

Handover Mechanism in Coordinated Multi-Point Transmission/Reception System

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Abstract:

Coordinated Multi-Point (CoMP) transmission/reception technology has been the focus of much attention recently and has become a key research interest in 3GPP LTE-Advanced due to its ability to improve both cell-edge and average system performance. However, CoMP technology requires brand-new handover mechanism, or else its real performance will be limited. This paper proposes a novel handover mechanism supporting CoMP based on the handover scenario in CoMP communication system architecture, including information sharing and signaling transmission procedure of CoMP cooperating sets handover and CoMP transmission points selection/update. The proposed scheme could not only support CoMP well, but also reduce the overhead of information exchange and signaling transmission.

1 Coordinated Multi-Point (CoMP) Communication Technology

With the development of mobile communication technology, mobile communication systems have improved greatly. However, user demands on multimedia services have also increased in response to higher rate and better quality. Research on next generation mobile communication technology is therefore focused on improving to spectrum efficiency, transmission rate, system throughput and cell edge performance. In recent years, CoMP technology has become an important research project^[1] of 3GPP LTE-Advanced standardization

work because of cell edge user performance promotion and system throughput improvement.

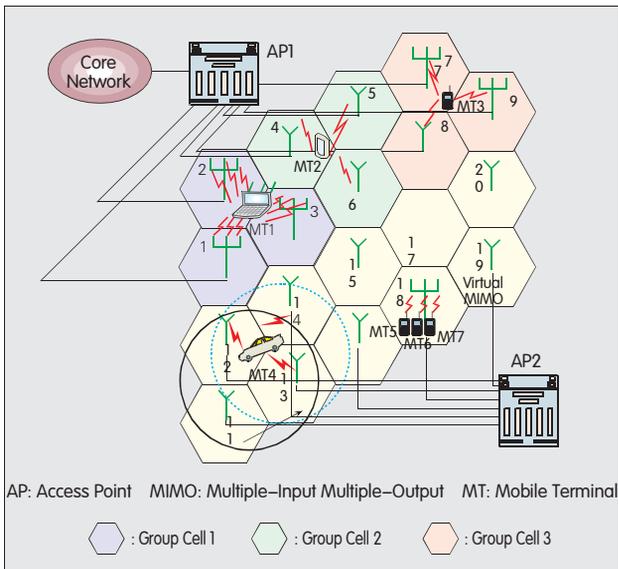
CoMP technology determines that the transmission points distributed independently at different geographical positions serve multiple users by employing different coordinated methods (such as joint transmission, Joint Processing (JP) and coordinated scheduling). The multiple transmission points can be: eNodeBs with a resource management module, baseband processing module and Radio Frequency (RF) unit, multiple RF units and antennas (like distributed antenna) with different geographical positions, or relay nodes.

1.1 Development of CoMP Communication Technology

CoMP communication technology originated from two important theories: Relay channel capacity analysis and multi-antenna diversity theory. The relay channel model^[2] is the most fundamental

model of CoMP communication technology, and the relay channel capacity analysis can be made for the capacity of the communication network composed of more than three nodes from the aspect of Information Theory. According to different conditions, the relay channel can be changed into a broadcasting channel or multiple access channel. Multi-antenna diversity theory^[3-4] is also referred to as Multiple-Input Multiple-Output (MIMO) technology. With such technology, the sending/receiving end is equipped with multiple antennas or antenna arrays, and the channel capacity between the sending end and receiving end is enhanced. This is achieved by utilizing the diversity gain of multiple space sub-channels formed by multiple antennas, which is a basic motivation for the emerging of CoMP communication technology. Research and development of multi-antenna diversity theory makes it possible to apply CoMP communication technology in actual communication

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◀ Figure 1.
Group Cell architecture.

systems.

Macro diversity technology for soft handover in CDMA mobile communication systems can be considered as the earliest application of CoMP communication technology in actual communication system. What is different from hard handover is that in soft handover, the user communicates with both the source eNodeB and the target eNodeB during its handover from one eNodeB to another. This improves handover success rate.

The research on distributed antenna system^[5] has also laid a foundation for CoMP. The generalized distributed antenna system^[6] marks the first introduction of CoMP into the distributed antenna system. Moreover, the advent of Group Cell theory^[7-10] (shown in Figure 1) introduces the concept of inter-cell coordinated communications, which is rudimentary to modern CoMP communication technology and marks the birth of CoMP communication technology for the whole cellular mobile communication system.

Orthogonal Frequency Division Multiplexing (OFDM) and MIMO have been thought of as key technologies for the next generation mobile communication system, and the study of OFDM-MIMO based coordinated communication systems has aroused widespread attention. New concepts like virtual MIMO, network MIMO and coordinated MIMO have been emerging

continuously and all belong to modern CoMP technology.

In 3GPP standardization research, the modern CoMP communication technology is seen as a multi-user CoMP transmission technology and has become one of the important research areas in LTE-Advanced systems.

1.2 CoMP Key Technologies

CoMP technologies are mainly divided into two classes: Joint Processing (JP) and Coordinated Scheduling/Coordinated Beamforming (CS/CB). JP improves user performance at the cell edge by Spatial Diversity (SD) gained from antennas from eNodeB side to the user side, and can be further divided into joint transmission and dynamic cell selection. Joint transmission implies that multiple cells use the same time-frequency resources to send Physical Downlink Shared Channel (PDSCH) bearing user data information to the user. Dynamic cell selection implies that, at the same time, User Equipment (UE) dynamically selects a cell and sends PDSCH to this cell. The CS/CB reduces Inter-Cell Interference (ICI) by utilizing the information exchange among cells and by the scheduling of resources (such as time, frequency and space). This includes beamforming vector scheduling, enhances cell edge performance and improves system throughput.

CoMP technology requires the

support of PHY layer transmission technologies such as MIMO, precoding, network coding, efficient channel estimation and joint detection. Meanwhile, the advanced and effective wireless resource management solutions are also an important factor affecting CoMP. Such resource management issues include cell resource allocation strategy, load balancing, selection mechanism of coordinated cells in joint transmission and effective handover strategies. Handover performance is the important factor in measuring mobile communication system performance and the handover strategy is key to realizing a ubiquitous network for users. With the introduction of CoMP, the handover scenario in the system changes so that the existing handover strategy cannot meet the handover requirements of new scenario. So designing workable handover strategy becomes an important issue in CoMP technology.

2 Analysis of Handover Scenario in CoMP Communications

In existing cellular mobile communication system handover scenarios, it is generally the user who triggers a handover process. At the time of communicating with the connected eNodeB, the user periodically measures the Reference Signal Receiving Power (RSRP) of the connected eNodeB and the eNodeB in the neighboring cell. When the RSRP of the connected eNodeB falls below a certain threshold while, at the same time, the RSRP of an eNodeB in the neighboring cell climbs above and maintains the threshold for a certain time, the handover is triggered. The handover involves a complicated information exchange and signaling transmission between the user, source eNodeB and target eNodeB. By cancelling the Radio Network Control (RNC) node, the 3GPP Long Term Evolution (LTE) system adopts hard handover technology instead of soft handover. For hard handover, the user must terminate the connection with the source eNodeB first and then establish a new connection with the target eNodeB.

After the introduction of CoMP, the

handover scenario changes. First, where the possible handover region is located at the cell edge, the communication quality is always bad. However, after the introduction of CoMP, the user may adopt CoMP mode, and a new handover strategy will be employed to support handover under both CoMP mode and traditional modes. Then, supposing that the handover occurs in the CoMP mode, the handover will be from one cell set to another instead of from one cell to another cell. For example, for joint transmission in CoMP JP, a new handover mechanism is required to coordinate the information exchange and signaling transmission among cells.

In the standardization of current LTE-Advanced mobile communication systems, backward compatibility is an all-important criteria. It requires the new handover mechanism to support handover under both CoMP mode and traditional mode, and should be based on the current handover mechanism. Therefore, the remainder of this article will focus on the modified part of the handover mechanism based on the existing LTE system handover mechanism. This article will also place particular emphasis on the improvement of the handover mechanism. Information exchange and signaling transmission between multi-cells or between multi-cell and user, based on that of the existing handover mechanism, provides the increased information exchange needed by CoMP and puts forward the corresponding information exchange and signaling transmission process.

3 Handover Mechanism Supporting CoMP

3.1 System Model

Based on the latest CoMP system model of 3GPP LTE-Advanced standardization, this article will analyze the information exchange and signaling transmission process during the handover in downlink CoMP JP scenario in a Frequency Division Duplex (FDD) system, because the modification of the information exchange and signaling transmission process in current handover mechanism under CoMP JP scenario is most

remarkable.

(1) Serving Cell

The serving cell is the cell sending PDCCH to UE. During the process of communication, the UE has one serving cell only.

(2) Measurement Set

This is a cell set for UE to perform periodical Channel State Information (CSI) measurement. It is quasi-statically configured by the eNodeB of the UE serving cell.

(3) CCS

The CoMP Cooperating Set (CCS) is the cell set that directly or indirectly sends PDSCH to UE.

(4) CTP

The CoMP Transmission Points (CTP) is a cell set that directly sends PDSCH to UE.

Here we adopt the commonly-used CoMP system model, where the CCS is selected from the measurement cell sets and CTP is selected from CCS, as shown in Figure 2.

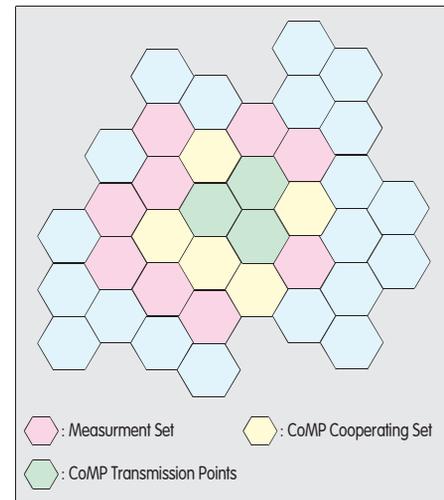
3.2 Feedback and Resource

Management Strategy Hypothesis

This paper supposes that CoMP UE feeds only report back to the serving cell. At the time of JP, the resource allocation, and scheduling and transmission parameters can be independently determined by the eNodeB of the serving cell, or be jointly determined by coordinated cells through negotiation. Because the UE only receives the PDCCH of the serving cell, the information above is summarized in the serving cell. Therefore, in order to lower the information exchange overhead and shorten the delay generated on the X2 interface, we suppose that the resource allocation, and scheduling and transmission parameters are determined by the eNodeB of the serving cell, and that the necessary information is transmitted to coordinated cells via the X2 interface.

3.3 Process of Handover Supporting CoMP

As previously mentioned, we generally introduce the handover process supporting CoMP transmission except the complete and complex information exchange and signaling transmission in



▲ Figure 2. CoMP system model.

the existing handover process.

3.3.1 Triggering the Handover Process

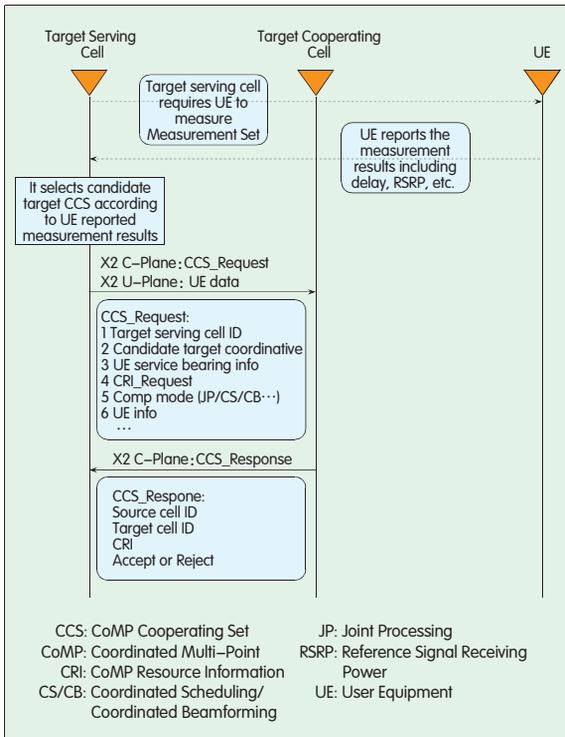
LTE-Advanced system standardization specifies that the PDCCH is sent to UE only by the serving cell, and that each UE, at the same time, belongs to only one serving cell. The PDCCH is used to send control signaling to UE, so its communication quality must be ensured. The handover process is triggered when the RSRP of the serving cell falls below a certain threshold while the RSRP of eNodeB in the neighboring cell surpasses the threshold value. Regardless of whether the UE is in the CoMP mode or not, the trigger of its handover process keeps same as that of the existing process.

3.3.2 The Handover Process in CoMP Mode

According to the definition of CoMP JP, when the UE is in CoMP mode, it corresponds to a CCS, and all cells in the CCS hold UE data information. At each time, the UE dynamically selects CTP. So in CoMP mode, besides handover between serving cells, CCS and CTP also require the handover mechanism to establish and update processes.

(1) Handover Process of CCS

The serving cell connected to UE after handover is called the target serving cell; the CCS and coordinated cells therein prior to handover are called source CCS and source coordinated cells; and the CCS and coordinated cells



▲ Figure 3. CCS handover process.

therein after handover are called target CCS and target coordinated cells. Based on these definitions, Figure 3 shows the CCS handover process.

Step 1: The eNodeB of the target serving cell sends a measurement order to UE through PDSCH, and requires UE to measure the cell channel quality in the measurement cell set (including RSRP, propaganda delay, etc). To ensure CCS establishment speed and CCS handover success, the UE does not measure detailed channel information, such as the channel matrix H, Channel State Information (CSI) and Channel Quality Information (CQI). The requirement of UE's measuring propaganda delay is aimed to ensure smaller delay from cell to UE in CCS and good for signal synchronization at the UE end during joint transmission.

Step 2: The UE measures the cells in the measurement cell set according to the measurement order in Step 1, and reports the corresponding measurement results to the target serving cell.

Step 3: The eNodeB of the target serving cell selects a candidate target CCS of UE according to the measurement results. The candidate

target coordinated cell needs to meet the following two conditions:

- RSRP meets the requirement that N cells with the maximum RSRP are selected according to the rule that RSRP is higher than a certain threshold or the MAX- N method. wherein, the exact threshold value and the number of N are quasi-statically configured according to the UE service demand and system load situation.

- The differences of propaganda delays from each target coordinated cell (including the serving cell) to UE are small. The candidate target coordinated cell can also be selected according to the threshold value set above or according to the MIN- N method.

Step 4: If the candidate target cell belongs to the same eNodeB as the target serving cell, Step 5 will be omitted; otherwise, the CCS of Interface X2, the communication interface between eNodeBs, will start the following process:

(a) The eNodeB of the target serving cell sends UE data information to the eNodeB of the candidate coordinated cell via the user plane of Interface X2.

(b) The eNodeB of the target serving cell sends a CCS establishment request to the eNodeB of the candidate coordinated cell via the control plane of Interface X2. The request includes the following messages:

- Target serving cell mark.
- Target candidate coordinated cell mark.

- Information related to UE service bearer and EUTRAN Radio Access Bearer (E-RAB). The same E-RAB information is sent from the source serving cell to the target serving cell when handing over with the serving cell.

- CRI_Request. The target serving cell requests the candidate target coordinated cell to report the state of resource usage inside the cell, defined as CRI. This information helps improve CoMP user resource allocation according

to the resource use state of each coordinated cell. The request includes a CRI report period. The coordinated cell reports CRI periodically when the CCS is not updated.

- CoMP_Mode, used for marking the requested CoMP modes including JP/CS/CB, etc.

- UE information. The CoMP is based on users, so the UE information should be shared.

Step 5: The eNodeB of the candidate target coordinated cell that receives the CCS establishment request sends a response to the eNodeB of the target serving cell via the control plane of Interface X2. The information includes:

- Message transfer source cell mark.
- Message transfer target cell mark.
- CRI. The candidate target

coordinated cell reports the cell's resource use condition periodically to the target serving cell according to the CRI report period in the CCS establishment request. If the target serving cell doesn't receive the CRI update, it will continue to use the current CRI.

- Acceptance/refusal. The target serving cell can decide whether to accept or refuse the CCS establishment request according to the cell condition; that is, whether to join CoMP.

Step 6: The candidate target coordinated cell not receiving Reject information joins the target CCS, and CCS handover finishes.

(2) CTP Establishment/Update Process

After the CCS handover process finishes, the CTP establishment/update process is initiated.

(a) CTP Establishment

Step 1: The target serving cell requires the UE to measure CSI of all the coordinated cells in CCS via PDSCH.

Step 2: The UE feeds back the CSI of all the coordinated cells in CCS to the target serving cell. In order to lower the feedback overhead, the UE only feeds back long-term CSI.

Step 3: The target serving cell selects a candidate CTP of UE according to the measurement fed back by UE and CRI fed back by each cell when CCS handover takes place, and the cells inside the candidate CTP meet both the channel quality requirement and cell load

requirement.

Step 4: The target serving cell requires UE to measure CSI of the cells inside CTP.

Step 5: The UE feeds back the measured short-term CSI and CSI corresponded band to the target serving cell.

Step 6: The target serving cell performs resource scheduling for UE according to the measurement results, and determines the transmission parameters for joint transmission.

Step 7: The target serving cell sends the CTP establishment/update information to each cell in CTP via the control plane of Interface X2. The information includes:

- Target serving cell mark.
- Transmission point mark.
- Resource allocation information,

that is, the related information allocated to CoMP UE downlink physical resource, including the position and number of Physical Resource Block (PRB).

- Physical-layer transmission parameters, including Precoding Matrix Indicator/Rank Indication (PMI/RI), modulation coding scheme, transmission mode (single user MIMO, multi-user MIMO, open/closed loop, diversity/multiplexing, etc.), antenna port, and synchronization information. The transmission parameters correspond to the resource allocation information.

- UE information. The CoMP is based on user, so the UE related information should be shared.

Step 8: The cell inside the candidate CTP respond the CTP establishment/update information to the target serving cell, including response cell mark and acceptance/refusal message, and the cell can select or refuse to join CoMP according to its condition.

Step 9: The target serving cell informs UE the actual CTP, scheduling message and transmission parameters through PDSCH, and starts CoMP data transmission.

(b) Cancellation of CTP

When requiring an update, CTP should be cancelled. The cancellation process is initiated by the target serving cell which sends the CTP cancellation message to the cells inside the original CTP. The message includes joint

transmission pause indication and resource release order.

At this point, the CTP establishment/update process ends.

4 Conclusions

The CoMP handover strategy introduces "Multiple Points" so that the scenario becomes a handover between multiple cells and multi-cell sets, rather than a traditional handover between individual cells. Therefore, the information exchange and signaling transmission between cells and between cells and users is more complicated. Effective handover mechanisms should be designed to reduce the overhead of information exchange and signaling transmission in CoMP scenarios and improve handover efficiency and success rate, which is pivotal to guarantee CoMP performance.

This paper analyzes the handover scenario in CoMP system architecture, and proposes a new handover mechanism supporting CoMP. The mechanism makes clear the exchanged information required by CCS handover and CTP selection/update, and provides a procedure of information interaction and signaling transmission that supports handover to lower overhead and improve handover success rate in the CoMP system.

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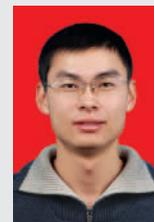
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