The Minimum Relative Delay First Strategy for Multipath Transmission

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Abstract. The Stream Control Transmission Protocol (SCTP) [1] is a transport protocol which was proposed and standardized by the Internet Engineering Task Force (IETF). The Concurrent Multipath Transfer (CMT) that was evolved based on SCTP’s multi-homing feature had become a hot research issue. CMT utilizes all available paths inside the SCTP association to further improve end to end throughput and fault tolerance capacity during the data transmission. Since the typical scheduling algorithms define how to schedule multi-streaming and multi-homing fixedly, the CMT cannot meet the specific requirements of different applications which limits the flexibility of the transmission protocol. Firstly, this paper introduced four kinds of scheduling algorithms, then a Minimum Relative Delay First (MRDF) strategy was proposed to compare the relative one way delay of different paths without clock synchronisation. The NS2 simulation platform operated in Linux virtual machine is adopted to compare the system performance.

Introduction

The Stream Control Transmission Protocol (SCTP) was proposed and standardized by the Internet Engineering Task Force (IETF) in October 2000. The protocol inherits the TCP congestion control mechanism and fixes some shortcomings which can provide stable and ordered data transmission service between the client and the server with multi-flow, multi-homing and initialization protection features, etc.

The IETF formally presented the concurrent multipath transfer (CMT) in currently revised RFC4960. The experiments verify that the system throughput of data transmission is obviously higher than SCTP. CMT can enhance the system reliability and fault tolerance, guarantee for the terminal continuity in mobile process and make full use of bandwidth to improve the throughput and service security. CMT can make use of all the paths within the SCTP association for parallel data transmission. It has four kinds of scheduling algorithms.

First Come First Serve (FCFS) [2] dispatches in order. In computer parallel task processing, it is regarded as the simplest task sorting strategy. No matter how long the task size and the required completion time is, the first task is processed firstly and then later task is processed. It is a non-preemptive strategy. The algorithm is easy to implement while the efficiency is not high. Because it takes into account the waiting time not the length of service time required for homework. Therefore, it conduces to the long-term job and CPU-intensive operations relative to the short-term operations and I/O busy operation.

Round Robin Scheduling (RR) [3] allows use shared resources in turn. It performs the same service for different packet flow queues. Such a scheduling method is fair to an equal-length flow queue while the Internet flow is formed by a variable-length packet. As a result, a service flow queue with a large packet length may receive more services than the small packet length which results in the unfair phenomenon between the queues. Moreover, the algorithm cannot guarantee the business needs delay in advance.

Strict Priority (SP) [4] is designed for business-critical applications. It sets different priorities for different queues. A queue with a higher priority takes precedence over a lower priority. As long as
there are packets in a higher priority queue, they are scheduled first. The strategy cannot guarantee that
services outside of high priority get reasonable bandwidth even starve to death, thus it cannot
guarantee the service quality of various applications fairly.

Weighted Fair Queue (WFQ) supports Generalized Processor Sharing (GPS). WFQ draws on the
concept of GPS which always prioritizes the sending packets with the smallest virtual end time. WFQ
is a fair scheduling algorithm and all the services share the bandwidth according to the average stream
rate.

The MRDF Strategy

Transmission protocols usually regard the Round-Trip Time (RTT) as an important parameter for
path performance evaluation [5]. RTT represents the total delay from the data sending to the
confirmation receiving. RTT consists of four parts: the link propagation delay, the send time delay,
the router cache delay and processing delay. Because the RTT contains information about the forward
and backward paths, it is not the most appropriate parameter to evaluate the path performance in a
multipath scenario. The one-way delay can be more conducive to improve communication quality.
Therefore we propose the Minimum Relative Delay First strategy and the algorithm redefines RTT as:

\[
RTT = t_{Fp} + t_{Fq} + t_{Bp} + t_{Bq}
\]

\( t_{Fp} \) and \( t_{Fq} \) represent the propagation delay and queuing delay of the forward path while \( t_{Bp} \)
and \( t_{Bq} \) represent the propagation delay and queuing delay of the backward path.

Figure 1 presents a simple two-way transmission scenario. The data sender includes two network
interfaces \( S_1 \) and \( S_2 \), respectively the data receiver includes two network interfaces \( R_1 \) and \( R_2 \). When a
packet is sent or received, the timestamp will be added to the header for calculating path delay and
other performance parameters. In Figure 1, the solid lines with bidirectional arrows indicate the
values which can be calculated based on timestamps, such as \( \Delta t_1 \) can be calculated by sending
timestamps. The dashed lines with bidirectional arrows indicate the values that cannot be calculated
based on timestamps, such as \( T_{Fp} \) cannot be accurately calculated due to the related clock skew. \( \Delta t_x \)
\((x=1, 2, 3)\) represents the difference between the corresponding timestamps of path 1 and path 2. As
all the timestamp values are known, a linear equation of \( \Delta t_x \) can be obtained according to the
relationship in the figure:
\begin{align*}
T_{F1} + T_{B1} &= RTT_1 \\
T_{F2} + T_{B2} &= RTT_2
\end{align*}

The equation is not affected by the packets arrival order or ACKs. By converting this linear equations system into a matrix format, it is obvious that the matrix rank is less than the equations number. It represents the system has infinite solutions. Unless the entire clock in the transmission system is synchronized, we cannot get the exact solution. However, the relative forward delay and backward delay between two paths \((T_{F1} - T_{F2}, T_{B1} - T_{B2})\) can be accurately calculated by the sufficient parameters. Thus we can schedule the system through the minimum relative delay.

### Simulation and Evaluation

In this chapter, we make NS2 simulation experiments using UDel SCTP module [6] which was modified and improved to support CMT and a variety of scheduling algorithms by the PEL laboratory.

![Simulation Topology](image)

Figure 2. Simulation Topology.

Figure 2 shows the NS2 simulation topology. The end paths present the last routing while middle paths present the corresponding internet environment. \(Band_1\) and \(Band_2\) respectively represent the bandwidth of \(path_1\) and \(path_2\). \(Delay_1\) and \(Delay_2\) respectively represent the end-to-end delay of \(path_1\) and \(path_2\). \(Path_1\) keeps loss rate at 1% while \(path_2\) changes lose rate gradually from 1% to 10%. The receiver buffer size is 64KB. The control variate method is adopted to modify values of \(Band_1\), \(Delay_1\), \(Band_2\), \(Delay_2\) parameters to contrast analysis of throughput, packet loss rate and other performance parameter of the transmission [7].

![Throughput](image)

Figure 3. Throughput RR vs MRDF.

Throughput represents the receiving data speed of receiver when there is no packet lost in the process of transmitting. Figure 3 presents the throughput performance of Round Robin and MRDF.
Both of the path bandwidths are 10Mbps and simulation time is set to 50s. The x-axis in the graph represents the buffer size in Packets and y-axis represents the throughput in Kbps. As we can see, the MRDF performs better in both two scenarios on throughput.

![Figure 4. Streaming Media Transmission RR vs MRDF.](image)

We simulate a MPEG-4 streaming media data transmission respectively with Round Robin and MRDF strategy on NS2 [8]. Round Robin performs the same service for it traverses all the paths in the linked list and polls for sending various video frames. MRDF sends I-Frames with the minimum relative delay path first to keep smooth. Figure 4 represents the 95th frames in the transmission process with MRDF and RR respectively. It is obvious the transmission with MRDF algorithm is clearer and the stream keeps fluency during the process of simulation.

**Summary**

This paper mainly proposed a minimum relative delay first scheduling algorithm for multipath transmission based on SCTP. We introduced four kinds of typical scheduling policies and contrasted their characteristics and defects. Then we analyzed the composition of the Round-Trip Time parameters and according to relative delay redefined the meaning. Through the NS2 simulation platform under Linux virtual machine, we set the path state parameters such as one-way delay and packet loss rate to compare and analyze the performance of the MRDF and RR. We verified the throughput performance of MRDF over a period of data transfer. We confirmed the flexibility and fluency of MRDF by simulating the streaming media transmission.

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