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Abstract—Concurrent Multipath Transfer distributes incoming traffic simultaneously between several paths to maximize network resource utilization and to improve quality of service. Voices over IP real time application is more sensitive to delay and requires bandwidth guarantee. In this paper, Efficient Bandwidth Estimation Management for VoIP Concurrent Multipath Transfer is proposed. The proposed technique estimates the bandwidth of each path from a group and selects multiple paths from SCTP multihoming association to transmit VoIP traffic with assured bandwidth guarantees. Simulation results are reported using Ns2 network simulator to show the efficiency of the proposed system.

Keywords- *CMT, SCTP, Multihoming, QoS, VoIP , Multipath Routing, probing*

I. INTRODUCTION

Voice over IP (VoIP) becomes popular cost effective service and used as an alternative to traditional PSTN telephone services. It requires more strict quality of service (QoS) like high availability of resources, good quality of voices, low delay and packet loss. Beside the requirement, implementation of VoIP faces the limited of bandwidth capacity [1].

Efficient Bandwidth utilization is an important criterion in VoIP services. Bandwidth is generally associated with complexity, algorithmic and processing delay. Static bandwidth allocation and over-provisioning provides good delivery time but poor bandwidth utilization. Adaptive bandwidth allocation becomes essential criteria for delay sensitive VoIP applications [2, 3].

Concurrent Multipath Transfer (CMT) uses multihoming feature of Stream Control Transmission Protocol (SCTP). Currently SCTP multi-homed technology is not utilized to transmit data on multiple paths. Because SCTP only uses one path for data transmission and leaves other paths for retransmission where as Concurrent Multipath Transfer (CMT) is the technology that utilizes the multi-homing technology to transfer data over all available network interfaces and paths based on SCTP multihoming feature.

SCTP is a reliable message oriented, multi stream, multihomming protocol. It provides a communication (association) between endpoints that support multiple IP addresses. A communication in SCTP involves association setup, data transmission, association shutdown. Association setup involves 4-way handshake between two SCTP endpoints (i.e. protocol instances). SCTP provides reliable transmission, detecting when data is discarded, reordered, duplicated or corrupted, and retransmitting damaged data as necessary. Multihoming provides greater survivability in case of network failures [4, 5, 6].

Link or node failures occur due to hardware malfunction or software error. Ideally, the routing system detects link failures, and reconfigures routing tables to send the packet to some other alternative path. The traffic via a failed link is also avoided. Reconfiguration of routing table in a network takes time, network becomes unbalanced. To avoid this unbalancing situation, multipath dispersion can be used.

To support multi-homing, SCTP endpoints exchange lists of addresses during initiation of the association. Each endpoint must be able to receive messages from any of the addresses associated with the remote endpoint. A single port number is used across the entire address list at an endpoint for a specific session. One of the IP addresses is designated as primary, while the other can be used as backup path. In case of failure of primary address or retransmission of lost packets can be done to a different address. This improves fault tolerance without interrupting any ongoing data transfer [7, 8, 9].

Multiple paths in a real network are likely to overlap with one or more links in the network and can share bottleneck bandwidth. Correlation between the paths is estimated based on novel probing Grouping-based Multipath Selection (GMS) mechanism [10, 11]. This method is capable of determining whether any two paths are strongly correlated or not. Bandwidth estimation on paths is not implemented with this approach, which can make the path correlation easier and can reduce data corruption and random delays. Multipath routing techniques is not yet widely deployed in practice, need arises to distribute traffic in multiple paths to improve network utilization and fault tolerance [12]. The proposed technique utilizes the Westwood bandwidth estimation approach [13] in Grouping-based Multipath Selection to disperse VoIP packet into concurrent multiple paths.

II. RELATED STUDIES

Several ideas and mechanisms for SCTP CMT are reviewed. M. Fiore et al., [13] have proposed a W-PR-SCTP to exploit all the bandwidth available on multiple interfaces. A bandwidth estimation process and a sender-based scheduler try to predict the delivery time of each chunk of data. The single-buffer architecture is replaced by a multibuffer structure providing each interface to have its own buffer. The multibuffer structure guarantees path independence but SACK handling at the source has to be modified.

Anand J. et al., [14] have proposed a new transport protocol, the Concurrent Multi-Path Real-time Transmission Control Protocol (cmpRTCP) to handle real-time streams (like video and audio) over IP-networks. cmpRTCP has been designed with a congestion controller and a real-time scheduler to provide best effort service. This ensures that every packet reaches the destination with no retransmission. The focus is to provide multi-path congestion control with improved QoS and reliability.

Janardhan R. Iyengar et al., [15] have proposed an algorithm to avoid the side effects of reordering introduced by CMT. To avoid unnecessary fast retransmission, this algorithm uses Virtual queue for each destination. Retransmission takes place from this virtual queue. Overly conservative congestion window growth at the sender and increased ack traffic is also reduced in this algorithm under the assumption of bottleneck queue on the end-to-end paths used in CMT is independent.

Preethi Natarajan et al., [16] have proposed a new CMT's failure detection and (re)transmission policies mechanism. CMT's failure detection and (re)transmission policies use PF state. ''Potentially-Failed" (PF) denotes the failure nodes based on a single timeout on a particular path of unsure sender. A PF destination is not used for data transmission or retransmission. Path failure on various situations like Single permanent path failure, Single short-term failure, Symmetric and asymmetric loss conditions has been reviewed to improve the performance of CMT.

Jianxin Liao et al., [17] have proposed a correlation-aware multipath selection procedure for concurrent multipath transfer. Based on a well-designed delay probing correlation between any two paths are identified. Multiple paths for CMT is selected based on Grouping-based Multipath Selection (GMS) mechanism avoiding shared bottlenecks between topologically joint paths.

Lukasz Budzi et al., [18] have proposed a handover CMT scheme, namely mSCTP and SCTP failovers. CMT for SCTP implements a new sender based architecture, where each path must have a separate buffer to avoid bottleneck sharing the multiple paths. Dwelling time, available bandwidth ratio and round-trip time, receiver buffer (rbuf) size parameters are taken into account for CMT multipath handover. mSCTP deals with handover procedures whereas SCTP failovers deals with congestion control and retransmission.

Chung-Ming Huang et al., [19] have proposed a Partially Reliable-Concurrent Multipath transfer (PR-CMT) for multihomed networks. In the multi-homed network devices are associated with multiple interfaces. Concurrent multipath transfer is utilized to transmit data over all available paths for better network resource utilization and leaves no paths idle.

In real-time applications like VoIP, NetMeeting and multimedia streaming applications data or packet is accepted after the expiry of their lifetime since it would become useless [17]. The partially reliable transmission is realized by the "timed reliable service". Data in PR-CMT are associated with lifetime. When the lifetime of the data is expired, PR-CMT would not transmit and retransmit the expired data. The approach mainly deals with improvement in transmission efficiency and less bandwidth consumption.

Dongmei et al., have proposed a bandwidth management technique for Multiprotocol Label Switched networks. This technique allocates and shares the bandwidth among many Label switched backup paths. Link usage information is distributed to all the nodes to estimate the amount of bandwidth to be shared. These backup paths are used to protect against link or node failure and bandwidth sharing among these paths increases network resource utilization [20].

J.F.Banu et al., [21] have proposed a network model to enhance the Quality of Service and to perform load balancing in MPLS network for voice applications. The trigger handler is proposed to check the balanced load in the system. If the network condition becomes unbalanced, the adaptive packet scheduler classifies the flows and routed to the best shortest multiple paths with the given QoS constraint. The VoIP traffic is routed along the most adequate path that has enough resource to meet a given target QoS.

III. PROPOSED METHODOLOGY

The proposed technique deals with concurrent transmission VoIP packets on multiple available paths. Each VoIP packets are transmitted on different available paths to utilize all the available path bandwidth efficiently by creating multiple active transmission queues stream.

Multipath routing has a potential to aggregate bandwidth on various paths, allowing a network to support data transfer rates higher than what is possible with anyone path is shown in Fig. 1. The multiple paths are selected using Grouping-based Multipath Selection [10] and bandwidth is estimated using the Westwood bandwidth estimation approach [13]. Multiple paths in a real network can be overlapped, edge-disjointed or node-disjointed with each other and can share bottleneck bandwidth. Therefore correlations between paths are computed to select best multiple paths.

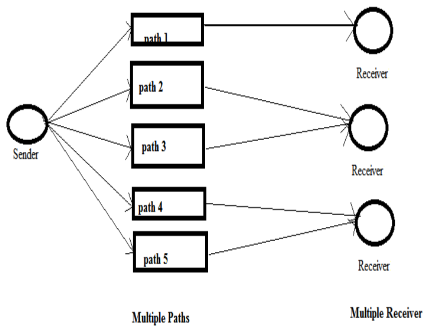

Figure 1. Multiple paths to Receiver

A. Westwood Based Bandwidth Estimation

Westwood bandwidth estimation [13] is capable of estimating all the bandwidth available on multiple end to end path interfaces through a standard probing mechanism of slow-start and congestion avoidance phases. The bandwidth estimation modifies only the sender side SCTP stack. Congestion window size and its threshold value are initialized. Bandwidth usage on the path is computed by using received Acknowledgments. From the received ACK the amount of data that has been delivered and round trip time is calculated. The difference in Round-trip time (RTT) of previous ack and current Ack is calculated. Difference in RTT called Δt or 50ms whichever is larger can be used in Eq. 1. The bandwidth estimation on each path is estimated as in Eq.1.

$$\text{Bandwidth (B)} = \frac{\text{amount of received data at time t1}}{\text{RTT time of (previous ack - current ack)}} \qquad (1)$$

Sample probe packets are sent in slow start phase and congestion window is noted. Estimated bandwidth is used to set congestion window and slow start threshold after the occurrence of congestion or after three duplicate acknowledgments or a timeout. The sample amount data delivered is filtered using low pass filter. The algorithm for bandwidth estimation is given in Fig. 2.

```
int cumul_ack = tcph->seqno_ - last_ack_;
        int cumul_ack1 = cumul_ack;
        myseqno_ = tcph->seqno_;
        if (cumul_ack > 1) {
        if (unaccounted_ >= cumul_ack) {
           unaccounted_-=cumul_ack;
           cumul_ack=1;
         } else
          if (unaccounted_ < cumul_ack) {
           cumul_ack-=unaccounted_;
           unaccounted_=0;     }        }
        if (cumul_ack == 0) {
         unaccounted_++;
         cumul_ack=1; }

        if (cumul_ack > 2) {
         cumul_ack=2;   }
        nackpack_ += cumul_ack;
        last_seq_+=cumul_ack;
        current_ts_=tcph->ts();
        current_echoed_ts_=tcph->ts_echo();
        double rtt_estimate = t_rtt_ * tcp_tick_;
        if ((rtt_estimate < min_rtt_estimate)&&(rtt_estimate > 0))
        { min_rtt_estimate = rtt_estimate;
                qest_=0;
                last_echoed_ts_=current_echoed_ts_;
                last_ts_=current_ts_;  }

                qest_=qest_+(current_ts_-last_ts_)-
               (current_echoed_ts_- last_echoed_ts_);
                last_echoed_ts_=current_echoed_ts_;
                last_ts_=current_ts_;
          qest_=cwnd_-(current_bwe_*min_rtt_estimate)
                   /(8.0*(double)size_);
```

Figure 2. Algorithm for Westwood bandwidth estimation

B. Group Based Multipath Routing

In Grouping-based Multipath [10] Selection more than one path can be selected to transmit data simultaneously by identifying the correlations between multiple paths. The multiple paths on the network can overlap or can share the same bottleneck through end-to-end path. It is difficult to find disjoint paths in a real network. Concurrent Multipath Transfer (CMT) uses multiple paths to transfer data simultaneously. The number of paths required can be selected by minimizing the correlation of selected path using Group based multipath selection procedure. The first step involves probing. Consecutive N probe packets are transmitted to different destinations. A sequence of matched packets and spacing is calculated. The spacing of packet-pair on the same path bottleneck is larger than the spacing between packets on different paths.

Second step involves grouping of the paths. In [10] grouping is done based on the shared bottleneck. In this proposed technique the grouping process takes input as a set of target Bandwidth. The multipath grouping procedure involves estimating bandwidth on each path from the above grouping of paths using Westwood approach.

Paths are grouped according to its representative bandwidth Bxy which has an identical source or destination address. A new bandwidth is only compared to its representative bandwidth of the group to determine whether it should join the group or not. However, if there is no representative bandwidth in the group, the new bandwidth is not joined to that group. Finally, if the new bandwidth cannot be joined to any existing group, a new group can be created with the bandwidth as representative bandwidth.

Selection process: the path with the highest bandwidth is selected from each group. If the number of required path by the application is less the selected path then the path with maximum bandwidth and minimum delay are selected within the selected paths.

C. Concurrent Multipath transfer

Using SCTP multihoming VoIP packets are transmitted simultaneously on multiple paths. Multihoming allows an association between two end points with multiple IP addresses (multiple interfaces) for each end point.

The concurrent SCTP multipath transfer involves association setup, data transfer and association shutdown. In an association multiple streams can be transmitted. The basic element in a CMT SCTP packet is the chunk. There are two types of chunks: the data chunk and the control chunk. Control chunk includes different signals for association initiation, initiation acknowledgement (ACK) and shutdown, congestion control etc.

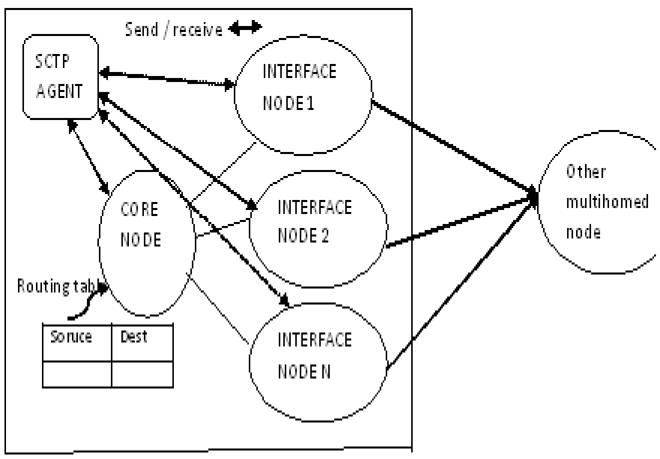

Figure 3. Multihoming node in ns2 simulation

CMT SCTP is simulated using Ns 2 simulator. But the current Ns 2 simulator does not support multiple interfaces for a single node. Therefore the node is logically multihomed [22]. Each multihomed node shown in Fig. 3 is actually made up of more than one node called core node and interface nodes. An SCTP agent simultaneously resides on all these nodes and actual traffic only goes to/ from the interface nodes. Whenever the SCTP agent needs to send data to a destination and does not know which outgoing interface to use, the agent firsts consults with the core node for a route lookup.

Then, the SCTP agent performs the send from the appropriate interface node. Incoming data are received at one of the interface nodes directly and passed up to the SCTP agent. The SCTP agent supports the features like Normal Establishment of an Association , Transmission of DATA Chunks ,Acknowledgment on Reception of DATA Chunks , Management Retransmission Timer , Multihomed SCTP Endpoints , Stream Identifier and Stream Sequence Number , Ordered and Unordered Delivery , Report Gaps in Received DATA TSNs , SCTP Slow-Start and Congestion Avoidance , Endpoint Failure Detection and Path Failure Detection . The sample Ns2 scripts describing CMT SCTP multihoming simulation is shown in Fig. 4.

```
set ns [new Simulator]
set nf [open sctp.nam w]
$ns namtrace-all $nf
set allc [open all.tr w]
$ns trace-all $allc
proc finish {} {
  exec nam sctp.nam &
  exit 0  }
set host0 core [$ns node]
set host0_if0 [$ns node]
set host0_if1 [$ns node]
$ns multihome-add-interface
$host0_core $host0_if0
$ns multihome-add-interface
$host0_core $host0_if1
set host1_core [$ns node]
set host1_if0 [$ns node]
set host1_if1 [$ns node]
$ns multihome-add-interface
$host1_core $host1_if0
$ns multihome-add-interface
$host1_core $host1_if1
$ns duplex-link $host0_if0
$host1_if0 .5Mb 200ms DropTail
$ns duplex-link $host0_if1
$host1_if1 .5Mb 200ms DropTail
set sctp0 [new Agent/SCTP]
$ns multihome-attach-agent
$host0_core $sctp0
set trace_ch [open trace.sctp w]
```

```
$sctp0 set trace_all_ 1
$sctp0 trace rto_
$sctp0 trace errorCount_
$sctp0 attach $trace_ch
set sctp1 [new Agent/SCTP]
$ns multihome-attach-agent $host1_core $sctp1
$ns connect $sctp0 $sctp1
set ftp0 [new Application/FTP]
$ftp0 attach-agent $sctp0
$sctp0 set-primary-destination
$host1_if0 # set primary before association starts;
$ns at 7.5 "$sctp0 set-primary-destination
$host1_if1" # change primary;
$ns at 7.5 "$sctp0 print cwnd_"
# print all dests' cwnds at time 7.5;
$ns at 0.5 "$ftp0 start"
```

Figure 4. sample simulation of multihoming SCTP in Ns2

IV. RESULTS AND DISCUSSIONS

Simulation setup: The proposed technique is simulated with the network simulator (ns-2). The topology consists of one multihomed sender and multihomed destination node. These nodes connected to 10 multihomed nodes. Different link bandwidth and delay are assigned between all the paths. VoIP traffic with random exponential loss rate of 0.05 is transmitted. QoS metrics like received bandwidth, throughput and delay are taken for evaluation. The proposed technique is compared with single path dispersion strategy.

Experimental Results - By varying the time from 10 sec to 60 sec at regular intervals received throughput is measured for proposed CMTSCTP and single path transmission is shown in Fig. 5. Similarly packet number and its delay time are counted for both CMTSCTP and single path transmission is shown in Fig.6. From the simulation results it is showed the proposed system increase throughput and decreases the delay.

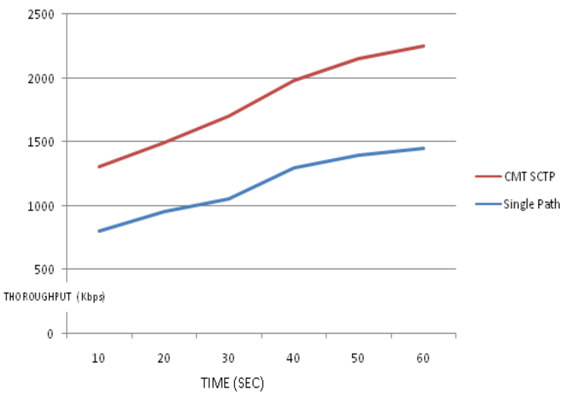

Figure 5. Time Vs Throughput

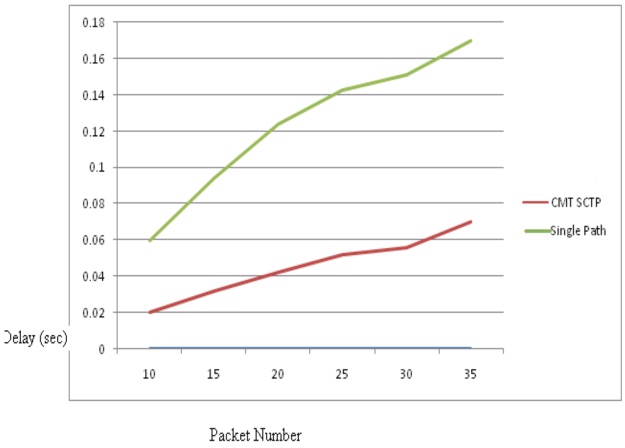

Figure 6. Packet Number Vs Delay

V. CONCLUSION

In this paper, Efficient Bandwidth Estimation Management for VoIP Concurrent Multipath Transfer is proposed. Westwood approach is used for bandwidth estimation on each group of multiple paths. Grouping-based Multipath Selection is used to select the best multiple paths by minimizing path correlation between end to end paths. The bandwidth estimation and CMT techniques is simulated using Ns2 simulator. It is observed that the proposed system increases the, bandwidth utilization and throughput. By various simulation results, it is shown that the proposed technique attains maximum resource utilization, load balancing, and provides fault tolerance network.

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