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System Level Performance Analysis of OFDM for UTRAN System

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Abstract: - In this paper, we present the system level performance analysis of the OFDM for UTRAN system in a multiuser, multicell and multiservice environment. First the OPNET-based simulation platform is introduced and its main modules and major functions are described; then based on this platform the modeling methodologies specified to OPNET and system level simulation are given, which includes interface between system and link level modeling, link adaptation including AMC modeling, HARQ modeling, etc. Next, the performance metrics are described specified to the system-level simulations. An in-depth performance analysis of the LTE system in a dynamic multiuser multicell and multiservice environment is given, Through the simulation results, we show that the OFDM for UTRAN enhancement achieves much higher system capacity and spectral efficiency than the traditional system such as WCDMA with MMSE receiver or Rake receive.

Key-Words: - OFDM; UTRAN; HSDPA; System level simulation; OPNET

1 Introduction

As the mobile radio systems evolve and become more integrated with daily activities, there is an increasing requirement for additional services requiring very high bit rates and higher system capacity. These include both services to individuals as well as multimedia broadcast and multi-cast services. OFDM (Orthogonal Frequency Division Multiplexing) [1]-[2] is a technology that has been shown to be well suited to the mobile radio environment for high rate and multimedia services. Examples of commercial OFDM systems include the Digital Audio Broadcast (DAB), Digital Video Broadcast Terrestrial (DVB-T) and the HiperLAN and IEEE WLAN (802.11a) wireless local area network systems.

HSDPA [3]-[4] as a new UMTS Release 5 feature proposed by the Third generation partnership project (3GPP) is taking account more higher demand in downlink packet data rate and quality. The HSDPA concept has been designed to increase downlink packet data throughput by means of fast physical layer (L1) retransmission and transmission combining, as well as fast link adaptation controlled by the Node B (Base Transceiver Station (BTS)). It introduces a downlink channel shared by multiple users providing data rates of more than 10Mbps, this transport channel carrying the user data with HSDPA operation is denoted as the High-speed Downlink Shared Channel (HS-DSCH). With HSDPA, two of the most fundamental features of WCDMA, variable SF and fast power control, are disabled and replaced by means of adaptive modulation and coding (AMC), extensive multicode operation and a fast and spectrally efficient retransmission strategy.(HARQ)

On one hand, OFDM has been and is being standardized in many wireless communication systems because of its nature advantage. On the other hand, OFDM-HSDPA is beneficial for both operators and customers. Recently, in 3GPP RAN [5], OFDM has been proposed for the HS-DSCH channel of WCDMA HSDPA. Simulations and researches on the system level of the evolutional techniques are thus very urgent; in this paper we give the modeling methodologies and the proposed simulation platform based on OPNET of OFDM for UTRAN enhancement.

The rest of this paper is organized as follow: in section II, the system model of OFDM HSDPA for LTE system is described briefly; then the simulation platform and the module entities of WCDMA HSDPA (OFDM) is investigated in detail in section III; in section IV, the key modeling methodologies of the proposed simulation platform are given. In section V, simulation results and analysis are given. Finally, we conclude our paper in section VI.

2 OFDM for UTRAN System Description

In this section, an initial reference system configuration is proposed to evaluate an OFDM downlink. The reference architecture is generic, and is compatible with the current 3GPP Rel 5 configuration [3]. In the proposed configuration, new data services are provided through the use of a separate 5 MHz downlink carrier, supporting the

OFDM HS-DSCH transmission. The reference architecture [5] is shown in Fig.1.

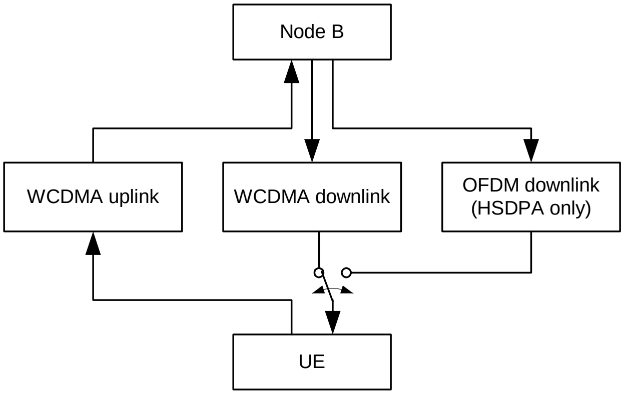

Fig. 1 Architecture for WCDMA HSDPA OFDM HS-DSCH

The separate OFDM DL carrier is operated using HSDPA features, such as link adaptation and HARQ. At this stage, it is assumed that network access is performed through the WCDMA architecture, and handover to the OFDM carrier occurs, when needed, for interactive background and streaming data services. In this case, a UE with OFDM HS-DSCH receiving capabilities would also have WCDMA receiving capabilities. In the first stage, the WCDMA link would be used to achieve the initial network access. However, when there is a requirement for high bit rate traffic, the HS-DSCH mode may be initiated, using either the WCDMA DL carrier (Rel 5 HSDPA) or the separate OFDM DL carrier.

Based on this initial reference scenario, a UE with OFDM HS-DSCH receiving capabilities is not required to receive the WCDMA and OFDM carriers simultaneously. This implies that, if there is a need for real time services, such as voice communications supported only on the WCDMA carrier, the UE would use the WCDMA mode. Note however that if OFDM proves to be useful in the HS-DSCH scenario, other services could also be mapped to the OFDM downlink in future work. In the proposed configuration, the current UMTS uplink carrier is reused and is considered to have sufficient capacity to support either a Rel 5 WCDMA DL carrier, or the separate OFDM DL carrier. There is no special assumption about the separate carrier frequency.

3 Simulation Platform of OFDM HSDPA for LTE

3.1 Platform

The dynamic simulation platform is constructed using OPNET Modeler [6] which is a packet-based, event-driven dynamic system level simulator and is very efficient for network simulations. The proposed network layer structure of the simulator is shown in Fig. 2 (for simplicity only 19 UEs are distributed in the cells, in actual simulations, a maximum 5700 UEs are supported in our simulator, i.e., 100 UEs per sector). The platform consists of four-tier cells, of which the first three-tier cells are the 19-cell macro cellular structure each of which is composed of three sectors, and the fourth tier cells (total 18 cells) are the "virtual" cells which are used for simulation purpose only and has no real meaning. This simulator is constructed according to the UTRAN structure as specified in [5] of which the system is divided into three parts, namely, user equipment, radio access network and core network. Since we only concentrate on the air interface and access network, only user equipment and radio access network are modeled. As shown in Fig. 3. Three major module entities, i.e., Node B, UE, RNC are modeled.

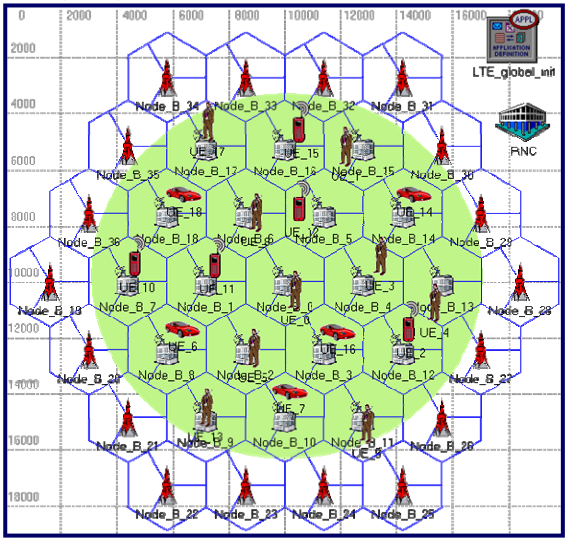

Fig.2 Simulation platform (19-cell layout, the outer 18 cells is the virtual cell which is for simulation purpose only)

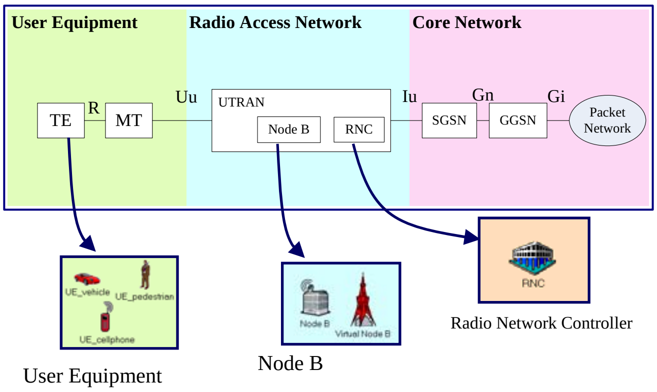

Fig.3 UTRAN and the model entities

3.2 Module Entities

3.2.1 Node B

In Node B module, the downlink OFDM interface and radio resource management (RRM) are modeled. The downlink OFDM interface is HSDPA based, that is, at one time instant (one TTI, e.g.), all the radio resources are allocated to one user who can achieve the largest system throughput. The radio resource management is the key module of Node B, which includes resource scheduling, link adaptation including AMC (Adaptive modulation and coding) and HARQ, handover, etc.

3.2.2 UE

The user equipment (UE), includes mobility model, application model, RLC_MAC model and downlink OFDM interface model. The mobility model is based on UMTS 30.03[7] macro-cell model; totally three types of traffic are modeled, that is, fullqueue, HTTP, FTP whose traffic characteristics are based on [5]; RLC_MAC model is the key part of UE, which includes functions such as channel measurement, measurement report feedback, data reception, statistics collection, etc.

3.2.3 RNC

In this part, RNC model is quite simple, which only includes the handover function.

3.3 Functions

In this subsection, we present the main functions of the proposed simulation platform which are listed as follows,

- Traffic source

Four different traffic sources are modeled to evaluate the performance of the OFDM for UTRAN system, that is, full queue, HTTP, FTP and NRTV (Near Real Time Video), the detailed traffic characteristics are referred to [5][7].

- AMC and HARQ

Ten modulation and coding sets (MCS) are simulated in the proposed platform. When the channel is favorite, higher order MCS is chosen for the transmission; otherwise lower order MCS is selected for a certain error performance.

For HARQ, chase combining [8] and IR (Incremental Redundancy) [9] are chosen for the HARQ scheme.

- Packet scheduling

Two packet scheduling algorithms are modeled, i.e., Round Robin (RR) and Max C/I (a.k.a. max throughput)[3].

- User traffic multiplexing

To realize the full frequency reuse (frequency reuse factor=1), user traffic mapping to the physical channel, i.e., the OFDM units, will be important for the system performance. In [5] a generic Costas sequence based traffic multiplexing scheme is proposed for the OFDM units scheduling, which is a "blind" scheduling scheme without considering the user's traffic profile or the wireless channel statistics. In [10][11], several OFDM-based frequency-time units allocation methods are proposed.

- Mobility and handover model

The mobility model used is the UMTS 30.03 macrocell mobility model [7].

4 Modeling Methodology

In this part, we give the major modeling methodologies used in the OPNET-based simulation platform.

4.1 Interface between system and link level modeling

The interface used in the simulation platform is divided into two parts, that is, link level operation and system level operation. The link level operation is done beforehand and the obtained results are stored into tables (we usually store the results into outer files and read them during the system level simulation) for system level lookup. Here a simulation step is the time interval during which the simulator performs a single computation (simulation), a simulation interleaving period is a transmission time interval (TTI).

Here the link level and system level steps are described as follows,

4.1.1 Link Level

The link level mainly provides the wireless channel characteristics in the forms of table, as illustrated in Fig.4;

1) Obtain SIR for each simulation step;

2) Measure Raw BER for each simulation step

3) Calculate function 1

Raw BER=f1(SIR); → 1^{st} table: Raw BER vs. SIR

4) Measure BLER for each interleaving period (TTI);

5) Calculate average Raw BER for each TTI;

6) Calculate function 2

BLER=f2(Raw BER); → 2^{nd} table: BLER vs. avg Raw BER

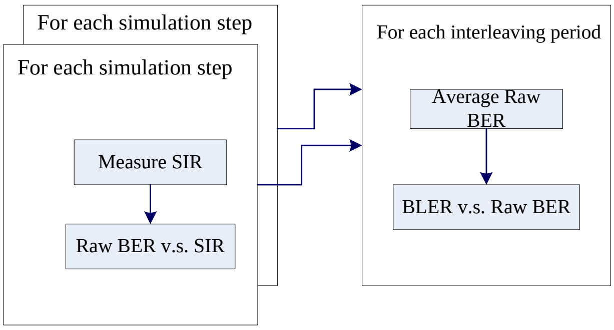

Fig.4 Link level simulation steps

4.1.2 System Level

1) Obtain SIR for each simulation step;

2) Obtain the Raw BER of each step by looking up 1^{st} table: Raw BER vs. SIR;

3) Calculate the average Raw BER for each interleaving period (TTI)

4) Obtain the BLER of each period by looking up 2nd table: BLER vs. avg Raw BER;

5) Block errors are randomly generated according to the BLER obtained in 4).

6) Block error decision and HARQ operation.

4.2 AMC Modeling

AMC is to decide the transmission modulation constellation and coding rate. The MCS (modulation and coding scheme) for each transmission block at the Node B is chosen according to the feedback SIR from the UEs. Since that for slowly fading channel the SIR also varies slowly, we can use the feedback SIR (about several TTI's delay) to choose which MCS should be used in the current transmission interval. The MCS selection enables the use of spectral-efficient higher-order MCSs when channel conditions are favorable while reverting to the MCSs that are more robust but with lower transmission rates when channel conditions degrade. Henceforth, we refer to the MCS selection as a mapping design. For example, the mapping is determined so as to maximize the instantaneous rate while maintaining certain target BLER (here this target BLER is the measured block error rate prior to HARQ operation). For other mapping criterions, refer to [12]

4.3 HARQ Modeling

4.3.1 Conventional ARQ

1) The first operations are the same as that of the 1)~5) steps in A.2 system level operation;

2) If the received packet block is in error, this block is discarded and a retransmission is requested

3) The retransmission packet block follows the same operation process as the initial packet.

4.3.2 Chase combining

Chase combining (also called H-ARQ-type-III with one redundancy version) is the simplest HARQ scheme. The basic idea is to send a number of repeats of each coded data packet and allowing the decoder to combine multiple received copies of the coded packet weighted by the SNR prior to decoding. This method provides diversity gain and is very simple to implement.

To illustrate chase combining modeling, we take one time slot as a simulation step, and three time slots form an interleaving period (a TTI). The diagram of chase combining is shown in Fig.5.

1) For the initial transmission, the process is the same as conventional ARQ;

2) If the first received packet block is erroneous, an NACK is sent back to the transmitter and the same copy of the entire coded block will be retransmitted;

3) For each simulation step (time slot), the current transmission and all the previous transmissions are combined together using maximal ratio combining (MRC); that is, the SIR of one time slot is the sum of all transmissions in this slot; then the summed SIR is mapped to Raw BER according to the 1st table (*Raw BER vs. SIR*);

4) Average Raw BER of one interleaving period (TTI) is calculated according to Raw BER1~3; (arithmetical mean can be used here)

5) By looking up the 2nd table (*BLER vs. avg Raw BER*), BLER of this TTI is obtained; then random error is generated according to the BLER;

6) If the packet block is still in error and the retransmission has reached the maximum allowed retransmission times, the packet is discarded; otherwise another retransmission is requested.

A simulation step = 1 time slot
a interleaving period (TTI) = 3time slots

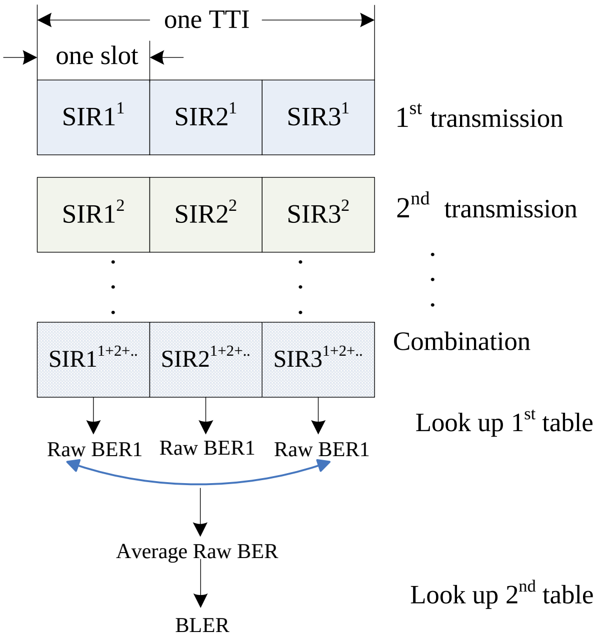

Fig.5 Chase Combining structure

4.3.3 IR (Incremental Redundancy)

Incremental redundancy is another H-ARQ technique wherein instead of sending simple repeats of the entire coded packet, additional redundant information is incrementally transmitted if the decoding fails on the first attempt.

1) For the initial transmission, the process is the same as conventional ARQ;

2) If the first received packet block is erroneous, an NACK is sent back to the transmitter and additional redundant information (parity bits) is incrementally transmitted;

3) Of the current transmission (whether initial or retransmitted packet), for each simulation step (time slot), obtain the Raw BER by looking up the 1st table (*Raw BER vs. SIR*);

4) Get the average Raw BER of all the transmissions (arithmetical mean can be used here);

5) Obtain the BLER according to 2nd table (*BLER vs. avg Raw BER*) of current transmission; (here the 2nd table is for each transmission, and the total number of 2nd table is the maximum allowed retransmissions times)

6) Random error is generated according to the BLER obtained in 5);

7) If the packet block is still in error and the retransmission has reached the maximum allowed retransmission times, the packet is discarded; otherwise another retransmission is requested.

5 Simulation Results

There are total 10 MCS sets used in the proposed simulator, that is, QPSK CR=1/3, QPSK CR=1/2, QPSK CR=2/3, QPSK CR=3/4, QPSK CR=4/5, 16QAM CR=1/3, 16QAM CR=1/2, 16QAM CR=2/3, 16QAM CR=3/4 and 16QAM CR=4/5. For each MCS set, the corresponding BLER v.s. post-receiver SIR is depicted in Fig.6 which is used as the interface between system level and link level.

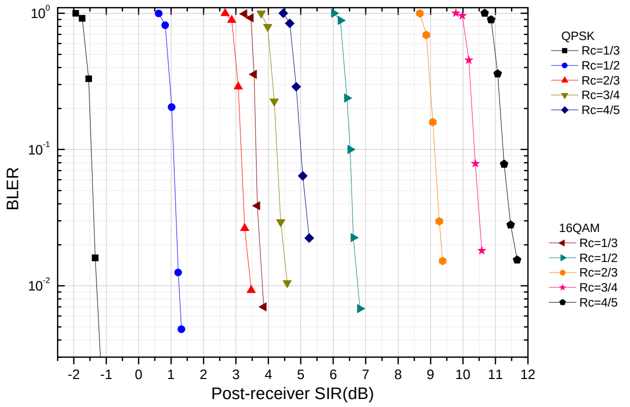

Fig. 6 BLER v.s. post-receiver SIR of 10 MCSs

The major simulation parameters are listed in TABLE I.

Fig.7 gives the full queue average OTA throughput vs. user number regarding the two scheduling methods–round robin and max C/I under PA3 and PB3 channel environments. For max C/I scheduling, chase combining and conventional ARQ achieve almost the same throughput (about 11.5Mbps), which is due to that for max C/I scheduling all the radio resources during a TTI are allocated to the user who can achieve the largest throughput in them, so in a cell all the resources are allocated to the users near to the cell site and the achieved SIR is very high and the highest MCS (16QAM Rc=4/5) is selected. For round robin scheduling, all the MCSs are selected and thus the achievable throughput (about 5.2Mbps~5.9Mbps) is much lower. Meanwhile PB3 can achieve a little higher throughput than PA3, since there is more frequency diversity.

TABLE I. Downlink System-level Simulation Parameters

Parameters	Explanation
Cellular layout	Hexagonal grid, 3-sector sites
Site to site distance	2800m or 1000m
Antenna horizontal pattern	70 deg (-3 dB) with 20 dB front-to-back ratio
Propagation model	L=128.1+37.6log10(R) dB
CPICH and other common channel power	10%, 10% of total cell power, respectively
HS-DSCH (OFDM) power	Max.80% of total cell power
Channel model	Pedestrian A and B
Shadow fading	As in UMTS 30.03 [7]
Max. num of retransmissions	3
Fast HARQ scheme	Conventional ARQ, Chase combing (CC) incremental redundancy (IR)
HS-DSCH TTI	3 slots (2ms)
MCS feedback delay	2 TTIs
Scheduling method	Round robin and max C/I
Interference modeling	Wrap-around
Traffic model	Full queue
User distribution	Uniformly

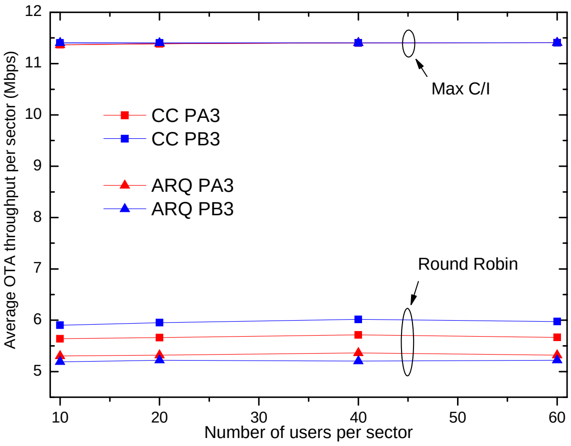

Fig. 7 Average OTA throughput

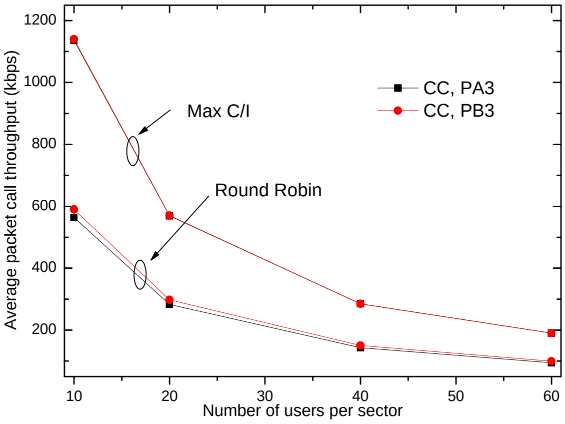

Fig. 8 Average packet call throughput

Fig.8 depicts the packet call throughput vs. user number performance. The average packet call throughput decreases as the number of users increases, and max C/I can achieve much higher than round robin, the same as that of OTA throughput.

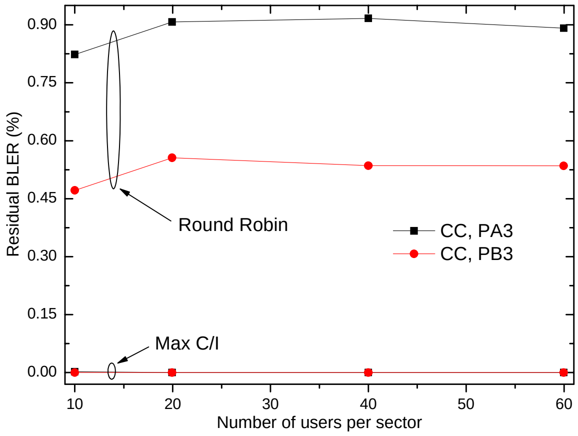

Fig. 9 Residual BLER

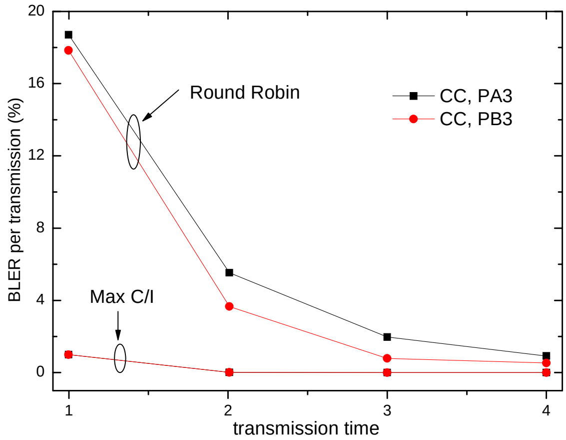

Fig. 10 BLER per transmissions

In Fig.9, the residual BLER is shown. For max C/I scheduling, the residual BLER is almost zero, since that only users near the Node B are served and the channel is favorable and achieved SIR is much higher. While for round robin scheduling all the users in a cell will be served, the residual BLER is higher relative to max C/I.

In Fig.10, BLER regarding each transmission is depicted, from which it is shown the BLER degrades rapidly as the transmission times.

6 Conclusions

Dynamic system level simulation platform and modeling methodology of OFDM HSDPA for LTE system: long-term evolution based on OPNET in a multiuser, multicell and multiservice environment are presented, and its performance is simulated and analyzed in this paper. We first introduce the proposed simulation platform and describe its main modules and major functions; then based on this platform the modeling methodologies specified to OPNET and system level simulation are given, which includes interface between system and link level modeling, link adaptation including AMC modeling, HARQ modeling, etc. Simulation results and performance analysis of the OFDM for UTRAN enhancement (LTE: long-time evolution) based on the proposed system level simulation platform are presented in detail. An in-depth performance analysis of the LTE system in a dynamic multiuser multicell and multiservice environment is given. Through the simulation results, we show that the OFDM for UTRAN enhancement achieves much higher system capacity and spectral efficiency than the traditional system such as WCDMA with MMSE receiver or Rake receiver, and it is well suited for the UTRAN long time evolution.

Acknowledge

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