A Stochastic Optimal Scheduler for
Multipath Transmission Control Protocol (MPTCP)
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Abstract

This memo presents a new stochastic optimal scheduler for the Multipath Transmission Control Protocol (MPTCP). The new scheduler is based on the Lyapunov optimization technique, which can make online control decision for data scheduling. Considering the payment of users for different paths, this memo makes a trade off between the throughput utility and the cost. The new scheduler can not only satisfy the demand of service, but also minimize the cost as much as possible.

Table of Contents

1. Introduction ................................................ 3
   1.1. Motivation ............................................ 3
   1.2. Overview of SOS-MPTCP ............................. 3
2. Conventions ................................................ 3
3. A New Stochastic Optimal Scheduler .......................... 3
   3.1. Admission Control .................................... 4
   3.2. Packets Allocation ................................... 4
   3.3. Purchasing Data Traffic ............................. 4
4. Building Queue .............................................. 4
5. Transmission Performance and Problem Optimization ......... 5
6. Stochastic Optimal Scheduler ................................ 5
7. Security Considerations .................................... 5
8. Implementation Considerations ............................. 5
9. References .................................................. 5
   9.1. Normative References ................................... 5
   9.2. Informative References ............................... 6
10. Acknowledgments ............................................ 6
1. Introduction

SOS-MPTCP is a new scheduler of MPTCP which can make online control decisions for data distribution. By taking advantage of queue stability, the new stochastic optimal scheduler can make a trade off between the throughput utility and the cost.

1.1. Motivation

The scheduler plays an important role in the data distribution. In the heterogeneous wireless network, the cost of each path is quite diverse and depends on the amount of packets assigned by the scheduler. Traditional scheduler just focuses on the transmission performance without considering the payment cost of users. This memo intends to fill the gap with the Lyapunov optimization technique.

1.2. Overview of SOS-MPTCP

This demo mainly describes the new scheduler of MPTCP. The objection of this scheduler is to maximize the throughput and minimize the corresponding cost to different communication operators. To achieve this goal, the following three important control decisions are to be made:

- How many packets of different connections can be admitted into transmission layer.
- How to distribute the admitted packets to all paths.
- How to purchase data traffic for different paths in advance.

2. Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119 [RFC2119].

3. A New Stochastic Optimal Scheduler

A number of paths which are available are denoted by \( J = \{1, 2, \ldots, j\} \). And there are different connections \( I = \{1, 2, \ldots, i\} \) of packets with diverse arrival rates from the application layer. In order to facilitate the analysis, we consider the system as a discrete time-slotted model divided by \( t = \{1, 2, \ldots, T\} \). In each time slot \( t \), a number of the \( i \)th connection of packets arrive at the system randomly. Let \( A_{i(t)} \)
denote the number of data packets of connection i in time slot t.
The unit price of path j is denoted by \( p_j \).

3.1. Admission Control

In each time slot, a lot of packets arrive at the transmission layer. To prevent the system from congestion, the admission control module decides that the total number of packets noticed by \( A_i(t) \) can be admitted into transmission layer. Therefore, \( A_i(t) \) SHOULD less than the number of arriving packets \( R_i(t) \).

3.2. Packets Allocation

After the packets of connection i are admitted into the transmission layer, the packets allocation module assigns packets to each path. The number of packets of type i distributed to path j in time slot t is denoted as \( A_{ij}(t) \). And this assignment should satisfy the constraint: \( A_i(t)=\sum_j (A_{ij}(t)) \). Each path maintains a queue for each connection of packets which can be transmitted later. We define the queue backlog \( Q_{ij}(t) \) of ith connection of packets assigned on the jth path as the number of pending packets waiting in the queue. We also define \( S_{ij}(t) \) as the number of packets which have been sent successfully and acknowledged.

3.3. Purchasing Data Traffic

In order to satisfy the service demand of users, they will purchase data traffic in advance from the communication operator. We use \( W_j(t) \) to denote the cost of paying for the path j belonging to respective operator in the time slot t. The total cost of the multipath transmission control system can be denoted by \( H_j(t) \) to maintain the consumption for the users.

4. Building Queue

According to the control framework described above, the dynamic updating of queue backlog can be defined as the equation:

\[
Q_{ij}(t+1) = \max[Q_{ij}(t) - S_{ij}(t), 0] + A_{ij}(t)
\]

Similarly, \( H_j(t) \) denotes the cost queue size of path j in the time slot t. Under the control decision of purchasing data traffic, the queue \( H_j(t) \) can be expressed as follows,

\[
H_j(t+1) = H_j(t) - \sum_j (S_{ij}(t) * p_j) + W_j(t)
\]
5. Transmission Performance and Problem Optimization

We define the time averaged throughput \( \text{SUM}_i \ (\text{Thr}_i(t)) = \lim_{t} \ (\frac{1}{T}) \text{SUM}_t \text{E}\{S_i(t)\} \). We also define a cost utility function \( \text{SUM}_j \ (W_j(t)) = \lim_{t} \ (\frac{1}{T}) \text{SUM}_j \text{E}\{W_j(t)\} \). It is challenging to tradeoff the transmission throughput and cost utility function. The transmission performance depends on the throughput and cost utility. Therefore, we NEED to construct an objective to take both sides into consideration.

The problem of maximizing transmission performance is defined as

\[
\text{Max} \ \{ \text{SUM}_i \ (\text{Thr}_i(t)) - \text{SUM}_j \ (W_j(t)) \} \\
\text{s.t.} \ Q_{ij} \text{ is stable}
\]

6. Stochastic Optimal Scheduler

In order to solve the problem mentioned above, we design a distribution approach by using Lyapunov optimization [SNO2010] which contains Lyapunov draft and queue stability. The value of \( A_i(t) \), \( A_{ij}(t) \) are calculated by the queue \( H(t) \) and \( Q(t) \). And \( H(t) \) and \( Q(t) \) are updated by the calculation results.

7. Security Considerations

This memo develops no new security scheme for MPTCP. SOS-MPTCP share the same security issues discussed in [RFC6824] with MPTCP.

8. Implementation Considerations

This approach is a new scheduler for MPTCP, which is named as "stochastic". We can select the scheduler through the socket-option MPTCP_SCHEDULER from the following four schedulers: "default", "roundrobin", "redundant", "stochastic".

9. References

9.1. Normative References

9.2. Informative References


10. Acknowledgments

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