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The Modified Mobile Concurrent Multipath Transfer for Joint Resource Management

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Abstract

In the recent times,Joint Resource Management (JMR) in heterogeneous environment has emerged as an important technology wherein bandwidth allocation to a user can be provided by different networks simultaneously. This is supported by Concurrent Multipath Transfer (CMT) algorithm to transfer data among two end-to-end paths of an mSCTP association in wireless mobile connectivity. SCTP based CMT technology can transmit data over multiple paths, thus achieving higher data transmission speed. The CMT, however, suffers with receiver buffer blocking problem in wireless mobile networks. A mobile CMT (mCMT) was introduced to further reduce the effect of buffer blocking but still there is a probability of receiver buffer blocking \cite{1}. Receiver buffer blocking is caused by the loss of data due to various reasons. In this paper, we propose a novel theoretical concept called modified mobile CMT (m\textsuperscript{2}CMT) to improve upon the performance of mCMT. It completely avoids receiver buffer blocking. In the proposed new technology of m\textsuperscript{2}CMT, three new concepts of Stream Manager, Handoff Manager and Link Status Indicator (LSI) are introduced. Stream Manager can increase the throughput and avoid receiver buffer blocking caused by error loss. Handoff Manager can reduce the data loss by using LSI during handoff process to avoid receiver buffer blocking.

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1. Introduction

The mobile nodes are designed to support several heterogeneous access networks. There is extreme need to develop methods that the mobile nodes have to access diverse networks concurrently to increase the throughput. This is called Joint Resource Management (JRM). To accomplish the service, we decide to use transport layer protocol. Stream Control Transmission Protocol (SCTP) is a message-oriented, reliable transport layer protocol that combines the best features of TCP and UDP \cite{2}, \cite{8}. In SCTP, a connection is called an association. The unit of data in SCTP is called a chunk. The SCTP has two important features of multistreaming and multihoming. The term Multistreaming refers to the capability of SCTP to transmit data into several independent streams of chunks in parallel. The term Multihoming refers in which one or both end points of a connection can consist of more than one IP address, enabling fault tolerant when network failure occurs. Multihomed nodes may be simultaneous connected through multiple...
access technologies such as 3G, Wi-Fi (802.11), etc. SCTP transmits data over primary path and other paths are used as retransmission paths. If the primary path fails, SCTP changes the transmission to one of the retransmission paths.

Concurrent Multipath Transfer (CMT) protocol uses SCTP multihoming over independent end-to-end paths [2]. Unlike SCTP, CMT can transmit data over all paths. CMT is a technology based on SCTP, however can fully utilize the multihoming technology to transmit data over all interfaces. The wireless mobile networks, however, have high data loss rate and frequent handoff problems. Data loss may occur due to error loss and handoff loss. Data loss may cause the receiver buffer blocking problem in CMT. For example, if data are lost in one path, the receiver buffer may be blocked by data of the same stream transmitted over the other paths. It defeats the very purpose of CMT concept.

In this study, we propose the modified mCMT (m²CMT) protocol based on mCMT [1], [5]. m²CMT can have higher throughput than mCMT. m²CMT can completely avoid receiver buffer blocking caused by error loss and handoff loss. The rest of the paper is organized as follows. In Section 2, preliminary concepts and terminology are given. In Section 3, the receiver blocking caused by error loss and handoff loss of mCMT are discussed. In Section 4, the design of m²CMT protocol is presented. Finally, conclusion remarks are given in Section 5.

### 2. CMT Technology

Iyengar et al. [2] proposed CMT that leverages SCTP’s multihoming support, and increases an application’s throughput via simultaneous transfer of new data over independent paths between multihomed source and destination hosts. However, CMT does not apply any scheduling for the data transmission. CMT allows data in the same stream to be transmitted over different paths. If data are lost in one path, the receiver buffer may be blocked by data transmitted over the other paths.

SCTP dynamic address Reconfiguration (SCTPDAR) [3] extends the multihoming feature of SCTP to support seamless IP handoff. SCTPDAR can dynamically add a new IP address into an SCTP association and set the new IP address to be the IP address of primary path to force the sender to transmit data through the new IP address. When the old IP address becomes inactive, SCTPDAR can dynamically delete the old IP address from the SCTP association.

Liao et al. [4] proposed cmpSCTP method, which was able to transmit data over all paths with soft handoff. cmpSCTP adopts multibuffer structure and uses two-level sequence number called Transmission Sequence Number (TSN) and Association Sequence Number (ASN). However, even with the multibuffer structure and two-level sequence number, cmpSCTP cannot avoid receiver buffer blocking.

Preethi et al. [6] proposed CMT-PF to reduce receiver buffer blocking occurs in CMT. To improve performance, they introduce a new “Potentially-Failed” (PF) destination state, and revise CMT’s failure detection and (re)transmission policies to include the PF state. However, this method should not completely avoid receiver buffer blocking problem.

Huang et al. [1] proposed mCMT method to improve transmission good put. mCMT uses path-oriented multistreaming and MIH-assisted handoff mechanism to reduce the occurrence of receiver buffer blocking. Path-oriented multistreaming is devised to transmit data with the same stream in the same path. It can reduce the occurrences of receiver buffer blocking caused by error loss; mCMT utilizes events provided by MIH to reduce handoff loss. With MIH event, mCMT can know the link status immediately. However, when a link is UP, mCMT immediately transmits data through this path, even though the signal strength is very low. This may be a cause of packet loss occurs. However still, mCMT does not avoid receiver buffer blocking.
3. Receiver Buffer Blocking Problem

In this section, the receiver buffer blocking problem caused by error loss and handoff loss is analyzed and discussed.

3.1. Receiver Buffer Blocking in mCMT Due to Error Loss

The main concern, which causes damage to CMT, is the receiver buffer blocking. This problem is reduced by mCMT proposed by Huang et al. [1]. mCMT uses path-oriented multistreaming to transmit data with the same stream in the same path. The data that need retransmission can be retransmitted over any path. Whenever a path is unreachable, streams, which are assigned to that path, are reassigned to other paths. The mCMT, however, cannot eliminate the receiver buffer blocking problem completely. Since a path can transmit new data of the stream, which are not allocated to that path, whenever that path is completely idle. i.e., still there is a chance to transmit data of the same stream to more than one path which causes receiver buffer blocking.

Fig. 1 shows the receiver buffer blocking caused by error loss in mCMT. Consider a Mobile Node (MN) establishes a mCMT association with a Correspondent Node (CN) through two independent paths. Path 1 is with lower bandwidth and high end-to-end delay than Path 2. i.e., here we assume Path2 is 3 times faster than Path1. Here, we consider mCMT support 2 streams called S1 and S2. Total data is 32 chunks. Hence, each stream should transmit 16 chunks. The CN transmits data of stream 1 through Path1 and Stream 2 through Path2 to MN. Thus, Path1 can transmit 4 data chunks per time t and Path 2 can transmit 12 data chunks per time t. At time t5, Path2 is Idle, the dispatcher module assigns new data of Stream 1 of Path1 to Path2. The data with TSN 9 is lost in Path1 during transmission. The data with TSN 13-16 of Path2 reaches a MN however cannot be delivered to the upper layer without data with TSN 9. When data are lost in one Path, the other path is continuing to transmit data to the receiver. If transmitted data on the other path belong to the same stream of the lost data, the receiver buffer is probably blocked.

3.2. Receiver Buffer Blocking in mCMT Due to Hand Off Loss

The mCMT can perform the transport layer handoff with the help of SCTP Dar in the multihomed wireless mobile network [7]-[9]. When the MN moves from one location to other, the MN gets a new IP address, and old IP address becomes unavailable. mCMT performs the handoff process as follows.
mCMT informs about the new IP address to the remote endpoint using ASCONF-AddIP message.

- When the previous address is unavailable, mCMT sends an ASCONF-DeleteIP message to the remote end point to delete the useless IP address.

- mCMT introduces one more message called ASCONF-PoFailure. MN uses this message to notify the CN that the old IP address is going to fail.

If a link is going to fail, the MN can send an ASCONF-PoFailure chunk to the CN. The CN would not send new data to the MN through the path that potentially fails. As a result, the handoff loss can be reduced. However, still there is a chance to occur handoff loss. As indicated by fig. 2, mCMT immediately transmits data to the path when the new link is UP without checking the signal strength. In some situations, the new link may not have enough signal strength to transmit loss and signal may be loss suddenly. In this situation, TSN 5-8 may be loss. However, Path2 transmits TSN 9-16 which causes receiver buffer blocking.

4. Design of $m^2$CMT

In this section the design of $m^2$CMT architecture is proposed. Fig. 3 shows the architecture of $m^2$CMT. The $m^2$CMT uses the sender buffer and receiver buffer to store data from applications based on the Stream ID and receive data from sender based on stream ID respectively. Each path has its own unsent queue. When the congestion window (cwnd) of one path is allowed to transmit data, data in the unsent queue are transmitted. $m^2$CMT introduces three important modules to increase the performance and avoid receiver buffer blocking.

- Stream Manager
- Handoff Manager
- Link Status Indicator.

4.1. Stream Manager

The Stream Manager is responsible for scheduling the data transmission. Stream Manager is planned to
transmit data with the same stream in the same path. Thus, if data are lost in one path, the other paths would not fill up the receiver buffer by incomplete data transmitted over the other paths. Thus, Stream Manager follows the principle of Path oriented multistreaming [1] with added functionality.

Stream Manager continuously monitors all the active paths and assigns maximum allowed data to transmit that path. If a path does not have maximum data to transmit that path or if a path is Idle, the Stream Manager can assign new data from the buffer which is assigned to other path and change the TSN, SI and SSN according to this path. Stream Manager informs about this change to the protocol to assign new numbers to the subsequent chunks coming from application. Hence, Stream Manager may able to change TSN, SI and SSN to increase the throughput. At the same time, the Stream Manager immediately informs about this change to protocol for next subsequent assignment of numbers to chunks.

The experiments show the performance increase and avoiding receiver buffer blocking problem of m²CMT by using Stream Manager. The data with TSN 9 is lost in Path1 during transmission. However TSN 13-16 of S1 is renumbered as TSN 33-36 of S2. Hence, there is no chance to occur receiver buffer blocking. Stream Manager transmits maximum data allowed through the path. At any point of time, Stream Manager does not allow to transmit data of same stream to other path which cause receiver buffer blocking. Thus, m²CMT can completely avoid receiver buffer blocking.

4.2. Link Status Indicator (LSI)

The m²CMT utilizes Link Status Indicator, placed in between network and link layer, to deal with handoff to reduce the effects of receiver buffer blocking of handoff loss. Link Status Indicator can provide (1) Link UP, (2) Link DOWN, (3) Link Going DOWN (LGD) and (4) Link READY events for m²CMT. Link Status Indicator monitors signal strength information from the active interfaces and generates the corresponding events.

- If the new link is available, LSI generates Link UP event. However, Handoff Manager does not allow transmit data through this path.
- If the link have enough signal strength (i.e., signal strength reaches the threshold value), LSI generates Link READY event. It allows the Handoff Manager to transmit data through this path.
- If the link is going to fail (i.e., signal strength goes below the threshold value), LSI generates Link Going DOWN (LGD) event. It instructs the Handoff Manager to stop sending data through this path.
- If the link is fail (i.e., no signal strength), LSI generates Link DOWN event. It informs to Handoff Manager immediately.

LSI continuously monitors the link status and informs to Handoff Manager immediately.

4.3. Handoff Manager

Handoff Manager takes care of the handoff process. Link Status Indicator can pass about link information and events from network interfaces to m²CMT. Thus, m²CMT can have more information to deal with handoff

- When the Handoff Manager receives Link UP event from LSI, the MN sends ASONF- AddIP chunk to the CN to add a new IP address to the existing association.
When the Handoff Manager receives Link DOWN event from LSI, the MN sends ASONF-DeleteIP chunk to the CN to remove the IP address from the existing association.

When the Handoff Manager receives Link Going DOWN (LGD) event from LSI, the MN sends ASONF-PoFailure chunk to the CN to stop sending data the IP address of the existing association. When the Handoff Manager receives Link READY event from LSI, the MN sends ASONF-SendIP chunk to the CN to send data to the IP address of the existing association.

Fig. 4 shows the ASCONF-SendIP chunk format. An ASCONF-SendIP chunk contains an IP address that is going to ready. If an interface is going to ready, the MN can send an ASCONF-SendIP chunk to the CN. The CN can send new data to MN over the path that is ready. Similarly, An ASCONF-PoFailure chunk [1], contains an IP address that is going to fail. If an interface is going to fail, the MN can send an ASCONF-PoFailure chunk to the CN. The CN stops sending new data to MN over the failing path.

Fig. 5 shows how to avoid receiver buffer blocking when handoff losses are with minimum signal strength. Handoff Manager can find out failure by using Link Going DOWN event from Link Status Indicator. Hence, Stream Manager stops transmitting. After link is down, a new link with weak signal strength appears and suddenly goes down. When the link is appear, Handoff Manager gets Link UP event from LSI. However Handoff Manager does not send any data through this path until it gets link READY event from LSI. As a result, the handoff loss can be reduced or avoided.

5. Simulation Results and Conclusion

Fig. 6 shows the transmission speed of CMT, mCMT and m²CMT for different error loss rates. It can be seen that as the loss rate increases, the transmission time also increases. When loss rate goes beyond 5%, transmission time of CMT increases rapidly. Initially, m²CMT shows similar performance to that of mCMT. If the loss rate increases further, proposed scheme m²CMT (bandwidth aware path-oriented multistreaming) performs better compared to mCMT. Fig. 7 shows the buffer full time at various loss rates. The buffer full time is defined as the time that the free buffer space is below 1500 bytes, which is the minimum SCTP packet size. Essentially, as the loss rate is increased, the buffer full time is also increased. The proposed model of m²CMT has performed better and shown lower probability of buffer full time at various loss rates.

Similarly, the proposed model has shown quite encouraging results for improved throughput during handoff process. Since, the newly proposed system undertakes transmission process only after having ensured that the signal has strength above certain threshold value which is enough to carry on transmission.

Proposed m²CMT architecture can support Joint Resource Management. The architecture contains 2 modules in Transport layer and 1 module in between Network and Link layer. The transport layer contains Stream Manager, which is responsible for assigning streams to paths. It increases the performance of CMT and avoids RBUFF blocking problem. Handoff Manager reduces the handoff loss which can happen frequently in mobile environments.
Handoff Manager continuously receives event messages from Link Status Indicator module positioned between Network and Link layer. Link Status Indicator sends 4 events to Handoff Manager, based on Signal Strength (i.e., Link UP, Link Ready, Link Going DOWN & Link DOWN). These modules improve performance and avoid R-buffer blocking problem in Concurrent Multipath Transfer environment.

REFERENCES


