Performance Improvement of Handover Scheme For An Established Long Term Evolution (LTE) Network

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Abstract— **This work studies the handover performance evaluation of Long Term Evolution and the effect of the handover parameters on the performance of the network. Optimizing the handover parameters is one way to greatly influence the amount of signaling overhead, especially in suboptimal situation after CDMA2000 to LTE migration. It was shown, that changing the parameter values hugely affects the amount of handovers. The analysis was based on measurements conducted in a live production network in Awka, Anambra State. The tests were conducted using the LTE 2600 MHz frequency band. The maximum bandwidth of 20 MHz was employed resulting to maximum of 100 allocated Resource Block (RBs). Since the setting of handover triggers is of primary importance for a good performance of the handover procedure, different triggering settings for the selected parameters have been performed. The optimal settings for each of the parameters were proposed and simulated using a system level simulator (LTE-Sim) developed in MATLAB. The performance evaluation of the network was carried out using the key performance indicators (KPIs) such as handover failure, cell throughput, and handover success rate and downlink traffic volume. Results obtained showed that relatively light test setup was enough to decrease the average amount of handovers to 45.29% per cell. The parameter values were set to 3dB offset, 1dB hysteresis and 640ms time-to-trigger (TTT), instead of the original 1dB offset, 1dB hysteresis and 640 ms TTT. By making the conditions of A3 event stricter, not only the amount of handovers was decreased, but the average downlink and uplink throughput was also increased.**

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***Index Terms*—Handover, Hysteresis, LTE, LTE Simulator, Time to Trigger**

1.0 INTRODUCTION

LTE is considered a fourth generation technology and an evolution of the third generation mobile network technology. It was designed to meet the need for increased capacity and enhanced performance. The main differences to 3G systems are a packet data optimized, cost efficient “all-internet protocol (IP)” architecture and an evolved, spectrally efficient air interface. The Long-Term Evolution (LTE) system was designed with the aim of providing a higher data rates and lower latency under various mobility conditions. Mobility at high speed has always been a challenge in wireless networks and LTE was designed to overcome this challenge. According to 3GPP TR 25.913, LTE system is expected to provide mobility support for User Equipment (UE) up to speeds of 500 km/h while maintaining an uninterrupted provision of high data rates and services. The continuous connectivity of mobile users within the cell without a reduction in services accessibility or UEs’ satisfaction in term of service performance poses a serious problem. The problem becomes acute when a user traverses to another cell. As a user crosses to another cell, the on-going processes on user’s device may need to be transferred to a new set of network nodes (base station, relay node and mobility management entity) within split second. This Handover needs to be successful in order to avoid call drop and improve downlink throughput. This work is interested in optimizing the performance of the handover scheme of an established Long Term Evolution (LTE) network to guarantee high QoS and improved user satisfaction.

2.0 LITERATURE REVIEW

A lot of works have been done in literature regarding handover improvement in LTE, some of these related works are discussed in this section.

The study in [1] considers the setting of Handover (HO) triggers of primary importance for the design of a good performing HO procedure. It is inferred that adaptation of the HO triggers on the basis of speed, propagation conditions and cell sizes is needed. Considering the difficulties in adapting properly the HO triggers, another solution using a series of HO triggers was proposed.

The impacts of triggering setting {hysteresis/TTT} on handover performance was also investigated in [2] for different scenarios with low, medium and high system loads. System level simulation have been done and it had been shown that the setting can affect the handover loss rate, system and service performance. The optimal setting for each case has been proposed.

The authors in [3] proposed a new handover optimization algorithm which changes the values of the hysteresis and time-to-trigger parameters in an automated manner in response to changes in the network performance. It picked the best hysteresis and time-to-trigger combination for the current network status and the results show an improvement from the static value settings.

A study by authors in [4] showed that interference coordination may improve the handover performance in LTE systems. They ran simulation of an LTE system that used fractional frequency reuse based Inter-cell Interference Coordination (ICIC). Residual block error rate (BLER) was used as one metric for handover performance and the number of unnecessary handovers as another metric. The details about simulation setup can be found in [4]. The study showed that no matter how the handover parameters were set, high residual BLER do appeared in high loaded cells. High residual BLER leads to high probability of radio link failures. In these cases, using ICIC on top of parameter optimization can overcome the problem of radio link failures without affecting the handover rates. They also show that the benefits of ICIC do not depend on the HO parameter values.

A Coordinated multipoint (CoMP)-based Handover Algorithm was proposed and compared with the LTE Hard Handover Algorithm in [5] while a new handover optimization algorithm for LTE network based on fuzzy logic was presented in [6]. The proposed handover optimization technique was evaluated and compared with four other handover algorithms. The proposed algorithm performed better than the other algorithms by achieving a minimum number of handover and having a maximum throughput than the self-optimization technique.

An efficient handover mechanism based on fuzzy logic was proposed in [7]. It was evaluated in terms of handovers completed, system throughput, and system delay based on UE speed. The suggested technique results were compared with other well-known handover algorithms at different UE speed scenarios. Results showed that the suggested technique effectively improved network performance by minimizing the average completed handovers while also providing an increased throughput.

From the literature reviewed, it can be observed that most of the works did not consider the effect of the various handover algorithms on the downlink and uplink Signal-to-Interference-and-Noise-Ratio (SINR) of the UEs. Also, little research has been carried out in the area of site investigation survey for high performance optimization of handover.

Handover procedure is one of the most important functions of a mobile system which tries to keep a UE connected to the best base station such that quality of service (QoS) of the ongoing session is met. In LTE, handover is user assisted and network controlled, and it is usually based on the downlink and/or uplink channel measurements which are processed in the user-equipment (UE).

The main goal of this work was to evaluate the handover performance of an established LTE network and to perform optimization on it. For this purpose some specific objectives are achieved: first the handover procedure within 3GPP LTE and the designing and optimization principles are studied, and the different parameters affecting handover are identified. Finally, using a dynamic system level simulator, the handover parameters are tuned according to the evaluation methodology for certain scenarios with the main objective to carry out the HO performance evaluation in terms of number of handovers, SINR, Throughput, Delay and Packet Lost.

3.0 Methodology

In this section, this study carried out preliminary field measurements in a network that supports GSM/WCDMA/LTE (using Awka, Anambra State as a case study) were the different handover parameters (RSRP threshold level, hysteresis margin, time-to-trigger) and key performance indicators (KPIs) of the network were obtained and analyzed. The data collected is used to characterize the handover performance of the network under study. Optimization on the measured data with a view of improving the handover performance of the network, was done on a system level LTE simulator developed in MATLAB.

Measurement Environment

The field measurements were carried out in an LTE network of Airtel Nigeria limited within the main city of Awka, Anambra State South East Nigeria (with longitude of 7.0678° E and latitude of 6.2069° N). This LTE network will be regarded as the test network. The nature of the field measurement is drive test, the drive test was conducted in a car, and the network data (short and long) collected with the aid of TEMS DT kit.

Drive Test Procedure

Drive test is performed using a vehicle and two measurement components: instrumented mobile phones (test engineering phones) and measurement receivers (RF scanner). The mobile phone gives information about the user experience of the network, and the scanner gives a complete overview about RF reception. The gathered data is recorded to a PC (laptop) and then analysed with proper software. For the purpose of this experiment, drive test was conducted in a car, and the network data (short and long) collected with the aid of TEMS DT kit. The laptop computer has a TEMS Investigation Drive Test Software installed which has to detect all connected hardware and provides interface to investigate/monitor the radio network during the drive test. The cell file (Airtel Cell file) was loaded on the laptop, this cell file contained information of all the Airtel LTE cells and their identifiers to enable one to identify the cell that is providing the service per time. The laptop computer was connected through an inverter to a DC source of a vehicle. The network interface design is the BTS (Base Transceiver Station) which is the source of the radio network under evaluation. The data collected includes data for serving cell as well as the neighbouring cells and the contain information about the entire network Key Performance Indicator (KPI); Call Setup Success Rate, Handover failure, Handover delay, Cell Throughput, Latency, Radio Capacity status etc. These collected data were then analyzed and deductions made.

Simulation Tool

The system level simulator employed for this research work was developed with MATLAB® using object-oriented programming and allows for study of various aspects of the LTE network including both the Evolved Universal Terrestrial Radio Access (E-UTRAN) and the Evolved Packet System (EPS). It supports single and heterogeneous multi- cell environments, QoS management, multi-user environment, user mobility, handover procedures, and frequency reuse techniques. Four kinds of network nodes are modeled: user equipment (UE), evolved Node B (eNB), Home Enb (HeNB), and Mobility Management Entity/Gateway (MME/GW). Four different traffic generators at the application layer have been implemented and the management of data radio bearer is supported.

Data Collection and Presentation

In this subsection, some of the data collected during the test drive from the test network are presented in Table 1.0.

Table 1.0: Test Statistics for the Test Network

Time	**4G eNodeB**	**Nr of Outgoing Intra-Freq Handover Execution Failures_ V(#)**	**Intra-Freq Handover Execution Success Rate_ V (%)**	**Intra-Freq Handover Success Rate_ V (%)**
2019-08-12 00:00:00	AN0013	21	96.47	96.47
2019-08-12 00:00:00	AN0014	3	99.06	99.06
2019-08-12 00:00:00	AN0029	0	100.00	100.00
2019-08-12 00:00:00	AN0034	0	100.00	100.00
2019-08-12 00:00:00	AN0035	0	100.00	100.00
2019-08-15 02:00:00	AN0013	52	87.19	87.19
2019-08-15 02:00:00	AN0014	5	96.93	94.05
2019-08-15 02:00:00	AN0029	0	100.00	100.00
2019-08-15 02:00:00	AN0034	0	100.00	100.00
2019-08-15 02:00:00	AN0035	0	100.00	100.00
2019-08-20 03:00:00	AN0013	40	87.10	87.10
2019-08-20 03:00:00	AN0014	0	100.00	99.11
2019-08-20 03:00:00	AN0029	0	100.00	100.00
2019-08-20 03:00:00	AN0034	0	100.00	100.00
2019-08-20 03:00:00	AN0035	0	100.00	100.00

From the default configuration settings of the test network the default value for the handover parameters are given as 1dB for both the offset and hysteresis and 640ms for the time to trigger. Table 1.0 showed that site AN0013 has the worst performance in terms of handover as can be seen by the handover success rate which in most cases was as low as 87.10%. Therefore, the site was selected for handover parameter optimization.

4.0 Simulation Results and Discussion

Simulation Setting

The system is modelled and simulated in the dynamic downlink system level simulator LTE-Sim. A radio network consisting of 7 cells of 5 MHz bandwidth with 25 resource blocks and 2 GHz carrier frequency was built. Each resource block is consisted of 12 subcarriers of size 15 kHz each. A time slot is 0.5ms in duration and the transmission time interval (TTI) is 1ms. A fixed number of users are uniformly distributed over the area with random initialized positions and they are moving at a fixed speed in random directions. The simulation parameters are presented in Table 2.0.

The simulator input-output representation is depicted in Fig. 1.0. The inputs of this simulator are tuneable parameters such as handover hysteresis, time to trigger, cell size, UE speed and number of UE's. The outputs are: Number of handovers, SINR, throughput, delay and packet lost.

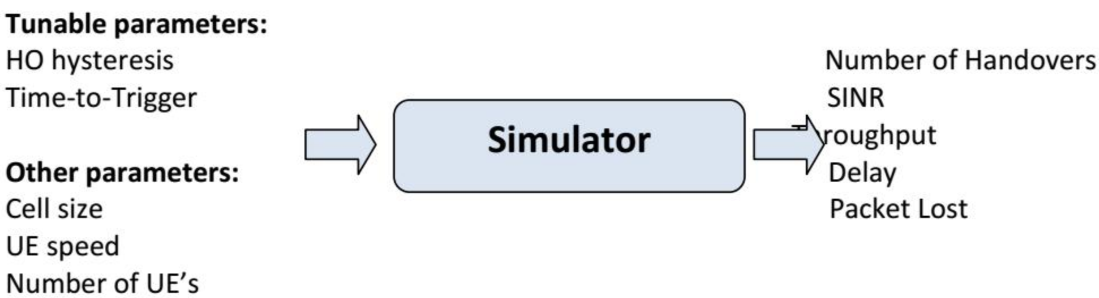

Figure 1.0: Simulator input-output representation

Table 2.0: Simulation Parameters.

Parameter	Value
Cellular layout	7 cells
Cell radius	500m, 1000m
Traffic model	INF BUF
BS Tx power	20w/43dBm
Antenna	Omni-directional with Gain of 14dBi
Channel model	3GPP typical urban
Carrier frequency	2600MHz
UE speed	(3Km/k, 30Km/h, 120Km/h)
Propagation model	COST 231
UE direction	Randomly chosen (0^o,360^o)
TTI	1ms

Subcarrier spacing	15KHz
Resource block	180KHz
Super frame time	10ms
Noise figure	2.5
Update time for UE position	1ms
Noise spectral density	-174dBm
Simulation time	60s
Max, Handover delay	30ms
System bandwidth	5MHz, 25RBs/TTI
Hysteresis/ Time-to Trigger	0dB/0ms, 3dB/960ms, 6dB/120ms, 9dB/0ms

Parameter Optimization

In the initial test setup and using the simulation parameter given in Table 2.0 each parameter (offset, hysteresis and time-to-trigger) was first increased by 100%, measured, decreased to 50% of the original value, and returned to the original value. Table 3.0 shows the average values of the KPIs obtained from these variations in the handover parameters.

Table 3.0: KPI Values for the Handover Parameter Variations

	Amount of HOs	E-UTRAN IPThroughput UE DL(Kbps)	E-UTRAN IP Throughput UE UL_V(Kbps)	Call drop rate (%)	Amount of Users	Handover Success Rate (%)
Default Value (1dB, 640ms)	388	12,841.87	603.65	0.99	31.53	93.90
Hysteresis -50% (0.5dB)	393	12,965.98	559.76	1.23	31.49	94.80
Hysteresis +100%(2dB)	380	12,985.62	573.64	1.13	31.54	94.65
TTT-50%(320ms)	390	13,104	688.24	0.52	30.94	95.76
TTT+100%(1280ms)	358	12754.24	569.74	2.86	30.8	95.74
Offset -50%(0.5dB)	366	12788.17	581.25	1.88	30.84	96.76
Offset +100%(2dB)	359	12656.2	504.03	2.1	30.86	96.72

It was observed from Table 3.0 that the parameter changes that should have significantly increased the amount of handovers, like halving the offset or TTT, did not increase the amount. However, increasing the offset and increasing the TTT reduced the amount of handovers.

To reach better results, more radical changes were made to the hysteresis and offset values while keeping TTT untouched. That resulted in more desired outcome. The procedure was iterated few times in order to estimate a function between offset+hysteresis and handover KPIs. Each iteration considered the guideline to keep hysteresis value smaller than offset. The offset and hysteresis values were changed, the results were analyzed and further changes were made based on the results from previous measurements. First the offset value of 6dB and hysteresis value of 4dB were set, meaning the offset was increased by 500% and hysteresis by 300%. In this setup, the signal from neighboring cell must be over 10dBs more powerful than the serving cell before handover is made. The amount of handovers dropped to practically 0 as shown by Figure 2.0. On the negative side, Figure 3.0 showed that the average downlink user throughput was decreased to 10000 kbps. Next the values were increased further to 9dB offset and 6dB hysteresis. It was observed from Figure 4.0 that the amount of handovers was decreased to 75 from the default number of 388. With the higher offset and hysteresis values, an UE does not do handovers to eNBs whose signal is only little stronger. An example of such scenario would be a user moving straight from one eNB to another. At the cell edge area where neither of the eNBs can provide a strong signal, a signal from third eNB may be the strongest. If the offset+hysteresis is high, the UE does not hand over to the third eNB but instead it waits until it is under good coverage of the new cell before abandoning the first serving cell.

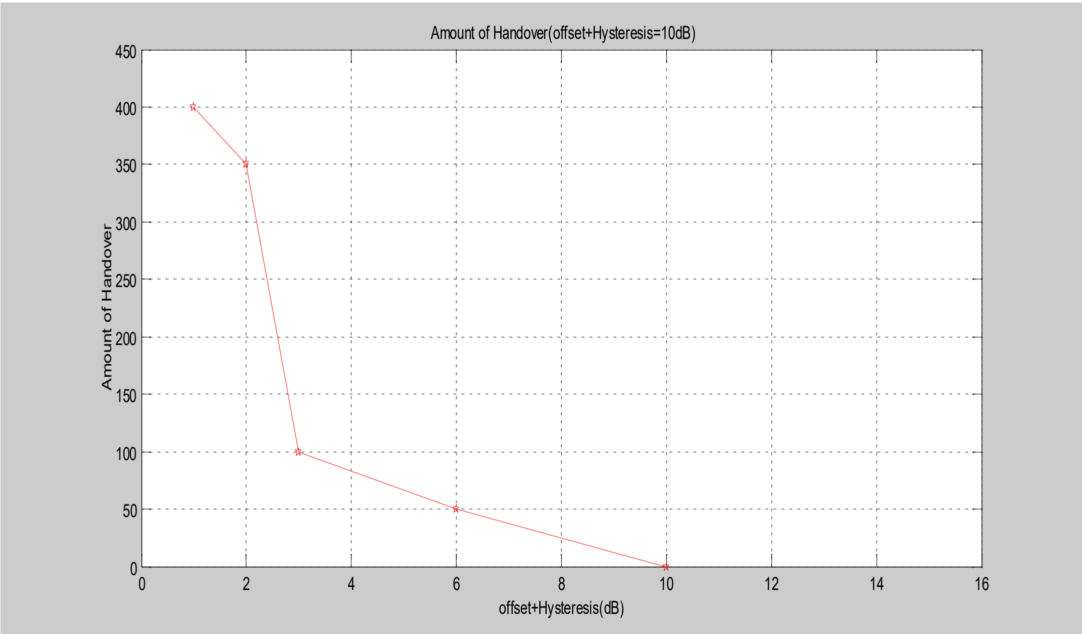

Figure 2.0: Amount of Handover for offset + hysteresis (10dB).

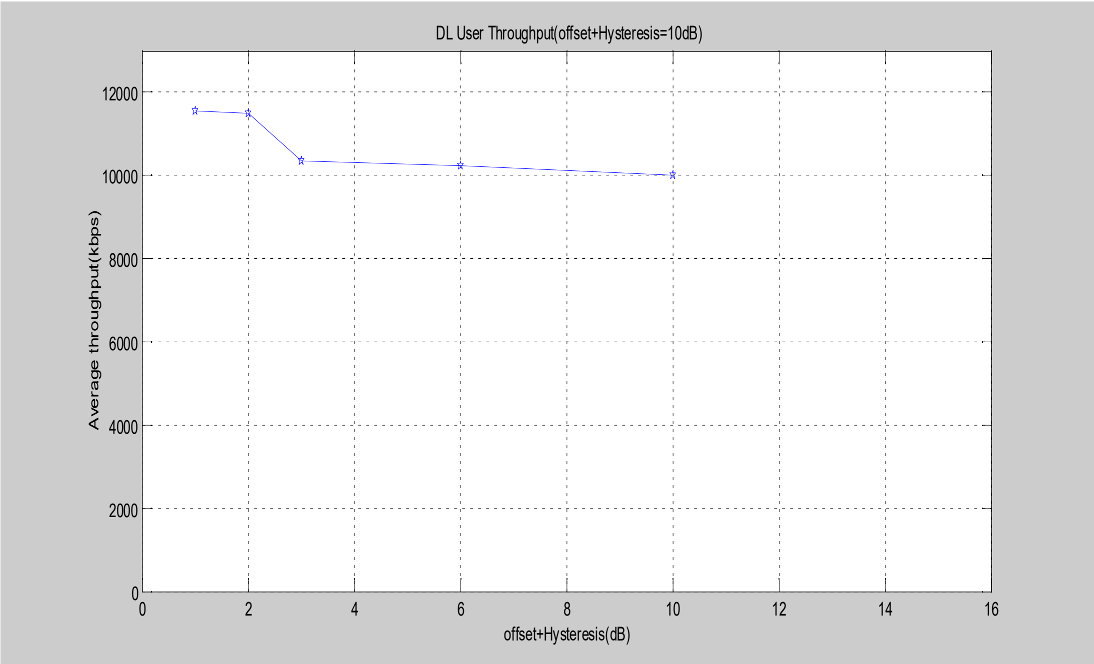

Figure 3.0: Average User DL Throughput for offset + hysteresis (10dB).

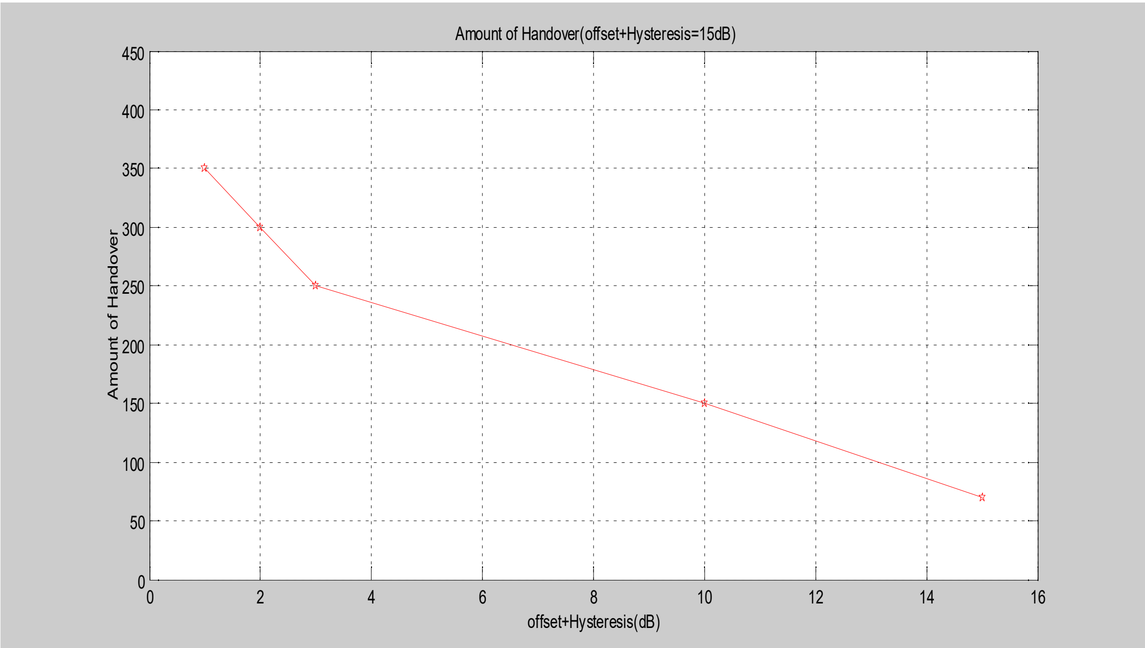

Figure 4.0: Amount of Handover for offset + hysteresis (15dB).

It was discovered that if the offset value was increased to 3dB while keeping the original hysteresis value of 1dB. These combination of parameters is adequate to prevent most of the handovers caused by ping pong effect.

From a lot of adjustment on handover parameters and the corresponding effect on the KPIs of the network. This study uses Table 4.0 to summarize the optimal values of the KPIs with the corresponding optimal values for the handover parameter.

Table 4.0: Average Values of the KPIs using the Optimized Handover Parameters.

	Amount of HOs	E-UTRAN IPThroughput UE DL(Kbps)	E-UTRAN IP Throughput UE UL_V(Kbps)	Call drop rate (%)	Amount of Users	Handover Success Rate (%)
Initial configuration	388	12,841.87	603.65	0.99	31.53	93.90
Offset increased to 3dB	212	13091.00	631.78	0.94	32.72	98.99
Difference	-45.3%	1.94%	4.66%	-4.31%	3.78%	5.42%

5.0 CONCLUSION

This work aimed to improve the performance of established LTE network, the main focus of the work was on optimizing the handover parameters of the network. The objective of the measurements related to the handover parameters was to remove unnecessary handovers by finding optimal values for handover offset, handover hysteresis and time-to-trigger. The tests were done using newly upgraded Airtel Nigeria Limited LTE networks in Awka, Anambra State. It was found out that handover parameters of the test network were not enough to provide reliable res radically changing behavior of one or few UEs under those eNBs.

However, with larger modifications of the parameters, vague trends of how the offset + hysteresis affect the chosen KPIs were identified. Based on these estimations, new values for the handover parameters were set to every eNB in the network. The offset value was increased 200%, from 1dB to 3dB. TTT value was kept the same at 640ms and hysteresis also remained the same 1dB. On average the amount of handovers were decreased 45.29% per cell. Additionally, both UL and DL user throughput were slightly increased, and call drop rate were decreased as well. The success rate of handovers was improved.

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