Quality of Service (QoS) in 4G Wireless Networks

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ARN laboratory, iNext research centre

University of Technology Sydney

by

Fatima Furqan

Supervised by

Professor Doan B. Hoang

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DEDICATION

To my Husband, Furqan Naeem and Kids, Ayaan Furqan and Abdul Hadi Furqan

To my Parents, **Muhammad Yousaf Shah** (late) and Maimoona Yousaf

Thank you for your love and support

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Student: Production Note: Signature removed prior to publication.

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THE AUTHOR'S PUBLICATIONS

International Conference Publications and Proceedings

FURQAN, F. & HOANG, D. B. Analysis of Parameters Contributing Performance and Coverage of Mobile WiMAX with Mix Traffic. 12th International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT), 20-22 Oct 2011. 313-318.

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ABSTRACT

Quality of Service (QoS) of 4th Generation Broadband Wireless Access (BWA) networks is directly affected by two factors: congestion in the network caused by changes in population density and application demand distribution; and varied attributes of network traffic such as minimum rate and delay requirements.

The current 4G BWA specifications define QoS parameters for each type of traffic, but do not provide QoS mechanisms including Radio Admission Control (RAC), scheduler and congestion prevention mechanism to ensure the QoS to existing and new connections within the network. Significant amount of research is dedicated to provide QoS and control congestion using RAC and scheduler. Current QoS mechanisms are inadequate to deal with network congestions and provide fairness among the traffic flows.

In this thesis, we have proposed a QoS framework and control algorithms for 4G BWA networks, Mobile WiMAX and Long Term Evolution (LTE). The framework includes a new load control mechanism, the Fair Intelligent Congestion Control (4G-FICC) and an intelligent admission control, the Fair Intelligent Admission Control (4G-FIAC), based on the QoS architecture of 4G BWA networks.

4G-FICC avoids and controls congestion at the base station of WiMAX and LTE networks, respectively. It avoids congestion through traffic balancing, while handles congestion when unavoidable, allocates resources fairly and minimizes resource underutilization. It estimates fair share of bandwidth for each type of service based on its current resource utilization, QoS constraints and load at the network. It ensures that the traffic is scheduled in a way that fairness is guaranteed among the traffic flows, without violating the QoS requirements of connections.

We have identified critical parameters of 4G-FICC and discuss the impact of various settings of these parameters on the network performance. Detailed and comprehensive simulations are performed in ns-2 and OPNET. The results show that 4G-FICC is always active in the network, whether the network is overloaded or underutilized. It performs extremely well in allocating resources fairly among different type of services, yet preserving

their QoS requirements in terms of throughput, delay and jitter. Furthermore, 4G-FICC is simple to implement, robust and relatively insensitive to parameter settings**.**

To ensure end-to-end delay and QoS, we propose a predictive RAC, the Fair Intelligent Admission Control for 4G networks (4G-FIAC). It admits or rejects an incoming connection based on the resource availability and the current load in the network. The key idea is to utilise feedback from the load control module to determine load in the network. The proposed RAC is based on the bandwidth borrowing and degradation of over provisioned connections in order to minimise blocking probability and maximise resource utilisation in the network.

Therefore, 4G-FIAC along with 4G-FICC avoids congestion in the network to guarantee QoS to end-users. Detailed and comprehensive simulations are performed in ns-2 and OPNET to show the efficiency of the proposed RAC scheme. Extensive simulations demonstrate that 4G-FIAC outperforms existing schemes in terms of blocking probability of different service classes and fair resource allocation.

In this thesis, we have performed a comprehensive study of parameters that affect both the capacity and coverage of 4G networks. It serves as a basis for designing effective QoS schemes for dynamic and mixed distribution of services. With thorough investigation of the impact of QoS schemes on the capacity and dimensioning of 4G networks, we have presented a general and efficient approach for the network operators to determine the extent to which current network configurations can effectively manage the dynamic variations in the access and core side of the network.

Different scenarios are presented in the thesis to evaluate the effects of QoS schemes on the capacity of the network. The results are valuable in assisting the network operators to determine the optimum point for re-dimensioning the network to minimise cost and ensure the QoS of connections in terms of throughput and delay.

The research results are not limited to 4G networks in particular, but can be applied to other next generation wireless technologies, to ensure QoS to users in the covered area.

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LIST OF ABBREVIATIONS AND ACRONYMS

AC	Admission Control
ACR	Allowed Class Rate
ARP	Allocation and Retention Priority
ASN-GW	Access Service Network-Gateway
BE	Best Effort
BER	Bit Error Rate
BP	Blocking Probability
BS	Base Station
BUR	Buffer Utilization Ratio
BW	Bandwidth
BWA	Broadband Wireless Access
CAP	Connection Arrival Procedure
CBR	Constant bit Rate
CC	Congestion Control
CCCH	Common Control Channel
CCM	Congestion Control Module
CDP	Connection Departure Procedure
CoB	Class of Bearers
CoS	Class of Service
CP	Cyclic Prefix
CPS	Common Part Sublayer
CS	Complete Sharing
CSN	Connectivity Service Network
DL	Downlink
DSL	Digital Subscriber Line
eNodeB	Enhanced NodeB
EPC	Evolved Packet Core

EPS	Evolved Packet System
ER	Expected Rate
ERRM	Extra Resource Reservation Module
ertPS	Extended Real time Polling Service
E-UTRAN	Evolved -Universal Terrestrial Radio Access Network
f(Q)	Queue control Function
FDD	Frequency Division Duplex
FIAC	Fair Intelligent Admission Control
FICC	Fair Intelligent Congestion Control
FTP	File Transfer Protocol
FTTH	Fiber To The Home
GBR	Guaranteed Bit Rate
GPC	Grant Per Connection
GPRS	General Packet Radio Service
GPSS	Grant per Subscriber Station
GSM	Global System for Mobile
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
HTTP	Hypertext Transfer Protocol
IEEE	Institute of Electrical and Electronics Engineers
IMT-Advanced	Internal Mobile Telecommunication- Advanced
IP	Internet Protocol
ITU	International Telecommunication Union
LE	Load Estimation
LTE	Long Term Evolution
MAC	Medium Access Control
MACR	Mean Allowed Class Rate
MBR	Maximum Bit Rate

MCS	Modulation and Coding Scheme
MME	Mobility Management Entity
MRTR	Minimum Reserved Traffic Rate
MSTR	Maximum Sustained Traffic Rate
NBN	National Broadband Network
NIST	National Institute of Standards and Technology
Non- GBR	Non Guaranteed Bit Rate
nrtPS	Non Real Time Polling Services
ns-2	Network Simulator-2
OFDMA	Orthogonal Frequency Division Multiple Access
OH	Overheads
PAPR	Peak-to-Average Power Ratio
PDCCH	Physical Downlink Control Channel
PDCP	Packet Data Convergence Protocol
PDN	Packet Data Network
PER	Packet Error Rate
PF	Proportional Fair
P-GW	PDN GW
PRACH	Physical Random Access Channel
PRB	Physical Resource Block
PUCCH	Physical Uplink Control Channel
Q_0	Target Operating Point
QCI	QoS Class Indicator
Qlen	Queue Length
QoC	QoS Class
QoS	Quality of Service
RAC	Radio Admission Control
RB	Resource Block
RE	Resource Element

RLC	Radio Link Control
ROHC	Robust Header Compression
RR	Round Robin
RRM	Radio Resource Management
rtPS	Real Time Polling Services
SAE	System Architecture Evolution
SC-FDMA	Single Carrier- Frequency Division Multiple Access
SDF	Service Data Flow
S-GW	Serving Gateway
SINR	Signal-to-Interference-to- Nose Ratio
SLA	Service Level Agreement
SNR	Signal-to-Noise Ratio
SS	Subscriber Station
TB	Transport Block
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TFT	Traffic Flow Template
ToS	Type of Service
TTI	Transmission Time Interval
UE	User Equipment
UGS	Unsolicited Grant Services
UL	Uplink
UMTS	Universal Mobile Telecommunication System
VBR	Variable bit Rate
VNI	Visual Networking Index
VoIP	Voice over IP
VP	Virtual Partitioning
WCDMA	Wideband Code Division Multiple Access
WFIAC	WiMAX Fair Intelligent Admission Control

WFICC	WiMAX Fair Intelligent Congestion Control
WiMAX	World Wide Interoperability for Microwave Access
WRR	Weighted Round Robin
3GPP	3rd Generation Partnership Project