Bearing Test for Gbps Broadband Wireless System

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Abstract – **In this paper, we propose a wireless channel testing method and construct the test platform for the Gbps broadband wireless system. The proposed method is implemented to evaluate the transmission performance according to the acquired field test results. The results have shown that the proposed channel test algorithm is valid and efficient, which can continuously show the variation of system throughput, frame loss rate and latency.**

Key words – ***IMT-Advanced***; ***bearing test***; ***RFC*** 2544

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1 Introduction

With the application of 3G mobile communication system in business worldwide, developed countries have changed their focus on R&D of exploration into studying for 4G mobile communication technology. In 2005, ITU (International Telecommunication Union) has officially renamed the 4G mobile communication into IMT-Advanced (hereinafter referred to as IMT-A). According to the schedule drafted by ITU, the World Radiocommunication Conference 2007(WRC-07) has fixed the worldwide spectrum allocation of IMT-A, the collection and standardization of key IMT-A technology has been developed in 2008[1], which vigorously promoted the research, development, standardization and industrialization of IMT-A mobile communication technology. Through extensive discussion, all circles have reached the basic consensus on the goal of 4G development: transmission rate up to 100 Mbps should be supported under high-speed mobile environment, and over 1 Gbps should be reached for nomadic and local wireless access environment[2-4].

At present, the world major well-known communication companies are engaging in the research and development of wireless communication system with data transmission rate topped 1 Gbps. By the end of 2004, Siemens, the German company, had first achieved wireless transmission speed of 1 Gbps in the lab[5]. The system worked in frequency channel of 5 GHz, with 100 MHz bandwidth, using multiple-antenna MIMO (Multiple Input Multiple Output) and OFDM (Orthogonal Frequency Division Multiplexing). In May, 2005, Janpanese company NTT DoCoMo announced that their lab products had arrived at the peak rate of 1 Gbps in filed test[6]. The sytem had 100 MHz bandwidth, using 16-ary Quadrature Amplitude Modulation, (16-QAM) and adopting combined technology of multiple-antenna MIMO and OFCDM (Orthogonal Frequency Code Division Multiplexing) with 4 transmitters and 4 receivers. In February, 2006, the company again announced that, in the on-site test conducted in its headquarter in Yokosuka, peak rate of 2.5 Gbps in transmission had been reached in downlink. The system had bandwidth of 100 MHz, using 64-QAM, and adopting 6 transmitters and 6 receivers[7].

At the same time, the testing methods for IMT-A begin to be researched as important work[8], the test′s main target is the field of RF[9]. China has also made important breakthrough in innovating the key technologies of the new generation of mobile communications. The first stage starting with the FuTURE plan from 2001 has basically come to a close, and the country's first integrated out-field test system had been established by the end of 2006. So far, integration test with mobile transmission rate over 100Mbps has been accomplished. A set of integration test platform which supports the new technology and testing envionrment has been initially built with preliminary test verification results featured by IMT-A technology. New technology chanlleges have boosted the test technology compared to

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the existing wired environment due to the complexity and variation of wireless channels. In this paper, we proposed a new bearing test method of the broadband wireless communications, which is different from the traditional performance test by using path loop-back, solving the technique of clock synchronization. This scheme meets with the requirements for Gbps broadband wireless communication systems bearing performance testing. The paper is arranged as follows: related research on the bearing test technology for Gbps broadband wireless transmission system(here inafter referred to as Gbps-System) is presented in section 1; the scope, indicator parameters and test principle are introduced in section 2; in section 3, the structure of the test environment is put forward; Tesing sheme is given in section 4; and in section 5, data results acquired from the actual test of the system and its analysis are provided; the conclusion is given in the end.

2 Scope, parameters and test principle for the bearing test

2.1 Scope

Generally, IP network devices play a very important role in IP networks. The performance of the IP devices directly influences the scale, stability and extendibility of the networks. As part of the performance test, bearing test mainly embodied the maximum support capacity of devices to various services and information flows.

As the customized provision is not established on the performance test for specific device by the IETF(the Internet Engineering Task Force), the test can be only implemented according to RFC2544 (Benchmarking Methodology for Network Interconnect Devices)[10].

2.2 Indicator parameters

1) Throughput

Throughput refers to the received number of correct bits during given period when the cache is not empty; the definition is shown as formula

$$S = \frac{\sum_{i=1}^{I_{\max}} Psize(i)}{T_0}, \tag{1}$$

where $Psize(i)$ is the size of the packet i, T_0 represents the continuous time of the test, $I_{\max}$ is the number of correct packets.

Throughput reflects the maximum data traffic processing ability of the tested device.

2) Latency

Latency is the delay of the data packet passing from sending point to receiving point. End-to-end latency is defined as the average of transmission latency of the blocked data packets, the definition formula is

$$Delay = \sum_{i=1}^{N} (\Delta T(i))/N, \tag{2}$$

where $\Delta T(i) = T_{\mathrm{Re}}(i) - T_{\mathrm{Tr}}(i)$ represents the transmission time of blocked data packet; $T_{\mathrm{Re}}(i)$ is the time when the correct reception of packet i is received; $T_{\mathrm{Tr}}(i)$ is the time when the traffic packet i is sent; N refers to the total number of transmission packets.

Latency reflects data packet processing speed of the tested device. Data packet transmitting to or retransmitting to a certain port should wait in the buffered queue of the device during testing when the system is busy to transmit, which is an important factor to cause latency.

3) Jitter

Jitter is the delay variation between two successive data packets. Jitter of a single data packet is defined as

$$Jitter(i) = \Delta T(i) - \Delta T(i-1), \tag{3}$$

end-to-end delay jitter is defined as the variance of transmission delay of blocked data packets, and the definition formula is

$$T_{\text{jitter}} = \sqrt{(\sum_{i=2}^{N} \Delta T(i))^2/N - (\sum_{i=2}^{N} \Delta T(i)/N)^2}, \tag{4}$$

jitter testing is necessary for the IP voice and video traffic. As in VoIP scene, jitter will be caused by different latencies among data packets in the same VoIP traffic. Latency is unable to be completely eliminated, thus jitter can only be controlled within certain range, and generally solved by adjusting buffer of the tested device.

4) Frame loss rate

Frame loss rate refers to the ratio of lost data packets to the sent data packets during testing

Frame loss rate reflects bearing capacity for a specific load of the tested device. Usually, frame loss rate testing is a supplement to throughput testing. According to the test demand, the throughput testing doesn't allow any lose of data frames, that means the test results are obtained under the circumstances are the network device is not overloaded. However, the frame loss rate testing is mainly carried out under the circumstance of network overload.

2.3 Test principle

The method based on traffic flow simulation, which is a out-of-band test technique, is always applied to the bearing test. Therefore, a third part test tool is used as an assistant to generate test flow with certain features according to the requirements of the test case, then the test results are obtained through the system under testing. The picture of logic relation in test is shown in Fig. 1.

During the test process, a service logic chain is established between two communication terminals (CT) according to the test purpose (TP) and the testing engineer can generate data flow with certain law through the test devices(TD), such as SmartBits600B network performance test instrument from Spirent Company. The test flow has the same performance feature as the actual service when passing through the Device Under Test (DUT)(or Network Under Test), thus the transmission performance of test flow can be used to represent that of the real flow.

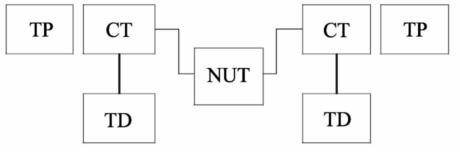

Fig. 1 The logic diagram of bearing test based on the simulated service traffic

3 Structure of Gbps-System bearing test

3.1 The tested system

As one remarkable achievement of Research and Development of Key Gbps Wireless Transmission Technology and Test system from National 863 Projects, the Gbps-System is the first wireless communication system in China with the ability to transmit data traffic at the rate up to 1 Gbps.

Based on the theoretical design of STF-SS-OFDMA (Space Time Frequency-Signal Spread-Orthogonal Frequency Division Multiple Access) solution, this Gbps-System has the ability to support a high rate of 1.7 Gbps in wireless transmission with bandwidth less than 100 MHz, and to realize rate of over 1 Gbps in transmuting distance of 50 meters. The main technical indicators of the system are listed as follows:

* Central carrier frequency: 3.5 GHz;
* TDD mode;
* MIMO: 6×6;
* Modulation: 16-QAM;
* Application Environment: indoor stillness;
* Transmission time for each physical frame: 5 ms, including the two up/down link switch protected slots, and 10 time slots (ratio: $DL : UL = 9:1$). Each time slot contains 52 OFDM symbols, and the length of each OFDM symbols is 9.375 μs.

3.2 Structure of test platform

Proposed bearing test platform for the Gbps-System is comprised of SmartBits600B network performance test instrument, dual-port test card (SPIRENT 3321A), gigabit switch(H3C S1208) and test console. The hardware modules satisfy the following conditions:

* 2 or more than 2 ports;
* Support two modes: electrical interface of 10/100/1 000 Mbps RJ45 and optical interface of 1 000 Mbps SFP on each port;
* Wire-rate traffic generation, transmission and testing various frame length and flow of different contents on per port;
* Each port can independently analyze bandwidth with 64 000 test flows, and other indicators such as packets lost, latency and jitter;
* Support to send real state application traffic;
* Each test device provides clock synchronization interface, and supports clock synchronization of GPS/CDMA.

The topology of this proposed test platform is shown in Fig. 2.

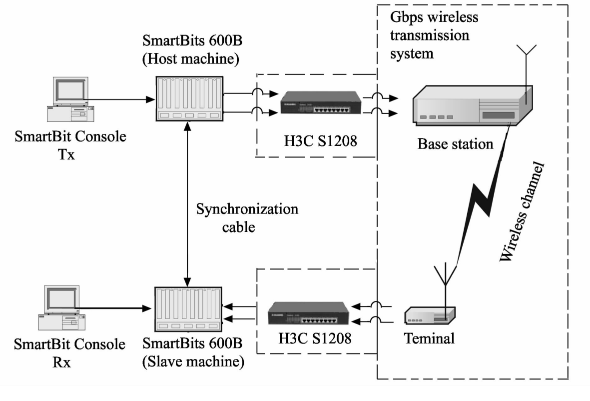

Fig. 2 Topology of the proposed test platform

4 Methods and steps for Gbps-System bearing test

In order to make better verification of the key technical indicators of the Gbps-System, the requirement for frame format is chosen as bytes of 64, 128, 256, 512, 1 024, 1 280 and 1 518 according to RFC2544.

Due to frame length of Gbps wireless transmission being 1 280 bytes in PHY, the length of the most optimal data packets is 1 280 bytes − 14 bytes (Frame header + pocket header owerhead) − 4 bytes (CRC check), which equals to 1 262 bytes. Considering the coverage requirement in the process of test parameters selecting, specific data packets with length of 1 262 is selected, and general data packets with lengths of 1 024, 512 and 128 bytes are available to be chosen.

4.1 Test methods

1) Throughput

The testing device transmits a certain amount of test packets at certain rate to the tested device and receives the data packets forwarded by the tested device[11]. Then the testing device calculates whether the number of correctly-received data packets is the same as that of the sent one. If the received ones are less than the sent ones, the sending rate should be reduced and the previous test process should be repeated till the two numbers are the same each other. And this sending rate is the maximum forwarding rate without packet loss by tested device, which equals to the throughput for the tested devices.

2) Latency

Latency test should be implemented after throughput test of the device. The size of packets being sent during test should be fixed, and the sending rate is set at the throughput value acquired from its test. Test packets in different sizes should be chosen for the test, because they may lead to different levels of throughput, thus the sending rate should be selected as the throughput value obtained from the test by using correspondence packets size. According to the requirements by RFC 2544, the test must be repeated at least 50 times, reflecting the statistic performance of DUT, covering different frame sizes without changing the configuration of the device, and then averages are taken in the report as results. As the difference between receiving time and sending time of frames is required to be compared in latency test, there is few orders of magnitude for no matter the transmission latency of message or bit latency, the test process has very high demands for time, which made the precise time synchronization between the sender and the receiver be very important in this test platform.

3) Frame loss rate

During the testing, the frame sending speed by testing devices started from the maximum of transmission media theory value, and successively reduced by 10% each time till there is no frame lost in two tests. As the frame loss is random, multiple repeated testing should be implemented for every test case to acquire statistic data. Finally the average of frame loss rate is given by repeating test 50 times. Frame loss rates of frames in different lengths should be respectively tested.

4.2 Test steps

1) Build a test environment according to the Topology in Fig. 2;

2) Disconnect two gigabit switches from the testing platform and the Gbps-System, turn on the G-bit system till the physical chain builds up;

3) Connect the clock synchronization interfaces of two sets of SmartBits600B through the clock synchronization cable till the host machine and slave machine of SmartBits600B are synchronized;

4) Connect two gigabit switches to the Gbps-System respectively, and establish a controlled dialogue between the host machine and slave machine of SmartBits600B through console till completion;

5) According to the established test case, simulated test flow is generated and sent to implement corresponded test items through the configuration of SmartBits600B console (T_x);

6) The SmartBits600B console (R_x) receives the simulated test flow and displays, then saves the results. This test case is finished;

7) Go back to Step 5 and enter the next test case till completed.

5 Test results and analysis

5.1 Throughput

Tab. 1 shows the detailed test results of throughput under the frame length of 1 262 bytes. From Tab. 1, it can be found that the throughput of the system is 900 Mbps when the frame length is 1 262 bytes, considering the signal overhead, the downlink rate of air interface is near 1 Gbps.

When the length of test frames is respectively 1 024, 512 and 128 bytes, and gradually decreased, the throughput of the system is decreased.

5.2 Latency

When frame length is 1 262 bytes, the test meters send the data packets at linear speed, the details of end-to-end latency test results of the Gbps-System are shown in Tab. 2.

From Tab. 2, it can be seen that with frame length being 1 262 bytes, the minimum latency of the system is close to the physical frame forwarding time in PHY. As it is a TDD system, the data packets will be temporarily stored in cache and wait for the next downlink time slot when meeting with the uplink time slot, which cause the maximum latency increases. While, with the frame length in test being decreases as 1 024, 512 and 128 bytes, the minimum latency of the system has no change.

5.3 Frame loss rate

In the case of the frame length being 1 262 bytes, the test meters send the test data packets at linear speed, Tab. 3 gives the details of end-to-end frame loss rate test results of the Gbps-System.

It can be seen from Tab. 3 that with the tested frame length of 1 262 bytes, the frame loss is zero, thus the frame loss rate is 0, all in sequence. With the decrease in length of frame under testing, the throughput of the system will decrease.

Tab. 1 Result of throughput capacity test

Frame size	ILoad	Tx frames	Rx frames	Lost frames	Lost/%	Throughput	Tx fps	Tx bps	Rx fps	Rx L3 bps	Rx L2 bps
1 262	90	2632605	2632605	0	0	90	87754	899999896	87754	873322832	899999896
1 262	90	2632605	2632605	0	0	90	87754	899999896	87754	873322832	899999896
1 262	90	2632605	2632605	0	0	N/A	87754	899999896	87754	873322832	899999896

Tab. 2 Result of latency test(μs)

Name	Frame size	OLoad	Tx frames	Rx frames	Min-Latency	Ave-Latency	Max-Latency	Tx fps	Tx bps	Rx fps	Rx L3 bps	Rx L2 bps
Total	1 262	90	2633383	2633381	435.6	835.827	1 090.8	87779	900265868	87779	873580257	900265185
A group	1 262	N/A	2633383	2633381	435.6	835.827	1 090.8	87779	900265868	87779	873580257	900265185
A 1-1→2-1	1 262	90.026 59	2633383	2633381	435.6	835.827	1 090.8	87779	900265868	87779	873580257	900265185

Tab. 3 Result of frame loss rate test

Name	Frame size	OLoad	Tx frames	Rx frames	Min-Latency	Ave-Latency	Max-Latency	Tx fps	Tx bps	Rx fps	Rx L3 bps	Rx L2 bps
Total	1 262	2633383	2633383	0	0	2633383	0	87779	900265868	87779	873580921	900265868
A group	1 262	2633383	2633383	0	0	2633383	0	87779	900265868	87779	873580921	900265868
A 1-1→2-1	1 262	2633383	2633383	0	0	2633383	0	87779	900265868	87779	873580921	900265868

6 Conclusions

This proposed test platform is the first bearing test ever built up to face up to IMT-Advanced-featured Gbps wireless transmission system, reaching valuable test result, verifying the bearing test methods for the future broadband wireless transmission system. The selection of test cases was comprehensive enough to cover the tests of main indicators in 23 layer bearing tests. The synchronization of test meters has been successfully achieved, which laid the foundation for the system bearing test under the future mobile environment.

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