Cisco 5G Vision Series: Licensed, Unlicensed, and Access-Independent Networks

What You Will Learn

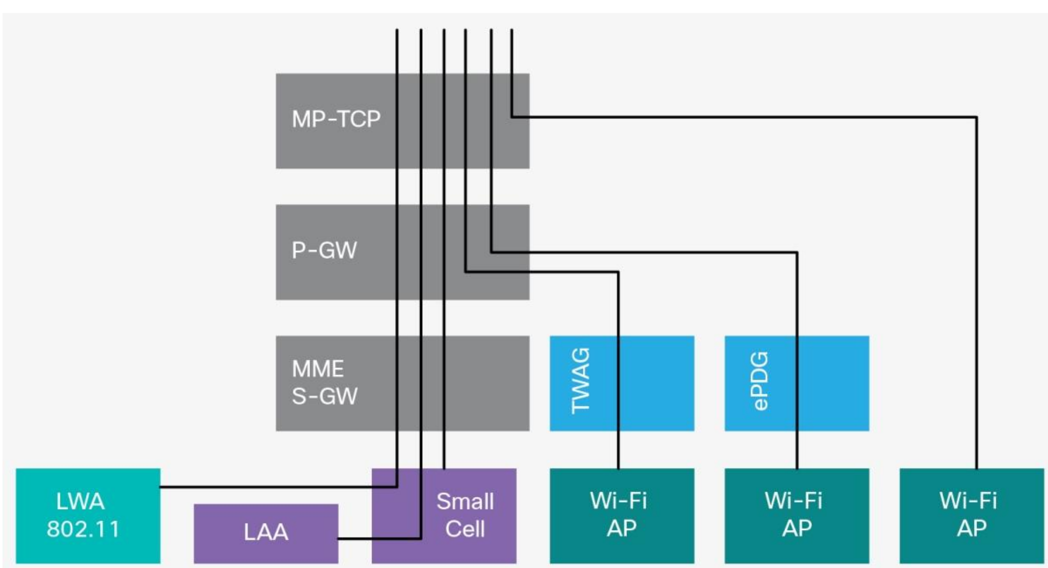
A very important capability of evolving mobile networks is the need to integrate and/or aggregate different radio access technologies (RATs) that span both licensed and unlicensed spectrum across 3GPP technologies such as fourth-generation long-term evolution (4G LTE) and fifth-generation (5G) mobile standards, IEEE technologies such as Wi-Fi, and Internet of Things (IoT) technologies such as long-range access (LoRA). This paper reviews different approaches to integration and aggregation and weighs their relative efficiencies and value as the industry evolves to 5G. Cisco engineers are working toward a common plug-in framework for all kinds of access technologies in the 5G core.

Integrating Licensed and Unlicensed Spectrum Assets

The integration of unlicensed network technologies such as Wi-Fi for use with conventional licensed cellular networks is now largely accepted as an essential ingredient of mobile network evolution. Compared to the potentially fragmented allocation of licensed spectrum, unlicensed 5 GHz solutions offer mobile operators the ability to use more than 450 MHz of unlicensed spectrum.

There are many different approaches to license-exempt spectrum integration and aggregation. Some of them integrate and aggregate license-exempt networks at the core network level, while others integrate and aggregate license-exempt capabilities at the radio access network (RAN) level. Several of the approaches are illustrated in Figure 1. This section focuses on those techniques for integrating and aggregating unlicensed spectrum at the RAN level.

Figure 1. Alternative Approaches for Licensed/Unlicensed Integration/Aggregation

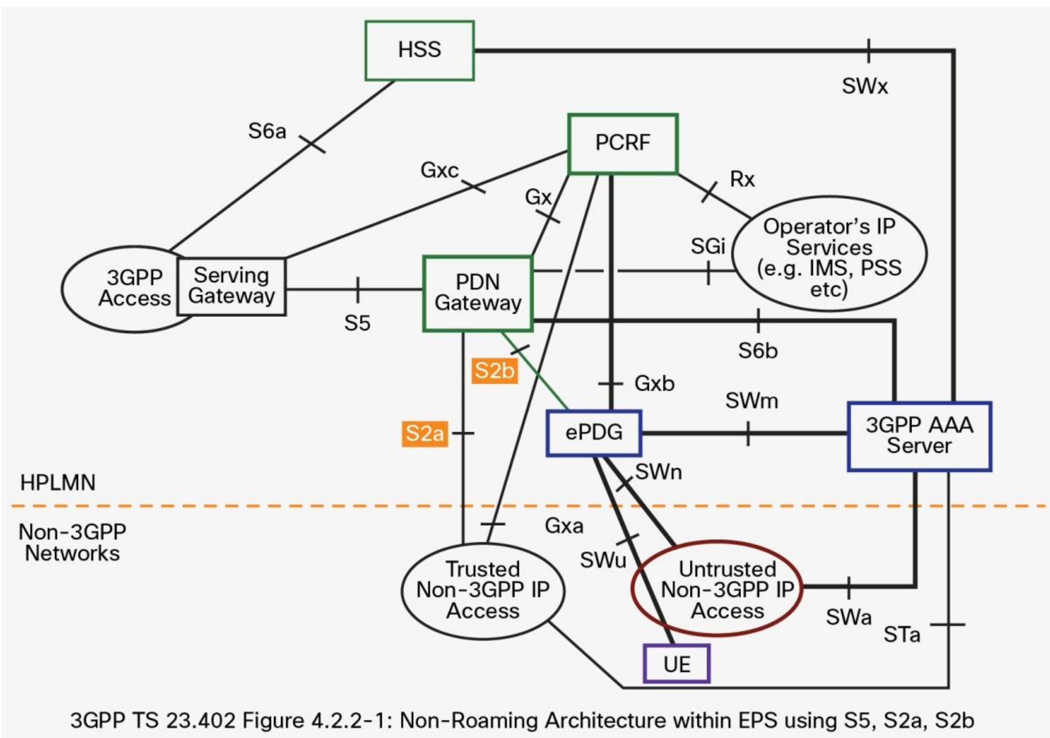


Wi-Fi Integration: Trusted Wireless Access Gateway and Enhanced Packet Data Gateway

The most basic forms of integrating licensed and unlicensed band technologies use the 3GPP architecture and interfaces from 3GGP technical specification (TS) 23.402 (shown in Figure 2). First there is the trusted non-3GPP IP access interface, which uses a trusted wireless access gateway (TWAG) to integrate Wi-Fi into the 3GPP core network through the S2a interface to the packet data network gateway (P-GW). This is usually used for offloading 4G data traffic to Wi-Fi. Then there is the untrusted non-3GPP IP access approach, which uses an enhanced packet data gateway (ePDG) to integrate Wi-Fi into the 3GPP core network through the S2b interface to the P-GW. This is usually used to enhance indoor coverage through voice over Wi-Fi (VoWi-Fi).

Connection managers in user devices, sometimes using the access network discovery and selection function (ANDSF), typically manage the interworking between the licensed band 4G access and unlicensed band Wi-Fi access. Note that TWAG and ePDG enable integration and interworking (that is, switching) between licensed and unlicensed bands through loose coupling at the network level. This provides flexibility and eases multivendor operation between licensed and unlicensed band solutions. However, these solutions have the disadvantage of not providing aggregation between licensed and unlicensed bands.

Figure 2. Trusted Wireless Access Gateway and Enhanced Packet Data Gateway Architectures

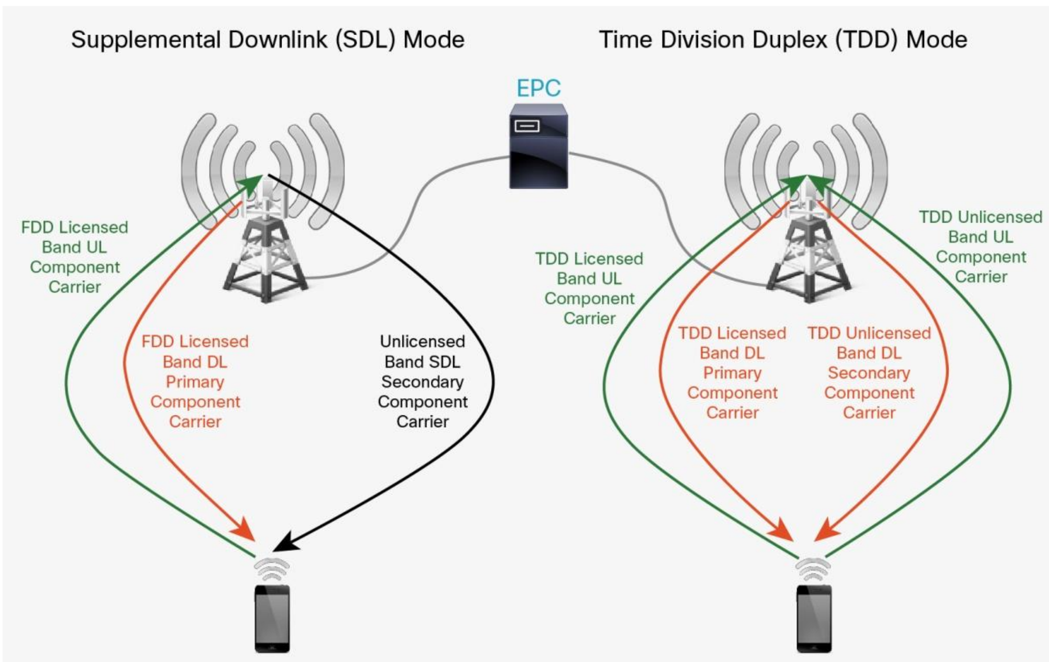


License-Assisted Access LTE

License-assisted access LTE (LAA-LTE) is a new licensed and unlicensed aggregation technique defined by 3GPP in Release 13 of its mobile broadband standards, which modifies the LTE signal so that it can be used in unlicensed spectrum. It's called "licensed assisted" because it requires the LTE carrier component used in the unlicensed spectrum band to be anchored by a primary component carrier in a licensed LTE spectrum band, as shown in Figure 3. Two options were standardized in Release 13. One features a supplemental downlink secondary component carrier, which is aggregated with a frequency division duplexing (FDD) primary component carrier in a licensed band. The other includes TDD carrier aggregation used to support the primary component carrier in the licensed band and the secondary component carrier in the unlicensed band.

Release 13 LAA-LTE includes mechanisms on the secondary component carrier to provide fair coexistence in the unlicensed spectrum band, most importantly a listen-before-talk (LBT) capability. LAA-LTE does have the advantage of providing aggregation between licensed and unlicensed bands, but it provides this through tight coupling at the radio access level (below the evolved packet core [EPC]). This often requires significant interoperability testing to provide multivendor solutions across the licensed and unlicensed bands.

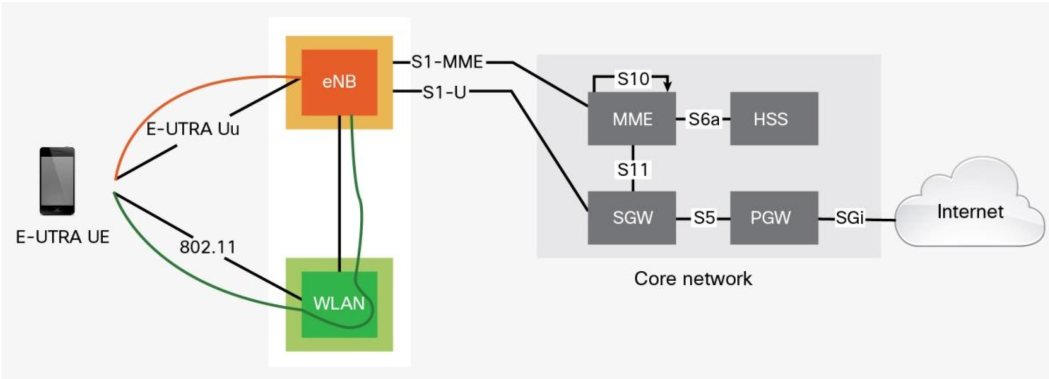
Figure 3. 3GPP Release 13 LAA-LTE Options



LTE-WLAN Aggregation

An alternative approach to LAA-LTE is called LTE-wireless LAN (WLAN) radio aggregation (LWA). It is similar to LAA-LTE supplemental downlink (SDL) mode in Figure 3, except that the unlicensed band SDL secondary component carrier uses the unmodified Wi-Fi air interface rather than LTE. This is done through aggregation of LTE and WLAN at the Packet Data Convergence Protocol (PDCP) layer or at the IP layer just above the PDCP layer. LWA aggregation was defined through the dual connectivity feature introduced in Release 12 (as opposed to using carrier aggregation), which means that the licensed band and unlicensed band transmissions can occur from two physically separated nodes (one being a WLAN access point), as shown in Figure 4. The LWA approach to aggregating licensed and unlicensed band spectrum has the benefit of making sure of fair coexistence in the unlicensed band because Wi-Fi LBT protocols are still used in the unlicensed component carrier. The LWA approach is also a looser form of aggregation than LAA-LTE because it uses the DC feature. But LWA is still not quite as flexible as network-level aggregation, which will be discussed in the next section.

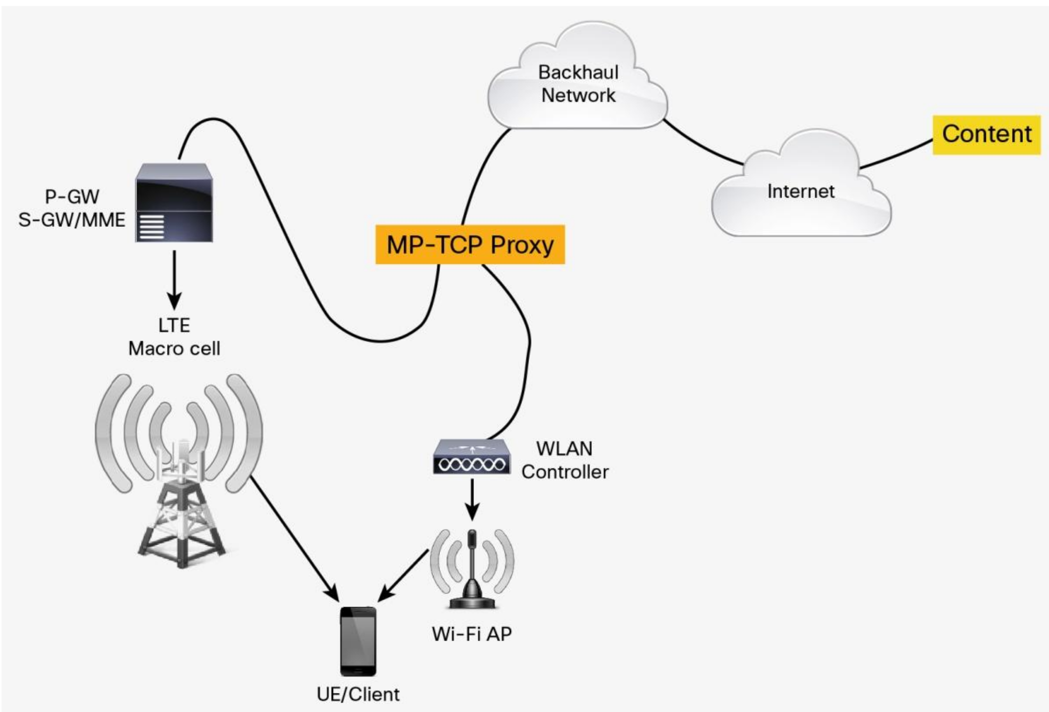
Figure 4. LTE-WLAN Aggregation (LWA)



Network-Level Aggregation

In the telecommunications industry today, other options are already emerging for multiconnectivity that can provide aggregation across licensed and unlicensed band solutions at the core network level. A few examples include multipath TCP (MP-TCP), as shown in Figure 5, and Quick User Datagram Protocol (UDP) Internet connections (QUICs). These options are very loosely coupled approaches that allow great flexibility in aggregating licensed and unlicensed band solutions from multiple vendors.

Figure 5. Multipath TCP



This paper has shown that there are many approaches to integrating and aggregating licensed and unlicensed band spectrum solutions. To date these approaches have been manageable because there are only a handful of air interfaces that are most commonly used for broadband data applications, which benefit the most from aggregation (for example, 3G, LTE, and Wi-Fi). With the advent of 5G and solutions such as mmWave band and the IoT, the number of air interfaces will expand rapidly, making intervendor interoperability a huge challenge if tightly coupled aggregation and interworking approaches continue to be used (for example, at the RAN level). Alternatively, a more loosely coupled aggregation and interworking approach to 5G and IoT through network-level aggregation will allow operators to deploy a pluggable access network that can provide multivendor interworking across any RAT in any licensed and unlicensed band. This is discussed in more detail in the next section.

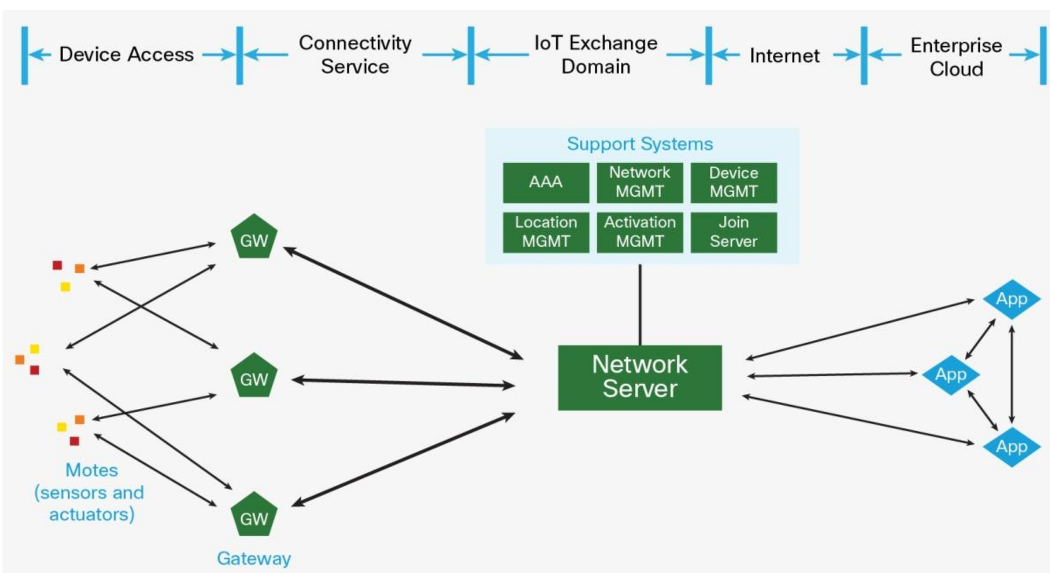
Pluggable Access Network

The 5G core must support devices without SIM cards as part of the goal of supporting heterogeneous access. It is a major objective of the Cisco® architecture to allow access networks to plug in transparently. This process is called the “onboarding” of an access network.

To promote innovation in the RAN, we are advocating a framework for creating a common plug-in for any access technology in the 5G core. For example, a vendor develops a powerful new low-power, wide-area (LPWA) technology at a price point that is very compelling for the operator. That technology comes with its own authentication, authorization, and accounting (AAA) framework. We propose that onboarding the vendor’s technology be accomplished by plugging it into the 5G core.

Consider an access example where a LoRA device can be plugged into the 5G core. Figure 6 provides a functional model of LoRA access.

Figure 6. LoRA Model for Access

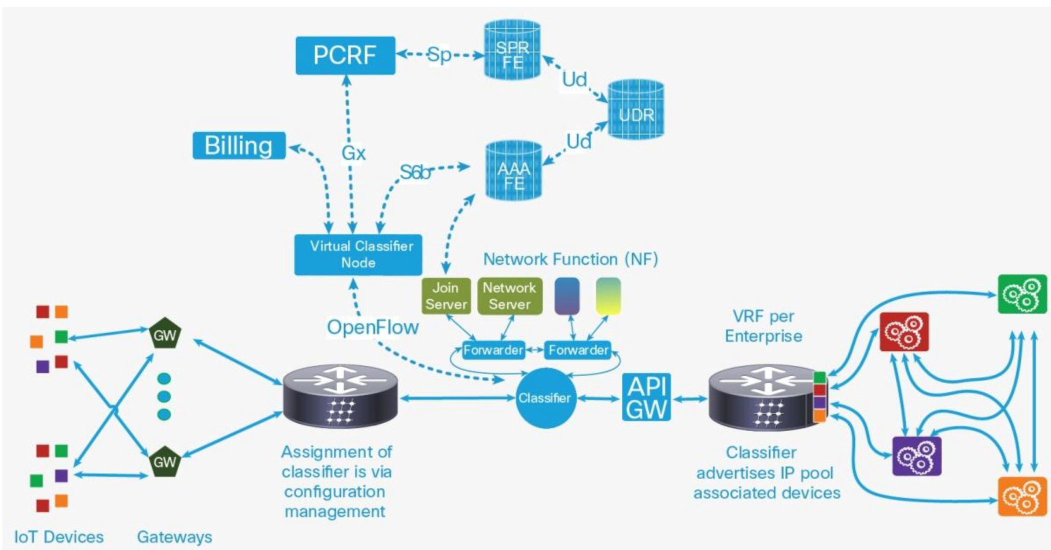


LoRA devices (called “motes”) normally don’t have an IP address and don’t require one. The gateway, however, can proxy an IPv6 address. The network server is an IP identity that manages IP access in the motes using their gateways. The join server handles the process of integration into the common functions that are shown in the rectangle at the top.

The onboarding could be accomplished as follows:

1. As shown in Figkure 7, the LoRA-specific network server functions and join server functions described in the LoRAWAN specification are included as service functions on a LoRA-specific service function chain.
2. LoRA-specific traffic is classified through interaction with the policy layer into a service chain specific to LoRA traffic.
3. Access control is within the 5G core set of common functions through an AAA front end to a usage detail record (UDR).
4. The network server resides on the LoRA-specific service chain.
5. An API gateway mediates between the LoRA traffic and those enterprises that consume the data from IoT sensors and control LoRA-based actuators.

Figure 7. Integration of LoRA into the Cisco 5G Core SGi-LAN: Example of Onboarding



Using service chaining, software-defined networking (SDN), and interaction with the policy layer as used in the Cisco concept for Gi-LAN, a LoRA access can be defined for the 5G core. Because the home subscriber server (HSS) plays no role in supporting LoRA access, the LoRA device identity information (EUI-64) is held in the UDR and exposed through an AAA front end.

Cisco's pluggable access-independent network architecture vision is ideally suited to provide flexibility to operators in deploying and providing integration, aggregation, and interworking across any current generation RAT (for example, 3G, LTE, Wi-Fi) and all future RATs (5G and IoT).

Conclusion

The flexible integration, aggregation, and interworking of licensed and unlicensed networks, spectrum, and multiconnectivity will be critical as new 5G and IoT RATs are introduced in the industry. Clearly there are a variety of approaches to these capabilities, with tradeoffs and different characteristics. Cisco is committed to providing the right solutions for each operator's particular set of needs and use cases. Our pluggable access-independent network vision will provide many benefits to all operators as they introduce 5G and IoT.

For More Information

For more information about the topics discussed in this white paper, visit:

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