An Interference Avoiding Wireless Network Architecture for Coexistence of CDMA 2000 1x EVDO and LTE Systems

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***Abstract*—Interference between two RAT (Radio Access Technology) wireless networks will lead to the system capacity deduction. In this paper, system capacity loss was analyzed by using snapshot method and the simulation results show that system capacity loss is closely related to the relative offset and antenna direction between two RAT wireless networks. Based on the interference analysis above, a novel wireless architecture was proposed by rotating antenna direction and adjusting offset between two RAT wireless networks. Simulation results verified that it can effectively avoid system interference.**

Keywords – Interference; LTE, CDMA2000 1x EVDO; Wireless Networks

I. INTRODUCTION

Long Term Evolution (LTE) is designed to reduce latency, improve capacity and coverage, and enhance Quality of user Experience (QoE) [1]. However, there will be the scenario of coexistence of LTE network and other RAT (Radio Access Technology) wireless networks due to the huge cost of network building and scarce frequency resource [2]. Previous works have focused on analysis of system interference in two wireless networks coexistence, the problem of wireless network layout influencing system performance still remains open [3-7]. So, it is essential to analyze interference between two wireless networks and explore wireless network architecture to reduce interference.

There are two kinds of interference analysis methods, analytical method and simulation method. Analytical method requires an accurate mathematical model abstracted from system level behavior of wireless network. Interference could be analyzed by mathematical derivation. The simulation method is a snapshot method developed from Monte Carlo method [9]. By establishing the system simulation platform, randomizing user's parameters such as position, speed, wireless channel state and running program periodically, statistics could be obtained in a cyclic snapshot way for interference analysis.

As it is difficult to get an accurate mathematical model for CDMA 2000 1xEVDO and LTE coexistence scenario, snapshot simulation method could be considered as a proper way for interference analysis. One simulation procedure including several snapshots of LTE system is described as in Figure 1.

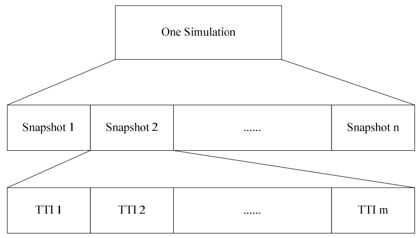


Figure 1. Basic process of snapshot method.

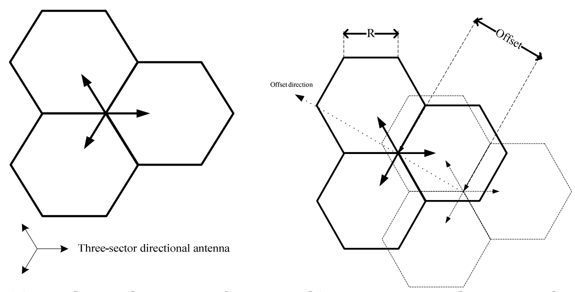
One simulation process is composed of n independent snapshots and each snapshot includes m continues TTIs (Transmission Time Interval). Simulation results of each snapshot are stored and the system performance can be obtained by averaging the stored results.

The rest of the paper is organized as follows. In Section II, interferences in two wireless networks coexistence scenario are briefly described. In Section III, simulation platform is introduced and simulation results were shown. A new wireless network architecture is proposed and verified in Section IV. Section V concludes the work.

II. INTERFERENCE IN COEXISTENCE OF WIRELESS NETWORKS

This section describes interference types in coexistence of wireless networks of CDMA 2000 1x EVDO and LTE systems.

A. *Coexistence of wireless networks*



(a) Single wireless network (b) Two RAT wireless networks

Figure 2. Wireless network architecture.

Figure 2(a) shows a one cell model for the wireless network architecture of three sector antenna. A cell is composed of three sectors represented as regular hexagon.

Figure 2(b) shows the coexistence of wireless networks architecture. As it can be seen, the LTE network is depicted in dashed line and CDMA 2000 1x EVDO is in solid line.

The network architecture of two systems is the same such as cell radius, antenna direction. But, there is a position offset between LTE and EVDO wireless network. The offset direction is depicted by a dotted line. The maximum of offset is $\sqrt{3}\cdot R$, where R is cell radius as shown in Figure 2(b). After normalization of offset, offset's range is from 0 to 1, where 1 presents the maximum offset $\sqrt{3}\cdot R$ and 0 indicates no offset between EVDO and LTE network architecture.

B. Interference types

Interference includes inter-cell interference and adjacent channel interference. Inter-cell interference is caused by inter-cell users which share the same frequency with victim user. Adjacent channel interference is mainly composed of adjacent channel leakage and adjacent channel selectivity [10]. Scenario of CDMA2000 1x EVDO AT interfering LTE eNB can be described as Figure 3 and interference to downlink is the same.

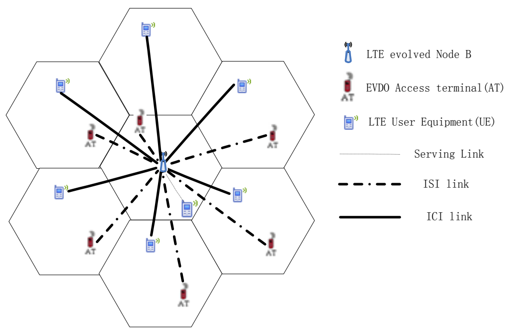


Figure 3. Scenario of EVDO AT interfering LTE UE.

LTE eNB in the center presents the serving station which has established uplink wireless connection to serving UE by dotted line. The serving UE is transmitting uplink data to this serving eNB which is interfered by inter-cell interference and inter-system interference. In addition, black solid line denotes interference from inter cell LTE User equipments (UE) and dashed line represents adjacent channel interference from EVDO system. The SINR (signal interference noise ration) of signal received by serving eNB can be calculated as following.

$$SINR = \frac{P_s}{P_{ISI} + P_{ICI} + N_0} \quad (1)$$

P_S, P_{ICI}, P_{ISI} present receiving signal power, inter-cell interference power and inter-system signal power respectively. N_0 is noise which is a constant once the working band wide is determined. The calculation methods for P_S, P_{ICI}, P_{ISI} had been described in 3GPP specification [10].

The performance of wireless networks coexistence can be evaluated by system capacity loss which is defined as following.

$$capacity\_loss = (1 - \frac{C_{coexistence}}{C_{single}}) \cdot 100\% \quad (2)$$

where, $C_{coexistence}$ denotes sector throughput of LTE (or EVDO) system under coexistence scenario and C_{single} denotes LTE (or EVDO) sector throughput without inter system interference [10].

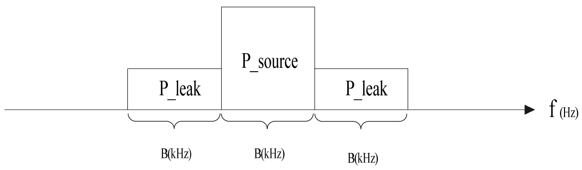


Figure 4. Definition of ACIR.

In order to measure system capacity loss in different inter-system interference level, Adjacent Channel Interference Ratio (ACIR, in dB) is introduced as an independent variable to adjust the adjacent channel interference rate and change interference intensity [10]. In Figure 4, P_source (in dBm) denotes the total power of aggressive system in B (KHz) bandwidth, P_leak (in dBm) means the leakage power on adjacent B(KHz) bandwidth channel. Then the ACIR is defined as follow:

$$ACIR = 10 \cdot \log(\frac{P\_source}{P\_leak}) \quad (3)$$

Once ACIR is fixed, P_leak could be calculated as

$$P\_leak = 10^{-\frac{ACIR}{10}} \cdot P\_source \quad (4)$$

III. Interference Analysis by Snapshot

A. Simulation Platform

The simulation platform is established according to 3GPP and 3GPP2 specifications [10-12]. When calculating inter-system interference, the simulation time period of EVDO sub-frame length (20/3 ms) has to be aligned to LTE system TTI (1ms). Figure 5 represents the process of time alignment. After time alignment, EVDO transmitting power during 1 ms remains unchanged.

Figure 6 shows the flowchart of snapshot process including initial layout of coexistence networks and procedure of each snapshot. A TTI process is composed of modeling the channel fading of LTE and EVDO system, scheduling (or rate controlling), calculating mean SINR of receiving signal considering interference signal power from the other system, and storing the system throughput of current TTI through link level interface.

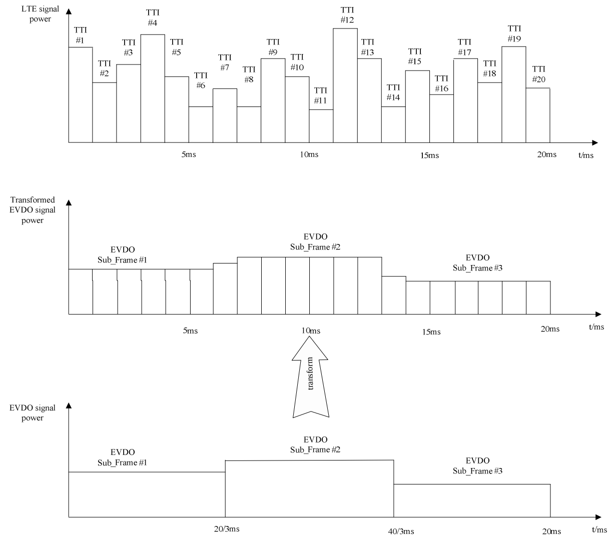


Figure 5. The process of time alignment.

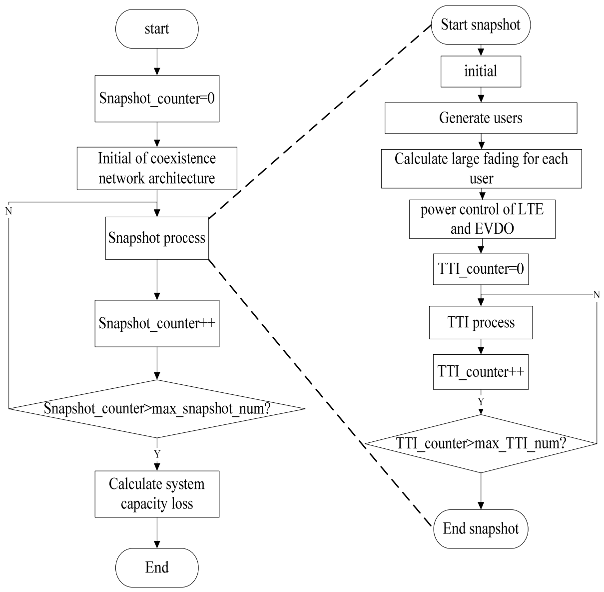


Figure 6. Flowchart of simulation platform.

The system parameters of CDMA2000 1xEVDO and LTE systems in simulation platform are listed in table I and table II according to the related specifications [10-12].

Table I. Parameters of LTE

Parameter	Downlink	Uplink
User Number per sector	16	16
Bandwidth	10MHz	10MHz
Carrier Frequency	2.005GHz	2.005GHz
Power control	N/A	Open Loop power control
Scheduling algorithm	Proportional fair	Proportional fair

Table II. Parameters of CDMA2000 1xEVDO

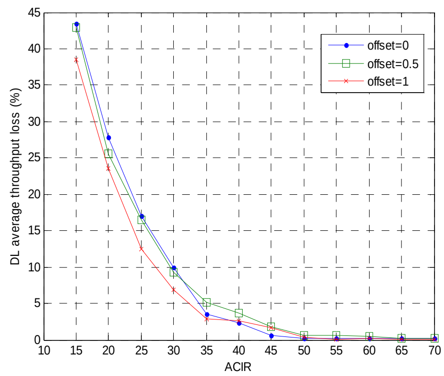
Parameter	Downlink	Uplink
User Number per sector	16	16
Bandwidth	1.25MHz	1.25MHz
Carrier Frequency	1.999375GHz	1.999375GHz
Power control	N/A	Close loop power control
Scheduling algorithm	Proportional fair	N/A
Rate control	N/A	Token bucket

B. *Simulation Results*

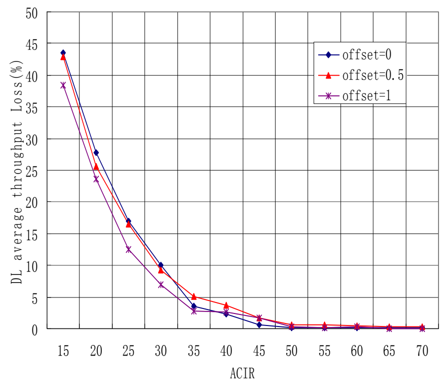
Downlink sector capacity loss and uplink sector capacity loss are taken as the system performance under different inter-interference scenarios.

(i) Downlink

EVDO downlink sector capacity loss interfered by LTE and LTE downlink sector capacity loss interfered by EVDO is illustrated in Figure 7(a) and Figure 7 (b) respectively.



(a) EVDO downlink sector capacity loss



(b) LTE downlink sector capacity loss
Figure 7. Downlink sector capacity loss.

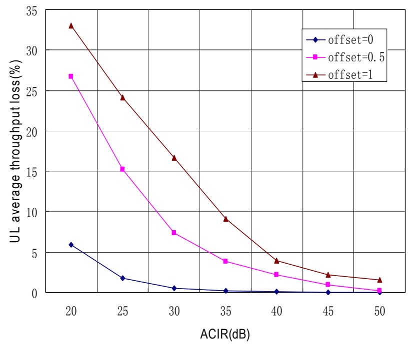
From each figure, we can find a common phenomenon that downlink capacity loss while offset=0 is more serious than the other two offset situations.

Comparing two figures above, EVDO is much easier to be interfered than LTE. As mentioned on parameter tables in Section II, LTE is working on a wider band than EVDO and both systems are working on the adjacent channels. The LTE leakage power to the adjacent channel is so wider in frequency domain that it covers EVDO working band totally. Quite different, the power leakage of EVDO in frequency domain could only cover a small part of LTE working band. As a result, EVDO downlink is much more vulnerable than LTE when interfering with each other.

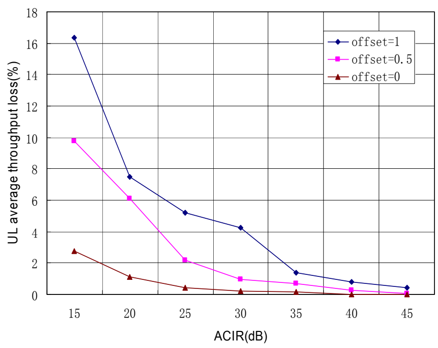
In order to limit capacity loss which should be less than 5% for example, the ACIR of LTE system should be larger than 32.5dB, 31dB, 31.5dB when offset is 0, 0.5, 1 respectively. For EVDO system, the ACIR should be larger than 34dB, 35dB, 32.5dB when offset is 0, 0.5, 1 respectively.

(ii) Uplink

EVDO uplink sector capacity loss interfered by LTE is shown in Figure 8(a) and LTE uplink sector capacity loss interfered by EVDO is illustrated in Figure 8(b).



(a) EVDO uplink sector capacity loss



(b) LTE uplink sector capacity loss

Figure 8. Uplink sector capacity loss.

The result shows that uplink capacity loss is the most serious when offset=1 among three offsets. After comparing Figure 8(a) with Figure 8(b), we can find that EVDO uplink is easy to be interfered than LTE. The reason is similar to downlink case.

In order to confine capacity loss within 5% for example, the ACIR of LTE should be larger than 15dB, 22dB, 25dB when offset is 0, 0.5, 1 respectively. For EVDO system, the ACIR should be larger than 21dB, 33dB, 39dB when offset is 0, 0.5, 1 respectively.

IV. A New Wireless Network Architecture

In order to reduce the system interference as described above, a new wireless network architecture is proposed, which is different from that presented in 3GPP specification [10]. This wireless architecture is shown in Figure 9.

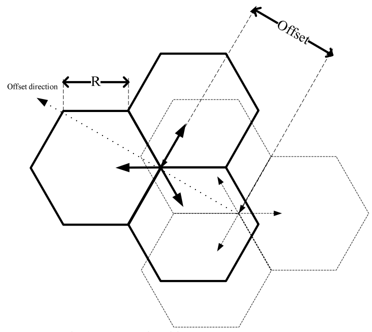
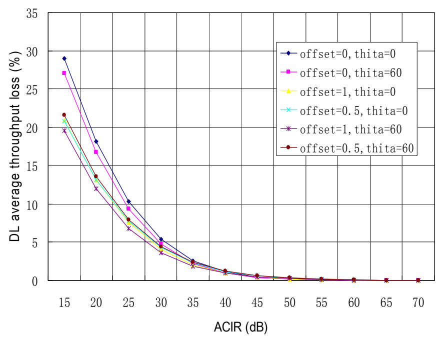


Figure 9. Definition of offset and antenna rotation.

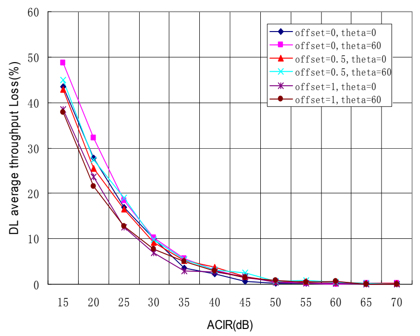
In Figure 9, solid line denotes LTE cell and dashed line means EVDO cell. Comparing to traditional network architecture in Section 2, the antenna of LTE rotates theta = 60 degrees and other parameters remain unchanged. The offset remains the same definition as defined in Section 2. In order to compare with system performance in traditional architecture, simulation results of capacity loss are shown in the same figure. Theta=0 represents traditional network architecture, while theta=60 represents new coexistence architecture. The result is shown as follows.

A. Downlink

In the new architecture scenario, downlink capacity loss of LTE and EVDO are shown in Figure 10(a) and Figure 10(b). The results show that system capacity loss under new coexistence architecture is reduced comparing to the system performance under traditional architecture when the offset is fixed. To confine capacity loss within 5% under the new architecture, ACIR of LTE should be larger than 30dB, 29dB and 27.5dB when offset is 0, 0.5 and 1 respectively. On the other hand, ACIR of EVDO should meet the minimum requirements of 36.75dB, 35.5dB and 35dB when offset is 0, 0.5 and 1 respectively.



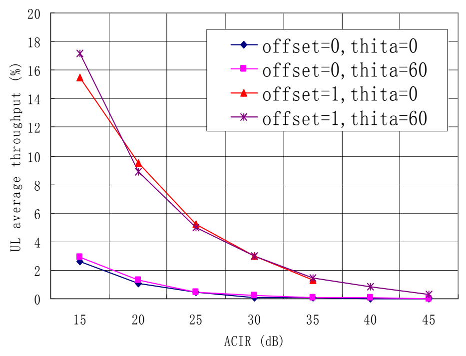
(a) LTE downlink capacity loss



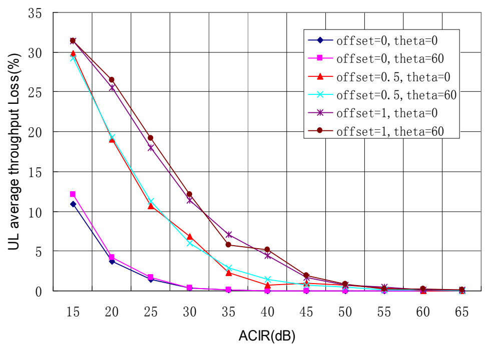
(b) EVDO downlink capacity loss
Figure 10. Downlink sector capacity loss.

B. *Uplink*

Under the new architecture, uplink capacity loss of LTE and EVDO is shown in Figure 11(a) and Figure 11 (b) respectively.



(a) LTE uplink capacity loss



(b) EVDO uplink capacity loss
Figure 11. Uplink sector capacity loss.

To confine capacity loss within 5% under the new architecture, ACIR of LTE should be larger than 19.5dB, 31.5dB and 40dB when offset is 0, 0.5 and 1 respectively. On the other hand, ACIR of EVDO should meet the minimum requirements of 15dB, 24.5dB when offset is 0 and 1 respectively. The result shows that under the new architecture, uplink capacity loss is reduced comparing to traditional wireless network architecture.

V. CONCLUSION

In the paper, system performance of LTE and EVDO under different wireless architecture was analyzed by snapshot simulation method. The simulation results show that with increasing offset between two RAT wireless networks, downlink capacity loss is decreased while uplink capacity loss is increased. After rotating antenna direction, interference is relieved in downlink and uplink. Furthermore, comparing to rotating antenna direction of each wireless networks node, adjusting offset between two RAT wireless networks is more effective to reduce inter system interference.

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REFERENCES

[1] 3GPP TR25.813, “Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Radio interface protocol aspects”, www.3gpp.org, Oct. 2006

[2] X. Chen, X.Jin, P.Moorut, R.Love, S. Yakun, W. Xiao, and et al., “Coexistence Analysis Involving 3GPP Long Term Evolution”, Vehicular Technology Conference, Fall. 2007 IEEE 66th pp. 225-229

[3] R.Zheng, X. Zhang, X. Li, Q. Pan, Y.Fang, and D.Yang, “Performance Evaluation on the Coexistence Scenario of Two 3GPP LTE Systems”, Vehicular Technology Conference Fall,2009 pp. 1-6

[4] M. Ng, S. Lin, J. Li, and S. Tatesh, “Coexistence Studies for 3GPP LTE with other mobile systems”, IEEE Communications Magazine, Volume: 47 , Issue: 4 2009, pp. 60-65

[5] P. Chang, Y.Chang, J. Zhou, and D.Yang, “Interference Analysis of TD-LTE and TD-SCDMA System Coexistence”, Networks Security Wireless Communications and Trusted Computing, Second International Conference on 24-25 April 2010 pp. 77-80

[6] J.Wang, D.Yang, and R. Zheng, “Interference Analysis and Coexistence Studies between E-UTRA and UTRA Systems”, Vehicular Technology Conference 2010 IEEE 71st, pp. 1-6

[7] X. Huang, Q.Cui and X. Tao, “Coexistence studies involving LTE-advanced”, Broadband Network and Multimedia Technology, 3rd IEEE International Conference on 26-28 Oct. 2010 pp. 273-277

[8] Y.R. Zheng and C. Xiao, “Improved Models for the Generation of Multiple Uncorrelated Rayleigh Fading Waveforms”, Communications Letters, 2002.6, pp. 256-258

[9] “Monte Carlo methods”, John Michael Hammersley, David Christopher Handscomb, 1964

[10] 3GPP TR 36.942 (V8.3.0). “Evolved Universal Terrestrial Radio Access (E-UTRA) Radio Frequency (RF) system scenarios”, www.3gpp.org, Oct.,2010

[11] 3GPP2 C.S0010-D V1.0 “Recommended Minimum Performance Standards for cdma2000 Spread Spectrum Base Stations”, www.3gpp2.org, Sept. 2010

[12] 3GPP2 C.S0011-D V1.0 “Recommended Minimum Performance Standards for cdma2000 Spread Spectrum Mobile Stations”, www.3gpp2.org, Mar., 2011

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