Quality of Service (QoS) in 4G Wireless Networks

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

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by

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2015
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.

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Signature of Student:

Date: 22nd May 2015
THE AUTHOR’S PUBLICATIONS

International Conference Publications and Proceedings


International Journals

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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<tr>
<td>AC</td>
<td>Admission Control</td>
</tr>
<tr>
<td>ACR</td>
<td>Allowed Class Rate</td>
</tr>
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<td>ARP</td>
<td>Allocation and Retention Priority</td>
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<tr>
<td>ASN-GW</td>
<td>Access Service Network-Gateway</td>
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<td>BE</td>
<td>Best Effort</td>
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<td>BER</td>
<td>Bit Error Rate</td>
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<tr>
<td>BP</td>
<td>Blocking Probability</td>
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<td>BS</td>
<td>Base Station</td>
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<tr>
<td>BUR</td>
<td>Buffer Utilization Ratio</td>
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<td>Bandwidth</td>
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<td>BWA</td>
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<td>CBR</td>
<td>Constant bit Rate</td>
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<td>CC</td>
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<td>Common Control Channel</td>
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<td>CoB</td>
<td>Class of Bearers</td>
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<td>CoS</td>
<td>Class of Service</td>
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<td>CP</td>
<td>Cyclic Prefix</td>
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<tr>
<td>CPS</td>
<td>Common Part Sublayer</td>
</tr>
<tr>
<td>CS</td>
<td>Complete Sharing</td>
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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
Q0  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
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<td>RLC</td>
<td>Radio Link Control</td>
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