Low power Wi-Fi opens doors in smart buildings and industry

Adding Wi-Fi 6 enhances current IoT applications while enabling many new ones.

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The proliferation of protocols enables many new applications in cities, buildings and vehicles.

According to the Wi-Fi Alliance, the organisation that promotes the use of Wi-Fi, the economic value derived from the technology is $3.5 trillion. (Global Economic Value of Wi-Fi 2021 - 2025.)

The alliance says there are 18 billion Wi-Fi devices in use and 4.4 billion annual shipments, of which 2.3 billion meet the latest Wi-Fi 6 standard. That makes Wi-Fi seriously big business, with much of its huge popularity down to Wi-Fi's internet protocol (IP) interoperability. This allows a Wi-Fi device to connect directly to the cloud using any of the millions of already-installed access points (AP).

Public Wi-Fi access will benefit from the new standard's high bandwidth and speed, for example allowing large numbers of users in malls or at airports to make quick purchases and stream videos or music.

Moreover, the adoption of Wi-Fi 6 has made the technology better suited to the IoT (internet of things), where it complements existing IoT technologies used for low power networks, for example, Bluetooth LE and Thread. Wi-Fi 6 offers higher throughput and longer range than these other protocols, allowing it to enhance existing IoT applications while enabling new ones.

Building Wi-Fi 6 for the IoT

Wi-Fi 6 introduced many enhancements to the specification but those most useful for IoT solutions are OFDMA (orthogonal frequency division multiple access), beamforming, longer symbol duration, target wake time or TWT, a new power saving mode (PSM) and basic service set (BSS) colouring (a method of differentiating between APs broadcasting on the same channel).

TWT and OFDMA make the most significant contribution to power saving and enable energy-constrained devices to use the benefits of Wi-Fi where it might not have previously been possible.

Earlier versions of the Wi-Fi standard do include PSM, but these are controlled by the AP and offer limited flexibility to the end device. Generally the end device has to remain awake to receive the AP's beacon ahead of any data exchange, which effects battery life.

By contrast, the TWT PSM included in Wi-Fi 6 enables the end device to individually negotiate a wake-up schedule with the AP. This allows it to sleep for defined periods, helping cut power consumption significantly and allowing data exchange to happen at the agreed wake-up time. A further benefit of TWT is that it enables interference mitigation by letting the AP allocate dedicated time slots for each end device's data transfer.

More sub-carriers allow larger sensor networks

The OFDMA employed in Wi-Fi 6 allows for a higher number of sub-carriers within a single Wi-Fi channel. For example, a 20MHz channel can be further divided into 117 sub-carriers each side of the channel's central frequency. Groups of sub-carriers can then be allocated to a certain end device while other groups can be allocated to different end devices depending on the data traffic requirement.

This technique is called multi-user uplink/downlink. It does add complexity to AP side of the link but not to the IoT end device because that only needs to operate with its dedicated sub-carrier frequencies. OFDMA is particularly useful for large IoT sensor networks with many end devices, but with each needing to send only a small amount of data, because it enables dynamic, flexible and highly efficient division of the available spectrum bandwidth. Using full specification Wi-Fi 6, up to 1,500 devices can be connected using a single AP. This can make Wi-Fi 6 particularly useful in, for example, airport applications, resolving the current challenges of sporadic coverage and time lags that hinder legacy services.

Without OFDMA, a large sensor network would typically generate a lot of channel congestion, as Wi-Fi client devices attempt to access the medium without much co-ordination, causing higher interference levels and resulting in reduced throughput.

The multi-user uplink/downlink feature will allow Wi-Fi 6 routers to improve wireless performance in the home, allowing greater use of smart home devices as well as resolving streaming difficulties with neighbouring users.

Nordic Semiconductor has introduced a Wi-Fi companion IC, the nRF7002, that will add low power Wi-Fi capabilities to embedded IoT systems. It can be used to enhance existing applications. For example, the high throughput is useful for scenarios when an IoT end device must transmit occasional high volumes of data – such as when the device performs over-the-air (OTA) updates for complex firmware.

New uses in home and industry

The companion IC is designed to complement the company's multi-protocol SoCs (system on chips) and cellular IoT SiPs (system in packages) and is controlled by the SoC or SiP's embedded Arm microprocessor. The companion IC incorporates co-existence technology to ensure it doesn't try to transmit on the 2.4GHz frequency at the same time as a Bluetooth LE SoC.

The combination of multi-protocol SoC or cellular IoT SiP and Wi-Fi 6 companion IC enables many new applications. For example, the companion IC boosts throughput to support applications such as security cameras. It also allows the addition of Wi-Fi location services to GPS asset tracking devices.

In the smart home, Wi-Fi's native IP interoperability is being leveraged by the Connectivity Standard Alliance's recently introduced Matter standard. This protocol works by building on top of existing smart home wireless technologies (Thread, Bluetooth LE and the Ethernet wired protocol) by providing a unifying application layer. Wireless Matter devices will use either Thread or Wi-Fi for transport (and Bluetooth LE for commissioning). The Matter application layer makes it simpler for Thread devices to communicate with a Wi-Fi network and from there to the cloud. Wi-Fi also boosts range and offers higher security for sensitive data transfers than Bluetooth LE.

In industrial automation or warehouse applications, the companion IC will play a vital role in making it easy to build a gateway between low power Bluetooth LE or IEEE 802.15.4 -based networks and the cloud.

The single band (2.4GHz) nRF7001 is for use in cost-optimised designs.

The nRF7002 Wi-Fi companion IC will add low power Wi-Fi capabilities to embedded IoT systems.

A dual band device

The nRF7002 is a dual band (2.4 and 5GHz) device which features a low power capable Wi-Fi radio, advanced security features and the 2.4GHz co-existence mechanism. The IC is compatible with earlier Wi-Fi standards (IEEE 802.11a/b/g/n/ac) in addition to Wi-Fi 6 (IEEE 802.11ax) and supports one spatial stream, 20MHz channel bandwidth, 64 QAM (quadrature amplitude modulation) and 86Mbit/s PHY throughput, OFDMA (downlink and uplink), TWT, BSS colouring and beamforming (on the receiver side). A 2.4GHz-only companion IC is also available.

When powered from a 2.9 to 4.5V supply, the companion IC's radio operates with a peak transmit current (2.4/5GHz) of 191/260mA and a peak receive current of 60/56mA. Sleep current, with real time clock (RTC) is 15µA and shutdown current is 1.7µA. With TWT (2.4GHz, 60s interval), the average current is 29.5µA, reducing to 18.2µA for one day intervals. Sensitivity (1DSSS, 2.4GHz) is -98.6dBm and TX (max) (2.4/5GHz) is 21/15dBm.

The device supports the Wi-Fi Protected Access (WPA)3 security protocol which features increased cryptographic strength and more robust authentication. This support for WPA3 removes some of the security burden from the host side.

The companion IC implements the IEEE802.11 physical layer (PHY) and medium access control (MAC) firmware only. The Wi-Fi driver and Wi-Fi and TCP/IP (transmission control protocol/IP) stack are held on the host processor. Communication between the MAC and the other parts of the stack is via the IC's SPI (serial peripheral interface) or quad SPI (QSPI). There is a development kit to introduce developers to a multi-protocol SoC and Wi-Fi companion IC.

The company also offer the nRF7001, which is a single band connectivity of 2.4GHz intended for use in cost-optimised designs.

Extending location services

The Wi-Fi companion ICs make it straightforward to add Wi-Fi SSID location services to existing products such as asset trackers.

For example, one can be used with a cellular IoT SiP to enhance location accuracy. Together with the company's nRF Cloud Location Services, the SiP can use cell-based (single- or multi-cell) and/or GPS-based (assisted- or predictive-GPS) location features. Wi-Fi SSID locationing is more accurate than cell-based location features and less power hungry than GPS.

Wi-Fi excels where GPS struggles. For example, among a city's high buildings, the GPS signal can be patchy, yet there is typically a high density of Wi-Fi APs. Wi-Fi is also good indoors where GPS fails. The Wi-Fi companion looks for a nearby AP and obtains its SSID. The cellular IoT SiP then sends the SSID to nRF Cloud, which in turn checks a Wi-Fi AP database. nRF Cloud then returns the location, with the degree of uncertainty, to the SiP, or elsewhere.

With its higher throughput, longer range and power saving features, Wi-Fi 6 is set to boost the capabilities of embedded IoT systems - opening new applications for wireless technology in virtually every market.

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