Smart TCP Approach to Handle Seamless Vertical Handoff

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ABSTRACT

The coexistence of 3G cellular networks with wireless local area networks (WLAN) has been a topic of great interest to the experts in recent years. Heterogeneous networks can complement each other in terms of data rate and coverage area. WLAN provides a high bandwidth data service over a small area while the 3G cellular network provides a higher mobility with lower bandwidth data service. When a mobile node switches between networks, vertical handoff (VHO) that ensures an uninterrupted data service becomes important. During VHO the conventional TCP scheme suffers packet reordering and premature timeout which causes severe throughput degradation. In this paper we propose a Sender based Freeze-TCP (SFTCP) scheme for seamless vertical handoff. SFTCP stops transmitting packets before the disconnection occurs in a way inspired by Freeze-TCP, then it probes link bandwidth after the reconnection to enable the full use of the newly available bandwidth. Instead of using conventional mechanism of freezing we propose a new technique where the mobile sender controls the freezing behavior. Through this approach we can have an immediate recovery upon reconnection as well as a significantly improved window adjustment to the newly available network conditions. Simulation results show that our proposed scheme can achieve faster recovery and improved throughput.

Keywords: **Vertical Handoff; Freeze TCP; bandwidth probing**

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I. INTRODUCTION

TCP [1,2] is widely used transport protocol for current internet applications. TCP carries more than 90% of all web traffic[2]. TCP was first created and optimized for conventional wire line networks where the symptom for congestion is packet loss. In wireless network packet losses are mainly due to high bit error rate(BER) and handoffs. TCP interprets these losses as the sign of congestion and invokes congestion control algorithm which results the shrinking of its congestion window which in turns reduces throughput abruptly. This throughput reduction leads to poor performance in wired cum wireless environments. When a user switches between cells in a mobile network, there are short disconnections because of handoffs. There have been many studies [3-6] concerning TCP performance improvement for handoff events. Many segments are lost during handoff if seamless handoff is not considered. Due to its complexity, seamless handoff is unlikely to be available for heterogeneous networks. As a result, segments will be dropped at the base station of the prior wireless link when handoff happens. If a mobile node goes through too many handoffs, its connection can be interrupted for a large time period which can be interpreted as disconnection as well. In order to get the high bandwidth the size of the cell should be small. But small cell sizes cause frequent handoffs. This increases latency which leads to serial timeouts at the TCP sender. In this case exponential back off retransmit timer reaches its upper limit because of serial timeouts which is more harmful for the throughput as compared to bit error or small congestion window.

The objective of the Freeze TCP[7] protocol was to avoid the performance degradation of TCP in wireless network which suffers from frequent handoff events. After upward vertical handoff (WLAN to 3G cellular network)[2] TCP Reno[6] suffers from retransmission timeout (RTO) events due to the small round-trip time (RTT) of WLAN. The RTT of a cellular network is much higher than that of a WLAN. This RTT discrepancy creates bursty loss due to the false RTOs, and causes severe performance degradation in TCP throughput. Due to the bursty losses the value of slow start threshold(ssthresh) decreases to 1 which causes TCP to enter into congestion avoidance phase (CA) and in CA the window size increases linearly which creates massive throughput degradation.

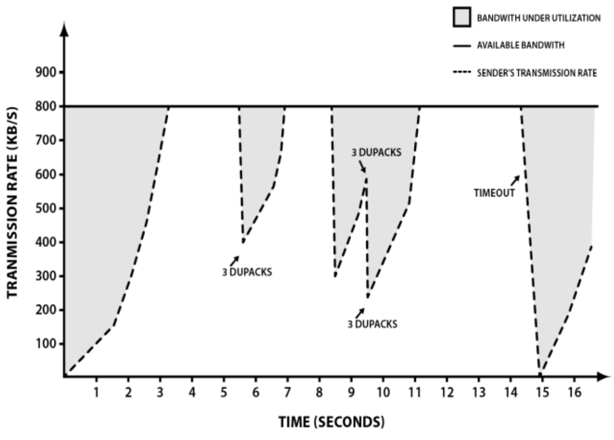

Figure-1: Bandwidth underutilization due to random loss

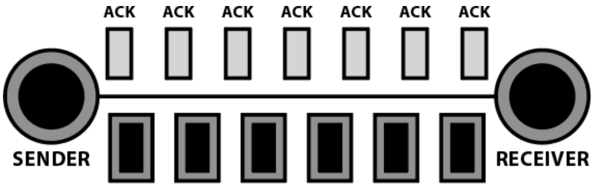

Figure-2: Full Pipe with 100% link utilization

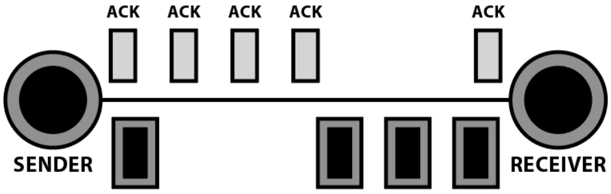

Figure-3: Underutilization of resource on a pipe

Figures 1 to 3 show the TCP bandwidth underutilization problem due to random loss. Freeze TCP in these situations can tackle the events efficiently because when it senses an imminent disconnection, it notifies the sender and prevents the sender from entering into slow start phase. When receiver gets strong signal, it again notifies the sender to awake immediately and resumes the connection with the same congestion window as it had before the occurrence of handoff.

In order to achieve seamless handover from one network to another, the multi-standard capability within mobile node should be considered. Generally, there are two types of handoffs that we normally see in mobile networks, Horizontal handoff and Vertical handoff. Horizontal handoff occurs between base stations that are using two similar systems with the similar data transmission configuration. On the other hand, Vertical Handoff is a handoff between base stations that are using different wireless network technologies such as WLAN and 3G cellular network. Figure 4 shows the different types of handoff in a wireless network.

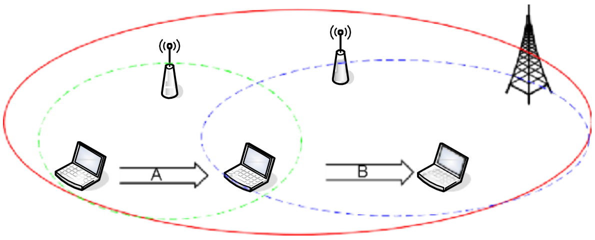

Figure 4: A: Horizontal handoff B: Vertical handoff

Horizontal Vertical Handoff [6] denotes the process of transferring an active call from one cell to another between BSs using different wireless network technologies, such as WLAN and 3G cellular network. The downward vertical handoff, on the other hand, defines a handoff from big coverage low-bandwidth networks to smaller coverage high-bandwidth networks. A vertical handoff can be handled by mobile IP/IPv6 [8] without disrupting the current connection. However, during a handoff, packets frequently get lost, delayed, or out of order, which can cause undesirable TCP congestion control and impair TCP performance. This is due to the fact that TCP congestion control is predicated on the idea that a connection's end-to-end path will mostly remain unaltered once it has been created.

In this paper we propose a sender-based Freeze TCP approach (SF TCP) where the sender senses the signal and takes the action accordingly. We implement an efficient link bandwidth probing technique which enables full use of the newly available bandwidth after a handoff. Rather than adopting the conventional mechanism of freezing we propose a new technique where the mobile sender controls the freezing behavior. Through this approach we can have an immediate recovery upon reconnection as well as a significantly improved window adjustment to the newly available network conditions. Simulation outcomes demonstrate that our suggested approach can lead to a quicker recovery and increased throughput.

The organization of this paper is as follows: Section II focuses on disconnection event analysis in the network. The impacts of handoff event on TCP performance are discussed in section-III. Section IV and V focuses on the core idea of Freezing and Sender based techniques respectively. We present our simulation results in Section VI and the paper is concluded in Section VII.

II. DISCONNECTION ANALYSIS

In this section we will present the various types of disconnection events and TCP’s behavior in response to this disconnection

A. Disconnection at the time of Connection Establishment:

After sending SYN segment, if the receiver gets disconnected and sender does not receive an ACK, TCP starts Connection Establish Timer [2]. If this situation continues up to 75 seconds, the connection establishment is aborted.

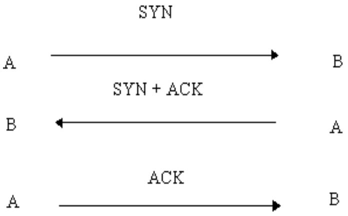

Figure 5: TCP Connection Establishment

B. *Disconnection right after Connection Establishment:*

Right after connection establishment if neither process at the ends of a TCP connection is sending data and nothing is exchanged between them and the connection remains idle for about 2 hours, TCP will use Keepalive Timer [2]. The server will send probe segment. 75 seconds apart and after 10 probes if the client doesn't reply the server will assume that the client is down and the connection is terminated immediately.

C. *Disconnection after Data Transmission:*

When Retransmission Timeout (RTO) expires the host takes attempt to retransmit first unacknowledged segment. RTO interval will be exponentially increased with the upper limit of 64 seconds. If response does not come then TCP will abort the connection after 12 unsuccessful retransmissions which takes on the order of 9 minutes. But, in case of receiver's response, sender will again send data by entering into slow start.

D. Disconnection at the time of Connection Closing:

To prevent a connection from constantly remaining in the FIN WAIT 2 state, the Fin WAIT 2 timer [2] is enabled. When the session enters the FIN WAIT 2 state, this timeout is set to 10 minutes. The FIN WAIT 2 timer is reset to 75 seconds when it fires. The connection is terminated when it fires once again. Connection termination process is shown in Figure.

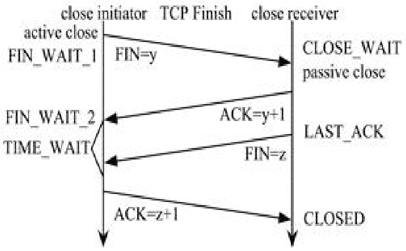

Figure 6: TCP Connection Closing

III. TCP FOR CONTROLLING HANDOFF

The phenomenon of wireless losses caused by frequent handoffs or other non-congestion losses is negatively impacted in HSR networks. Some work has been done in investigating transport layer issues during handovers such as those in [8-10]:

Investigations of transport layer problems during handovers such as have been conducted. Traditional TCP, for instance, suffers from numerous handoff concerns with regard to mobile data transfers, connection glitches, and service continuity. Vehicular ad hoc network, or VANET [11] is a wireless network which ensure drivers' comfort and safety in moving vehicles. Using the New Reno variation of TCP, which is currently the most popular variant, Sinky and Hamdaoui [14] analyze and suggest solutions to these problems. The difficulty is to effortlessly retain a mobile user's connection during a handoff with little to no noticeable delay. These problems are just a few of the many ones that led to the creation of MPTCP[12-14]. MPTCP makes use of numerous TCP subflows, it is crucial to comprehend the core problems that TCP handoff causes. RVeno[16], a novel congestion control method for HSR networks that aggregates WiFi and Evolution for Railway (LTE-R) communication paths. RVeno, a cutting-edge traffic management strategy, clearly outperforms the current MPTCP congestion control methods in terms of throughput.

Our proposal in this research is a sender-based method to Freeze TCP [8], in which the sender detects the signal and responds appropriately. We employ a productive connection bandwidth probing method that allows us to fully utilize the newly freed up bandwidth following a handoff. Freeze TCP detects an upcoming disconnection caused by a poor signal or by any other issue brought on by wireless communications that advertises a zero-window size (ZWA- zero window advertisement). This advertisement warns the sender of any upcoming disconnections and stops the sender from entering the slow start phase. When the receiver reports that the advertised window is zero, the sender enters persist mode, stops any session-related retransmit timers, and stores the value of the congestion window. The inter-probe period is then progressively backed off up to 1 minute before the transmitter broadcasts zero window probes (ZWPs), after which the probe interval becomes constant (1 min). The sender attempts to send probes continuously until the receiver's window opens.

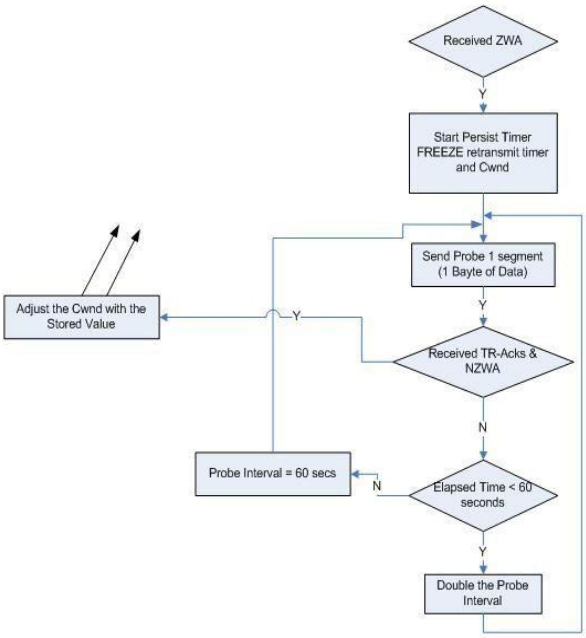

Figure-7: Freeze TCP sender

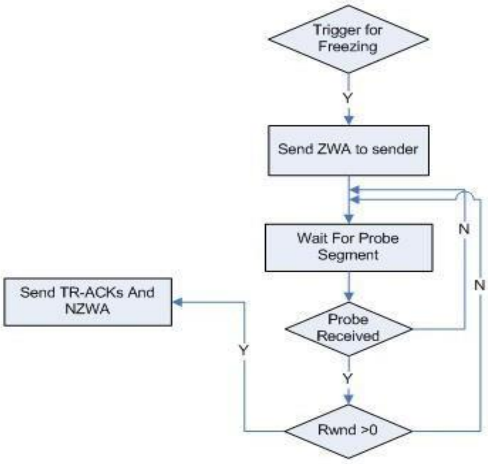

Figure-8: Freeze TCP receiver

Resuming the connection with the same congestion window it had before the handoff, the receiver transmits 3 Acks (TR-Acks) with Non Zero Window Advertisement (NZWA) to instantly awake the sender. Figures 7 and 8's flow charts depict the Freeze TCP Sender and Receiver's behavior in action. The mobile station must have dual mode physical interfaces and protocol stacks that can switch their interfaces based on the network environment in order to interoperate between WLAN and 3G cellular networks.

IV. SENDER BASED FREEZING

In Sender Based Freeze TCP(SFTCP), the sender immediately freezes if the measured signal strength goes down below a certain threshold. The Congestion Window(cwnd) and Slow Start Threshold(ssthresh) values are stored before freezing and using these values the new congestion window value will be calculated with the main focus being to obtain the available bandwidth very quickly and efficiently.

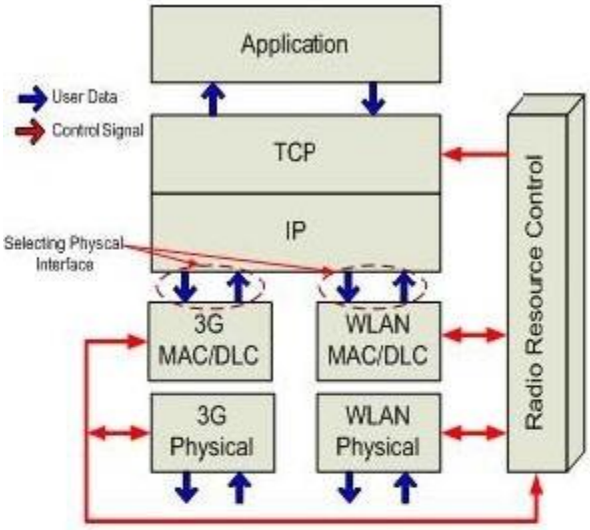

Figure-9: Radio Resource Controller (RRC)

Figure 9 shows the protocol stack of a mobile host. Here, a mobile host installs two different types of network interface cards and checks the Radio Resource Control (RRC) module's received signal strength and velocity. Based on the measurement data, it chooses a suitable physical interface and informs the TCP layer of the handoff. Figure 10 depicts the SFTCP's data flow characteristics.

A. *Detailed States of SFTCP:*

SFTCP's total operations are carried out in four major phases: Freezing, Restoring, Bandwidth Estimation and Probing. These states have been implemented in TCP sender and the purpose of these states is to enable the state transition and synchronization with the standard TCP behavior. Figure 11 represents the state diagram of SFTCP

1) Sender enters into the Frozen state and stores the current congestion window and ssthresh value. Sender cancels all the retransmit timers to avoid spurious retransmission.

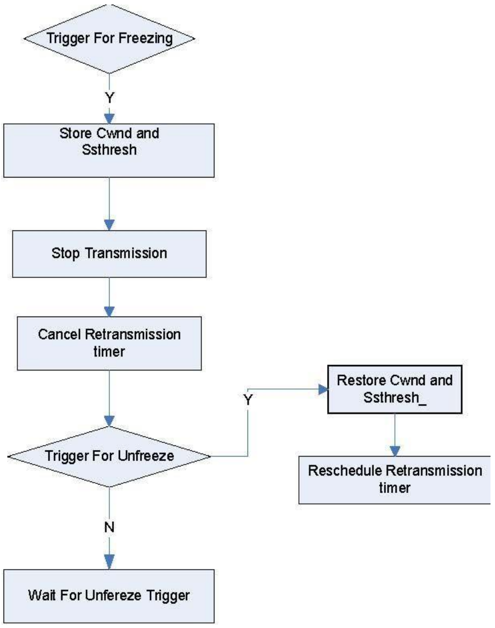

Figure-10: Data flow Behavior of SFTCP

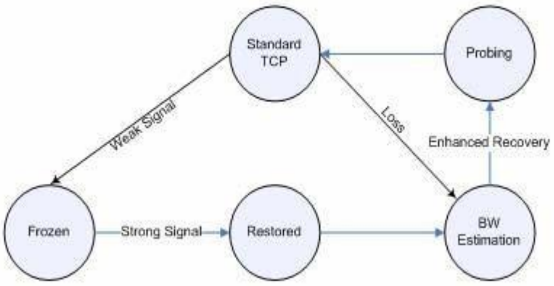

Figure-11: State Diagram of SFTCP

2) When RRC receives a strong signal from the physical layer, it informs the TCP sender and the sender tries to enter into the Restoring phase. The retransmission timer is restarted and the sender uses the stored cwnd and ssthresh values for the new connection.

3) After restoring the parameters, the TCP sender will wait 1 RTT to check whether congestion happens in the link. If there is no congestion, the sender will enter into the second slow start regardless of its previous congestion window state. If the network suffers any loss within this one RTT period, the sender will enter into the modified congestion avoidance phase where the rate of the growth of CWND will be: cwnd = cwnd + 2/cwnd.

4) If loss is detected in the modified congestion avoidance state the sender will enter into the standard congestion avoidance state. In this case the bandwidth will be measured by using TABE[14] method and *ssthresh_* will be adjusted by using the following formulas:

$$Bw_n = \frac{Bw_{n-1} * RTT + X_n}{RTT + T_n} \qquad ssthresh = \frac{RTT_{\min} * Bw_n}{Seg\_size}$$

When the nth ACK reaches the sender, Bw_n is the predicted bandwidth, T_n is the gap between two subsequent ACKs, X_n is the size of the packet, RTT_{min} is the minimum round-trip time, and Seg size is the TCP segment's length in bits.

V. SIMULATION RESULTS

One of the elements in TCP that controls how many bytes can be sent out at any given moment is the congestion window (CWND) [1]. The sender is responsible for maintaining the congestion window, which prevents excessive traffic from overloading the link between the sender and the recipient. TCP Sequence (seq) numbers aid in the orderly transport of data between TCP streams. The TCP client sends the seq number, which indicates how much data has been transferred for the session (also known as the byte-order number). The experiment was conducted using Network Simulator NS-2.31[17] where Sequence numbers and CWND's performance were assessed over time.

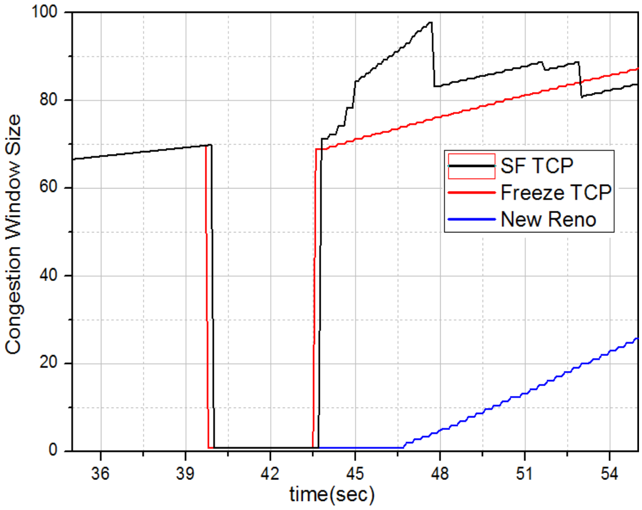

Figure 12: Congestion window size vs. time for downward VHO

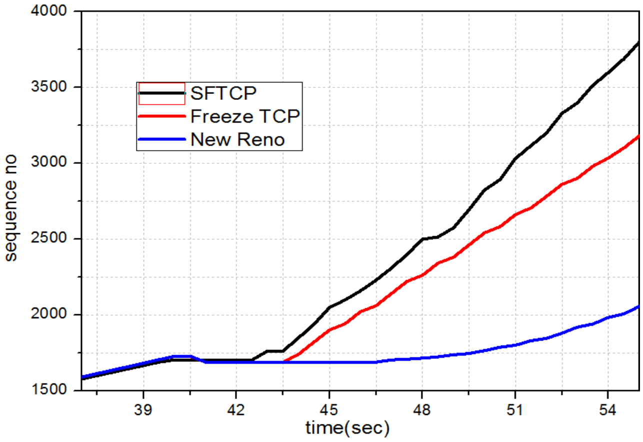

Figure 13: Sequence No. vs. time handoff for Downward VHO

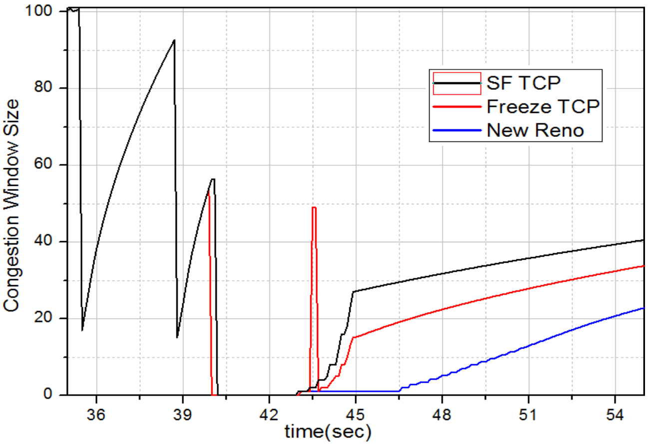

Figure 14: Congestion window size vs. time for Upward vertical handoff

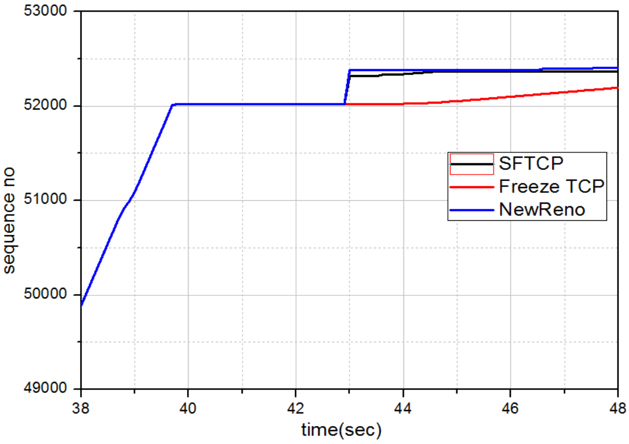

Figure 15: Sequence No. vs. time handoff for Upward VHO

Here we have compared our schemes with receiver-based Freeze TCP protocol and standard TCP New Reno protocol. We considered FTP application for hybrid network topology with single sender and receiver. For 3G network the bandwidth and round-trip time have been assumed as .38 Mbps and 300 *m* sec respectively whereas these readings are 11Mbps and 10 *m* sec for WLAN. The packet size is set to 1000 bytes. We assume the handoff occurs at 40 sec and is completes at 43 sec.

For a downward vertical handoff, Figures 12 and 13 display the relationship between congestion window and time and the sequence number and time, respectively. Here, we can see that SFTCP started off slowly the second time after reconnecting, but it quickly increased its data rate and stabilized it. Figure 14 and 15 show the TCP performance for upward vertical handoff, in which the available bandwidth is decreased. Here the general Freeze TCP approach is very aggressive as it uses frozen congestion window value after reconnection even if it switches to low bandwidth network. As a result, the congestion window value of Freeze TCP decreases significantly and the network suffers massive throughput degradation. With our SFTCP, the congestion window grows slowly after reconnection and its performance is identical to TCP New Reno.

VI. CONCLUSION

In order to get better performance during vertical handoffs in heterogeneous networks composed of WLANs and 3G cellular networks, we introduced a Sender based Freeze TCP (SFTCP) approach. When using SFTCP, a TCP sender that has detected the upcoming handoff initiates the freezing and restoration processes. To enable the mobile node to fully utilize the newly available bandwidth upon reconnecting, we implemented a modified slow-start. The results of our simulations clearly show that when there is a sudden increase in available bandwidth, the proposed SFTCP system can be very successful for downward VHO.

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Biographies and Photographs

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