Deployment of the First Commercial LWA Service

Yuan-Kuang Tu, Cheng-Hua Lee, Chia-Horng Liu, Chung-Yung Chia, and Yuan-Kai Chen, Chunghwa Telecom
Yi-Bing Lin, Chunghwa Telecom and National Chiao Tung University

Abstract

This column reports the deployment of the first commercial LWA service. The deployed LWA network reuses and is merged with the existing individual LTE and WLAN networks. Our experience indicates that this approach allows quick establishment of LWA service, which nicely resolves the coexistence problems arising from deploying the LTE system in unlicensed spectrums. Specifically, in the initial stage, selected LWA hotspots with the required service were built in two months. Through this deployment, we show how Chunghwa Telecom utilizes unlicensed spectrum to open up additional capacity to support LTE service. Specifically, the throughput of an LWA site can be more than twice of that for an LTE eNB. Also, through an LWA eNB, an LWA-capable user equipment can indirectly perform seamless handover between a Wi-Fi AP without mobility capability and a standard eNB. This indirect handover time is less than 400 ms plus the standard EAP-SIM authentication time for Wi-Fi.

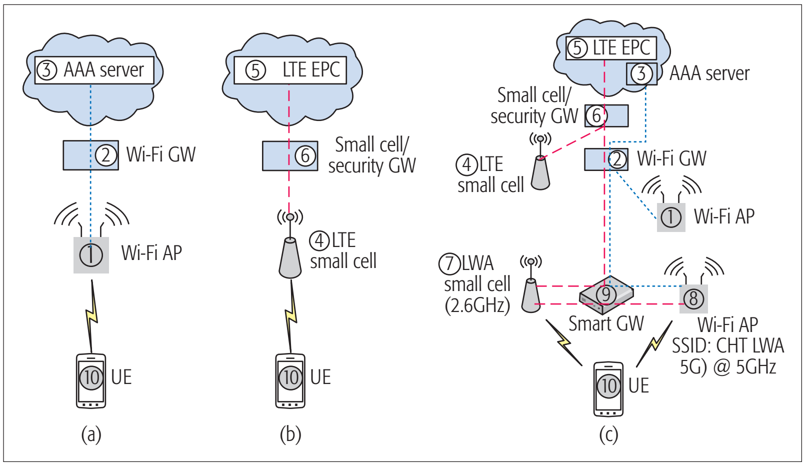

FIGURE 1. CHT's small cell network, Wi-Fi AP network, and LWA network configuration: a) WLAN network; b) LTE network; c) LWA network.

Introduction

Most mobile operators attempt to utilize unlicensed spectrum to open up additional capacity to support LTE service. Unlicensed spectrum is particularly suited to indoor deployments, which is a key market for mobile operators as roughly 80 percent of wireless data is consumed indoors. By utilizing Wi-Fi to carry LTE traffic, LTE and Wi-Fi link aggregation (LWA) is a palatable way to bring LTE and Wi-Fi together [1]. LWA cleverly uses the well-established Wi-Fi protocols and coexistence mechanisms to carry LTE traffic to offer exceptionally fast data speeds. This article describes the LWA network deployed by Chunghwa Telecom (CHT), the largest telecom operator in Taiwan, and shares first-hand experience of LWA service development.

The Deployed LWA Network

In April 2017, CHT launched the world's first commercial LWA service. In the initial stage, selected LWA hotspots have been deployed in three cities of Taiwan within two months. They are collocated with Wi-Fi access points (APs) originally deployed for CHT's WLAN service. In other words, CHT's LWA network overlaps with the hotspots of the original WLAN network, and the overlapped service areas can support both Wi-Fi users and LTE users with or without LWA-capable user equipments (UEs). In CHT's WLAN network (Fig. 1a), every Wi-Fi AP (1, Fig. 1) is connected to the Internet through a Wi-Fi gateway (Alcatel-Lucent 7750; 2, Fig. 1). A Wi-Fi user is authenticated by EAP-SIM through the authentication, authorization, and accounting (AAA) server (Fig. 1c) in CHT's dedicated intranet. For the LTE network deployed by CHT (Fig. 1b) [2], every LTE eNB (small cell; 4, Fig. 1) is connected to the LTE Evolved Packet Core (EPC; 5, Fig. 1) through a small cell/security gateway (SMEC SP14 HeNB Gateway; 6, Fig. 1). Each gateway can accommodate more than 3500 eNBs.

In CHT's LWA service deployment (Fig. 1c), an LWA evolved NodeB (eNB) (7, Fig. 1) is collocated with one or more standard Wi-Fi APs (8, Fig. 1) that need not be modified [3, 4]. The eNB and the corresponding AP are connected by an optical link with 500 Mb/s

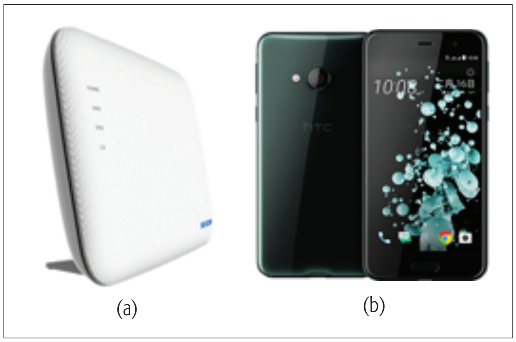

FIGURE 2. The LWA eNB and the LWA-capable UE: a) Sercomm LWA eNB; b) HTC U Play.

downlink and 250 Mb/s uplink through a gateway (Alcatel-Lucent I-040GW; 9, Fig. 1). Northbound, the gateway connects to the EPC through both the Wi-Fi gateway and the small cell/security gateway. Southbound, the gateway connects to one LWA eNB and one or more Wi-Fi APs. This configuration reuses and integrates the original LTE and WLAN networks and can be operated independently. In Fig. 1c, the pure WLAN traffic from the Internet is delivered to the UE through Path 1: (2) -> (9) -> (8) -> (10). The pure LTE traffic is delivered through Path 2: (5) -> (6) -> (4) -> (10). The LWA's LTE traffic is delivered through Path 3: (5) -> (6) -> (2) -> (9) -> (7) -> (10). The LWA's WLAN traffic is delivered through Path 4: (5) -> (6) -> (2) -> (9) -> (7) -> (9) -> (8) -> (10). In LWA's split mode, the downlink traffic is delivered to the UE through both Paths 3 and 4. Specifically, all packets are first sent to the LWA eNB through Path 5: (5) -> (6) -> (2) -> (9) -> (7). Then the traffic is split into two paths. In the LTE path, the packets are sent to the UE through (7) -> (10), which is the same as Path 3. In the WLAN path, the packets are delivered through (7) -> (9) -> (8) -> (10).

The Wi-Fi APs are operated with 80 MHz bandwidth at the 5 GHz frequency band. The peak application layer throughput of an AP is around 300 Mb/s. We create a new SSID for the Wi-Fi AP so that the connected LWA-capable UEs (10, Fig. 1)

FIGURE 3. Commercial LWA deployment at the NCTU campus.

(a) (b)

FIGURE 4. Building C and the LWA site.

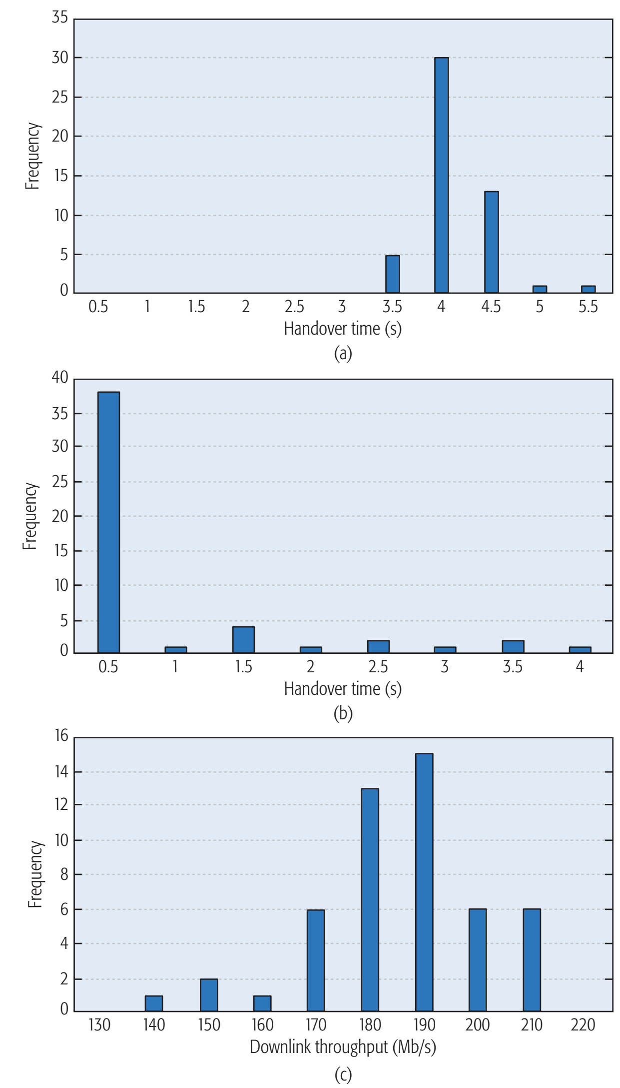

FIGURE 5. Histograms of handover times and throughputs: a) macrocell to LWA small cell; b) LWA small cell to macrocell; c) average downlink throughput during handover.

can be distinguished from the original Wi-Fi users. The SSID is not broadcast in the air. Instead, it is hidden to avoid an unexpected association attempt. The eNBs (SCB107Ev2; Fig. 2a) operated at 2.6 GHz are manufactured by Sercomm. The peak downlink throughput of the eNB is 150 Mb/s. In the current stage, 10,000 LWA-capable handsets (HTC U Play; Fig. 2b) are provided by HTC with the Helio P10 processors of Mediatek.

Performance Evaluation

We have conducted LWA performance measurements in four indoor sites, A (the stadium), B (a research building), C (a library), and D (a student restaurant), deployed on the campus of National Chiao Tung University (NCTU; Fig. 3); Fig. 4 illustrates LWA site C. The distances among these sites are 206 m (A–B), 307 m (B–C), 100.5 m (C–D), 359.7 m (A–C), 476.1 m (A–D), and 402 m (B-D), respectively. The NCTU campus is also covered by a macrocell (a standard LTE eNB). In the past, the NCTU campus was covered by zonal Wi-Fi APs, and the data connections were disconnected when the users moved out of the coverage of the APs.

With the LWA service, the data connections can be switched between LTE and WLAN seamlessly. For example, consider a user with an LWA-capable UE. The user makes a data connection at site C, and the packets are delivered to the UE through both LTE and WLAN in the split mode [3]. When the user moves from site C to site D, the UE leaves the radio coverage of LWA eNB/Wi-Fi AP in building C. The LWA mechanism automatically switches the downlink transmission from the split mode to pure LTE mode. Then the standard Third Generation Partnership Project (3GPP) handover procedure is executed to switch the connection from the small cell (LWA eNB) to the macrocell (macro LTE eNB). At this point, the downlink transmission is conducted at LTE only. When the user moves to building D, the connection is switched to the LWA eNB of site D, and then, following the 3GPP LWA activation procedure [3], the downlink packets are delivered to the UE through both LTE and WLAN in the split mode again. We have conducted measurements for handover between the macrocell and LWA eNBs (in the split mode) at sites C and D under the typical daily background traffic. The throughputs of the LWA sites range from 290 Mb/s to 307 Mb/s, which double that of a standard eNB. That is, in terms of throughput, the aggregation efficiency is about 70 percent. We note that if the LWA sites are connected to the EPC by skipping the small cell/security gateway, more than 90 percent of aggregation efficiency can be achieved, and the throughput is three times that of a standard eNB.

These performance results under commercial background traffic are consistent with the laboratory experiments reported in [5]. The histograms of the handover times and throughputs for 50 measurements are illustrated in Fig. 5. The average handover time form the macro eNB to LWA eNB (in the split mode) is 3.9 s with EAP-SIM authentication at the Wi-Fi AP and 400 ms without Wi-Fi authentication. For handover from a Wi-Fi AP to the macrocell, the average elapsed time is 640 ms. Figure 5c shows the average downlink throughput measures during handover. The average throughput is 180 Mb/s, which is still higher than that of the original LTE small cell.

Discussion and Summary

This column describes the development of the first commercial LWA service in the world. The deployed LWA network reused and was merged with the existing individual LTE and WLAN networks. Our experience indicates that this approach allows quick establishment of 40 LWA hotspots with the required service in 2 months.

In the first stage, the LWA service was deployed in the hotspots of downtown areas where LTE users need large download throughputs. In the NCTU campus, LWA is used in mobile learning for high-quality video streaming to LWA-capable UEs. The handover time is less than 400 ms plus the standard EAP-SIM authentication time for Wi-Fi. The throughputs of the LWA sites range from 290 Mb/s to 307 Mb/s, double that of a standard eNB. In the laboratory environment at the Industrial Technology Research Institute (ITRI) [5], we reported the peak throughput of LWA to be 450 Mb/s with carrier aggregation (150 Mb/s for LTE and 300 Mb/s for Wi-Fi) for a single UE. In an enhanced version, the peak throughput of the LWA is 900 Mb/s, where the eNB transmits 200 Mb/s LTE data to a UE by carrier aggregation and transmits 700 Mb/s data to a PC via a Wi-Fi AP. Both the UE and the PC can receive data without packet loss under the target bit rates.

CHT's commercial deployment showed that LWA nicely resolves the coexistence problems arising from deploying the LTE system in unlicensed spectrum. In the CHT LWA network, the original LWA capacity can be doubled or tripled, and users enjoy data connections that can seamlessly switch between LTE (licensed band) and WLAN (unlicensed band). In the future, we will continuously increase the LWA throughput and extend the LWA service areas. New features in 3GPP Release 14, such as uplink enhancement, will also be considered in our development and rollout roadmap.

Acknowledgment

The authors would like to thank Yao-Chun Tsou, Po-Hsueh Wang, Chung-Ho Wang, and Sz-Hsien Wu of CHT Telecom Laboratories for their valuable support.

References

[1] S. Sirotkin, "LTE-Wireless Aggregation (LWA): Benefits and Considerations," Intel White Paper. 2017

[2] 3GPP. "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall Description; Stage 2 (Release 13)," TS 36.300, V13.4.0, June 2016.

[3] 3GPP. "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE-WLAN Aggregation Adaptation Protocol (LWAAP) Specification (Release 13)," TS 36.323, V13.0.0, Mar. 2016.

[4] P. Nuggehalli, "LTE-WLAN Aggregation," *IEEE Wireless Commun.*, vol. 23, Aug. 2016, pp. 4–6.

[5] Y.-B. Lin, Y.-J. Shih, and P.-W. Chao, "Design and Implementation of LTE RRM with Switched LWA Policies," tech. rep., NCTU, 2017.