November 28, 2018

WIRELESS SYNCHRONIZATION OF MULTI-PROTOCOL ACCESS POINTS

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ABSTRACT

Techniques are described herein for leveraging observation receivers on Access Points (APs) to listen in-band to transmissions in the band of another AP. This enables performing time synchronization between devices without requiring any packet exchanges between devices to accomplish the synchronization.

DETAILED DESCRIPTION

The advent of multiprotocol Access Points (APs) which support 802.11 (Wi-Fi®) and 3rd Generation Partnership Project (3GPP) modes (4G, 5G) introduce new time and frequency synchronization requirements when used in Time Division Duplex (TDD) coexistence groups.

3GPP synchronization requirements are very stringent, and traditionally difficult and expensive to implement. This is a cost of doing business by the Service Providers (SPs). The spectrum being offered to enterprise/commercial interests (e.g., Citizens Broadband Radio Service (CBRS)) is creating a demand for lower cost solutions which are deployed, in most cases, within the coverage space of a Wi-Fi network.

Wi-Fi capabilities of the multiprotocol APs offer great flexibility to implement over-the-air solutions for synchronization. A unique Wi-Fi based solution for 3GPP synchronization requirements between TDD small cells is presented herein.

Precise time synchronization required for TDD 3GPP systems is provided by leveraging a multi-protocol radio that uses receive-only, observation Reception (Rx) paths to accomplish time sync without any disruption to service. Long Term Evolution (LTE) Licensed Assisted Access (LAA) is one example usage. In LTE-LAA, the anchor and unlicensed band AP need to have tight timing synchronization. Figure 1 below shows how the Observer (OBS) Rx on the CBRS anchor and the OBS Rx on the LAA APs observe the others' service band.

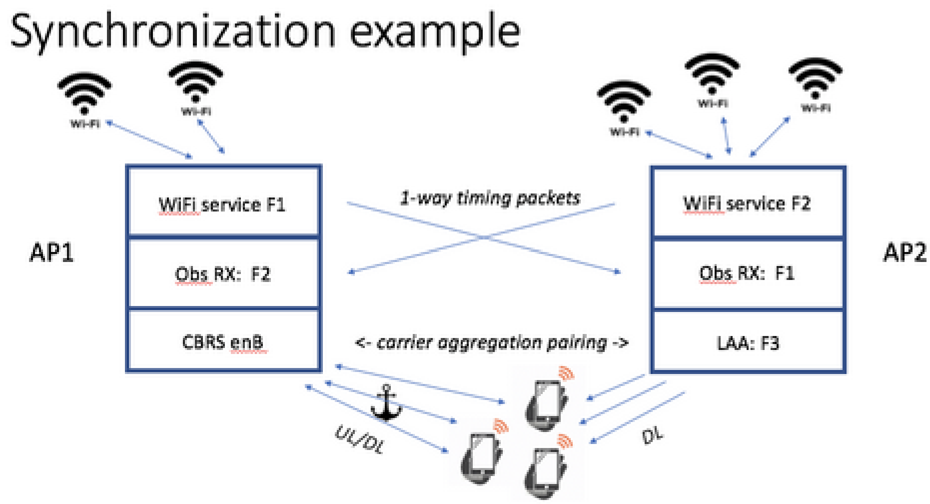

Figure 1

In this example, the Wi-Fi service is used to perform synchronization for the CBRS/LAA anchor/offload network without any specific two-way exchange occurring between the two APs. There is only observation with the OBS Rx paths, assuming that the radios in each AP share a clock (same Application Specific Integrated Circuit (ASIC), which is becoming more typical). Instead, the typical two-way exchange to provide time synchronization is split across bands into two one-way observations that provide the same T1 (Transmission (Tx) device 1 to device 2), T2 (Rx of Tx device 1 to device 2), T3 (Tx device 2 to device 1), and T4 (Rx of Tx device 2 to device 1) of a two-way exchange but without the disruption of tuning on/off channel.

As illustrated in Figure 2 below, conventional APs that implement a single protocol (e.g., Wi-Fi) have a simple architecture with familiar north bound and radio access.

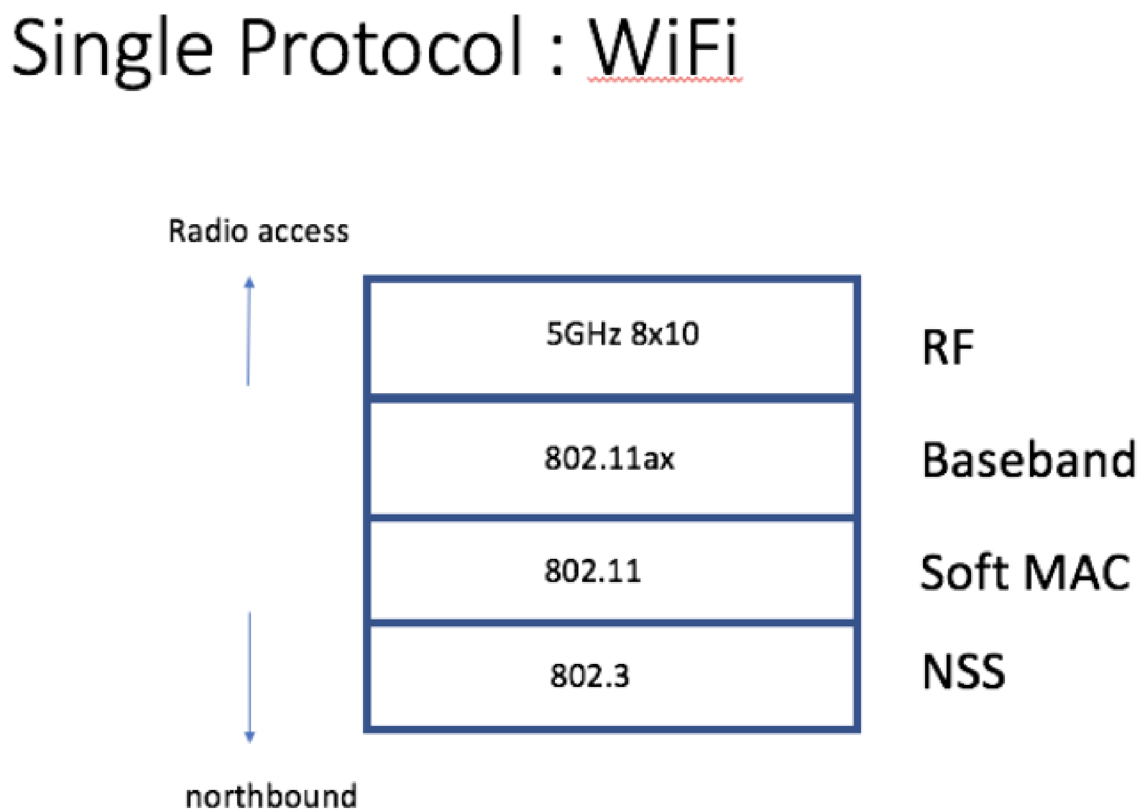

Figure 2

As illustrated in Figure 3, multiprotocol APs are a new, flexible type of AP which contain configurable baseband and Media Access Control (MAC) engines in Digital Signal Processor (DSP) and General Purpose Processor (GPP) based System on Chips (SoCs), simultaneously enabling more than one over the air protocol. Typical combinations include Wi-Fi and CBRS (LTE), Wi-Fi and LAA, Wi-Fi and 5G (New Radio (NR)), and 4G (LTE) and 5G (NR). Also, observation receivers are added to provide greater utility and monitoring functions.

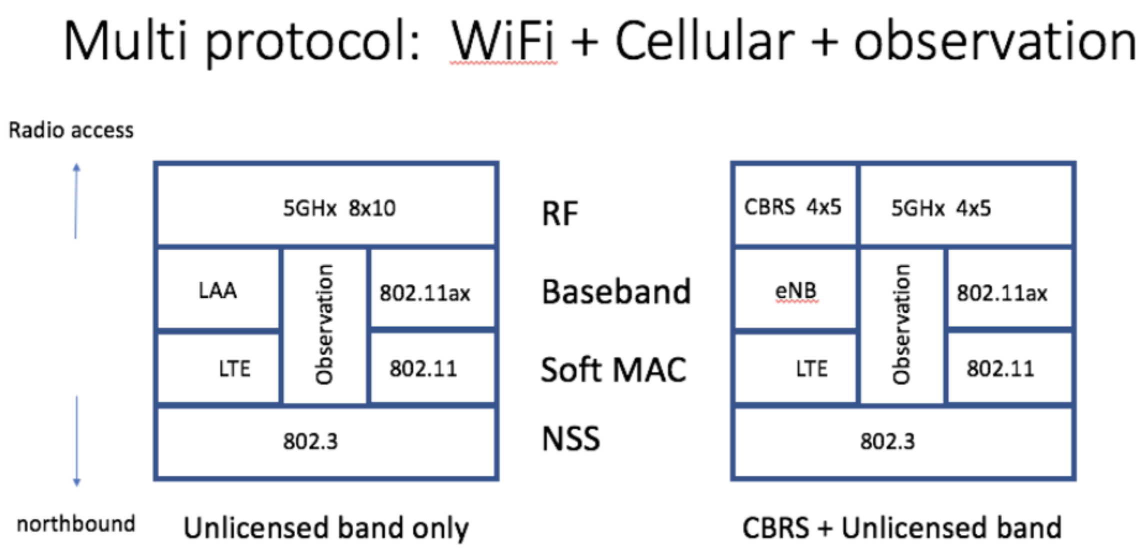

Figure 3

3GPP technical specs for 4G/5G TDD devices demand (1) high frequency accuracy (100 ppb) and (2) tight timing requirements for devices with overlapping coverage (1.5 us). Advanced modes such as inter Base Station (BS) Carrier Aggregation (CA) push this requirement to 130-260 ns. Typically, the devices are disciplined by Global Navigation Satellite System (GNSS) devices or by cellular Network Listen (NL) functions to derive frequency and timing from other GNSS-disciplined BSs. As long as BSs can “hear” each other, only one BS needs to be so disciplined, and the remaining APs may be “slaved” to this “master” node. Institute of Electrical and Electronics Engineers 1588 Precision Time Protocol (PTP) wireline protocols over the Local Area Network (LAN) are also employed to distribute this reference clock, albeit with some added error, making some CA schemes challenging. This also forces a requirement for any LAN switching equipment to implement the 1588 boundary clock function.

A new requirement is entered whereby a TDD anchor cell (e.g., CBRS) must be associated with one or more cross band CA cells (e.g., 5 GHz unlicensed band LAA). These anchor and LAA cells may be implemented on a multi-protocol AP. PTP suffers from inaccuracy due to both queuing delay variation from the network congestion as well as clock error because of the clock drift. LAN segmentation can affect the number of hops, impacting accuracy, and each intermediate switch must implement the boundary clock function. In all, sub-microsecond synchronization can be difficult to achieve in all scenarios. CA/LAA APs, in the interest of economy, may only be equipped with unlicensed band radios, precluding any NL capability on a cross band anchor frequency. At the same, the licensed band anchor APs may have unlicensed band (Wi-Fi) capability. Because each of these multiprotocol APs has a single SoC (implying the same clock domains in a common baseband architecture), cellular and Wi-Fi functions may be easily cross synchronized. A robust synchronization protocol is described which is implemented over Wi-Fi links between the multiprotocol APs. As illustrated in Figure 4 below, the absolute time/frequency reference of an anchor/master AP (said reference implemented by conventional means) may be propagated freely throughout the network.

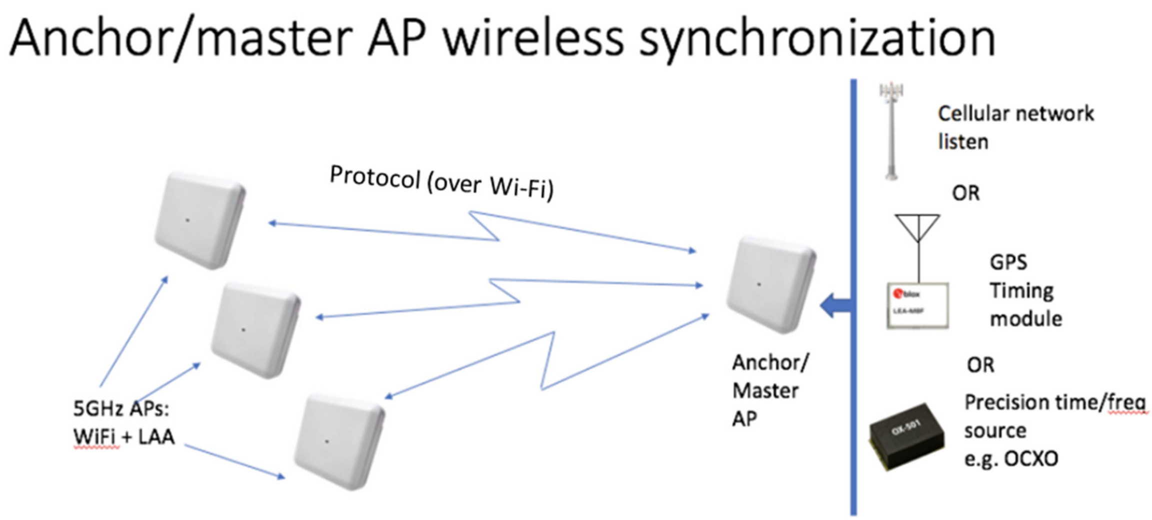

Figure 4

The Wi-Fi physical layer may be used to accomplish synchronization in excess of 3GPP requirements. One example includes the availability of passive OBS Rxs, tuned cross-channel to adjacent APs, which offers even more flexibility in lowering the protocol's overhead. Elements of this solution include time of flight measurement to cancel propagation delay error, enabling new precision location and security services; use of 5 GHz OBS Rxs to tune to neighbor AP 5 GHz service channel, thereby negating the need for channel change; and Tx packets with specific payloads for best frequency offset estimation.

In 802.11az, there is an exchange set up between two service radios (both with Tx and Rx) and those radios must be tuned to the same channel. As described herein, these two service radios operate on different channels. Rx-only observation radios tune to the channel of the service radio of the opposing AP. No direct exchange of timestamps is done over-the-air between service radios, like in 802.11az.

As described herein, there is no wireless exchange required to provide the timestamp. The OBS Rxs simply tune to the channel of the other radios transmissions and listen for beacons, which can include a high-resolution timestamp. The beacon transmissions may be coordinated across devices so that they do not occur too far apart in time (to control clock drift).

The transmitted beacon from the service radios are received at the opposing observation receivers and the Rx timestamp is taken. That creates four timestamps that can be shared over the wire or in a later beacon payload.

A calibration procedure is also performed to avoid differences in channel impulse responses across the two channels. This procedure involves comparing channel estimates between channels.

In 802.11az, the AP locations are known, while in the scenario described herein, the AP positions are not known. In this scenario, the pseudo-range includes the Time of Flight (ToF) between APs and would need to be removed for time synchronization to work between APs. Therefore, the iterative solution to track it out would not work for this situation. Instead the ToF exchange may be relied upon (from the 11mc and 1588 PTP) but it is performed over two frequency channels.

Dedicated monitor radios may be used to leverage dedicated scanning radios to hear the transmissions of the BSs without having to tune the primary radio off channel.

The system described herein can coordinate so that these beacons can occur nearly simultaneously, which avoid clock drift impairing a single exchange. Clock drift may still impair synchronization between beacons, but the raw single beacon estimate should not require correction due to clock drift.

In summary, techniques are described herein for leveraging observation receivers on APs to listen in-band to transmissions in the band of another AP. This enables performing time synchronization between devices without requiring any packet exchanges between devices to accomplish the synchronization.