Handover Mechanisms in 3GPP Long Term Evolution (LTE)

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

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 with 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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ABSTRACT

The Long-Term Evolution (LTE) network is a new radio access technology (RAT) proposed by the Third Generation Partnership Project (3GPP) to provide a smooth migration towards the fourth generation (4G) network. Long Term Evolution-Advanced (LTE-A) is a major enhancement of the LTE standard proposed by the 3GPP to meet the 4G mobile communication standards.

Handover is one of the key components in cellular network mobility management. Handover is a mechanism that transfers an on-going call or data session from one base station (BS) to another BS or one sector to another sector within the same BS. Hard handover has been adopted in LTE and LTE-A systems by 3GPP due to the flat IP-based architecture and the lack of a centralized controller. The use of hard handovers reduces the complexity of the handover mechanism and minimizes the handover delay. However, the hard handover approach causes call drops that may result in lost data during a session. The objective of this thesis is to provide the basis for improving handover performance in the LTE and LTE-A systems.

A C++ system level simulator that can dynamically model the large and complex downlink LTE and LTE-A was developed as part of this research work followed by a proposed handover parameters optimization method. The simulation results show that the handover parameters optimization method can effectively minimize the unnecessary number of handovers while maximizing the system throughput.

Under an initial assumption of an ideal mobile cellular channel (i.e. the mobile cellular channel is not subject to any impairment), this thesis proposes a new handover algorithm in the LTE system and three new Coordinated Multiple Transmission and Reception (CoMP) handover algorithms in the LTE-A system. The simulation results show that the proposed handover algorithm outperforms well-known handover algorithms in the LTE system by having less number of handovers, shorten total system delay whilst maintaining a higher total system throughput. The performance of the proposed CoMP handover algorithms are evaluated and compared with open literature CoMP handover algorithm via simulation. It is shown via simulation that the proposed

CoMP handover algorithms can improve the system throughput and minimize the system delay in a saturated system scenario in the LTE-A system.

A more practical LTE-A system where the mobile cellular channels are subject to impairments is considered for performance testing of selected CoMP handover algorithms. The impairments for a practical LTE-A system are assumed to be in two scenarios: outdated feedback and missing feedback. It is shown via computer simulations that the system throughput and system delay are very sensitive against outdated Channel Quality Information (CQI) feedback and missing CQI feedback. Furthermore, a handover failure caused by an inappropriate feedback increases the number of unnecessary handovers which require additional resources in the network and may significantly degrade the system performance.

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LIST OF ACRONYMS

1G	First Generation
2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
4G	Fourth Generation
ACK	Acknowledgement
AMC	Adaptive Modulation and Coding
AMPS	Analogue Mobile Phone System
BBC	Break-Before-Connect
BER	Bit Error Rate
BLER	Block Error Rate
BS	Base Station
CA	Carrier Aggregation
CBB	Connect-Before-Break
CBR	Constant Bit Rate
CBTC	Communication Based Train Control
CC	Chase Combining
CCS	CoMP Coordinating Set
CCSn	Central Control Station
CS	Cell Selection
CS/CB	Coordinated Scheduling / Beamforming
CSI	Channel State Information
CTS	Cooperative Transmission Set
CTP	CoMP Transmission Point
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
CoMP	Coordinated Multiple Point
CP	Cyclic Prefix
CQI	Channel Quality Information

CRC	Cyclic Redundancy Check
DL	Downlink
DSSS	Direct Sequence Spread Spectrum
EDGE	Enhanced Data Rates for GSM Evolution
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
eNB/eNodeB	Enhanced Node B
EPC	Evolved Packet Core
EPS	Evolved Packet System
FIFO	First-In-First-Out
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
GBR	Guaranteed Bit Rate
GPRS	General Packet Radio Services
GSM	Global System for Mobile Communication
GTP	GPRS Tunnelling Protocol
HARQ	Hybrid Automatic Repeat Request
Hata	Okumura-Hata
HOA	Handover Algorithm
HOL	Head-of-Line
HSDPA	High-Speed Downlink Packet Access
HSPA+	High-Speed Packet Access+
HSUPA	High-Speed Uplink Packet Access
IEEE	Institute of Electrical and Electronics Engineers
IMT-Advanced	International Mobile Telecommunications Advanced
IP	Internet Protocol
IR	Incremental Redundancy
ISI	Inter-Symbol Interference
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union – Radiocommunication
JP	Joint Processing
JTACS	Japanese Total Access Communications System
LHHAARC	LTE Hard Handover Algorithm with Average RSRP Constraint

LTE	Long Term Evolution
LTE-A	Long Term Evolution - Advanced
MAC	Medium Access Control
Max-Rate	Maximum Rate
MCS	Modulation and Coding Scheme
MIMO	Multiple-Input Multiple-Output
MME	Mobility Management Entity
MRS	Mobile Relay Station
MS	Mobile Station
MSE	Mean Square Error
NACK	Negative Acknowledgement
NMT	Nordic Mobile Telephone
NRT	Non Real-Time
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access
P-GW	Packet Gateway
PAPR	Peak-to-Average Power Ratio
PDC	Personal Digital Communications
PDF	Probability Distribution Function
PDSCH	Physical Downlink Shared Channel
PDN	Packet Data Network
PF	Proportional Fair
PHS	Personal Handy-phone System
PHY	Physical
PLR	Packet Loss Ratio
PRB	Physical Resource Block
QAM	Quadrature Amplitude Modulation
QCI	QoS Class Identifier
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RACH	Random Access Channel
RAT	Radio Access Technology

RB	Resource Block
RE	Resource Element
RLC	Radio Link Control
RLF	Radio Link Failure
RNC	Radio Network Controller
RR	Round Robin
RRC	Radio Resource Control
RRM	Radio Resource Management
RSRP	Reference Signal Received Power
RSS	Received Signal Strength
RT	Real-Time
S-GW	Serving Gateway
SAW	Stop-and-Wait
SC-FDMA	Single Carrier-Frequency Division Multiple Access
SINR	Signal-to-Interference-plus-Noise-Ratio
SSDT	Site Selection Diversity Technique
SSHO	Semi-Soft Handover
TACS	Total Access Communications System
TAU	Tracking Area Update
TB	Transport Block
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TPS	Transmission Point Selection
TSN	Transmission Sequence Number
TTI	Transmission Time Interval
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UTRAN	Universal Terrestrial Radio Access Network
VoIP	Voice over IP
WCDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access

LIST OF SYMBOLS

α	Proposed parameter in LTE Integrator Handover Algorithm
β	Forgetting factor proposed in RSS Based TTT Window Handover Algorithm
γ	A decimal constant factor proposed in Capacity Integrated CoMP Handover Algorithm
σ	Shadow fading standard deviation
$\sigma_{\mu 0}$	Variance (mean power)
$\mu\_ap_i(t)$	Approximated uncorrelated filtered white Gaussian noise with zero mean of process *i* at time *t*
$\mu_i(t)$	Priority of user *i* at scheduling interval *t*
μ_n	Uncorrelated filtered white Gaussian noise with zero mean of of the *n*th sinusoid
$\rho_i(t)$	Shadow fading autocorrelation function,
$\gamma_{i,j}(t)$	Instantaneous SINR of user *i* on PRB *j* at time *t*
$\theta_{i,n}$	Doppler phase of process *i* of the *n*th sinusoid
$\zeta(t)$	Frequency flat Rayleigh fading at time *t*
$\xi_i(t)$	Shadow fading gain of user *i* at time *t*
$a(h_m)$	Mobile antenna correction factor
$c_{i,n}$	Doppler coefficient (which represents a real weighting factor) of process *i* of the *n*th sinusoid
$Capacity_C(t)$	Capacity indicator of cell *c* at time *t*
Capacity Threshold	Decimal constant factor proposed in Capacity Integrated CoMP Handover Algorithm
d_0	Shadow fading correlation distance
$dir_i(t)$	Direction of user *i* at time *t*
$\lvert dis_i(t)\rvert$	Magnitude of distance of user *i* from eNB at time *t*
D_{pc}	Web browsing reading time
$DIFs\_i(t)$	The RSRP difference of the user *i* at serving cell at time *t*

$DP_{l,i}(t)$	Delay of the *l*th packet of user *i* at time *t*
$Efficiency_{i,j}(t)$	Efficiency (in bits/RE) of PRB *j* of user *i* at time *t*
f	Frequency of the transmission
$f_{i,n}$	Discrete Doppler frequency of process *i* of the *n*th sinusoid
f_{max}	Maximum Doppler frequency
$FDIFs\_i(t)$	Filtered RSRP difference value of user *i* at serving cell *s* at time *t*
$G(t)$	Gaussian random variable of user *i* at time *t*
$gain_{i,j}(t)$	Channel gain of user *i* on PRB *j* at time *t*
h_b	Height of the eNB
h_m	Height of the user terminal
$HisRButilize_c(t)$	Historical RB utilize value of cell *c* at time *t*
Hys	Hysteresis parameter for handover event
HO_{t_i}	Number of handovers of user *i* at time *t*
ICI	Inter-cell interference
$I_i(t+1)$	Indicator function of the event that packets of user *i* are selected for transmission at scheduling interval *t+1*
J	Total number of PRBs
$loc_i(t)$	Location of user *i* at time *t*
Mn	Measurement result of the neighbouring cell
$mpath_{i,j}(t)$	Multi-path fading gain of user *i* on PRB *j* at time *t*
Ms	Measurement result of the serving cell
N	Total number of users
N_o	Thermal noise
N_d	Number of embedded objects in a web browsing packet call
N_i	Number of sinusoids of process *i*
$N_{service}$	Total number of users of a service
Np	Total number of periods
Ocn	Cell specific offset of the neighbour cell
Ocs	Cell specific offset of the serving cell
Ofn	Frequency specific offset of the neighbour cell frequency
Off	Offset parameter for handover event
Ofs	Frequency specific offset of the serving cell frequency

$pdiscard_{c\_i}(t)$	Total discarded packet size of cell *c* whichever earlier received by UE *i* at time *t*
$pdiscard\_service_i(t)$	Total size of discarded packets (in bits) of user *i* of a service at time *t*
$pl_i(t)$	Path loss of user *i* at time *t*
$prx_i(t)$	Total size of correctly received packets (in bits) of user *i* at time *t*
$psize_{c\_i}(t)$	Total packet size of cell *c* whichever earlier received by UE *i* at time *t*
$psize\_service_i(t)$	Total size of all packets that have arrived into the eNB buffer of user *i* of a service at time *t*
$ptransmit_{c\_i}(t)$	Number of transmitted bits of cell *c* received by UE *i* at time *t*
P_{total}	Total eNB transmit power
$PRBmax_c$	Total PRBs in cell *c*
$PRBuse_c(t)$	Total PRBs being used in cell *c* at time *t*
$r_i(t)$	Instantaneous data rate (across the whole bandwidth) of user *i* at scheduling interval *t*
$R_i(t)$	Average throughput of user *i* at scheduling interval *t*
RB_{max}	Maximum available number of PRBs
$RButilize_c(t)$	RB utilize value of cell *c* at time *t*
RE_{data}	Total number of REs specified for downlink data transmission
$RSRP_{avgS\_i}$	Average RSRP received by user *i* from serving cell *S*
$RSRP_{i,j}(t)$	RSRP of user *i* on PRB *j* at time *t*
$\overline{RSRP}_i(t)$	Average RSRP of user *i* among all PRBs at time *t*
$RSRP_{S\_i}(nTm)$	RSRP received by user *i* from serving cell *S* at *n*th *Tm*
$RSRP_S$	RSRP received from the serving cell
$RSRP_T$	RSRP received from the target cell
$RSRP_{T\_CCS}$	RSRP received from the target cell in the CCS
$RSRP_{T\_CTP}$	RSRP received from the target cell in the CTP
$\overline{RSS}$	Filtered RSS measurement
$\overline{RSS}(nTu)_S$	Filtered RSS of the serving cell at *n*th *Tu*
$\overline{RSS}(nTu)_T$	Filtered RSS of the target cell at *n*th *Tu*

service PLR	PLR of a type of service (either RT or NRT service)
S_E	Web browsing embedded object size
S_M	Web browsing main object size
T	Total simulation time
T_p	Web browsing parsing time
Tm	Handover measurement period
Tu	An integer multiple of Tm
THO	Total number of handovers
$TOA_{l,i}$	Time of arrival of the lth packet of user i in the eNB buffer
$v_i(t)$	Speed of user i at time t
$W_i(t)$	Delay of the HOL packet of user i at time t
X	Resolution in pixel
Y	Resolution in pixel