AIN SHAMS UNIVERSITY
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Link Adaptation Impact on TCP Performance in 3G CDMA Systems

A Thesis

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To the soul of my beloved father
whom I will never forget

To the soul of my beloved Professor
Dr. Bahnassy M. Nossier
whom I will never forget

To my sweet lovely babies
"Sara", "Mahmoud", and "Noran"

To my beloved wife, mother, brother and
sisters for their help and support

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ABSTRACT

HSDPA is an evolution of the third generation mobile network standards to achieve higher bit rates. Also, *HSPA+* has become one of the promising access techniques. It enables high data rates and backward compatibility with the deployed *3G UMTS* networks.

The aim of the current work is to study, analyse, and propose some sort of enhancements to the Transmission Control Protocol (TCP) based services over the ongoing HSPA systems. This will be done via an analytical modelling and its corresponding numerical solutions in different operational conditions. The current work will focus on the effect of limited buffer size in the Radio Network Controller (RNC) part. In addition, it will expand its obtained results to more realistic cases such as rate adaptation in conjunction with the Adaptive Modulation and Coding (AMC) systems.

The first contribution, in this thesis is the processing of a complete analytical model used to evaluate the effect of TCP and the Radio Network Sub-system (RNS) buffer size for different rate values on HSDPA network performance. The performance will be assessed by means of the evaluation for both of the buffer overflow probability and the Retransmission Time Out (RTO) blocking probability. Differently from the previously published works, a novel treatment of HSDPA performance is done by considering the interaction between blocking and RTO probabilities.

The second contribution, is to evaluate the overall dropping probability (P_T) for the TCP packets over HSDPA by using the RTO blocking probability (P_{RTO}) and the buffer over flow blocking probability (P_B) that was mentioned in the first contribution. Also, the effect of rate variation on the overall dropping probability will be evaluated. The overall packet drop probability had been taken under investigation with respect to the used buffer size simultaneously with the RTO constrains. In addition, the presented thesis takes into consideration the performance enhancement that would be done by deploying the rate adaptation mechanisms. The interaction between RNS buffer size and the TCP layer is also investigated. An analytical model will be derived to evaluate the overall drop probability and the correspondence between TCP retransmission time for different normalized air time.

Finally, the third contribution is to study the impact of deploying AMC schemes and the effect of having practical channel models with multipath fading over the obtained SNR and its influence over the *TCP/RTO* in HSPA+ Rel'9. This will be done by estimating the overall TCP/RTO probability via a detailed mathematical analysis. This gives a special concern about the impact of deploying adaptive coding and modulation schemes. In addition, this thesis investigates the effect of multipath fading over the obtained SNR and its influence over the TCP/RTO. The novelty of this thesis comes from the physical layer parameters influence on the performance of the other upper layers.

The results obtained are close to the previously published results for both of the first and the second contributions. The model confirms that the lower the congestion rates of TCP, the higher the application service rate. Additional insight on the HSDPA system behaviour and interactions with RNS buffer size and TCP/RTO is provided. The presented work analyses the HSDPA and proposes a method to select the appropriate service rate for having minimal overall dropping probability. The results show that, decreasing the network service rate has a significant improvement on the overall drop probability. A small change in service rate enhances the overall system performance by increasing the utilization of air interface. In other words, the network performance will be more independent of the normalized air time as the difference between the service rates decreases. In order to get lower value of P_T, it is recommended to keep the normalized air time below 50% for all values of used buffer sizes.

Key Words: TCP/RTO; probability; HSDPA performance; finite RNS buffer size; rate adaptation; HSDPA+; modeling; AMC; and SNR mapping techniques.

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LIST OF ABBREVIATIONS

16QAM	16-ary Quadrature Amplitude Modulation
3G	Third-Generation
3GPP	3rd Generation Partnership Project
64QAM	64-ary Quadrature Amplitude Modulation
ACK	ACKnowledgment
AIMD	Additive Increase, Multiplicative Decrease
AMC	Adaptive Modulation and Coding
AMPS	Advanced Mobile Phone System
AQM	Active Queueing Management
ARP	Allocation and Retention Priority
AWGN	Additive Wight Gaussian Noise
BLER	BLock Error Rate
BMC	Broadcast/Multicast Control protocol
BTS or Node-B	Base Transceiver Station
CAC	Call Admission Control
CDMA	Code Division Multiple Access
CPICH	Common PIlot CHannel
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
cwnd	Congestion window
DCH	Dedicated Channel
DCS	Digital Communication System
DSL	Digital Subscriber Line
E-AMPS	Extended Advanced Mobile Phone Service
E-DCH	Enhanced Dedicated Channel

EDGE	Enhanced Data for GSM Evolution
EGPRS	Enhanced General Packet Radio Service
FACH	Forward Access CHannel
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
F-DPCH	Fractional Dedicated Physical CHannel
FEC	Forward Error Correction
FLA	Fast Link Adaptation (FLA)
FT	Fair Throughput
FTP	File Transfer Protocol
GERAN	GSM/EDGE Radio Access Network
GPRS	General Packet Radio Service
GSM	Global System for Mobile
HARQ	Hyper Automatic Repeat reQuest
H-RNTI	HS-DSCH Radio Network Temporary Identifier
HS- DPCCH	High-Speed Dedicated Physical Control CHannel
HSDPA	High Speed High Speed Downlink Packet Access
HS-DSCH	High-Speed Downlink Shared CHannel
HSDSCH	High-Speed Downlink Shared CHannel
H-DSCH	High-Speed Data Transport CHannel
S-DSCH FP	High-Speed Downlink Shared Channel FrameProtocol
HSPA	High Speed High Speed Packet Access
HSPA+	Advanced High Speed Packet Access
HS-SCCH	High-Speed Shared Control CHannel
HSUPA	High-Speed Uplink Packet Access
IETF	Internet Engineering Task Force
iid	independent and identically distributed

IMS	Internet protocol Multimedia Subsystem
IMT-2000	International Mobile Telecommunication 2000
IP	Internet Protocol
IW	Initial Window
MAC	Medium Access Control
MAC-d	dedicated MAC
MAC-hs	high-speed MAC
Max C/I	Maximum Carrier-to-Interference ratio
MCS	Modulation and Coding Scheme
MIMO	Multiple Input Multiple Output
MP3	Moving Picture Experts Group Layer-3
MSS	Maximum Segment Size
MTS	Mobile Telephone Service
MTU	Maximum Transfer Unit
MUD	Multi User Detection
NACK	Negative ACKnowledgment
NMF	Nakagami Multi-Path Fading
NMT	Nordic Mobile Telephone
OSI	Open System Interconnection
PCS	Personal Communication Service
PDC	Pacific Digital Cellular
PDCP	Packet Data Convergence Protocol
PDF	Probability Distribution Function
PDP	Power Dispersion Profile
PDU	Protocol Data Unit
PDU	Payload Data Unit
PF	Proportional Fair

PHS	Personal Handy phone System
PKt	Packet
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RED	Random Early Detection
RLC	Radio Link Control
RNC	Radio Network Controller
RNS	Radio Network Sub-System
RR	Round Robin
RRC	Radio Resource Control
RRM	Radio Resource Management
RTO	Retransmission Time Out
RTP	Real Time Protocol
RTT	Round-Trip Time
RWIN	Receiving Window
SF	Spreading Factor
SGSN	Serving GPRS Support Node
SMTP	Simple Mail Transfer Protocol
SNR	Signal to Noise Ratio
SRNC	Serving Radio Network Controller
ss thresh	slow start threshold
SW	Stop and Wait
TACS	Total Access Communications System
TC	Turbo Code
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TDMA	Time Division Multiple Access

TFRI	Transport Format Resource Indicator
TSN	Transmission Sequence Number
TTI	Transmission Time Interval
UDP	User Datagram Protocol
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UTRA	Universal Terrestrial Radio Access
UTRAN	UMTS radio access network
VoIP	Voice over IP
WAP	Wireless Access Protocol
WCDMA	Wideband Code Division Multiple Access
WiFi	Wireless Fidelity
WiMAX	Worldwide interoperability for Microwave Access
WLL	Wireless Local Loop
WSSUS	Wide-Sense Stationary Uncorrelated Scattering
WWW	World Wide Web

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