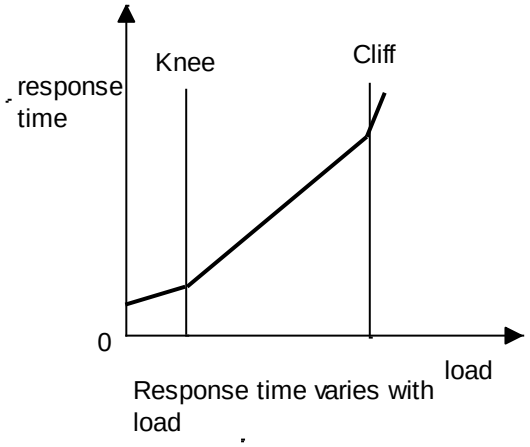
2. TCP Congestion Control Technology

TCP (transmission control protocol) is an end to end connection oriented transmission control protocol and for the application to provide reliable data transmission service, plays a very important role in guaranteeing the network communication performance. RFC793 gives a formal definition of TCP. With the passage of time, in the actual application error has been detected and in some areas demand has also undergone a change. RFC1122 describes in detail the content and some bug fix solutions. RFC1323 has been further expanded. Each support TCP machine has a TCP transport entity. It is either a process, or a user process is, or is a part of the kernel, it manages TCP streams, and with the interface between the IP layer. TCP entity receiving local user process data flow, and split them into less than 64KB (in practice, taking into account in each frame to IP and TCP header, so it is usually not more than 1460 bytes of data) of the slice, and then to separate IP datagram sent each a piece. When datagrams containing TCP data arrive at the destination host, they are submitted to the TCP transport entity, the TCP transport entity reconstruction of the original byte streams. TCP has the following characteristics: 1. Connection oriented service. High reliability. Full duplex communication. The streaming transmission. The transmission reliable connection establishment and release. It provides flow control and congestion control.

Refers to the network congestion is in the number of the packet switching network packet transfer too much, because of storing forwarding nodes have limited resources caused by network transmission performance degradation. In when the network congestion occurs, usually there will be data loss, increase the delay, throughput degradation, serious when even lead to the phenomenon of the "congestion collapse".

When the network load is small, throughput increase with the increase of the load, there is a linear relationship between response time, slow growth. When the load reaches the network throughput capacity, showing a slow growth, response time increases sharply. This point is called Knee. If the load continues to increase, the router to packet loss, when the load exceeds a certain amount, the throughput dropped sharply, which said for the cliff. It can be seen that the load in the vicinity of the Knee network

is the most efficient. Congestion control is the network node to take measures to avoid congestion occur or respond to congestion.



Response time varies with load

In the graph, the load is kept in the vicinity of the Knee. Congestion control mechanism actually contains congestion avoidance and congestion mitigation. The purpose of the former is to make the network run in the vicinity of the knee, the occurrence of congestion avoidance; while the latter is the network operation in the area on the left side of the cliff. The former is a "precautionary measures and maintain the network of high throughput, low delay, to avoid congestion; the latter is a" recovery "measures, allow the network to recover from congestion, into the normal operating state.

Networks can provide the resources are not sufficient to meet the users demand is the main reason for the occurrence of congestion. These resources include the processing ability of the cache space, link bandwidth capacity and intermediate nodes. Due to the Internet design mechanisms that lead to the lack of "admission control ability, so when the network resources are insufficient, can limit the number of users, and can only rely on to reduce the quality of service to continue to service for customers, is the" best effort "service. Although congestion is caused by the scarcity of cyber source, but only increased resources and can not avoid the occurrence of congestion.

The relative shortage of resources is the fundamental cause of the congestion. These resources include link bandwidth, allocated processor time, buffer, memory, and so on. Consider a specific flow, if in a certain period of time for the arrival of the traffic control ineffective, beyond the allocation of network resources, it will lead to network congestion. Congestion always takes place in the network resource "relative" shortage. Where congestion happens not equilibrium reflects the imbalance of Internet, congestion of the main reasons are summarized as follows: insufficient storage space. Bandwidth capacity is insufficient. CPU processing speed is slow. The network topology and the routing is not a reasonable choice, will lead to network congestion.

The purpose of congestion control is under the limited network resources, through the constraint and allocation of traffic reduce data loss, increase the throughput of the network, make full use of existing network resources. As a result, the congestion control usually starts from two aspects: the communication quantity and the quantity of the communication. Traffic constraint is that control access to network traffic, to match the network capacity; traffic allocation is reasonable processing and forwarding the arrival of the network data, to achieve network traffic equilibrium.

From the point of view of control theory, congestion control can be divided into two categories: open loop control and closed loop control. When flow characteristics can be exactly specified, performance requirements can be obtained in advance, and is suitable for use of open-loop control; when the flow characteristics cannot accurately describe or when the system does not provide resource reservation, and is suitable for using a closed-loop control. Closed loop control is mainly used in Internet.

Closed loop congestion control divided into the following three stages: to detect network congestion; congestion information reported to the congestion control; congestion control point according to the congestion information to take corresponding measures to eliminate congestion. Can adapt to the changes of network congestion control, but its performance is affected by the feedback delay is large.

When the delay between congestion and control points is large, its performance will be severely reduced.

TCP congestion control is mainly involved in slow start, congestion avoidance, fast retransmission and fast recovery. The slow start mechanism to detect the Internet to ensure that it does not take too much of sending the message segment in a congested environment.

3. Heterogeneous Network Transmission Control Technology

In order to solve the challenges faced by the traditional TCP in heterogeneous networks, researchers put forward many different network characteristics of the improved scheme against. In the different network environments, the congestion control mechanism is optimized to achieve TCP performance enhancement. This paper mainly discusses the general wired networks, satellite networks, wireless network, high-speed optical fiber network of several typical network of heterogeneous. Here are a brief introduction to the typical TCP algorithms used in these networks:

NewReno TCP on Reno in the "fast recovery / fast retransmission" algorithm to add. The main idea is: the network connection has been in a rapid recovery phase, until the window with a loss of all data recovery is completed, source end before exiting quick recovery. When the network to send the same window of a plurality of packet loss, at the source end start fast retransmit algorithm before, destination send duplicate ack informs the source end retransmission packet loss, this ack confirmed only the partial loss of data, but not all, it is known as the PartialACK. NewReno algorithm is the use of PartialACK to detect multiple data packets lost in the same window. In the fast recovery phase, source end retransmission the a bag, look forward to the return of a cumulative ACK, validate package source end of all data. If after one RTT, the source end received is a partial ACK, source end continue to retransmit a packet, rather than dropping out of the fast retransmit phase.

Vegas TCP (hereinafter referred to as Vegas) is based on the measurement of TCP technology. Proposed by L.S.Brakmo et al. In 1994. The detection bandwidth to avoid congestion mechanism, round-trip time (RTT) measurement network status using the data packet transmission, thereby comparing the expected values of the transmission rate and the actual transmission rate to determine the increase or reduction of the congestion window (CWnd), more efficient use of the available bandwidth.

In 2002, Casetti Claudio and other proposed Westwood TCP method (hereinafter referred to as Westwood). Westwood is also a kind of TCP algorithm based on measurement. The method, source end by monitoring from destination ack rate, available bandwidth measurement network connection, and take this as the basis, after the occurrence of congestion, adjusting the source end of the congestion window and slow start threshold.

Highspeed TCP congestion control is similar in principle and Reno, need after the slow start phase, the congestion avoidance phase, the congestion avoidance phase of the algorithm using AIMD (additive increase multiplicative decrease) addition increase multiplicative decrease) mode, the difference is factor of increasing the I / D strategies in the window and a window reduction factor B has changed, is no longer the original settings of 1 and 1 / 2, in order to change constantly with the increase of the congestion window a (W) and B (W). Its essence is to increase / decrease the magnitude of the congestion window within a RTT.

Due to the heterogeneous network is a composed of different network structure and different access technology of a hybrid network, it combines a variety of network characteristics. How to make the network, realize the superior function,, there are still a lot of aspects need research: for heterogeneous networks, it is difficult to have a unified TCP implements a form, for to solve the various performance issues in heterogeneous network environment faced by TCP. Can not distinguish between the different causes of packet loss. At present there is no unified mechanism for a good reason to identify a variety of data loss, need further study. If only to take measures to improve the performance of TCP in a single level, it will be difficult to give consideration to the influence of various factors. So how to Mac, TCP

and IP layers of control factors together, TCP cross layer design will also be a subject for further research.

4. Improved TCP Mechanism Based on link Selection TCP-selective

Because of the importance and urgency to enhance TCP performance in heterogeneous networks, there has been a lot of different TCP enhancement schemes, but most of the previous protocol is optimized for the performance of a specific network environment, such as: according to the random packet loss of Westwood; based on RTT measurements of Vegas; for high bandwidth high speed TCP (highspeed) and so on. However, because of the changing communication environment, there is no a complete scheme can be well applicable to the different characteristics of the network.

Therefore, this article in order to improve the overall performance of TCP of considering a new TCP options, its purpose lies in: according to the type of links to call and adapt to congestion control mechanism at the transport layer through in a single server using different TCP congestion control algorithm, match with the actual link quality.

Because TCP is end to end the agreement, it is not clear that internal network, most of the TCP congestion control mechanism can only rely on packet loss to determine network, thereby triggering congestion control. For heterogeneous networks, this mechanism has seriously affected the performance of TCP. Therefore, it is necessary to establish a link information acquisition scheme, the TCP to understand the link state, so that the use of suitable congestion control mechanism. The link information acquisition scheme is mainly divided into two types, which are implicit and explicit. The implicit acquisition is the type of the link by which the receiver or transmitter is implicitly inferred by some parameters. Explicit acquisition is informed by other layers of information, enables the sender to the transport layer to the current network state can clearly distinguish the link type and quality. Implicit access link information using the parameters usually have a transmission packet round-trip time (RTT), ACK rate, because there are many factors that affect the variation of these parameters. The estimation of link status misjudgment of the greater risk. Therefore, in this paper, we consider the explicit type chain road information acquisition.

Explicit link information to get ideas: in communication, as a result of the lower more clearly the current network situation. Therefore, this paper considers the use of cross layer design, by adding a link type link type option in the IP header options, each after a link, by the intermediate router nodes record the link information, the receiving end according to the information of link types in judgment, and then type values explicit notice sending end, the TCP sending end according to the value of this type of link to select the appropriate TCP congestion control algorithm.

When type fast for the Link type, if the call to the traditional TCP, one for each TCP connection is lost Package after the window is halved, and then return to the maximum window of the cycle is very long. When the link type is a type of satellite, if the use of traditional TCP, one is high transmission delay might slow the growth of the congestion window. During the slow start, the user must wait for a round-trip delay

After the new data package can be issued to bring more obvious efficiency decline. Larger delay variation will interfere with the estimation of RTT, which affect TCP timing mechanism, bring unnecessary timeout retransmission, then changes the size of the window is sent in error, reduce the bandwidth utilization; second satellite link due to the influence of weather condition, the multipath effect, shadow effects, bit error rate is greatly improved, and traditional TCP will not distinguish data packet loss due to transmission errors or due to congestion, packet loss causes are interpreted as network congestion. When a damaged data packet is received, even in the absence of congestion, the size of the window also immediately becomes half of the original, easy to cause the miscarriage of justice, on the performance of TCP over satellite links produced great impact. Therefore, it should be suitable for satellite link

TCP congestion control algorithm, consider the Vegas and its improved algorithm. When the link type is a type of wireless, if the traditional wired environment TCP technology applied to wireless environment based on, cause substantial performance loss. In the wireless environment, cause of packet loss is no longer the only, it may be caused by congestion, may also be caused by wireless link errors. So in a wireless network how to distinguish packet loss reason and thus make the correct response (i.e., congestion and invokes congestion control algorithm, reduces the packet sending rate; in wireless packet loss, explicit retransmission, keep the original sending rate) has become the key to improve the TCP performance over wireless networks. Under the environment of this kind of link, we consider calling for wireless link of TCP congestion control algorithm, representative of Westwood and other improved algorithms. When the link type wired type, the traditional TCP initially is oriented this kind of network environment and design, so the assumption also reflects the network bearing the characteristics, assumes that packet loss due to network congestion caused by. So we can use the TCP congestion control algorithm which is suitable for the wired connection, usually using NewReno.

5. Heterogeneous Network TCP Several Algorithms to Improve

With the development of wireless communication, how to improve the performance of TCP wireless network environment has become a research hotspot in recent years. Due to wireless and wired environment compared to usually have high bit error rate (BER), change of bandwidth, delay and frequent mobility, so the traditional based on wired environment TCP technology application in wireless environment, resulting in the performance of greatly diminished. Westwood improved the performance of TCP protocol, which could be used in delay, high - bandwidth product and the existence of random and bursty errors in wireless links, and has high efficiency and good fairness and friendliness. This section on the basis of TCPWestwood, introducing the idea of active congestion control, the algorithm in the lack of network bandwidth is improved. The simulation results prove that, the improved algorithm have better performance. Westwood's basic principle and the key lies in: (1) beginning back through the observation of the ACK time interval to continuously estimate available bandwidth of the network; (2) when the receiving end detects three duplicate ack. According to the real-time estimation of the bandwidth reset (rather than as Reno, ssthresh is set to cwnd/2) and CWnd ssthresh; when the RTO timeout occurs, according to the real-time estimation of the bandwidth re set the ssthresh, and CWnd is set to 1. Westwood to the accurate estimation of the available bandwidth is get the raise precondition and important guarantee of its performance, described below the bandwidth estimation technique.

Westwood by bandwidth estimation algorithm, the aiad (Addi- tive increase adaptive decrease) congestion control mechanism, improve the performance of TCP. Its advantage lies in: (1) only modify the sender's congestion window control mechanism, without intermediate routers support, with the current network structure with interoperability and compatibility. II in the wireless network performance is superior, the bandwidth of the accurate estimation and threshold setting makes after the retransmission can fully use of network resources, does not appear due to the random loss of available bandwidth utilization rate is not high.

But at the same time, Westwood is also not perfect. It has shortcomings as follows: in the slow start phase, Westwood still use the Reno's slow start mechanism. A slow start in bandwidth probing stage, because the network is not clear, the blind will slow start threshold (ssthresh) sets for the receiver advertised window size, high threshold value will lead to more packet retransmission waste network resources, but also directly caused the RTO, result in decreased throughput. (2) the congestion avoidance phase, Westwood also used Reno is blind increase mechanism, if in the linear part of the increase in close to the state of network congestion, Reno increasing mechanism easily lead to network fast again congestion, increase the frequency of network congestion, which decrease the efficiency of the network. Westwood use of bandwidth estimation technique to improve the performance of TCP protocol, so that it can be applied to delay, high - bandwidth product and the existence of the random and bursty errors in wireless links, but there are also drop in throughput, network utilization rate is

reduced. Therefore, this section of the algorithm to optimize the proposed improved algorithm TCP-Westwood-e.

1)The introduction of active congestion control concept, through different network bandwidth utilization state with different congestion control system mechanism.

2)In the fast recovery phase, when received partial confirmation, do not exit fast recovery phase, only when the timeout or to receive all the data to confirm the exit quickly recovered.

Reno congestion control algorithm in the slow start phase, Reno with exponential increase window, the sender each received a determined data ACK packet increases its window a packet; in congestion avoidance phase, Reno is AIMD (additive increase multiplicative decrease additive increase multiplicative decrease), the sender after receipt of a confirmed data ack increases its window size 1/W. Whether it is in the slow start phase or in the congestion avoidance phase, after receiving three duplicate acks will congestion window is reduced to half of the original. If the retransmission timer expires, the congestion window is set to a packet size. In order to overcome the shortcomings of traditional TCP in high speed environment limitations, to improve the throughput of TCP connection, it is necessary to Improve TCP congestion control algorithm, as the network bandwidth is sufficient when the congestion window more fast growth strategy, when network congestion occurs under the more moderate decreasing strategy. In this way, the new TCP congestion control algorithm - Highspeed is proposed to come out.

6. Summary and Outlook

In this paper, we mainly study the performance enhancement of TCP in heterogeneous networks. Showed scale, heterogeneous, dynamic characteristics because of the development of computer network, traditional TCP transmission control mechanism has encountered great difficulties and challenges for heterogeneous networks. Today in the rapid development of network technology, improvement of existing TCP protocol, TCP performance over heterogeneous network environment optimization is the urgent need to study the problem of. Therefore, it is very important to study the TCP performance enhancement technology in heterogeneous networks. Based on the heterogeneous network transmission control mechanism of in-depth study, analysis of the problems of traditional TCP in heterogeneous network environment has, based on the limitation of single versions of TCP in heterogeneous networks proposed their own solutions, and improve the different TCP versions. In this paper, a new TCP congestion control mechanism TCP-selective is proposed, which is based on the IP packet header.

Add the type Link option method, using the router node to record the link type information. Receiver to determine the value of the link type, showing notifying sender, then the sender according to different type of link value selection for different TCP congestion control algorithm, through the choice of method to meet needs of different link characteristics, so as to improve the heterogeneous network under the overall performance of TCP. Due to the limitation of time and for related content remains to be further in-depth research and analysis, mainly has the following several points:

1)For heterogeneous network link information scheme to obtain further optimization is needed, because link information access to assist other layers. In the actual heterogeneous network realization is to be studied.

2)The improved algorithm of different versions of TCP, still further study to obtain better performance.

3)In this paper, we further analyze the scheme discussed in this paper by means of experiment and heterogeneous network environment. This paper mainly based on the theory and simulation analysis, so that it can be better implemented in the practical application, it is necessary to in the actual heterogeneous network environment for further optimization.

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