Performance Testing of CoMP Handover Algorithms in LTE-Advanced

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***Abstract*—Coordinated Multiple (CoMP) Transmission and Reception technology is expected to enhance the Long Term Evolution – Advanced (LTE-A) system throughput and reduce the packet loss ratio (PLR) compared to the LTE system. However, this could lead to system capacity overload and saturated system throughput issues within a highly congested network. To address this situation, this paper describes three proposed CoMP handover algorithms for the LTE-A system. These algorithms take one or more decision criteria into consideration to increase system capacity. System performance of each proposed CoMP handover algorithm is evaluated and compared with open literature via computer simulation. Simulation results are provided with a handover parameters optimization and a discussion of the performance testing.**

Keywords-3GPP LTE-Advanced; Handover Algorithm; CoMP Transmission/Reception; Joint Processing;

I. INTRODUCTION

One of the major attractions of mobile communication is service continuity for mobile users. Handover (HO) plays a fundamental role while balancing traffic load and supporting service continuity. HO can be categorized as hard HO and soft HO. Hard HO is commonly used when dealing with handovers in the legacy wireless systems as well as in the Long Term Evolution-Advanced (LTE-A) system [1]. The hard HO is a category of HO procedures where all the old radio links in the user equipment (UE) are abandoned before the new radio links are established. Coordinated multipoint (CoMP) transmission and reception technology is a key technique in LTE-A to improve the cell-edge data rate and average data rate, and is suitable to increase the spectral efficiency (and hence the capacity).

Two types of CoMP schemes were evaluated for LTE-A system: Joint Processing (JP) and Coordinated Scheduling / Beamforming (CS/CB). JP provides multiple data transmissions for each UE among multiple cooperated eNodeBs while CS/CB supports single data transmission for each UE at serving eNodeB with user scheduling/beamforming decisions made with coordination among cooperated eNodeBs [2]. Fig. 1 shows an example of CoMP with CS/CB and JP transmission in a distributed network architecture.

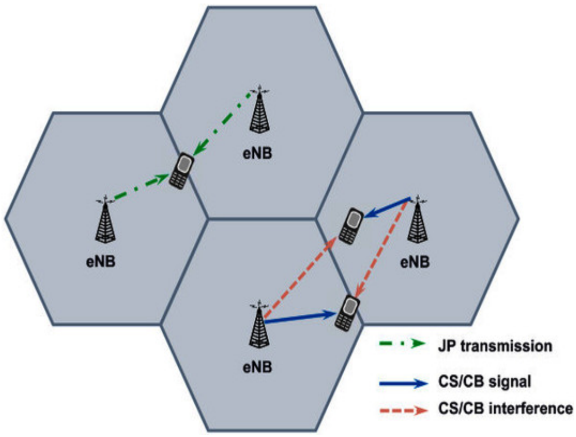

Fig. 1: Example of CoMP in a distributed network architecture System [3]

A HO algorithm is needed for making a HO decision. Due to the characteristic of multiple data transmissions JP provides, a new HO algorithm supporting JP in LTE-A system is essential. Handover Mechanism in CoMP [4] is able to improve the system throughput performance by allowing multiple transmissions for each UE at any time. However this mechanism could lead to a system capacity overload and high system delay due to multiple resources each UE required among multiple eNodeBs. Hence a new HO algorithm supports CoMP and takes system capacity into consideration in LTE-A system is necessary.

In this paper, three proposed CoMP HO algorithms are introduced. The parameters of each CoMP HO algorithm are optimized followed by a simulation of performance testing of three poposed CoMP HO algorithms and open literature with mixed real-time (RT) and non real-time (NRT) traffic.

The rest of this paper is organized as follows: three proposed CoMP HO algorithms in LTE-A system are discussed in Section II followed by discussions on the simulation environment, traffic model, performance metrics, and optimization in Section III. Section IV contains optimized performance testing with mixed RT and NRT traffic followed by the conclusion in Section V.

II. CoMP Handover Algorithms in LTE-Advanced

Three proposed CoMP HO algorithms in the LTE-A system are discussed in this section.

I. Limited CoMP Handover Algorithm [5]

Limited CoMP Handover Algorithm involves four concepts: serving cell, measurement set, CoMP coordinating set (CCS), and CoMP transmission points (CTP). A serving cell is the cell which takes the responsibility of making HO decision and maintains the connection of each UE to the network. An UE can only attach to one serving cell at each time instant. A measurement set is a set of cells whose reference signal received power (RSRP) can be received and reported by the UE to the serving cell. A CCS is a set of cells which are selected by the serving cell from the measurement set. Furthermore, A CTP is a set of cells chosen from the CCS by the serving cell for sending downlink data directly to an UE.

Three HO parameters are involved in the Limited CoMP Handover Algorithm: measurement period, HO margin (HOM), and time to trigger (TTT) timer. A measurement period acts a time period that is used for checking the handover condition periodically. A HOM is a parameter that represents the threshold for the difference in RSRP between the serving and the target cell. A TTT value is the time interval that is required for satisfying the HOM condition.

The Limited CoMP Handover Algorithm starts when the UE joins the network by camping on the cell whose RSRP is the highest or the cell which was instructed by previous serving cell. Then UE starts to feedback the serving cell with the measurement set which is the RSRP measurements received from all cells in the network. Serving cell selects a set of cells with highest RSRP in the measurement set as a CCS. The CTP selection will be recursively executed by serving cell until reaching the end of CCS based on the follows:

$$RSRP_{T\_CCS} < RSRP_S - HOM \qquad (1)$$

where $RSRP_{T\_CCS}$ and $RSRP_S$ are the RSRP received by an UE from the target cell in the CCS and the serving cell, respectively.

The target cell in the CCS will be ignored if Equation (1) is satisfied, otherwise the target cell in the CCS will be added into CTP. After CTP selection is finalized, serving cell performs HO condition check in CTP based on the Equation (2) expressed as follows:

$$RSRP_{T\_CTP} > RSRP_S + HOM \qquad (2)$$

where $RSRP_{T\_CTP}$ and $RSRP_S$ are the RSRP received by an UE from the target cell in the CTP and the serving cell, respectively. A flowchart of the Limited CoMP Handover Algorithm is given in [5].

II. Capacity Based CoMP Handover Algorithm [6]

A resource block (RB) utilization value is used in the Capacity Based CoMP Handover Algorithm and it evaluates the proportion of total used RBs to total RBs in each cell and describes the current state of the cell's capacity. It can be expressed as:

$$RButilization_c = RBused_c(t) / RB\max_c(t) \qquad (3)$$

where $RBused_c(t)$ denotes the total resource block been used of cell c at time t and $RBmax_c(t)$ denotes the total resource of cell c at time t. A higher RB utilization value indicates the cell becomes a saturated state, therefore a cell reselection needs to be considered when more UEs are going to be handed over to this cell. On the other hand, when the cell is having a lower RB utilization value, this cell is capable for accommodating more incoming UEs.

In the Capacity Based CoMP Handover Algorithm, the serving cell selects a set of cells with the lowest RB utilization value from the measurement set as CCS. The serving cell performs the CTP selection based on selecting a set of cells with the highest RSRP from CCS. A HO will be triggered when the Equation (2) is satisfied during the entire TTT duration, otherwise CTP starts transmitting data to the UE and waits for the next measurement period expires.

III. Capacity Integrated CoMP Handover Algorithm [7]

A historical RB utilization value is introduced in Capacity Integrated CoMP Handover Algorithm and it can be mathematically expressed as:

$$HisRButilize_c(t) = \frac{\sum_{t=1}^{t} RButilize_c(t)}{t} \qquad (4)$$

where t is the current time instant, $RButilize_c(t)$ denotes the RB utilize value of cell c at time t obtained from Equation (3). $HisRButilize_c(t)$ is the historical RB utilize value of cell c from time 1 until time t.

A new HO parameter is introduced known as the capacity indicator in the Capacity Integrated CoMP Handover Algorithm. Capacity indicator represents the proportional combination of historical RB utilize value and RB utilize value in current time instant and it can be further expressed as:

$$Capacity_C(t) = (1-\gamma) * HisRButilize_C(t-1) + \gamma * RButilize_C(t) \qquad (5)$$

where $HisRButilize_c(t-1)$ and $RButilize_c(t)$ is the historical RB utilize value and RB utilize value of cell c at current and previous time instants, respectively. γ is a constant factor between 0 and 1. The closer the γ equals to 1, the capacity indicator will be based on more portion of the RB utilize value at the current time instant. On the other hand, the closer the γ reaches 0, the capacity indicator will be based on more portion of the historical RB utilize value at the previous time instant. A capacity indicator represents the current state of the cell's capacity and takes the cell's historical measurement into concern. A cell's capacity condition is expressed as following:

$$Capacity_c(t) \leq Capacity\ Threshold \quad (6)$$

where $Capacity_C(t)$ is the capacity indicator of cell c at time t. Capacity Threshold is a decimal constant factor between 0 and 1. A capacity threshold value is used for determining appropriate target cells whose current and historical capacities are able to accommodate the incoming UE.

In the Capacity Integrated CoMP Handover Algorithm, the target cells within the measurement set which satisfy the Equation (6) will be recursively selected as CCS by the serving cell. Moreover, the CTP selection will be recursive based on selecting a cell with the highest RSRP from CCS. A HO will be triggered when the triggering condition (2) is satisfied fulfilled the entire TTT duration; otherwise the CTP transmits data to the UE and waits for the next measurement period expires. A flowchart of the Capacity Integrated CoMP Handover Algorithm is given in [7].

III. Simulation Environments and Performance Metrics

The performance of three proposed CoMP handover algorithms and the open literature is evaluated using a computer simulation. The system parameters used in the simulation are listed in Table I.

TABLE I. 3GPP LTE-A System Parameters

Parameters	Values
Cellular layout	Hexagonal grid, wrap around (reflect), 7 cells
Radius	100 m
Carrier Frequency	2 GHz
Bandwidth	5 MHz
Number of RBs	25
Number of sub-carriers / RB	12
Sub-carrier Spacing	15 kHz
Slot Duration	0.5 ms
Number of OFDM Symbols / Slot	7
Path Loss	Cost 231 Hata model [8]
Shadow fading	Gaussian distribution [9]
Multi-path	Rayleigh fading [10]
Modulation and Coding Scheme	QPSK, 16QAM, and 64QAM
HARQ / Retransmission	Enable / 3 times [11]
Packet Schedule Algorithm	Proportional Fair
Handover Algorithm (HOA)	5: CoMP Handover Algorithm [4] 6: Limited CoMP Handover Algorithm 7: Capacity Based CoMP Handover Algorithm 8: Capacity Integrated CoMP Handover Algorithm
Data Traffic	NRT Traffic: Web browsing D_{pc}= 30 ms [12] RT Traffic: 1 Mbps Constant Stream
NRT / RT traffic	75 users
User's position	Uniform distributed
User's direction	Randomly choose from [0,2π], constantly at all time
User's velocity	3, 30, 120 km/hr
Simulation time	10000 ms
Scheduling Time (TTI)	1 ms
Measurement interval	10 ms
Size of CCS and CTP	3 and 2
γ / Capacity Threshold	0.75 / 0.9

The parameters for each CoMP handover algorithm are optimized using the approach in [13]. The optimized parameters of all CoMP handover algorithms under three speed scenarios are summarized in Table II.

TABLE II. Optimized Parameters of CoMP Handover Algorithms

km/hr	HOA 5	HOA 6	HOA 7	HOA 8
3	[HOM, TTT] = [4, 5]	[HOM,TTT] = [4, 4]	[HOM, TTT] = [5, 3]	[HOM, TTT] = [4, 3]
30	[HOM, TTT] = [4, 5]	[HOM,TTT] = [5, 4]	[HOM, TTT] = [4, 1]	[HOM, TTT] = [5, 1]
120	[HOM, TTT] = [5, 4]	[HOM,TTT] = [5, 3]	[HOM, TTT] = [5, 5]	[HOM, TTT] = [5, 0]

The performance testing of four CoMP handover algorithms are on the basis of system throughput.

System throughput is defined as the total number of bits correctly received by all users and can be mathematically expressed as:

$$\text{system throughput} = \frac{1}{T}\sum_{t=1}^{T}\sum_{i=1}^{I} \text{ptransmit}_{c\_i}(t) \quad c \forall CTP_i \quad (7)$$

where I is the total number of UEs, T represents the total simulation time, and $ptransmit_{c\_i}(t)$ denotes the number of transmitted bits of cell c whichever earlier received by UE i at time t. Cell c belongs to CTP of UE i.

IV. SIMULATION RESULTS

Fig. 2 shows the system throughput of four CoMP handover algorithms with mixed RT and NRT traffic under three different user's speeds in LTE-A simulation. HOA6 offers the highest system throughputs of 106.374 Mbps and 91.4014 Mbps at 3 and 30 km/hr scenarios, respectively. HOA6 offers the second highest system throughput of 63.641 Mbps at 120 km/hr scenario. HOA6 performs a lower system throughput at 120 km/hr scenario is because the mechanism in HOA6 constantly checks the RSRP of the target cells in CCS which increases the feedback messages and signaling overhead from UEs at any time instant, therefore the system throughput is affected and decreased in 120 km/hr scenario.

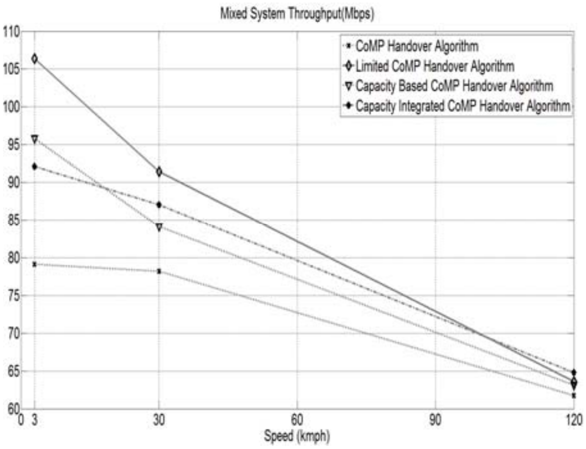

Fig. 2: System Throughput of Four CoMP Handover Algorithms for Mixed RT and NRT Traffic in LTE-A

HOA7 and HOA8 offer the second highest and the third highest system throughputs of 95.8426 Mbps and 92.1148 Mbps at 3 km/hr scenario. HOA8 outperforms HOA7 in the scenarios of 30 km/hr and 120 km/hr due to the assistance of the Capacity Threshold factor which restricts the cells in the measurement set become the target cells in the CCS of each UE. Therefore the available radio resources in the target cells in the CCS can be further utilized by other UEs, thus the system throughput is enhanced.

HOA5 has the lowest system throughput of 79.1266 Mbps, 78.2245 Mbps, and 61.7326 Mbps at 3 km/hr, 30 km/hr, and 120 km/hr scenarios, respectively. HOA5 fully uses the multiple transmission points of each user in the system which makes each eNB saturated in the system and results the lowest system throughput in every speed scenario.

V. CONCLUSIONS

Three proposed CoMP handover algorithms for LTE-A system are introduced in this paper. Performance testing of each CoMP handover algorithm is evaluated and compared to the open literature via simulation. It is shown via simulation that the Capacity Integrated CoMP Handover Algorithm provides the highest system throughput with Mixed RT and NRT traffic at 120 km/hr. The performance testing of four CoMP handover algorithms with individual RT and/or NRT traffic will be the focus of the future studies.

REFERENCES

[1] K. Ronny Yongho, J. Inuk, Y. Xiangying, and C. Chao-Chin, "Advanced handover schemes in IMT-advanced systems [WiMAX/LTE Update]," *Communications Magazine, IEEE,* vol. 48, pp. 78-85, 2010.

[2] 3GPP, TR36.912, version 10.0.0, "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Feasibility study for Further Advancements for E-UTRA (LTE-Advanced) (Release 10)," 2011-03.

[3] T.-T. Tran, Y. Shin, and O.-S. Shin, "Overview of enabling technologies for 3GPP LTE-advanced," *EURASIP Journal on Wireless Communications and Networking,* vol. 2012, 12-01 2012.

[4] C.-C. Lin, K. Sandrasegaran, and S. Reeves, "Handover algorithm with joint processing in LTE-advanced," in *Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2012 9th International Conference on*, 2012, pp. 1-4.

[5] C.-C. Lin, K. Sandrasegaran, X. Zhu, and Z. Xu, "Limited Comp Handover Algorithm For LTE-Advanced," *Journal of Engineering,* vol. 2013, p. 9, 2013.

[6] C.-C. Lin, K. Sandrasegaran, X. Zhu, and Z. Xu, "Performance evaluation of capacity based CoMP handover algorithm for LTE-Advanced," in *Wireless Personal Multimedia Communications (WPMC), 2012 15th International Symposium on*, 2012, pp. 236-240.

[7] C.-C. Lin, K. Sandrasegaran, X. Zhu, and Z. Xu, "On the performance of capacity integrated CoMP handover algorithm in LTE-Advanced," in *Communications (APCC), 2012 18th Asia-Pacific Conference on*, 2012, pp. 871-876.

[8] H. H. A. Toskala, *WCDMA FOR UMTS Radio Access for Third Generation Mobile Communications*, 3rd ed. Nokia, Finland: John Wiley & Sons Ltd, 2004.

[9] M. OHASHI and K. SHIRAKI, "Correlation Model for Shadow Fading in Mobile Radio Systems," presented at the Electronics Letters, 1991.

[10] C. Komninakis, "A fast and accurate Rayleigh fading simulator," in *Global Telecommunications Conference, 2003. GLOBECOM '03. IEEE*, 2003, pp. 3306-3310 vol.6.

[11] J. C. Ikuno, M. Wrulich, and M. Rupp, "PERFORMANCE AND MODELING OF LTE H-ARQ," presented at the International ITG Workshop on Smart Antennas (WSA) Fraunhofer Heinrich-Hertz-Institut, Berlin, Germany, 2009.

[12] 3GPP TR25.892, version 6.0.0, "Feasibility Study for Orthogonal Frequency Division Multiplexing (OFDM) for UTRAN Enhancement (Release 6)," June 2004.

[13] C.-C. Lin, K. Sandrasegaran, H. A. M. Ramli, and R. Basukala, "Optimized Performance Evaluation of LTE Hard Handover Algorithm with Average RSRP Constraint," *International Journal of Wireless & Mobile Networks (IJWMN),* April 2011.