TARGET CELL COVERAGE AWARE HANDOVER ALGORITHM FOR ULTRADENSE HETEROGENEOUS NETWORKS

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To my family, for all your love and support.

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ABSTRACT

Network densification is considered as the leading approach to meet the expectations of high data rates, sub 1ms latency, negligible packet loss rates, flexible deployment and other key network and user performance attributes however, several obstacles such as interference management, mobility management, back haul implementations, etc. exists that prevent a full commercial rollout. One of these hurdles includes the significant increase in number of handovers for mobile users due the ultra-dense deployment strategy of eNBs. In this work, we attempt to tackle this problem by developing a novel Cell Coverage Aware (CCA) strategy which augments the conventional strongest cell approach by factoring Target cell coverage size. Network performance attributes such as throughput, end to end delay, jitter and packet loss ratio for video streaming, VOIP and web browsing applications were monitored since they directly impact user QoE. Simulations were performed using NS3 discrete event simulator. In order to validate to performance of our approach, we perform a comparative analysis of our algorithm and the traditional approach under various traffic types. Results show that a handover saving of 33.3% can be achieved with CCA for considered topology at the cost of a marginal reduction network performance.

ABSTRAK

Penguatkuasaan rangkaian dianggap sebagai pendekatan utama untuk memenuhi jangkaan kadar data yang tinggi, latensi sub 1ms, kadar kehilangan paket yang tidak dapat dielakkan, penggunaan fleksibel dan rangkaian kunci dan prestasi pengguna lain tetapi beberapa halangan seperti pengurusan gangguan, pengurusan mobiliti, jarak belakang pelaksanaan, dsb. wujud yang menghalang pelan komersil sepenuhnya. Salah satu halangan ini termasuk peningkatan jumlah bilangan penyumbang bagi pengguna mudah alih disebabkan oleh strategi penggunaan ultra-padat eNBs. Dalam usaha ini, kami cuba menangani masalah ini dengan membangun strategi baru Cope Cover Aware (CCA) yang menambah pendekatan sel terkuat konvensional dengan memfaktikkan saiz liputan sel Sasaran. Ciri-ciri prestasi rangkaian seperti penghantaran, kelewatan akhir, rugi dan nisbah paket untuk penstriman video, VOIP dan aplikasi penyemak imbas web dipantau kerana mereka memberi kesan langsung kepada pengguna QoE. Simulasi dilakukan menggunakan simulator peristiwa diskret NS3. Untuk mengesahkan prestasi pendekatan kami, kami melakukan analisis perbandingan algoritma kami dan pendekatan tradisional di bawah pelbagai jenis trafik. Keputusan menunjukkan bahawa penyerahan 33.3% boleh dicapai dengan CCA untuk dianggap topologi pada kos prestasi rangkaian pengurangan kecil.

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LIST OF ABBREVIATIONS

3GPP	-	3rd Generation Partnership Project
4G	-	4th Generation
ARQ	-	Automatic Repeat Request
BCCH	-	Broadcast Control Channel
CC	-	Component Carrier
CCA	-	Cell Coverage Aware
CCCH	-	Common Control Channel
CoMP	-	Coordinated Multi Point
COMP-JT	-	Coordinated Multi Point Joint Transmission
DCCH	-	Dedicated Control Channel
DFT	-	Discrete Fourier Transform
DTCH	-	Dedicated Traffic Channel
eNB	-	Evolved Node B
EPC	-	Evolved Packet Core
EPS	-	Evolved Packet System
E-UTRAN	-	Evolved Universal Terrestrial Radio
FDD	-	Frequency Division Duplex
FDM	-	Frequency Division Multiplexing
FFT	-	Fast Fourier Transform
GPRS	-	General Packet Radio Service
HARQ	-	Hybrid Automatic Repeat Request
HeNB	-	Home eNB
HetNet	-	Heterogeneous Networks
HSS	-	Home Subscriber Server
IDFT	-	Inverse Discrete Fourier Transform
IFFT	-	Inverse Fast Fourier Transform

IP	-	Internet Protocol
ISI	-	Inter-symbol Interference
ITU-R	-	International Telecommunications Union - Radio Communications Sector
LTE	-	Long Term Evolution
LTE-A	-	Long Term Evolution Advanced
MAC	-	Medium Access Control
MCCH	-	Multicast Control Channel
MIB	-	Master Information Block
MIMO	-	Multiple Input Multiple Output
MME	-	Mobility Management Entity
NAS	-	Non-Access Stratum
OFDM	-	Orthogonal Frequency Division Multiplexing
OFDMA	-	Orthogonal Frequency Division Multiple Access
OPEX	-	Operational Expenditure
PAPR	-	Peak-to-Average Power Ratio
PBCH	-	Physical Broadcast Channel
PCCH	-	Paging Control Channel
PCFICH	-	Physical Control Format Indicator Channel
PCRF	-	Policy Control and Charging Rules Function
PDCCH	-	Physical Downlink Control Channel
PDCP	-	Packet Data Convergence Protocol
PDSCH	-	Physical Downlink Shared Channel
PDU	-	Protocol Data Unit
PHICH	-	Physical Hybrid ARQ Indicator Channel
PHY	-	Physical Layer
PLR	-	Packet Loss Ratio
PRACH	-	Physical Random-Access Channel
PRB	-	Physical Resource Block
PUCCH	-	Physical Uplink Control Channel
PUSCH	-	Physical Uplink Shared Channel
P-GW	-	Packet Data Network Gateway

QoS	-	Quality of Service
RACH	-	Random Access Channel
RE	-	Resource Element
RLC	-	Radio Link Control
RLF	-	Radio Link Failure
RRC	-	Radio Resource Control
RSRP	-	Reference Signal Received Power
RSRQ	-	Reference Signal Received Quality
RSSI	-	Received Signal Strength Indicator
SC-FDMA	-	Single Carrier Frequency Division Multiple Access
S-GW	-	Serving Gateway
TCP	-	Transmission Control Protocol
TDD	-	Time Division Duplex
TTI	-	Transmission Time Interval
TTT	-	Time to Trigger
UDP	-	User Datagram Protocol
UDN	-	Ultra-Dense Networks
UE	-	User Equipment
UMTS	-	Universal Mobile Telecommunications System
UTRAN	-	Universal Terrestrial Radio Access Network

LIST OF SYMBOLS

C	-	Capacity
ϵ	-	Member of set
Hz	-	Hertz
I	-	Interference power
m	-	Spatial multiplexing
N	-	Noise power
$\boldsymbol{\Delta}$	-	Difference
$\mathbb{R}$	-	Real number
W	-	Bandwidth

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The projected burst of data traffic by a factor of 1000 coupled with a 10-fold increase in number of connected devices (up to 50 billion) from current levels and sub millisecond latency by the year 2020 has been extensively documented [1]. These network performance demands are needed to realize a diverse range of applications such as remote surgery, machine to machine communication, etc. and cannot be implemented with state of the art 4G technologies (3GPP LTE-A). In retrospect, the evolution of 4G technology from LTE (3GPP release 8) to LTE-A (3GPP release 10) was massively supported by cell size reduction [2]. Since LTE employed macro base stations in a homogeneous network topology, spectral efficiency and hence, network capacity quickly approached its theoretical limits. The introduction of low powered small cells such as femtocells, picocells, micro cells and relay stations allowed for a substantial extension of these performance boundaries [3]. The deployment of small cells overlaid with a high-power macro base station is known as a heterogeneous network topology. Table 1.1 below shows the types of cells available within a heterogeneous network [4]

Table 1.1: Base station types [4]

Cell Type	Output Power (W)	Cell radius (km)	Users	Locations
Femto cell	0.001 -0.25	0.001 - 0.1	1 - 30	Indoor
Pico cell	0.25 - 1	0.1 - 0.2	30 - 100	Both
Micro cell	1 - 10	0.2 - 2.0	100 - 2000	Both
Macro cell	8 to >50	8 - 30	>2000	outdoor

The improvement in network performance by the employment of small cells is leveraged by the Shannon capacity theorem. An increase in the number of base stations will lead to a proportionate increase in network capacity. Moreover, since base stations are now closer to UE, the effect of path loss is reduced hence, improving SNR, data rates and latency [5]. This means that increasing the number of cells (network densification) promises even greater performance. This is the principle behind the invention of Ultra Dense Networks (UDN).

Ultra-dense deployment of heterogeneous cells is expected to satisfy projected data traffic demands in future cellular networks together with other enabling technologies such as Multiple Input Multiple Output (MIMO) antennas and millimeter wave (mm wave) communications [6]. Ultra-Dense Networks (UDN) will support easy and unsupervised dense deployment of heterogeneous small cells varying in power, capacity and coverage as seen in figure 1 below [7].

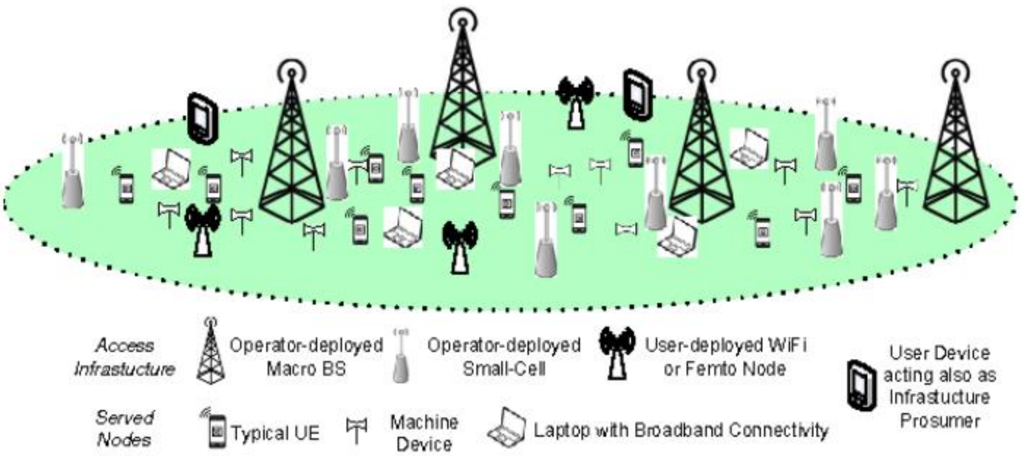

Figure 1.1 An Ultra-Dense network **[7]**

UDN is not only expected to improve network capacity, but also bolster network coverage. Small cells are used primarily in the data plane while macro cells may be used in both control and data planes and control plane only depending on the architecture. Key differences between UDN and traditional cellular networks are outlined in Table 1.2 below [8]:

Table 1.2: Comparison between UDN and traditional networks [8]

ITEM	**UDN**	**Traditional Cellular Network**
Deployment scenarios	Indoor, Outdoor Hotspot	Wide coverage
AP density	More than $1000/km^2$	$3\text{-}5/km^2$
AP coverage	Approximately 10m	Hundreds of meters and more
AP types	Pico, femto, UE relay, Relay	Macro/Micro BS
AP backhaul	Ideal/non-ideal, wired/wireless	Ideal wired
User density	High	Low/medium
User mobility	Low mobility	High mobility
Traffic density	High	Low/medium
Deployment	Heterogeneous/Irregular	Single layer, regular cell
System bandwidth	Hundreds of MHz	Tens of MHz
Spectrum	> 3GHz (up to mm Wave)	<3GHz

UDN does not come without its complications; these include-and are not limited to- network architecture, backhaul implementation, interference management and mobility management [8]. Of these myriad of challenges, mobility management poses a unique problem since cell reselection or handover (HO) frequency dramatically increases due to increased number of cells with relatively smaller coverage areas compared to macro cells in legacy networks. Studies have shown that throughput as well as other Quality of Service (QOS) parameters of UE deteriorates substantially during HO [9]. Moreover, control signaling overhead increases substantially thereby, increasing the risk of Handover Failure (HoF) [6]. This implies that the probability of HoF increases in UDN due to increased HO frequency. Moreover, it is likely-by virtue of Evolved Node B (eNB) density- that a UE can be in the coverage area of several eNBs at the same time with some or even all neighboring eNBs seemingly eligible candidates for handover based on traditional

HO discriminator engines which rely on a single parameter such as Received Signal Strength (RSS), Data rates, etc. This means that traditional HO decision techniques cannot be used in UDN; thus, an optimized approach which considers relevant network and QOS criteria for HO is mandatory for choosing the best candidate cell keeping in mind the cumulative effect of each decision on network performance and Perceived Quality of Service (PQoS).

1.2 Research objective

The aim of the research is to develop a robust handover decision making algorithm that minimizes handover failure rate in UDN HetNET while maintaining user quality of experience (QoE). In order to achieve this aim, the following objectives are outlined:

1. To integrate cell coverage data into legacy handover decision algorithms in order to minimize handover rate in UDN HetNET
2. To test and validate approach via simulation
3. To perform a comparative performance analysis between proposed algorithm and conventional algorithm in order to contextualize obtained results.

1.3 Scope of work

This work focuses on the mobility management problem in UDN HetNets with the purpose of developing, testing and analyzing the performance of an optimized handover algorithm. In this regard, the following assumptions are made

1. No interference mitigation/management scheme (e.g. eICIC or COMP) implemented for brevity. Although this may have some effect in the obtained results, we can safely model this effect as a linear function of the output such that a linear correlation exists between results of current work and future implementations in which interference management is considered.

2. All backhaul P2P connections in EPC use fiber links as opposed to mm Wave technology projected to be the primary backhaul traffic carrier in UDN.
3. For brevity, we only study the network behavior and performance in downlink data plane. Uplink performance will contribute to our future studies.

1.4 Thesis structure

Chapter 2 will introduce the necessary technological background in order to understand the study of this thesis. Subsequently, chapter 3 will discuss previous related work done and review literature accordingly. The proposed solution, implementation and testing methodology will be given in chapter 4. The results and findings will be presented in chapter 5 along with performance analysis. Final review of the thesis and proposals for future work will be outlined in chapter 6.

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