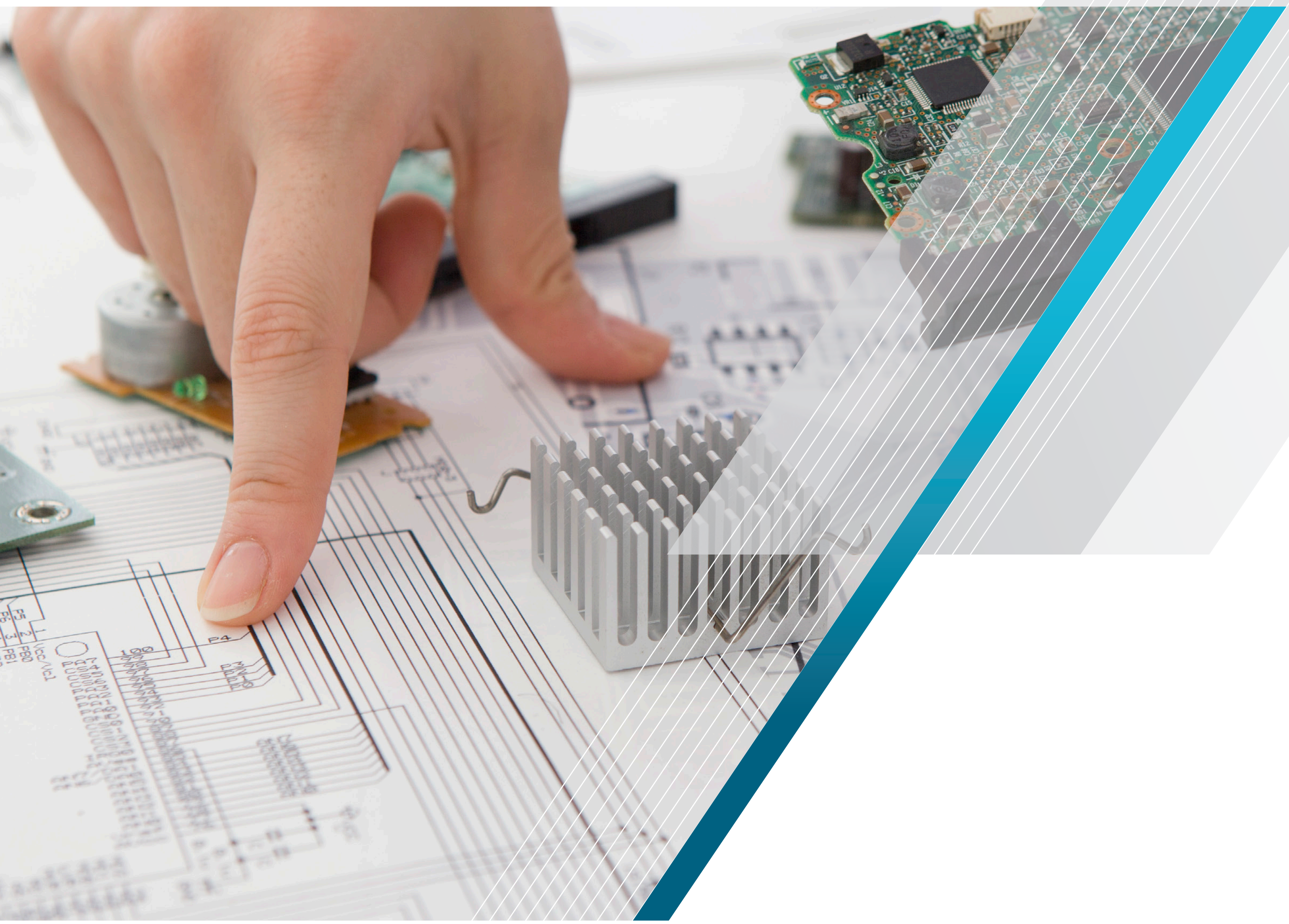
Selecting the Right Wireless Module

TUTORIAL



Tektronix®

Wireless Module Selection Guide for IoT Hardware Developers

The disruptive IoT Growth Projections

Wireless embedded modules (WiFi, Bluetooth, Bluetooth Low Energy, ZigBee …) have made simpler the development of IoT device hardware. Yet, there are many factors to consider when you are at the stage to choose one of them for your IoT hardware development project. This paper highlights some of the key choice factors.

Embedded electronic devices are now adding the capability to be accessible from the Internet or are able to push data to the "Cloud". This new trend in connecting smart electronic devices (the things) to the Internet is called the Internet of Things (IoT).

There is a switch from the era of "Internet of People" to the era of "Internet of Things". Many research studies have envisioned that 20 to 50 billion smart devices or "things" will be connected to the internet by 2020. The attractiveness of the IoT market is driving the creation of many new businesses.

The Internet of Things, along with other breakthrough technologies, will revolutionize nearly every industry. However, the three verticals below are already seeing big changes:

- ***Industrial:*** *delivery services tools, factory and office automation, smart farming, smart metering, smart vending machines, etc.*
- ***Consumer devices:*** *home appliances such as home thermostats and refrigerators, TV set top boxes, connected car devices, etc.*
- ***Wearable devices:*** *smart watches, fitness & health monitoring devices, etc.*

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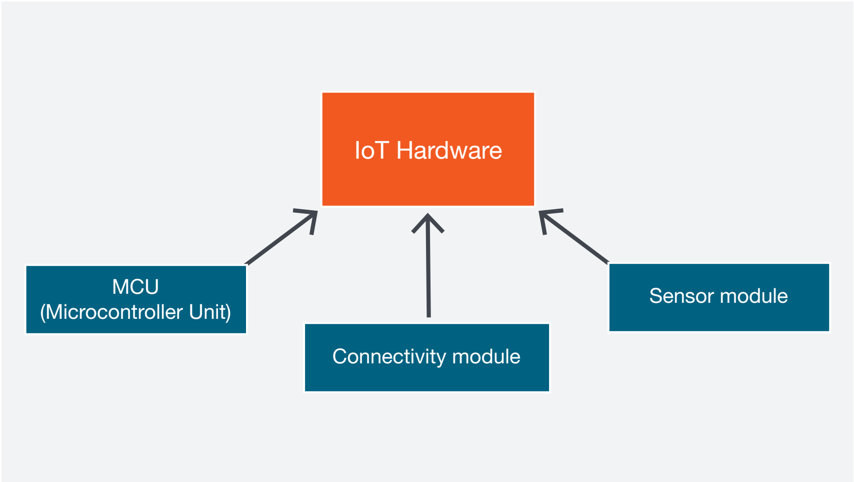


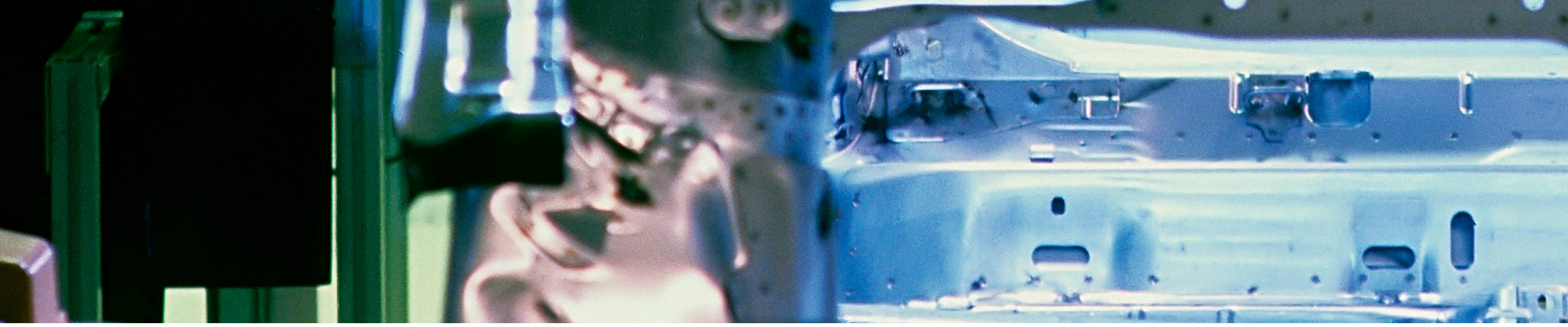
Figure 1. *There are a number of factors driving the proliferation of IoT ready devices.*

Source: Raymond James research.

IoT Device Hardware

The main hardware components of an IoT device are:

- **MCU (Microcontroller Unit):** the processing unit together with the memory device.
- **Connectivity module:** wireless or wired connectivity module enabling the device to communicate with other devices.
- **Sensor module:** temperature, proximity, movement, humidity, current, voltage, etc. >>



IoT Hardware Development Solutions

As in any design activity, there are several approaches to designing IoT hardware and devices. Some common design approaches include:

Make versus Buy: The first choice to make is a make versus buy decision. The expertise, resources, and RF knowledge required to develop a working and ready for the market IoT hardware is quite high and difficult to achieve for many organizations. Very often, time to market pressure doesn't allow to spend time building that expertise and knowledge from nothing. However, the decision of developing an in house wireless connectivity can increase an IoT project budget by 50,000.00 USD to 150,000.00 USD. The targeted production and sales volume needs to be large enough to compensate this investment.

Chip design solution: The development starts from the integrated circuit chips (wireless transceiver chip, MCU chip, etc.). IoT development team will need to design the whole system, select the required components in order to get a working IoT device.

SOC design solution: This is the approach where the IoT development team starts from a System on Chip (SOC) component. The SOC can integrate the main chipsets (MCU + wireless transceiver). Still some work need to be done as the development team will need to put the SOC together with antenna and other components to get a working IoT device.

Embedded Module solution: This is the development approach that is closer to final product. The embedded module consists of a ready to use solution that will drastically cut down the hardware development work.

A typical implementation board of an IoT device based on a wireless embedded module is shown in Figure 2.

To avoid the risk of failure and project delays, many companies will go through the "module" path. That doesn't mean however that they are engaged in an easy path. The wireless module selection is another challenge.

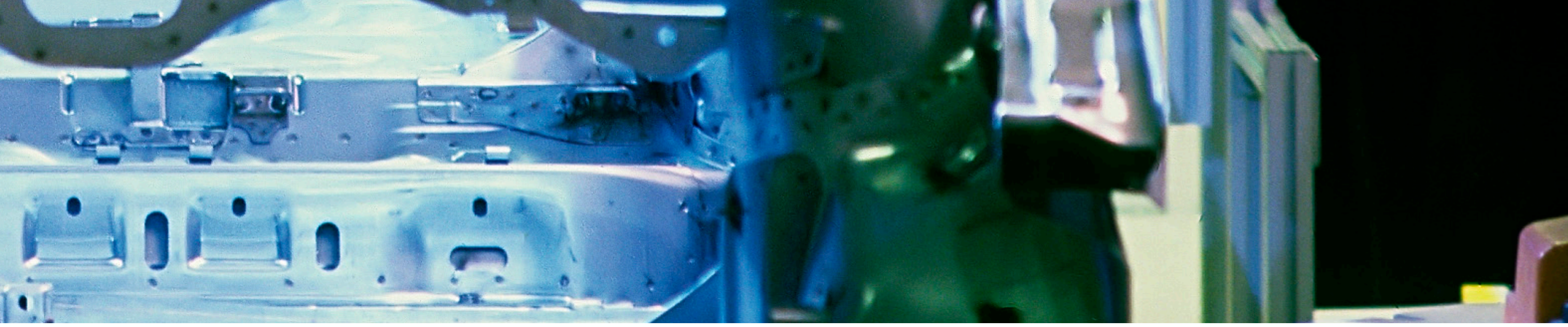
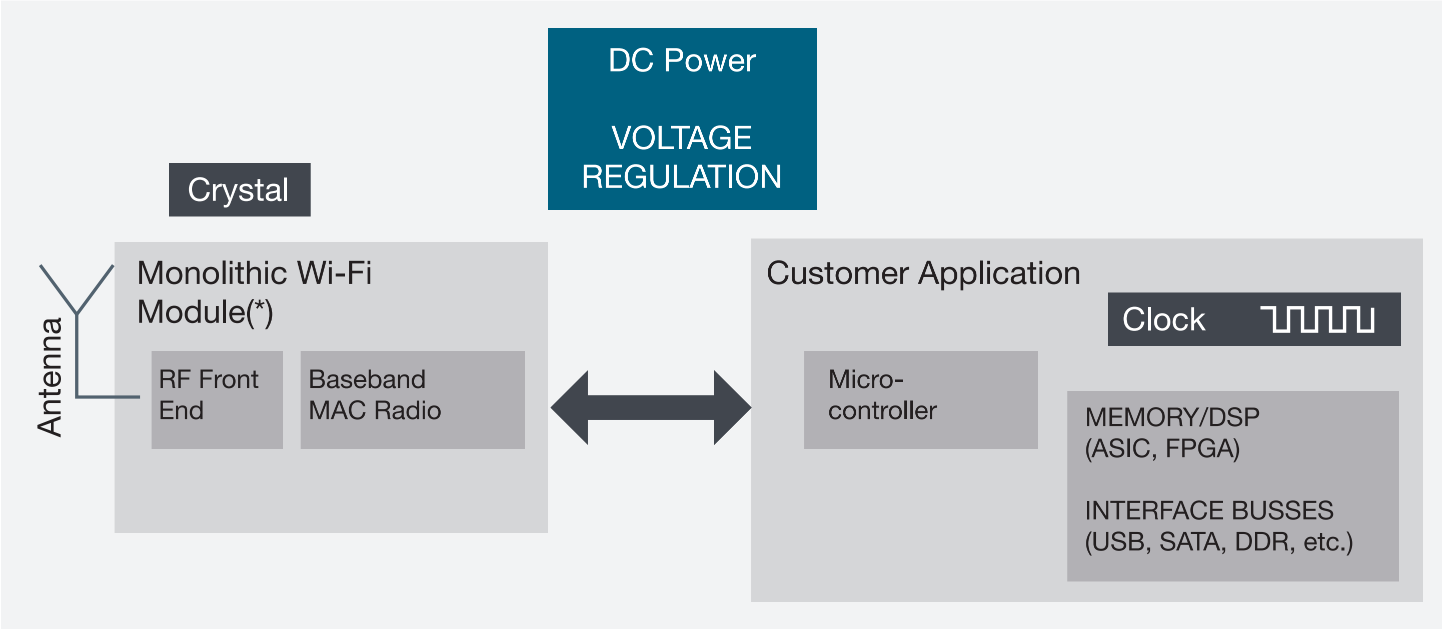


Figure 2. A typical implementation board of an IoT device based on a wireless embedded module.



"To avoid the risk of failure and project delays, many companies will go through the "module" path. That doesn't mean however that they are engaged in an easy path. The wireless module selection is another challenge."

> "Industry consortiums have emerged to standardize wireless communication protocols. Choosing an embedded wireless module also means choosing a wireless standard."

Wireless Module Selection

Here you are in the process of selecting a wireless module for your IoT device and you have heard of the different wireless technologies that are available (WiFi, Bluetooth, Bluetooth Low Energy, ZigBee, etc.). Now you want to make sure you will take the right decisions at this stage of your IoT project. While you are doing this, many questions will arise. However, your first question might be about the communications protocol you intend to use.

Layers	Functionalities
Layer 7: Application	Management of the application services (data formatting, applications interfaces, data encryption, etc.)
Layer 6: Presentation	
Layer 5: Session	
Layer 4: Transport	These layers enable the connection between 2 network nodes that are not physically linked (ensures routing of data packets from one address to another)
Layer 3: Network	
Layer 2: Link (MAC)	These layers ensure the management of the communication mechanism between network node devices that are physically connected by a communication media
Layer 1: Physical (PHY)	

Figure 3. *Network communication protocols are organized (stacked) and standardized in 7 layers.*

Communication protocol basics:

A communication protocol can be presented as a set of functionalities and agreements enabling communications between devices sharing the same network. Network communication protocols are organized (stacked) and standardized in 7 layers following the OSI (Open System Interconnection) model (Figure 3).

Important Functionalities Needed in a Wireless Protocol

An IoT device is part of a network. Thus, the IoT device will need to communicate with other devices sharing the same network and using the same communication protocol. The IoT connectivity solution can be implemented following the OSI (Open System Interconnection) protocol layers.

Wireless protocols or Radio protocols rely on a physical layer based on RF technology that uses electromagnetic waves to transmit and receive information. Also the use of radio spectrum is heavily regulated. So there is a dedicated frequency band (one or several radio channels) dedicated to the radio protocol. The radio protocol is expected to control the access of network devices to the radio channels, offers a mechanism that ensures error free transmissions, and ensures confidentiality of messages being exchanged between the different network devices. There are many functionalities offered in radio communication protocols. To fulfil that, the radio protocol's PHY layer enables addition of specific information to the data packets such as synchronization headers, error correction, data encoding (Manchester, NRZ) and interleaving, modulation, frequency hopping, etc. Figure 4 is a typical PHY layer frame of a simple radio protocol.

What's in a Typical PHY Layer Frame for Simple Radio Protocol?

The typical PHY Layer Frame is composed of 5 pieces: the preamble, synchronization word, length, data field, and CRC.

Figure 4. *Diagram of the PHY layer frame.*

- *The "Preamble" data is a set of alternating "1" and "0" bits that will allow receivers to detect a valid data frame and synchronize with the signal clock.*
- *The "Synchronization word" known by network devices and allow them to recognize the beginning of the radio frame.*
- *The "Length" data indicates how long will be the "data" field.*
- *The "data" contains the information that needs to be exchanged.*
- *The CRC (Cyclic Redundancy Code) enables the receiver to verify if the data being transmitted is error free.*

This formatted radio frame is modulated onto a carrier frequency and transmitted through the air via the radio transceiver (transmit/receive) system. >>

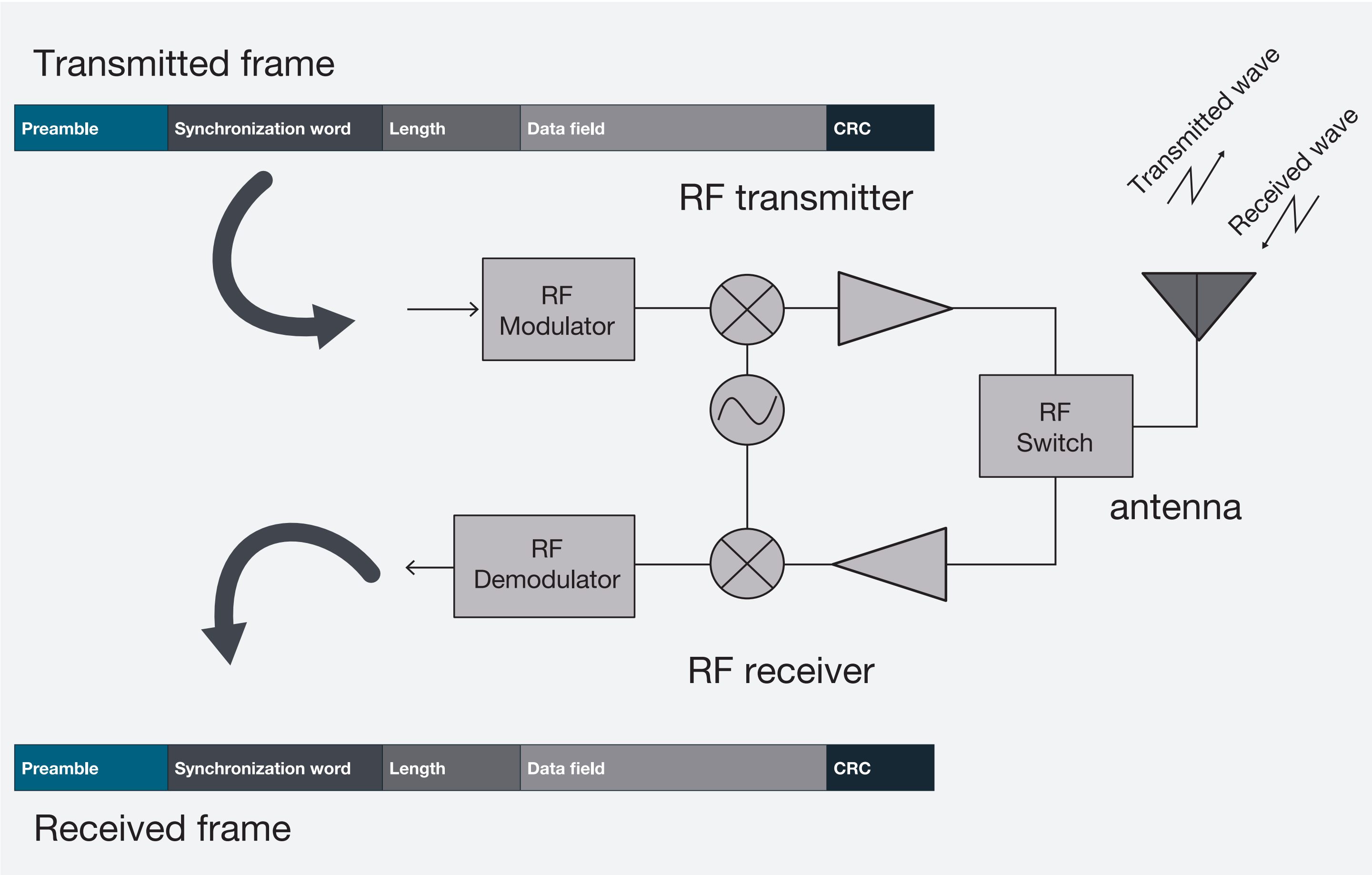
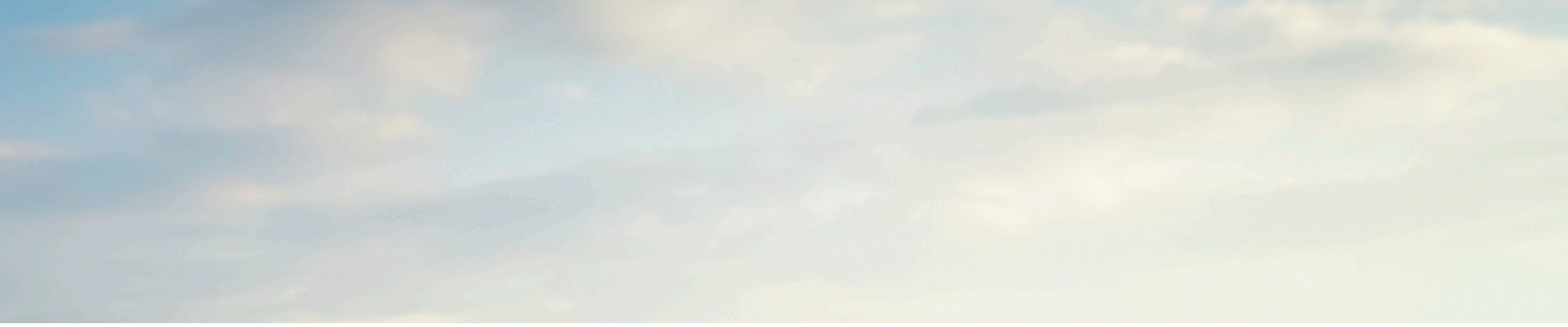


Figure 5. *A diagram of the main components of the radio transceiver system.*

When the device needs to send data to another device, the data (bits) are formatted into protocol frames, modulated on to a carrier frequency, then sent (transmitted) by the antenna system. On the other hand, when the device receives a signal through its receiver channel, it demodulates it to recover the data frames included in the signal.



The implementation of IoT wireless connectivity requires comprehensive test and measurement tools to validate and verify the signal integrity through the whole transmit and receive chains, but also the power consumption, its emissivity, and its immunity to other radio frequency systems. Tektronix's RF test solutions is a one place shopper for all test tools needed for a successful implementation of your IoT devices.

It wouldn't be efficient and cost effective if everyone had its own proprietary radio protocol. There are industry consortiums that have emerged to standardize wireless communication protocols. So, choosing an embedded wireless module also means choosing a wireless standard.

Wireless module technology considerations:

Embedded Wireless modules are generally developed to offer a communication protocol following one of the standardized wireless protocols.

Candidate Wireless protocols for IoT networks: Basically, all communication systems that can offer data transmission services will be candidates for IoT communications. For simplification, some of the communication standard names given here will just take a PHY layer name.

Cellular standards: Cellular standards are dedicated to voice and data communication with long range coverage (10's kilometres). Today's mobile communication services (voice and data) are using cellular communication technologies. From the beginning of cellular standards development, many technologies have been adopted and continue being used today (GSM/GPRS/EDGE, UMTS/WCDMA, HSPA, LTE, LTE-A, etc.). Cellular networks cover all major cities in the world. But there are some rural areas not very well populated where cellular network systems are not deployed. Also cellular communication services are not free of charge.

Satellite: Satellite communications will overcome the cellular network coverage shortages. However, satellite communication services are more expensive than cellular communication services.

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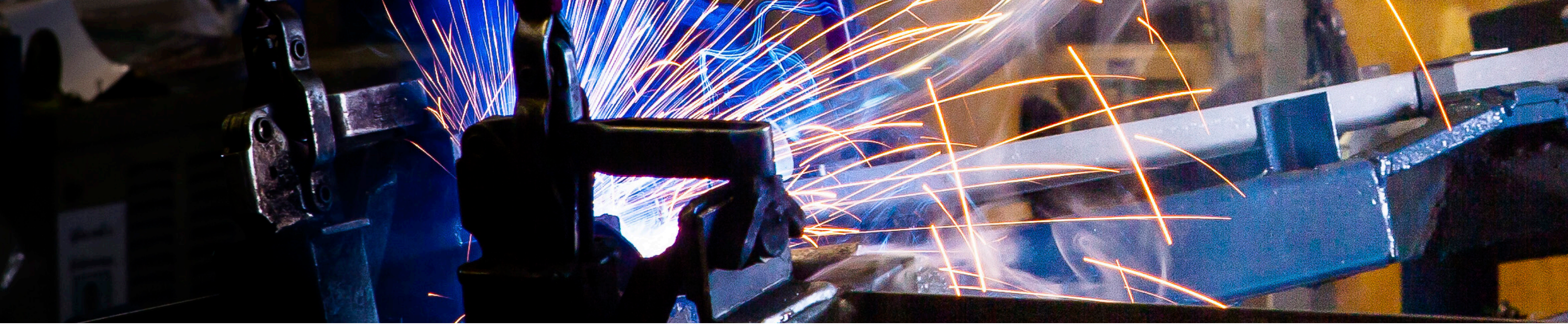

__Figure 6.__ Over the last 20 years, several WLAN standards have been developed by the IEEE wireless LAN consortium from 802.11 a/b/g to 802.11ad protocols today.

Standard	Approved	Freq Band	Bandwidth	Modulation	Data Rate (bps)
Original IEEE 802.11	1997	2.4 GHz ISM Band	20 MHz	DSSS	1M, 2M
IEEE 802.11b "b"	1999	2.4 GHz ISM Band	20 MHz	CCK and PBCC	5.5M, 11M
IEEE 802.11a "a"	1999	5 GHz ISM Band	20 MHz	OFDM	6M - 54M
IEEE 802.11g "g"	2003	2.4 GHz ISM Band	20 MHz	OFDM and PBCC	6M - 54M 22M, 33M
IEEE 802.11n "n"	2009	2.4, 5 GHz ISM Band	20, 40 MHz	OFDM	7M - 150M (per stream)
IEEE 802.11ac "ac"	2013?	5 GHz ISM Band	20, 40, 80, 160, 80+ 80 MHz	OFDM	7M - 867M (per stream)
IEEE 802.11ad "ad" or WiGig	2012	60 GHz	2200 MHz	Single Carrier and OFDM	385M - 4620M 693M - 6756M

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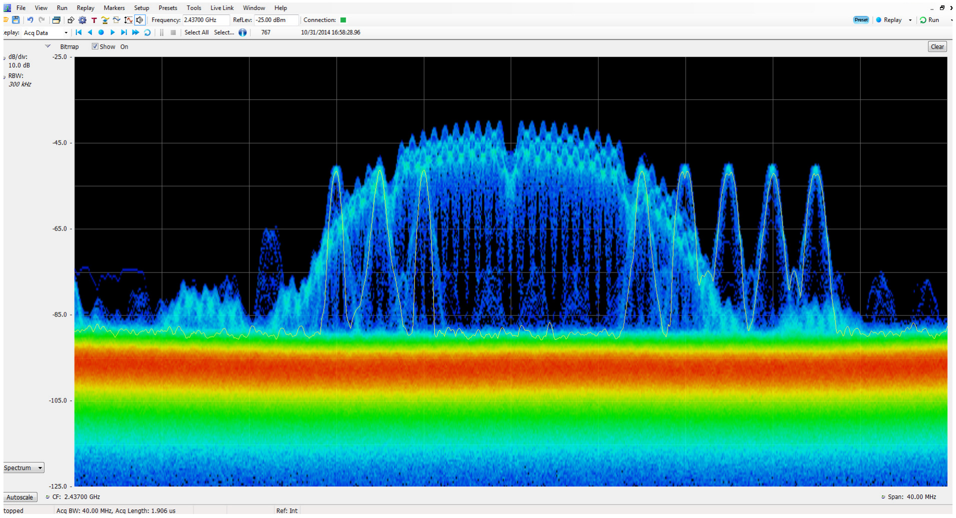
The Tektronix's application note on WLAN module selection __http://info.tek.com/www-how-select-your-wi-fi-module.html__ goes deep into selection criteria if you want to choose WLAN as a connectivity system for your IoT device.

WLAN (Wireless Local Area Network) standards: Both cellular and satellite communication systems are providing long range connectivity. They are also using licensed frequency bands and not free of charge to the end user. The WLAN communication standards offer short range connectivity (10's meters) and use license free frequency bands (2.4GHz or 5GHz). Thus WLAN standards offer free of charge connectivity services. Over the last 20 years, several WLAN standards have been developed by the IEEE wireless LAN consortium from 802.11 a/b/g to 802.11ad protocols today.

Figure 7. *A real-time spectrum analyzer can instantly digitize the whole span you're observing, allowing you to see and characterize signals as they are happening.*



Bluetooth, Bluetooth Low Energy: The Bluetooth protocol offers radio connectivity in a shorter range than the WLAN systems. The Bluetooth connection will not reach a range above few meters. It also has a lower data rate than WLAN but uses the same 2.4GHz license free frequency band.

The Bluetooth Low Energy uses less sub-carriers to transmit and receive data. The Bluetooth Low Energy technology enables Bluetooth connectivity with a more efficient use of power. You can get everything you need to know about Bluetooth standards from this single poster downloadable from *http://info.tek.com/www-Bluetooth-Specifications-Poster.html*.

The Bluetooth technology uses a modulation technique with frequency hopping; which enables it to use several sub-carriers in the 2.4GHz band; thus avoiding collision with other radio systems using the same 2.4GHz frequency band (WLAN, microwave oven, video transmitters, etc.). Figure 6 shows a captured spectrum sample in the 2.4GHz band using *Tektronix's RSA306B* USB spectrum analyser. One can distinguish the coexistence of Bluetooth sub-carriers and WiFi 802.11b signal in the same frequency band.

IEEE 802.15.4: IEEE 802.15.4 is a standard which specifies the PHY and MAC layers of low data rate wireless personal area networks (LR-WPANs). The frequency bands of 802.15.4 are:

- 868.0–868.6 MHz: Europe,
- 902–928 MHz: North America, up to ten channels (2003), extended to thirty (2006)
- 2400–2483.5 MHz: worldwide use, up to sixteen channels (2003, 2006)

The IEEE 802.15.4 is the basis for the ZigBee, ISA100.11a, WirelessHART, and MiWi specifications, each of which further extends the standard by developing the upper OSI layers.

Internet of Things driven standards: Low Power Long Rang: SIGFOX, LORA, LTE for M2M, 802.11ah, etc. Following the strong requirement for low power consumption on IoT devices, we have seen the development of long range low power connectivity standards dedicated to Internet of Things. Among those are: SIGFOX™, LORA™, and the 3GPP LTE for M2M under standardization.

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Security: One of the biggest IoT industry threat is security failures. Data encryption capability on the module is a must have functionality when your IoT system needs to be protected.

Regulatory and Industry standards compliance/ qualifications requirements: Like all electronic products, IoT devices need certification from regulatory compliance bodies in order to be sold in the different market places. There are 2 types of certifications:

- Regulatory compliance certification: which is issued by regulatory agencies like FCC, ETSI, Industry Canada, etc.
- Wireless Standard certification: which is issued by wireless standard consortiums such as the IEEE 802.11 or the 3GPP.

During wireless module selection, these compliance need to be seriously considered to avoid having a product banned in one region of the world.

Major Wireless embedded module vendors: Some of the major wireless module vendors are: CSR, Qualcomm, Broadcom, Blue Giga, Murata, Freescale, Texas Instruments, Microchip, Panasonic, Laird Technologies, ConnectBlue, Ublox, Fujitsu, Telit, Gemalto, Sierra Wireless, Silicon Labs, and many others.

Beyond the technology considerations: When selecting a module vendor, beyond the technology considerations, it is important it is important to consider other factors:

- Quality & robustness
- Future-proof & Long term availability
- Vendor's application industry vertical focus, global presence, quality manufacturing, and support operations

The wireless protocols can be classified following some key technology considerations.

- *Frequency band and geography of deployment*
- *Range*
- *Power consumption*
- *Network topology*

That classification has been done by Texas Instruments on their application note "Wireless connectivity for the Internet of Things".

> "The possibility of using an appropriate set of hardware/ software testing tools for IoT devices integration is therefore a considerable asset."

Conclusion: Design and Pre-production test considerations

Bringing a high performance electronic device to market requires thorough analysis and complete testing of the device functionalities in all development phases from design to production. Many IoT device developers learn it the hard way when they integrate a complete device without running required tests. The journey from design to market introduction of IoT objects is not always an easy path. Only few products are introduced on the market within schedule and budget. Regulatory / Industry standardization compliances and certification, devices power consumption, or RF interference impact of the IoT devices are major sources of project delays. The possibility of using an appropriate set of hardware/software testing tools for IoT devices integration is therefore a considerable asset.

Up to now, test instruments have not been available to the majority of system integrators due to their complexity and their price point which is unrealistically high for IoT development budgets. Traditional Test and Measurement equipment (spectrum analyzers, RF generators, and performance oscilloscope and digital multi-meters) have been financially dimensioned for high-Capex organization; which is not the case for the majority of SMEs at the heart of IoT devices integration.

Tektronix has introduced innovative, efficient, and affordable test instruments that can improve the speed of IoT devices integration, thus accelerate market introduction of IoT products.

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Rev. 020916

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