SIEMENS

White Paper

Wi-Fi 6 in the Industry

Industrial requirements for IEEE 802.11ax

Wireless networks are rapidly progressing, driven by the requirements of a wide variety of users. The current IEEE 802.11ax standard is the first Wireless LAN (WLAN) standard with the primary goal of increasing the equal treatment and thus the throughput per user, in other words, per device.

At the same time, improvements are being propelled that will lead to an efficient operation even in battery-powered applications such as Automated Guided Vehicles (AGVs) or mobile end devices. The keyword here is the topic of the Internet of Things (IoT).

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Technically, these improvements are realized by:

- Orthogonal Frequency-Division Multiple Access (OFDMA) – division of the spectrum into smaller subchannels to reduce overhead
- Target Wake Time (TWT) – improvement and extension of the low-power functionality to obtain longer runtimes even when battery-powered
- Spatial Reuse – more efficient use of the frequency spectrum

For real-time requirements existing in the industrial environment, the standard lacks specifications for the use of OFDMA as well as improvements for the roaming behavior of the clients (the change from one Access Point to the next Access Point). In addition, particularly at the beginning of the rollout of IEEE 802.11ax, the already installed, old clients will largely negate the potential performance gains.

The trend in automation is toward automation protocols with hard real-time requirements that are operated in parallel with data-intensive applications such as augmented or virtual reality. In order to operate all applications via a wireless connection, adjustments to the mechanisms already present in the standard are needed.

Here, it will not only be necessary to utilize the possibilities of the new standard, but also to go beyond and create further added value in the automation regarding real time and reliability.

Why another IEEE 802.11ax white paper?

The use of Wi-Fi 6 in the digital factory or in the process industry is not described in the white papers already available.

Against the backdrop of many years of experience in the implementation of wireless automation solutions, the white paper examines the technical improvements of the standard with regard to the fields of application in industrial and automation environments.

The content of the white paper presents the following topics:

- The history of the WLAN standard with a footprint of now about 35 billion devices sold since 2010
- The challenges that every interested person and professional already knows when it comes to WLAN (also known as Wi-Fi)
- The technical details and achievements of the new standard
- The possible uses and implications for industrial applications
- The open issues of wireless technology

Market development

The first WLAN standard was released in 1997 with a maximum data rate of 2 Mbit/s.

Among others, the Wi-Fi Alliance with its compatibility efforts has contributed greatly to making the use of Wi-Fi possible in a convenient manner, however with a very strong focus on the largest application area, namely the consumer market.

Wi-Fi has been prospering in different industries for years – supporting mobile equipment, machine communication, logistics and intralogistics processes, and individual rotating or mobile process and manufacturing steps. A few facts to visualize the last paragraphs:

- Business transactions with Wi-Fi are currently valued at around USD 2 trillion worldwide
- In industrialized countries, almost every private household has an Access Point
- Wi-Fi has become an indispensable part of mobile applications

Why Industrial Wireless LAN?

The WLAN standard has been developed over the years primarily with the following scenarios in mind:

- Static work on a laptop
- Static links between, for example, buildings

Only over time have mobile applications, which also actively need a short transition period between different Access Points, become more relevant. One example is voice and video data. These scenarios differ from the environment and hardware requirements as well as the communication requirements of industrial applications.

To implement applications such as intralogistics shuttle systems, heavy-load overhead monorails, crane automation, or AGVs, the following requirements are placed on the WLAN communication – depending on the application:

- Ensured fast response times
- High availability of the communication
- Very fast roaming for mobile applications

Added to this are factors such as simple commissioning and maintenance. These requirements are not placed on a standard WLAN per se, which is why an extension of the standard to the requirements of the applications delivers substantial added value.

The environmental conditions compared to an (air-conditioned) office differ in the industrial environment. The table (see below) describes possible challenges and how the devices are designed accordingly.

Challenge	Solution
Use in the freezer area or steel works	Extended temperature range of the devices
Attachment to vibrating surfaces	Special hardware stress tests, special connection technology for the cables (Ethernet FastConnect or M12)
RF and voltage spikes	Increased insulation values both at the voltage input and at the RF module
Environment impacted by water and dust	Hardening of components through increased protection class such as IP65

Table: Hardware requirements

IEEE 802.11ax (Wi-Fi 6) in automation and digitalization

This chapter describes the objective of the standard and the most important technical innovations, as well as their added value and limitations with regard to industrial applications. With Wi-Fi 6, a WLAN standard is entering the market for the first time, whose main focus is not exclusively on increased gross data rates. The main motivation the authors of the standard had in mind was to increase the number of WLAN clients and thus the efficiency in environments with many users.

The objectives here:

- Greatly increased average data rate in an environment with a large number of users
- More efficient use of the frequency spectrum
- Increased runtime of battery-powered devices

Objectives essential for automation solutions were not focused on:

- Allowable maximum latency with regard to a client
- Improvement of the speed of a roaming process for mobile applications
- Maximum duration for a roaming process

These will continue to require specialized solutions in the future. This chapter describes the most important functions of the new standard and relates these to possible advantages in targeted application.

Orthogonal Frequency-Division Multiple Access (OFDMA)

Principle of operation

The greatest advantage IEEE 802.11ax provides is OFDMA, a completely new type of data transmission for WLAN. WLAN currently utilizes Orthogonal Frequency-Division Multiplexing (OFDM) for the data transmission. With OFDM, only one participant can communicate at a given time. The communication channel is fully used during the data transmission (see figure 1). With IEEE 802.11ax, OFDMA is introduced for the data transmission. Here, a communication channel is divided into up to nine subchannels, so-called resource units (RUs). These subchannels can be distributed to different users so that they can communicate at the same time (see figure 2). OFDMA is used in mobile communications technologies such as 4G and 5G and – thanks to its increased efficiency – is now also finding its way into WLAN.

Implications

If there is the possibility of not having to integrate older clients into an application or of being able to treat them separately, it is possible to benefit as follows from the OFDMA access:

- Serving of multiple users in less time
- More efficient transmission of small data packets
- A better way to implement QoS (Quality of Service) mechanisms

What does that mean specifically for industrial applications?

OFDMA by itself is not enough for executing critical automation tasks.

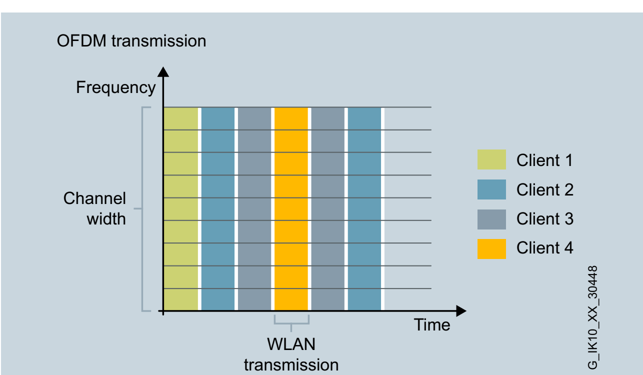

Figure 1: OFDM communication

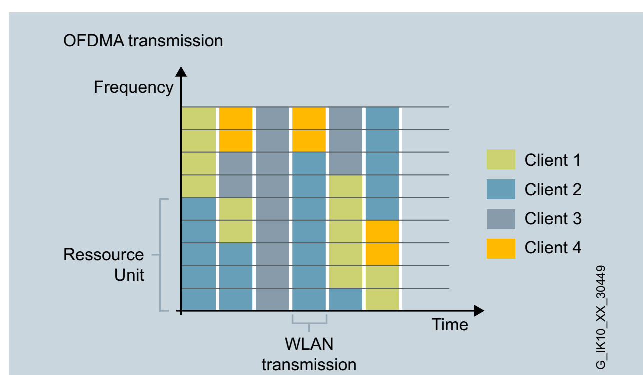

Figure 2: OFDMA communication

By developing a polling mechanism based on OFDMA, it will be possible for industrial applications to achieve low latencies permanently at an Access Point in pure Wi-Fi 6 environments. What must also be considered here is the roaming behavior, i.e., the change of a client from one Access Point to another. There is no improvement in the standard here and the maximum time for the roaming process is dependent on the client. The maximum time for a transition between the Access Points cannot be calculated.

To create a deterministic behavior that is suitable for automation applications, special solutions outside of the standard are required. As an essential part of the standard, OFDMA – when applied correctly – makes it possible to establish increased fairness between the users at an Access Point. However, this alone does not improve maximum latency.

Target Wake Time (TWT)

Principle of operation

The increasing need to support IoT devices and competition from other technologies were the motivation for revising the low-power functionality. IEEE 802.11ax extends the mechanisms for energy saving and makes them more efficient. TWT enables trigger-based data transmission.

The Wi-Fi (WLAN) clients can now "go to sleep" between sending and receiving packets and only wake up at an agreed time, if necessary after many hours, in order to resume the data transmission. There are different options for using the mechanism as energy-saving and flexible as possible (see figure 3).

- Individual TWT:
  The time for the next transmission is exclusively agreed between Access Point and client.
- Broadcast TWT:
  The time for the next (multicast) transmission is specified by the Access Point – also for groups of Wi-Fi (WLAN) clients.
- Opportunistic Power Save (PS):
  The client reacts to the data packets of the Access Point; no fixed time interval is negotiated.

Implications

This feature brings several advantages for industrial applications, including:

- Longer runtime of battery-powered applications, e.g., shuttles and AGVs, insofar as the Wi-Fi client can control the feed-in of the respective device
- Interference-free, since planned access of the individual clients to the communication channel

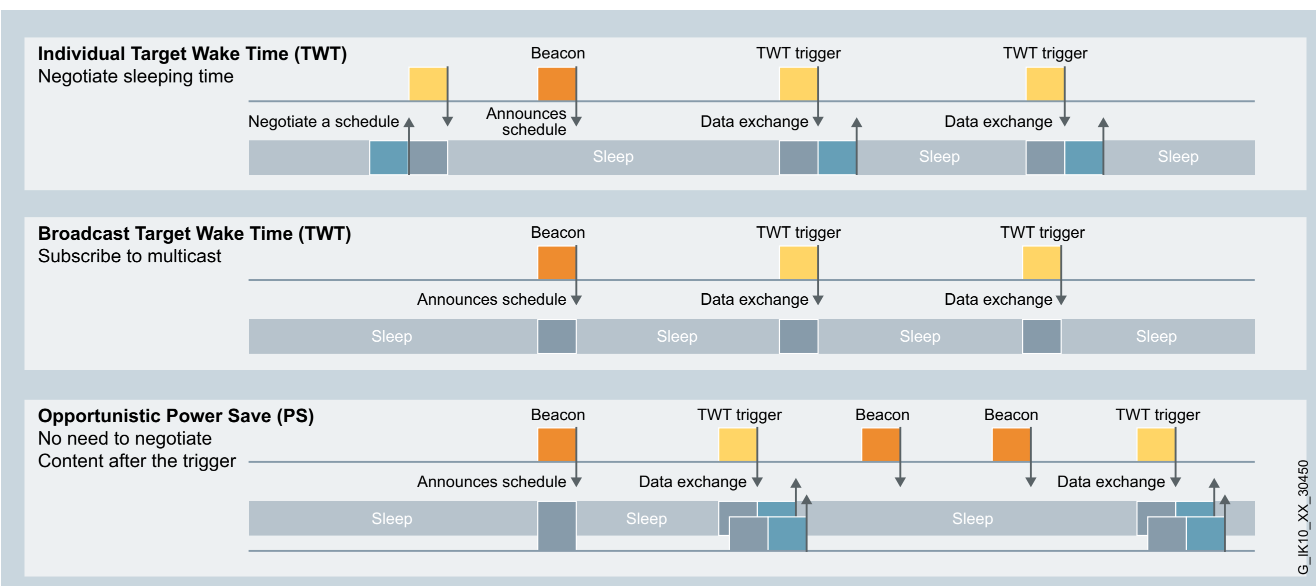

Figure 3: Target Wake Time (TWT)

Spatial Reuse

Principle of operation

Wi-Fi as a shared medium with a varying number of channels in the 2.4 GHz and 5 GHz bands always requires a good planning of the installation. The objective of this frequency planning is, among other things, to prevent or at least minimize effects due to overlapping channels of the same frequency. The resulting effects are referred to as Co-Channel Interference (CCI) or Overlapping Basic Service Set (OBSS) (see figure 4).

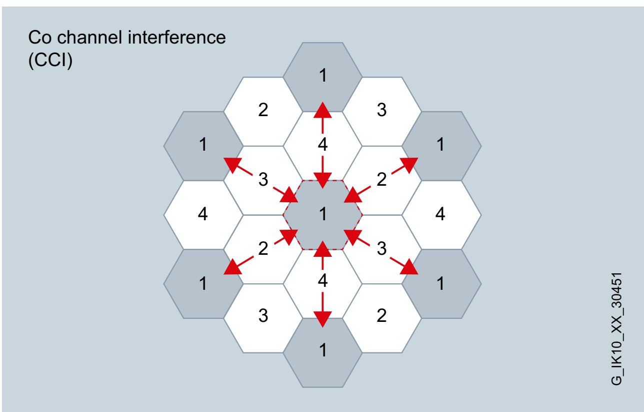

Figure 4: Co-Channel Blocking

With the so-called Spatial Reuse by means of BSS (Basic Service Set) Coloring, the standard wants to enable the reuse of channels, even if they are relatively close together locally, which would normally lead to strong interference. For this purpose, a "color" (de facto a number) is assigned to the BSS of an Access Point. With this color assignment, the users can communicate even if the channel is actually occupied by users of a different color, provided that they are not transmitting too strongly on the channel. This can be pictured as a disco, in which there are of course a lot of loud background noises. The human ear is nevertheless able to filter out the speech color of the dialog partner (see figure 5).

Implications

Spatial Reuse as a technology is newly defined in the standard. In theory, it enables a considerably more efficient use of the spectrum and new paradigms when planning facilities. The following advantages can be achieved in industrial applications:

- Easier coordination between different equipment suppliers in a factory
- In industrial IoT environments, a better distribution of the clients to different, interference-free Access Points

However, it will be necessary to wait first and see when and how this feature is implemented in chipsets and which promises from the standard are kept. The implications of Spatial Reuse for productive facilities can then be estimated from this.

Further improvements

The improvements listed in this chapter make it possible to get more out of the WLAN (Wi-Fi) technology in special applications. For the majority of industrial applications, however, they are categorized as less gainful than the technologies described in the previous chapters.

Uplink MU-MIMO
(Multi-User Multiple Input/Multiple Output)

MU-MIMO, which was already introduced with IEEE 802.11ac (Wi-Fi 5), but was hardly implemented and used, is now also specified for the uplink. It makes it possible – per antenna – to speak to any client on the same channel. What sounds outstanding in theory has to overcome the following challenges:

- To be able to distinguish the streams, the clients must learn the transmission path before the data transmission and again if the position or environment of one of the clients changes even slightly. This creates overhead and a certain latency (see figure 6).
- Learning the transmission path requires increased computing power for the necessary mathematical operations.

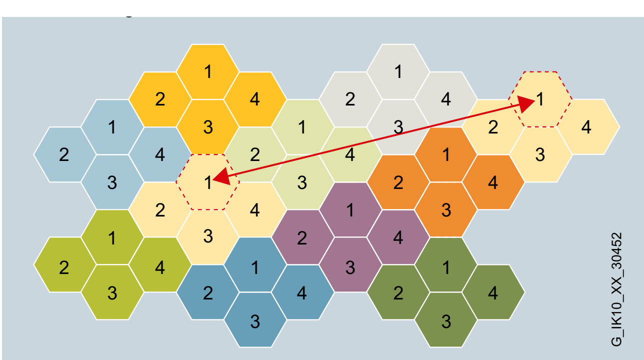

Figure 5: BSS Coloring

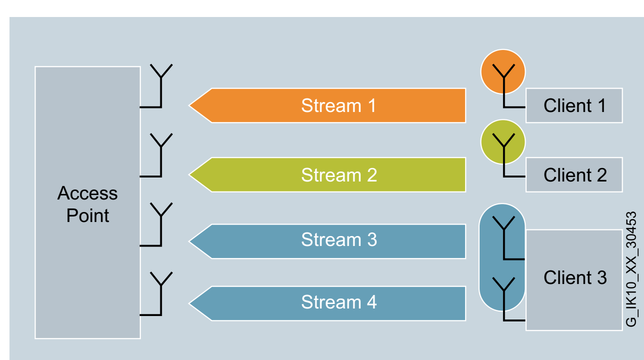

Figure 6: Uplink MU-MIMO

This technology is therefore most useful in static arrangements with large amounts of data to be transmitted. That combination of static arrangement and large amounts of data to be transmitted is rarely encountered in industrial environments.

Increased interference immunity and range

For use outdoors and for greater range, a longer prefix and the so-called Dual Carrier Modulation are introduced, in which the same signal can be sent in two different frequency ranges within the channels used. These mechanisms reduce the maximum data rates, but increase the robustness in difficult environmental conditions.

Higher modulation: 1024-QAM

So far, up to 256 bits are transmitted per symbol (256-QAM). Under good conditions, IEEE 802.11ax will increase this to up to 1024 bits via higher modulation (1024-QAM). This feature increases the achievable maximum data rate, which is helpful in many applications. However, a high data rate alone is often not deciding, since it is also about a fair distribution of this data rate so as not to cause timeouts.

Open issues

The following issues are still open when it comes to the use in automation applications:

- Legacy clients:
  In environments with clients of older standards, the advantages of the new technology are limited or void.
- OFDMA for real time:
  Real time and deterministics were not focused on when designing OFDMA. Time critical / deterministic requirements as necessary in many industrial applications need a guaranteed maximum response time between clients and Access Points. This requires adaptions in the software of Access Points and clients.
- The IEEE 802.11ax standard does not bring improvements to the roaming behavior of clients. The roaming behavior continues to depend on:
  - How the client scans the individual channels.
  - Which settings on the client with regard to scanning and roaming behavior are possible.
  - How many channels are used in an application.
  - Whether a central radius server or other login mechanisms are used.
  - Whether and how the standards such as IEEE 802.11r/k/v are supported by Access Points and clients.

  The roaming time of a client can ultimately be between a few milliseconds and several seconds.

  In order to avoid this unacceptable behavior in critical applications, a special solution is required that enables the maximum time for a roaming process to be calculated and kept very short.

Conclusion

With IEEE 802.11ax, the IEEE has succeeded in making great strides for the future of WLAN. It is the first WLAN standard that focuses on the fair handling of many users and not exclusively on an increase of the gross data rate. The resulting technical improvements and optimizations deliver a toolbox that, when applied correctly, enables significant performance gains – also for the industrial sector.

Robust Industrial Wireless LAN products from Siemens, both with the functions of the standard and with industrial extensions, will continue to facilitate the wireless operation of applications with high performance and reliability in the future.

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