LTE Small Cell v.s. WiFi User Experience

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Abstract: This document summarizes a set of tests of user experience in indoor hotspot scenarios with two small cell solutions, LTE Pico and WiFi. The analyses and tests results show that LTE small cell has very good stability in providing the satisfied user quality of experience, especially in high load scenarios. As observed from the whole set of tests, LTE small cell is more suitable for the scenario with high UE density as in operator deployed networks or enterprise networks.

1. Introduction

Industry predictions have shown that the future data services will lead to an exponential data traffic growth by 1000 times[1] [2]. According to these statistics, 80% of the traffic will be indoor and at hot spots[3]. To meet the large capacity demand indoor and at hot spots, two popular solutions are now being discussed: expending the deployment of WiFi, or deploying small cells based on enhancements of the cellular technology[4]. Both systems keep evolving in the corresponding standard organizations, e.g. small cell enhancements for LTE, which are currently being standardized in 3GPP Rel-12 (to be frozen in 2014Q3), are also known as LTE-Hi; as well as IEEE802.11ac (to be frozen in 2014Q1) for WiFi enhancement. This document provides an analysis and test results for the user experience of the commercial-level LTE small cell, as well as a comparison with the other small cell solution, namely WiFi.

2. Performance Analysis and Evaluation

2.1 User Experience Test of Typical Services

2.1.1 Test Environment & Scenarios

The performance comparison is based on LTE macro eNodeB and WiFi Access Point (AP), where LTE is based on Rel-8 while WiFi is based 802.11n.

The test environment is single cell scenario without inter-cell interference, with the detailed configurations listed in Table 1. These set of tests focus on single cell scenario, since WiFi is mainly for indoor isolated deployment thus it would be hard to test the inter-cell interference mitigation effect without a centralized WiFi access controller (AC).

Considering that WiFi is a TDD system, we chose TD-LTE small cell in the comparison of user experience test.

Test environment configuration	LTE small cell	WiFi
Scenario	Single Cell	Single cell
Carrier frequency	2.6GHz	2.4GHz
Tx Power	23dBm	24dBm
NodeB/AP Type	TD-LTE eNodeB, based on LTE Rel-8	AP: TP-Link router(TL-WR1041N), based on 802.11n
UE/STA Category	5 Test-UEs (Category 4)*	5 high category STA in total, where 3STA is laptop, 2STA is router configured as STA.
uplink-downlink / special subframe configurations	(8:1:1) / (10:2:2) for Downlink(DL) (1:1:3) / (10:2:2) for Uplink(UL) (3:1:1) / (10:2:2) for DL and UL	N/A
Antenna configuration	DL: 2x2 UL: 1x2	DL: 2x2 UL: 2x2

*Note: Category 4 type UE can support up to 150Mbps at 20MHz with 2 antennas.

Table-1: Test environment and scenario configuration of LTE small cell and WiFi

2.1.2 QoS Test of Typical Services

The user experience is tested for some typical services, including Ping latency, FTP downloading time and bitrate, online video playing. The tests results are summarized in the following section.

1) Ping latency

Test metric: Ping latency in milliseconds with an application of uploading small data packet to a server. Different load scenarios are simulated with 0~4 concurrent FTP users.

Test method:

1. Send 32kB packet data to server, record ping latency under heavy load scenario.

2. The heavy load scenario is such that concurrent FTP users are increased one by one and one user sends a ping packet.

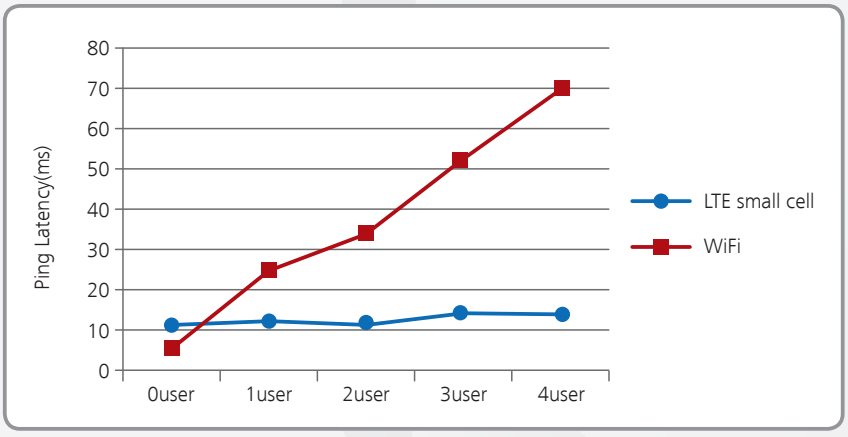

Figure-1: Ping latency comparison between LTE small cell and WiFi

Figure 1 shows that the ping latency of LTE remains stable around 10ms, while the ping latency of WiFi increases dramatically, from 7ms to 70ms with increasing number of concurrent FTP users, due to the contention based resource competition scheme in WiFi.

2) FTP downloading time

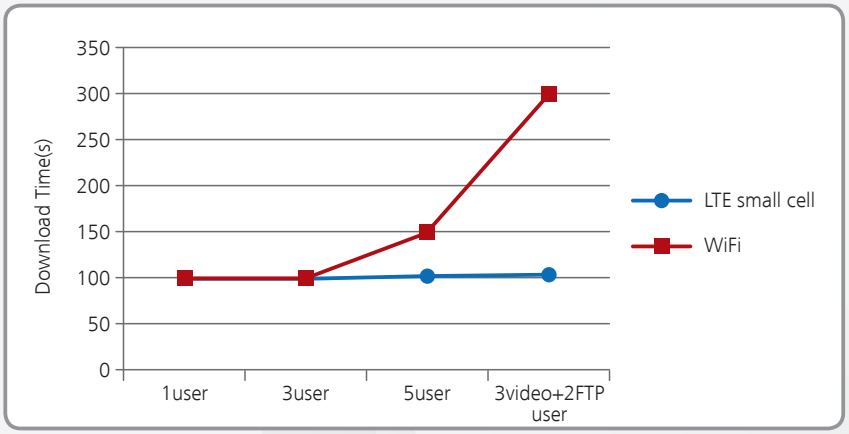

Figure-2: FTP Downloading time comparison between LTE small cell and WiFi

The FTP downloading time is tested in single user and multiple user scenarios, as shown in Figure 2. It is observed that the FTP download time with LTE small cell is almost the same in multi-user and single user conditions. For WiFi, however, the download time increases obviously when the total traffic load of the WiFi AP reaches a certain level.

3) Online Video Service

Online movie/video services are becoming more and more popular and will be the dominant services in the future mobile broad band (MBB) system[5]. The quality of online video service is tested in a scenario with high traffic load in the same cell, with three video users and two FTP users accessing the cell simultaneously, as shown in Figure 3.

(a) LTE Small cell (b) WiFi

Figure-3: Online Video download rate

It is observed that under heavy load scenario with concurrent FTP and online video users accessing one cell simultaneously, the online video downloading bitrate of WiFi is lower than that of LTE small cell, and also varies from time to time which leads to some interruption and discontinuity during the video playing period. With the same scenario, LTE small cell users have a much smoother online video experience.

2.1.3 Robustness Test of Cell Throughput versus Number of Users

The cell throughput of both LTE and WiFi are tested for different user density scenarios, by recording every user FTP uplink and downlink bit rates for the single cell scenario with different numbers of active users, as shown in Figure 4.

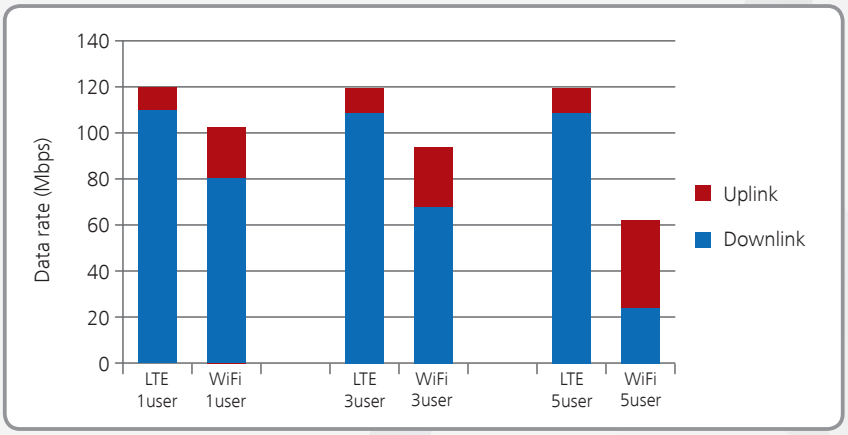

Figure-4: FTP DL & UL throughput comparison between LTE small cell and WiFi

It is observed that in order to support the same type of services, the LTE cell throughput in both downlink and uplink remains constant, independently of the number of served users. However, the downlink and uplink data rates of WiFi decrease as the number of served users increases, leading to unpredictable downlink and uplink throughput per user.

2.2 Link-adaptation Mechanism Comparison

LTE and WiFi have different link adaptation and retransmission mechanisms, according to the specifications:

- LTE Rel-8: HARQ + turbo code, with modulation from QPSK to 64QAM
- WiFi IEEE802.11n: ARQ + convolution code, with modulation from QPSK to 64QAM[6]

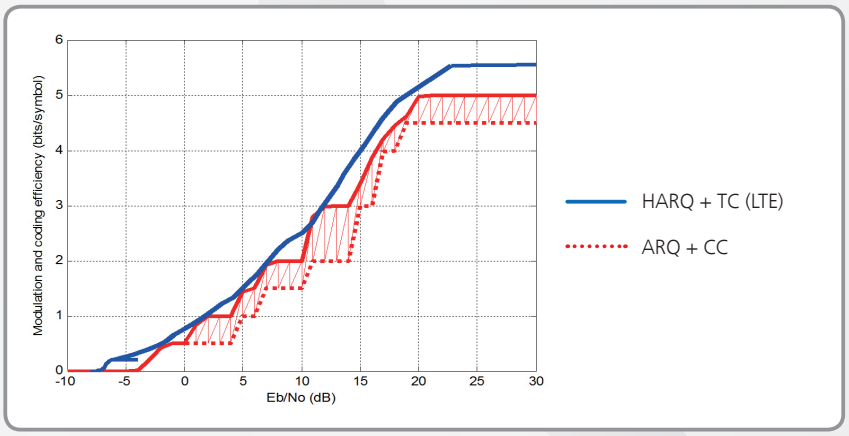

Figure-5: Link modulation and coding efficiency comparison between LTE and WiFi, with corresponding link adaptation mechanisms

Figure 5 shows the relationship between the modulation and coding efficiency and SINR, for both LTE and WiFi. It is observed that the modulation and coding efficiencies of LTE is better than WiFi. This is due to the fact that WiFi does not have dynamic link adaptation, thus the scheduling efficiency varies a lot for different configurations. Figure 5 shows the potential modulation and coding efficiency with well-planned initial modulation and coding scheme selection with ideal channel quality estimation or with 1dB estimation error. Commercial WiFi routers, however, have quite diverse configurations, thus some may have even worse efficiency than that in Figure 5.

It is worth noting that both IEEE 802.11ac and LTE Rel.12 introduce higher-order-modulator up to 256QAM in downlink, which improve the peak modulation and coding efficiencies to 6.67bits/symbol (WiFi) and 7.43bits/symbol (LTE), respectively.

2.3 Summary

According to the above test and analyses, LTE Small Cell provides good performance with more efficient scheduling mechanism and better guaranteed QoS of typical services compared to WiFi:

- Ping latency of LTE Small Cell in multi-user scenario is almost the same as that in single-user scenario, while ping latency of WiFi increases dramatically with increasing number of served users.
- Under heavy load scenario, the FTP downloading time in WiFi is quite high, and the online video playing is not very smooth with some interruptions. With the same loaded scenario, LTE Small Cell users can have a stable FTP downloading time and smoother online video experience.
- The link adaptation mechanism of LTE small cell provides better link performance than WiFi.

3. Standard Evolution and Industrial Environment

3.1 Standard Evolution

3.1.1 Standard Evolution Roadmap of LTE Small Cell

LTE Small Cell keeps evolving in 3GPP, as shown in the LTE standard roadmap in Figure 6. The latest LTE Small Cell Enhancement (SCE) work items were setup in Rel-12, and are expected to be completed in June 2014[7][8].

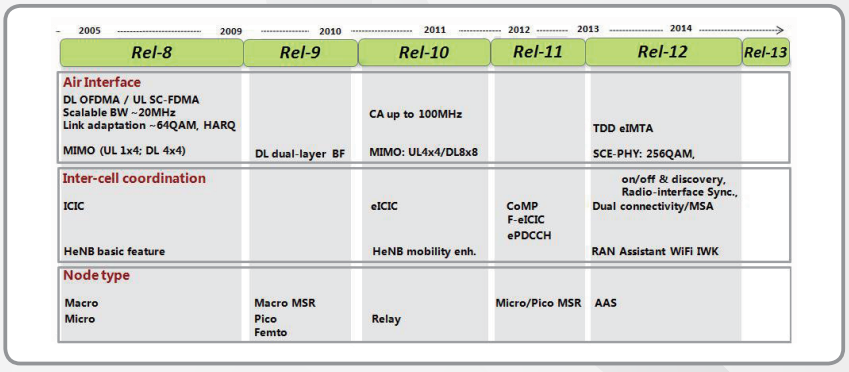

Figure-6: LTE small cell standard evolution roadmap

3.1.2 Standard Evolution Roadmap of WiFi

The IEEE802.11 series standard evolution is shown in Figure 7. The core WiFi functionality standard evolved to 802.11n and 802.11ac based on the requirement of wider bandwidth and higher data rate for local fixed access. There is an ongoing study on HEW (high-efficient WLAN) for the potential further enhancement. Considering the QoS enhancement and new service support (e.g. video transport stream), other 802.11 standard evolution branches are introduced, e.g. 802.11ae and 802.11aa.

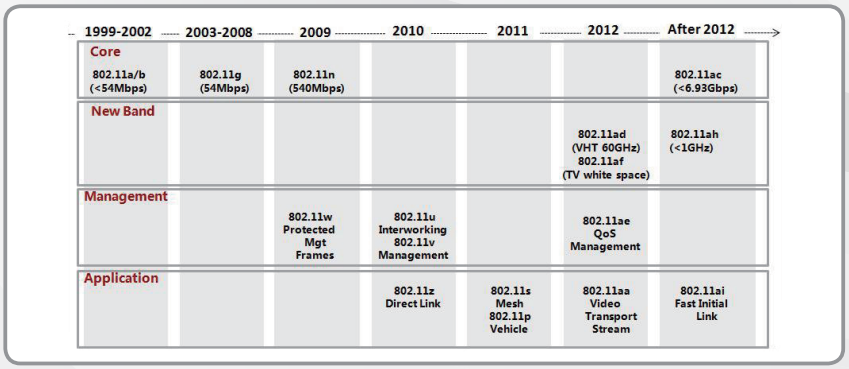

Figure-7: IEEE802.11 series standard evolution roadmap

3.2 Industry Ecosystem Analysis

3.2.1 Deployment Scenarios of LTE Small Cell

For LTE small cell deployment scenario, the main deployment scenario is in the cellular network deployed by a mobile network operator, where LTE small cell can provide the capacity enhancement and coverage extension for macro cell with the compatible QoS and the efficient coordinated resource management by taking the advantage of the close coupling between macro cell and small cell.

There are also scenarios with some hotspot and enterprise small cell coverage deployed by third party, where LTE small cell can also provide the high capacity for the coverage of the third party area with the limited access and authentication, guaranteed security and QoS. The small cell network can work in a standalone way without interworking with operators' macro cell.

Recently, the potential LTE small cell operation aggregating a supplemental carrier in unlicensed spectrum starts to attract some attention in the industry and is under discussion.

3.2.2 Deployment Scenarios of WiFi

The main WiFi deployment scenario is residential deployment, e.g. to provide the extension of wireline wideband for the local fixed access from home, which mainly contains one or few APs and STAs, low cost requirement, and with low QoS requirement.

In recent years, due to limited spectrum resources, some operators started to deploy Carrier Grade WiFi (CGW) as a complement to their macro cellular network, for offloading cellular traffic in some hotspot areas. Generally the telecommunication level WiFi AP is much more expensive than a residential AP, and also supports interworking with 2G/3G or 4G networks.

To provide a convenient access to internet, e.g. wireless city project, some third party or government may also deploy WiFi access in hotspot areas, some of which adopt telecommunication level AP to support continuous coverage of the hotspot area and to permit access of more users than residential networks. However, it is still hard to guarantee the security and QoS.

3.3 Commercial Maturity Analysis

From the commercial scale point of view, both LTE and WiFi are very successful. Both 3GPP and WiFi alliance are paying attention to the interworking between WiFi and cellular network as well, while some latest specification requires upgrade of terminal implementation and test. The industry chain of both LTE small cell and WiFi are analyzed as follows.

Chipset and Terminal Maturity:

- LTE protocol phase I (LTE Rel-8) and WiFi phase II (IEEE802.11n) already released a lot of commercial chipsets and terminals. LTE FDD and TDD specification are commonly defined, which makes it easy for chipset design and terminal implementation to support both modes.

- WiFi phase III (IEEE802.11ac) is in the roadmap of many vendors, similar as LTE small cell enhancement (e.g. Rel-11/12).

Candidate spectrum:

- LTE small cell may be deployed in the same spectrum as macro cells, and may also have some small cell specific spectrum. The first batch contains bands that are already assigned to LTE system, e.g. 2.3GHz and 2.6GHz. The second batch consists of potential small cell specific bands, e.g. 3.5GHz or spectrums with a bit higher frequency. There is discussion for potential application in the 5.8GHz band as well.

- WiFi residential spectrum is mainly in 2.4GHz, which is already very crowded. The second batch is around the 5GHz area. The third batch is 60GHz and some potential bands below 1GHz, e.g. TV white space.

4. Conclusion

This paper provides the analysis of the small cell solutions based on both LTE and WiFi, with a focus on the user experience test.

LTE Small Cell is suitable for the typical service application in the cellular network deployed by an operator or a large scale enterprise. With close coupling with the Macro layer, the operator can easily manage LTE Small Cell and control the user experience with the unified interface of the traditional LTE system, and support good mobility performance. The LTE air interface is well designed for supporting a substantial number users, guaranteed security and QoS in diverse deployment scenarios, and complex traffic situations.

WiFi is most suitable for application in residential or small coverage deployment with a smaller number of users, such as the home, isolated hot spot or small scale enterprise. The contention based scheduling and network management of high user density scenario is the bottleneck for WiFi. To improve its performance in the cellular scenario, higher cost is expected.

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