Simulation-based investigation of TCP file transfers over UMTS

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Abstract: This paper mainly describes the simulations that help better understand the implications and requirements when TCP traffics are carried over UMTS that is characterized by moderate bandwidth bearers with relatively high link error. Especially it was of great interest to gain insight that contributes to implement the Over-The-Air (OTA) service provisioning models in 3G environments.

1 Introduction

In recent years, much development and deployment activity has centered around 2.5G and 3G technologies. Along with objectives like increased capacity for voice channels, a primary motivation for these is data communication, and in particular Internet access [1]. Furthermore, with the initial deployment of 3G services in the U.K. this year, more personalized and profitable 3G services such as video content downloading, mobile game, mobile commerce, device management and even software defined radio will be enabled through Over-The-Air service provisioning model that describes the ability to download and install content over a wireless network, typically on demand.

Accordingly, TCP performance over highly unpredictable environment like the mobile radio channel becomes the key issues. However, research has shown that the performance of current TCP control mechanisms is inadequate in wireless networks [2]. Designed for wired networks originally, TCP assumes that network congestion has happened whenever a packet is lost. It then invokes appropriate congestion control actions such as reducing window size. However, wireless networks posses unignorably high link error rate and TCP often misinterprets packet losses caused by link errors as congestion. As a result, its performance suffers in wireless networks when TCP unnecessarily invokes congestion control, causing reduction in throughput and link utilization.

In this paper, we try to use simulation tool to quantify and visualize the problems and to obtain better understanding of the influence poor link quality upon TCP file transfers behavior. With special focus on the different sizes of data, the paper also intends to provide some reasonable advices for implementing OTA service provisioning.

2. Simulation Experiment

Due to the complex algorithms included in the TCP protocol, it is almost impossible to predict the performance of TCP in real environments. To obtain more realistic projections about the performance of TCP used over UMTS we performed simulations with some reasonable abstractions.

2.1 Simulation software

All simulations have been done with NS 2 (Network Simulator version 2.1b9a)[3]. This discrete event simulator provide a rich library of modules including the different flavours of TCP and CMU wireless network extension that implemented an 802.11 MAC layer, and a wireless network channel model with a 250m transmission range.

2.2 Simulation model

A simple three-node and two-link topology is chosen in order to get a clearer picture of how the radio link affects TCP file transfers with less consideration of other factors.

The three nodes, Mobile Host, Base Station and a FTP Server, line from left to right. The leftmost Mobile Host (MH) could in the reality be a UMTS mobile phone. The node in the middle as named represents the Base Station (Node B in UMTS) while the rightmost node represents a FTP server residing on the Internet.

The links between MH and BS and between BS and FTP server are configured to emulate the effective delay and bandwidth in radio link and wired link respectively.

Note that to obtain more realistic projections about the performance of TCP over UMTS, some reasonable abstractions of UMTS link are made. The simulation model is entirely on the RLC level; the actual physical layer and MAC layer are not modeled and only the block error arisen from the physical layer was taken into consideration. Furthermore, in the light of the fact that increasing the transmission power will reduce the error rate, we assume that the block errors are kept at a predefined level (10% BLER) and uniformly distributed.

2.3 Parameter space

For parameters of radio link, we base our choice of the most common values: TTI:20ms, retransmission delay: 60ms; BLER 0% vs. 10%; bearer speed: 384,144 and 64 Kbps.

For TCP parameters, we base our choice of according to [1]. TCP variant: New-Reno; MTU (Maximum Transfer Unit): 576Byte Vs. 1500 Bytes; Delayed ACK: on; RTO: 3s; Initial Window Size: 2; Timestamp Option: on.

2.4 Simulation scenario 1: verifying the choice of window size

TCP over 2.5G/3G should support appropriate window sizes based on the Bandwidth Delay Product (BDP) of the end-to-end path [1]. In theory, sending window needs to be as large as possible, however an unlimited maximum window would be unrealistic, mainly due to the limitation of buffer size of receiver. The first simulations would be done to verify the choice of window size that is large enough for full link utilization of an error free link.

The simulation results shown as Figure 1, 2,3,4 indicate the changing of sending window size over time.

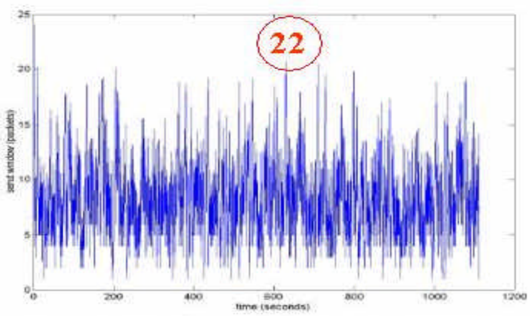

Figure 1: 384 kbps with packet size of 576 bytes

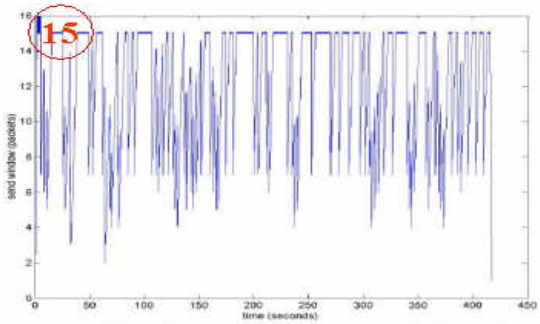

Figure 2: 384 kbps with packet size of 1500 bytes

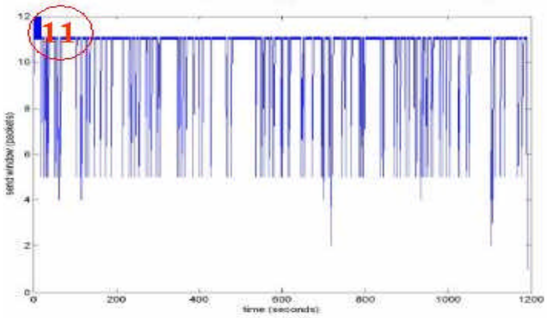

Figure 3: 144 kbps with packet size of 576 bytes

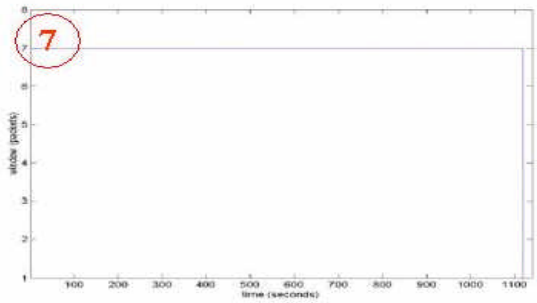

Figure 4: 144 kbps with packet size of 1500 bytes

We observed that the maximum sizes of sending window in 384 Kbps with pocketsize of 576 bytes, 384 Kbps with pocketsize of 1500 bytes, 144 Kbps with pocketsize of 576 bytes and 144 Kbps with pocketsize of 1500 bytes are 22, 15, 11, 7 respectively.

Specially, Figure 3 serves as a good illustration of the congestion window being halved when a fast retransmission occurs. And in Figure 4, when TCP do not do any fast retransmission, the congestion window does not decrease at all and keeps at level of 7 segments all through except for the initial slow start phase, which is too short to be seen in the figure.

2.5 Simulation scenario 2:

To clearly see how the TCP file transfers are affected over UMTS radio link, a large file with the size of 10 Mbytes is chosen. By using a large file, general conclusions are more probably to be made.

The simulation results are showed in Figure 5.

Bearer Speed (kbps)	Packet Size (bytes)	Max Window (segments)	Increased in time (%)	
			10% BLER link	0% BLER Link
384	1500	22	24	12.13
	576	15	226	179.9
144	1500	11	11.8	0.7
	576	7	20.3	7.9
64	1500	9	11.4	0.3
	576	6	11.1	0.1

Figure 5: Increase of transfer time in a link with 10% BLER Vs. an error free link

We found that with the packet size of 1500 bytes, the performance of TCP file transfers is obviously better than those with the packet size of 576 bytes. This corresponds well with [4].

The results also show that a high link error (10% BLER) make a little influence on the performance of TCP when 64 kbps bearer are used. The increased time of 11% is mainly arisen from 10% radio block retransmissions, and not due to TCP congestion control. Also, the 144 kbps bearer in combination with 1500 bytes packet size shows the similar feature and correspond well with the Figure 4.

In the link with 0% BLER, poor performance of TCP data transfers (long transfer time) attributes to the underachievement of TCP congestion control. From Figure 5, we found that the higher speed bearer combined with a small packet size result in the severest degradation of TCP performance whether in a link of very high error ratio or in an error free link.

3. Analysis and Summary

In summary, to quantify the effect of high-error-rate link on TCP performance, New-Reno TCP is used for simulations over an abstract RLC layer of UMTS. The radio block error ratio (BLER) is set to 10 % and a large file is emulated to transfer. The results from these simulations are consistent with our estimation that TCP does not handle well in the high-error-rate radio link, due to the fact that TCP often misinterprets packet losses caused by link errors as congestion. However, valuably, we found that the worst performance of TCP file transfers was obtained at the relatively high bearer speed of 384 Kbps in combination with a relatively small packet size. On the contrary, a lower bearer speed of 64 kbps does not necessarily cause the reduction in TCP throughput and link utilization, even in a high10% BLER link (only radio link retransmission steal capacity). Additionally, we also observed that a larger packet size always perform better than smaller ones no matter what bearer speed and BLER are introduced. The insight we gained by these simulations is that in order to maximize link capacity, a wider range of factors such as packet size and bearer speed need to contemplate interactingly, instead of dedicating to a lower BLER at a price.

4. Future work

The limited times as well as the limited form in which the paper is represented leave some work undone. To make more accurate and general conclusions, a further investigation of small file (less than 200k bytes) transfers will be the major concern next.

5 References

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