Fig.1: Low-power, low-cost Wi-Fi modules enable nearly any device to connect with smart phones, tablets and cloud-based applications across The Internet of Things (IoT) and Machine-to-Machine (M2M). (Courtesy of Econais)

Next Generation Smart Miniature Wi-Fi Modules Accelerate IoT and M2M

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Abstract

802.11 Wi-Fi embedded wireless modules simplify developing products for the IoT and M2M markets. WiSmart embedded modules make it quick, easy and inexpensive to get automation, collection, and monitoring products onto the internet for home, business and industrial applications. Smart wireless modules, like the Econais EC19D01, integrate CPU, Wi-Fi, and Cloud-Connectivity. These next generation modules come complete with libraries of included software, example code, elimination of driver development, ultra low power consumption, and highly cost competitive. The new standard is a single chip solution that is plug-and-play out of the box.

Introduction

While the first Internet revolution changed the way people work, communicate and did business at the close of the 20th century, the Internet of Things (IoT) is changing the way computers, embedded systems, and so-called smart objects communicate and work with each other. In 2020, it is estimated that there will be more than 50,000,000,000 (that's 50B) machines connected to the IoT – nearly 5 times more devices than people on the planet. Many of the inhabitants of the cyber-ecosystem will use Wi-Fi technology as a conduit for their autonomous machine-to-machine (M2M), machine-to-people (M2P), and people-to-machine (P2M) transactions. We will explore how this connectivity can be provided by modular Wi-Fi subsystems and why a growing number of manufacturers are designing with them. You'll get to look inside a Wi-Fi module and see how these embedded systems reduce design risk, improve time to market, and, lower the total solution cost. In addition, we'll show you how Econais' WiSmart

modules and custom Wi-Fi solutions offer the right mix of embedded processing resources, Wi-Fi connectivity, and cloud-enabled connectivity features to help your products deliver the full power of the IoT to the target applications in the smartest way.

Why Wi-Fi?

IoT based applications have already fueled a growing demand for new classes of smart, IoT-capable products, including smart utility meters and traffic sensors, cloud-based healthcare monitoring systems and advanced security and monitoring equipment. All these products require reliable, low-cost Internet connectivity, which is frequently supplied by embedded Wi-Fi wireless technology (Fig.2). Wi-Fi technology's excellent range, high data rates, global standards, and almost ubiquitous installed infrastructure have made it the access technology of choice for most IoT applications. Wi-Fi's range (up to 400m line of sight) makes it a clear winner for many wireless systems which have widely-dispersed nodes. In addition, some applications such as security cameras, real-time data acquisition or factory automation systems need connections that support multi-megabit data streams.

Fig.2: Wi-Fi's range, capacity and near-universal availability make it the best choice for connected appliances and IoT-enabled devices which need to interact with cloud-based services. (Courtesy of Xively)

Wi-Fi also offers designers unmatched versatility. Thanks to nearly 20 years of evolution, the IEEE 802.11 (a.ka. Wi-Fi) standard now contains a number of implementation options that can be tailored to meet nearly any application's price, performance and power requirements. The robust protocol includes

numerous enhancements for specialized applications, such as in-vehicle systems, streaming media, or hot spots, as well as several levels of security to choose from, including WPA, WEP, SSL, TLS for both personal and enterprise requirements – making it suitable for mission-critical IoT systems.

Wi-Fi can also dramatically reduce the deployment costs and accelerate the rollout of large IoT-based applications by taking advantage of existing free and commercial access infrastructures commonly available throughout North America, Europe, and the rest of the world.

Adding Wi-Fi to Your Products

Some of the questions your design team needs to consider during the selection process include:

- Which of the Wi-Fi standard's optional functionalities does your application require? This includes items like Wi-Fi Direct, security set-up features, roaming and support for special data types or higher-layer protocol stacks such as DLNA, UPnP, AirPlay or even out of the box and mass configuration (i.e. ProbMe™).
- Will you need a dedicated MCU to manage and control the Wi-Fi transceiver and support some, or all, of the 802.11 protocol stack? Or can some of these tasks be handled by the MCU that's already running the other elements of your application?
- Are there other functions it would be better for the MCU to take care of? Or should they be off-loaded, as in the case of audio, video or other real-time data streams, to hardware codecs?
- Which interface will the Wi-Fi subsystem use to communicate with the host system (GPIO, USART/UART, I2C, SPI, USB, SDIO) and how will the host control it?
- If your product is battery-powered, how will the addition of Wi-Fi affect the design's energy budget, and what are the best strategies to accommodate it?
- Do you plan to use an external antenna or an integrated antenna?
- How much time does your team have to get the product to market?
- Which countries do you plan to ship your product to, and what are the certification requirements for each of them (FCC, EC, IC, TELEC, VCCI, etc.)?
- Does your development plan include realistic estimates of the time and resources required to achieve those certifications – and can you afford the investment?
- Should your design team "roll their own" Wi-Fi solution from discrete components, modify the generic reference design supplied by the Wi-Fi device's vendor, or purchase an embedded module?

The issues which determine whether it's best to use a discrete or an embedded Wi-Fi solution are as varied as the applications themselves, but there are a growing number of situations where compact, off-the-shelf, Wi-Fi modules (Fig.3) are more cost-effective than discrete solutions – especially when rapid time-to-market is critical for success.

Fig.3: Econais EC19D is the next generation of compact, energy-efficient Wi-Fi modules which can provide nearly any application with wireless data connections that deliver consistent performance, reduced development costs while reducing design risk. The EC32L is resource rich and has a range of processing and memory options for most any application. (Courtesy of Econais)

To understand why embedded Wi-Fi modules play such an important role in IoT applications, let's look at what it takes to add Wi-Fi capability to a design using both approaches. Typically a host MCU and a Wi-Fi chipset are integrated as a system-on-chip (SoC). The SoC contains a dedicated processor and specialized accelerator hardware which support the lower layers of the 802.11 protocol stack, its media access control (MAC) function, as well as the packetization of the transmitted data stream and reassembly of incoming packets. The SoC frequently also includes an RF transceiver. The host MCU supports the higher-layer elements of the 802.11 protocols and other application-specific functionality. It is also responsible for exchanging data and control signals with its host system via a standard parallel or serial interface.

A Wi-Fi subsystem also includes several types of software elements. The platform-specific firmware that resides closest to the hardware layer supports the transport layer processing, MAC protocol, and other 802.11 functionality. The drivers for the host system interface also reside here. If the Wi-Fi subsystem's MCU has sufficient processing power, it can also be used to support the TCP/IP protocol stack and other networking functions such as DHCP, client/server stacks and cloud services support (i.e. Xively, ThingWorx, IFTTT/ZAPIERS, and others). Where this is not possible, these functions must be offloaded to the host system, although it usually adds complexity to the development process.

Discrete Wi-Fi Solutions - Pros and Cons

Until recently, manufacturers wishing to add Wi-Fi capability to their products would have to either adapt a Wi-Fi silicon vendor's reference designs to their needs, or invest even more resources to create a full-custom design. In addition, a chipmaker's reference software/firmware must be configured to support any optional features, protocol stacks or 3rd-party applications. This approach also required manufacturers to track and support the ever-evolving standards of the IEEE 802.11 committee and other industry standards organizations (e.g. the Wi-Fi Alliance and DLNA to name a few). If their products were

sold overseas, they also had to maintain compliance with the import/export certifications of the telecommunications registration bodies for each country where their devices would be sold or shipped.

Historically, Wi-Fi subsystems implemented with discrete components were almost always the most cost-effective solutions for high-volume consumer electronics and other products with static designs and manufacturing runs measured in the 100's of thousands or more. But the make/buy equation has shifted as the cost of Wi-Fi modules has steadily declined while development costs have held or even increased in response to the global marketplace's growing and ever-changing demands.

There are many other factors which can add to the actual cost of a discrete Wi-Fi solution including:

- Most generic reference designs aren't compact enough to fit inside the tight confines of many IoT devices. However, the engineering resources, time and risk associated with designing a custom Wi-Fi subsystem rise steeply as the layout's footprint shrinks.
- Many Wi-Fi reference designs' standard software loads lack important application-specific features, such as the protocol stacks needed to implement cloud connectivity. 3rd-party software can often fill these gaps, but even integrating pre-certified code into a complex environment frequently adds to a project's schedule, budget, expense and risk.
- While silicon vendor's reference designs can simplify many aspects of integrating a Wi-Fi device, the diplexer, antenna, PA/LAN and the RF connections along the transmit/receive signal chain are all places where even small design errors can cause impedance mismatches, inadvertent signal traps and other problems which impact the transceiver's performance. Avoiding these potential hazards requires specialized RF expertise that's frequently not available in today's leanly staffed engineering teams. Worse yet, recruiting and reataining someone with the necessary skills from a shrinking pool of truly capable RF engineers can be difficult and costly.
- In addition, certification of Wi-Fi designs for compliance with FCC and other regulatory agencies (EC, IC, TELEC, VCCI, and others) can be long, costly and uncertain. In some cases, a product's certification can take longer than its development cycle; even assuming a design team gets it right the first time.

Modular Wi-Fi Solutions to the Rescue

Embedded Wi-Fi Modules provide designers with near-turnkey solutions where they can quickly integrate into their devices' compact form factors without compromising performance. Their higher production volumes can easily justify the use of advanced design, manufacturing, and testing practices that insure they are rugged, reliable, and easy to integrate. Modular Wi-Fi solutions also provide several other important direct and indirect savings:

- The time and expense of testing and certifying Wi-Fi Modules for compliance with RF compatibility, communication and safety regulations is absorbed by the module manufacturers and spread across production volumes.
- Integrating embedded Wi-Fi modules into new and existing products requires dramatically fewer hardware and software engineering resources than discrete solutions.

- Pre-assembled modules eliminate the non-recurring engineering and tooling costs required to manufacture and maintain discrete solutions in-house.
- Simply swapping in the right module or using a module already certified for every country can accomplish supporting multiple countries with the same product design.

As a result, Wi-Fi modules are often able to provide manufacturers and systems integrators with higher quality and a lower overall solution cost than an in-house solution. They also offer a number of other compelling advantages for low- and moderate-volume products including:

- Lower design risk, reduced time to market.
- Design teams can focus their resources on developing the value-add elements of their project instead of maintaining the expertise required to develop and integrate a Wi-Fi subsystem.
- Manufacturers enjoy lower ongoing overhead by letting the module vendor take responsibility for tracking evolving standards, regulatory issues and the associated compliance engineering.
- Plug-in Wi-Fi solutions enable manufacturers to bring new products onto the IoT as quickly as possible and quickly upgrade older appliance designs. Replaceable modules also enable easy production and field upgrades to maintain standards compliance or meet evolving requirements.

Low-cost modular radios help manufacturers respond quickly to emerging market opportunities. Products ranging from wearable health trackers and bathroom scales to industrial and automotive diagnostic equipment can now all serve as conduits of data streams and control signals from mobile phone applications and cloud based services. They also accelerate development of new market opportunities by bringing IoT connectivity and other capabilities to products that may hot have been previously considered (Fig.4).

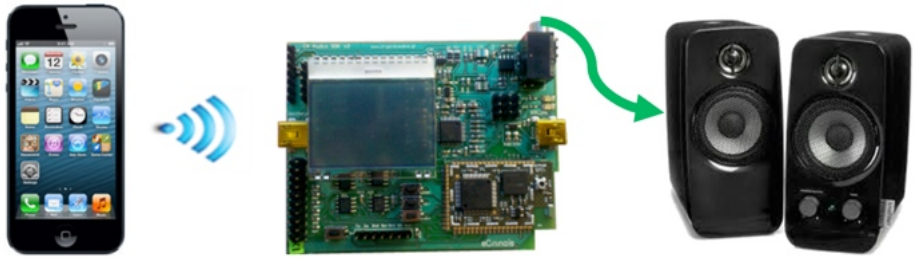

Fig.4: In addition to IoT applications, Econais' WiSmart platform offers cost-effective solutions for wireless headphones, speakers and other Wi-Fi audio products (WiSAudio). Reference hardware/software designs are also available which enable a Smartphone or PC to stream digital audio files to any stereo system within range of a home's Wi-Fi network. (Courtesy of Econais)

Conclusions

The distributed and cloud-based applications that are reshaping the global economy rely on smart, IoT-enabled devices that support autonomous machine-to-machine (M2M), machine-to-people (M2P), and people-to-machine (P2M) transactions. Thanks to Wi-Fi technology's range, capacity and widespread availability in public and private infrastructures, many of these devices will use it as their connection to the IoT.

Manufacturers must choose whether it's better to spend the resources to create their Wi-Fi solution, purchase a standard pre-integrated Wi-Fi module, or engage a 3rd-party vendor to assist with other semi- or full-custom options. But regardless of how they're implemented, IoT-capable Wi-Fi solutions require three basic resources order to succeed:

- An MCU capable of handling input, output, and robust control of data and device
- A robust Wi-Fi subsystem capable of quick and consistent transmissions with the network
- Native cloud access to support remote access, adaptive control, and distributed monitoring

Econais ***general-purpose*** Wi-Fi modules provide guaranteed performance, fast time-to-market, and dramatically lower indirect costs, which make them more cost-effective than in-house solutions. In addition, they offer several important, industry-exclusive advantages, including a powerful 32-bit applications processor and pre-integrated firmware that supports virtually all IoT activities.

Econais also offers ***application-optimized standard products*** help further reduce solution cost by optimizing the hardware and software required to perform the tasks defined by applications such as:

- Smart, multi-sensor thermostats used in energy monitoring, management and conservation applications.
- Wireless, camera-equipped door locks which enable remote viewing and access control.
- Multimedia servers and wireless amplifiers for home, office and portable use.
- Wi-Fi bridges which enable "legacy" equipment to access wireless networks and the IoT via their existing serial/USB/SPI connections.
- Add wireless high fidelity streaming audio and video capabilities to nearly any embedded design.

Although application-optimized standard products can be very cost competitive with discrete solutions in many applications, there are situations where other approaches should be considered. Econais offers a full range of design options to match any application, budget, or level of design expertise which fall roughly into three paths:

- Pre-engineered modules and pre-developed applications provide turnkey solutions.
- More experienced design teams can use the same modules as the basis for semi-customized Wi-Fi solutions. Econais can provide hardware and software development kits plus the

necessary high-quality software tools to help your design team solve their integration issues while limiting development cost and schedule.

- Econais custom design services provide selected customers with cost-effective full-custom designs that can be custom-tailored to the needs/budget of a specific application. Econais provides rapid turnaround and guaranteed results.

See the section "*The Econais Advantage*" to learn about some of the specific features, technologies and services that make Econais Wi-Fi solutions the smartest, smallest, fastest, most cost-effective way to put a design on the IoT.

The Econais Advantage

Introducing the EC19D, EC19W, and EC32L development ecosystem

Fig.A: Econais' embedded wireless modules are supported by a comprehensive development ecosystem, which enables rapid development and certification of Wi-Fi enabled products. (Courtesy of Econais)

Even at the dawn of the IoT, Wi-Fi is required to meet new challenges which are nearly as diverse as the applications its finding in Smart Objects, the Internet of Things and the applications which use them. At the dawn of the IoT, embedded systems, especially those used in industrial systems and distributed or cloud-based applications, Econais is playing a key role in helping Wi-Fi technology satisfy the stringent requirements it encounters in this new frontier. While price continues be a key driver for Wi-Fi solutions, they must now also deliver higher performance, lower power consumption while supporting a broader variety of specialized applications and higher-layer protocols.

Smart Things Demand Smart Solutions

Econais offers a full range of Wi-Fi connectivity solutions created specifically to help designers meet these new challenges. From easy-to-use embedded modules and software development kits (SDK) to

custom design and manufacturing services, each reflects Econais' deep expertise in Ultra Low Power (ULP) and high-performance wireless product design. Equally important, they all benefit from Econais' WiSmart technologies, which we'll explore shortly. But first, let's look at some of the features which make Econais embedded Wi-Fi modules the shortest path to wireless connectivity and the IoT for nearly any application.

For example, the Econais EC19D01 module illustrated here (Fig.B) supports the IEEE 802.11b/g/n standards at actual data rates of up to 20Mbits/s. The compact system measures 8x8x1.5mm and consumes 10uA in standby and 1.16mA during normal operation.

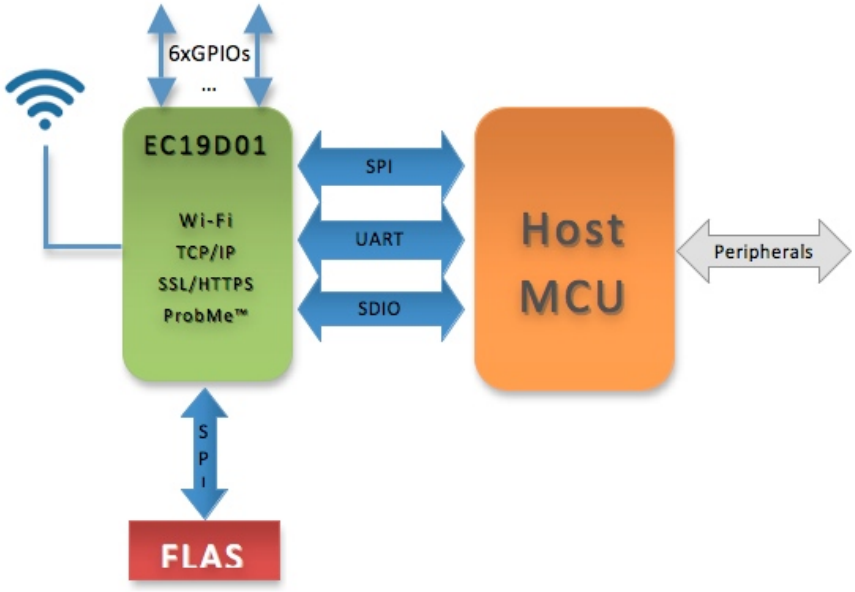

Fig.B: System diagram of the Econais EC19D01 802.11b/g/n Wi-Fi Module. (Courtesy of Econais)

Like nearly all Econais embedded Wi-Fi modules, the EC19D01 includes an MCU which supports the 802.11 protocol stack, a full featured TCP/IP Stack with the accompanied network applications, data security and also provisioning methods for device configuration. It is also responsible for exchanging data and control signals with the host system via standard Serial, SPI or SDIO interfaces.

The EC19D01 module's radio uses an advanced architecture to deliver high performance and energy efficiency. The radio section is an important part of all of Econais' pre-certified, internationally compliant solutions, which dramatically shorten acceptance cycles and time to market. The process will accelerate further in April of 2014, with the introduction of the EC19W that is equipped with internal flash and integrated antenna and pre-certified for all agencies.

The module's 32-bit processor is powerful enough to support full Wi-Fi functionality, TCP/IP connectivity, multiple higher-layer protocol stacks, with "overhead" to spare for custom applications like High Fidelity audio, multiple streams of video, or streaming serial data streams. All Econais modules

make good use of the processing power with a rich complement of embedded software and APIs that can be easily configured to a particular application's requirements (Fig.C).

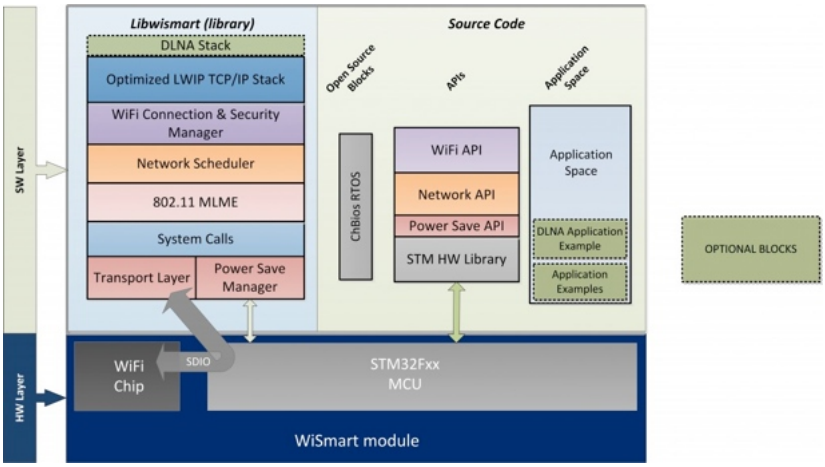

Fig.C: Block Diagram of an EC32L Econais module and software libraries. (Courtesy of Econais)

In addition to basic 802.11 capabilities, the firmware includes support for advanced Wi-Fi features such as Wi-Fi Direct with P2P-Client and P2P-GO plus the full range of security options (WPS 2.0, WEP and the personal and enterprise versions of WPA/WPA2). A HTTPS/SSL security stack, a DHCP Client/Server, a Configurable Web Server and standard TCP/UDP Sockets, complements its on-chip TCP/IP protocol stack.

The application software module also includes Xively™ cloud services support to assist in the development of cloud-based applications. In a similar manner, home entertainment and home automation applications are supported through Digital Living Network Alliance's (DLNA/UPnP) protocol stack. Unique and proprietary ProbMe™ mass configuration technology built into modules allows for simplified out of the box configuration and rapid registration of devices on existing Wi-Fi networks.

To address the needs of specialized applications, Econais also offers a selection of embedded modules whose processing power, resources, and memory have been optimized for a particular application space. By only providing the needed amount of processor resources, memory, serial/parallel and audio/video I/O, Econais enables designers to achieve the most cost-effective solution while still retaining the quality, reliability, and rapid time to market of its full-featured products. Econais' design services bring the same technology and know-how to the semi-custom and full-custom designs they create for selected customers.

Econais WiSmart = Cloud Connectivity Without Tears

Econais' WiSmart technology seamlessly integrates its products' embedded intelligence, wireless connectivity and Cloud Connectivity resources to help designers create smarter, more cost-effective IoT-

enabled and Cloud-connected solutions. All embedded modules are supported by a powerful set of development tools which make it easy to select and customize any the pre-tested protocol stacks, applications, drivers and other resources Econais includes with its products. In addition, Econais has partnered with Xively Public Cloud service specifically built for the Internet of Things; to license its Cloud services API.

Econais WiSmart solutions already enjoy low power, low cost, and small size. By adding native support for Xively's Cloud services API, they can now be easily integrated within sensors and monitors to support ***Cloud-Based Services*** such as:

- Remote/cloud-based utility metering & Smart Grid
- Healthcare monitoring & telemedicine,
- High fidelity audio and video streaming
- Remote monitoring, data acquisition, and control
- Security applications

These, and many other applications, can benefit significantly from cloud access primarily by using the cloud for:

- Remote data logging (requiring little to no onboard memory resources)
- Remote data monitoring (to track and even predict performance metrics)
- Adaptive, optimized, and automated control from web programmable user profiles (requiring a minimum of onboard processing or computation)
- Distributed data collection, trending, and forecasting
- Remote control and configuration by users from anywhere in the world

Econais has built its business on enabling smarter, more cost-effective embedded Wi-Fi solutions. With the addition of WiSmart technologies, it now also offers the smallest, fastest, most cost effective way to put your design on the IoT.