Wi.232DTS vs. WiFi for Embedded Applications

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1. Introduction

There are many choices the embedded designer has today when considering embedded wireless solutions. There are standards based solutions including Bluetooth™, WiFi™, and Zigbee™. There are also several proprietary solutions from companies like Radiotronix, Maxstream, and Aerocomm.

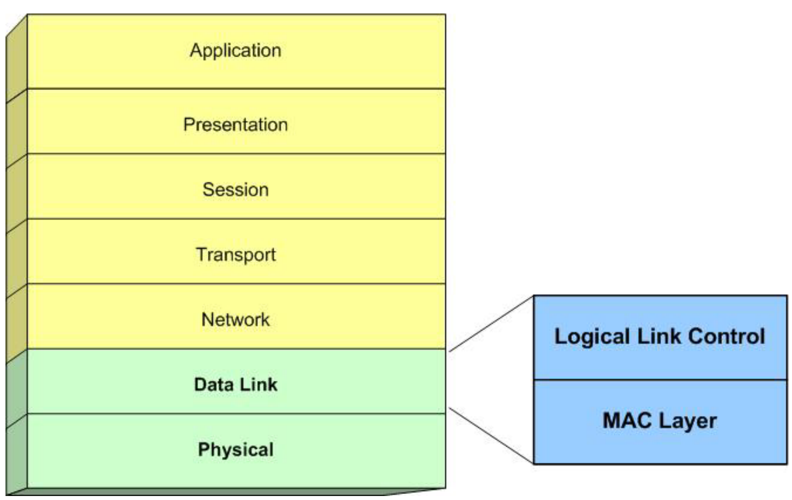
In many battery powered, low data rate applications, our WiSE™ embedded wireless solutions are the best choice among these. In this paper, we will compare the Wi.232DTS module to the WiFi™ standard, evaluating differences in cost and performance.

2. WiFi vs. Wi.232DTS from a network perspective

WiFi uses 802.11xa(b) radio technology for data communications. 802.11xa(b) was originally designed to replace the industry-standard wired ethernet adapters with a wireless adapter that provides the same functionality. The 802.11x standard specifies a PHY (physical) and MAC (medium access control) layer. There are 3 possible PHY layers:

- FHSS
- DSSS
- IR

Fundamentally, the three different PHY layers are incompatible. Therefore, 802.11x compliant products will only work together if their PHY layers are exactly the same. If two 802.11x hardware manufacturers use different PHY layers, FHSS and DSSS for example, the products will not work together.



802.11x defines a single MAC layer that works with all three PHY layers. This provides a unified programming interface to higher layers, hiding the complexities and inconsistencies of the PHY layer.

As shown in the diagram, the ISO MAC layer is actually a sub-layer of the data link layer in the ISO 7-layer network model.

Under the ISO definition, the MAC layer is responsible for providing access to the network, which allows any node on the network to transmit information. It accomplishes this with an access method, such as CSMA (carrier sense multiple access). It has no knowledge of how the logical or physical addressing works in the network.

The logical link control layer (LLC) is responsible for generating and interpreting commands that control the flow data and perform recovery operations in the event that the received data has errors or a transmission is lost. To accomplish these tasks, the LLC must adhere to some strict, hardware-based addressing scheme. In 802.11x, 48-bit addresses (called MAC addresses) are used to allow the LLC layers in network nodes to talk to each other.

The 802.11x definition of the MAC layer actually incorporates the functionality of the ISO data link layer, including both the MAC and LLC sub-layers. It would be more appropriate to say that the 802.11x standard defines a physical and data link layer.

The Wi.232DTS module is designed for embedded applications where serial cabling (RS-232/422/485) is being replaced. These applications can be point-to-point, point-to-multipoint, or multipoint-to-multipoint. As a result, there is no common addressing scheme among these applications. For this reason, we implement only the physical and MAC layers of the ISO network model. Our MAC layer is designed to make the wireless network function like an Ethernet network at the physical level:

- A carrier sense multiple access method is used to arbitrate which node can transmit
- Data that is transmitted by one node is received and passed to higher layers, via the UART interface by all of the other nodes "physically" connected to the network
- Nodes are "physically connected" by being on the same physical channel, much like Ethernet nodes are "physically connected" by being on the same physical wire

The net result is that the Wi.232DTS module operates as a virtual wire, and requires little or no software changes to implement in an existing product. In contrast, adding 802.11xx hardware to an existing embedded product that uses UART based communications would require significant redesign and drastically impact cost.

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There are many other benefits that the Wi.232DTS module offers over a WiFi solution; they are discussed below.

3. Hardware integration

Integrating a Wi.232DTS module into an existing design is very simple and inexpensive. Simply connect the module to the UART of your existing microcontroller, attach an antenna (which is available from several suppliers, including Radiotronix), and provide power. The module requires less than 1 sq. in. of board space, operates from a 2.7 - 3.6V power supply, and has 5V tolerant I/O. The module is in a convenient surface-mount pick-and-place compatible package, making it very manufacturing friendly.

In contrast, 802.11x chipsets are designed to interface to PCI or PCMCIA buses, which require additional I/O from your existing microcontroller and a significant amount of external interface circuitry. 802.11x solutions generally require several square inches of board space and many components, increasing manufacturing cost and reducing productivity.

The result is that the Wi.232DTS will take hours to integrate compared to weeks or months of design time required for an 802.11x solution. The Wi.232DTS module will cost less in production and require less board space.

4. Software integration

In most embedded applications that use UART based serial communications, the Wi.232DTS module will require little or no software integration. Establishing a wireless link between two embedded UARTs is as easy as connecting a Wi.232DTS module to each UART, attaching an antenna, and providing power to each module. The module comes from the factory pre-configured to operate "out of the box". Although the module is very easy to use out of the box, it does have a powerful command mode that allows the application firmware to control many of the operational parameters of the module, such as data rate, operating channel, encryption, etc..

In contrast, the 802.11xx solution requires additional hardware drivers to be written to handle its Ethernet style hardware interface. This can take several weeks to write and several months to completely debug.

5. Range performance

5.1. Link Budget

A typical 802.11x link budget is between 90 and 94 dB. This will give an effective range performance of 300-500 feet outdoors and 50-75 feet indoors.

In contrast, the Wi.232DTS module link budget is 114dB at the highest RF data rate (152.34kbit/sec) and 122dB at the lower RF data rate (4.8kbit/sec).

For every 6dB of link budget improvement, range is effectively doubled. Using this rule of thumb, a Wi.232DTS solution operating at its maximum data rate will operate at 4 times the distance of an 802.11xx solution. In fact, we have had customers report that the Wi.232DTS was communicating at 3+miles in a line-of-sight environment. Likewise, we have had customers report indoor range performance in excess of 1000 feet.

5.2. Operating Frequency

Higher frequencies are more directional and propagate worse through free space. In general, when the frequency is doubled, range is cut in half (assuming the same transmit power and receive sensitivity).

The Wi.232DTS module operates in the unlicensed 902-928MHz band while 802.11x operates in the 2.4GHz unlicensed band. Thus, the Wi.232DTS module gains an additional 6dB in link budget. The Wi.232EUR module is available for European applications, and is functionally identical to the Wi.232DTS module except for the operating frequency (868 MHz) and the number of channels (15).

Additionally, it just so happens that 2.4 GHz is the resonant frequency of water, which is bad for a couple of reasons.

This results in two negative effects for 802.11x solutions. First, water significantly attenuates the RF energy, reducing performance in humid environments (e.g., outdoors during a rainstorm) as well as human-worn applications. Second, microwave ovens emit considerable energy in the 2.4GHz band and are a significant source of interference for 802.11x devices.

The reason that the 802.11x specification authors chose 2.4 GHz as an operating frequency band is because it has general worldwide acceptance, allowing one physical product to be sold around the world. The reason that this frequency has worldwide acceptance is obvious, microwave ovens must operate at 2.4 GHz and every uses them. The choice of 2.4 GHz was a marketing choice, not a technological choice.

In addition to 2.4 GHz, a new 5.8 GHz band is becoming popular for 802.11x applications. While it may offer more bandwidth and less interference than 2.4GHz, the new 5.8GHz band does not offer technical advantages over the 900MHz band regarding range performance and multi-path interference rejection.

The net result of the chosen frequency plans is that the Wi.232DTS module will likely achieve 8X range performance over an 802.11x solution.

5.3. Data Rate

802.11x was designed for high data rate (>1 mbit/second) applications. High data rates require wider bandwidth, increasing noise power in the band, and reducing the receiver sensitivity. While 802.11x solutions are very efficient at high data rates, they are very inefficient (from a power and bandwidth perspective) for low data rate applications.

The Wi.232DTS module was designed to operate at data rates from 4.8kbit/second to 152.34 kbit/second. It can be "tuned" to maximize power and bandwidth efficiency for a given embedded application. The resulting increase in bandwidth efficiency, and thus receiver sensitivity, yields the improved link budget.

6. Power Consumption

Wi.232DTS modules were designed for embedded, portable applications. It operates in 3 modes:

- Sleep
- Active

These modes allow the module to be used in applications that are line-powered or battery-powered using primary or secondary cells.

802.11x solutions, in contrast, do not offer comparable low power modes. The technology does support operation from secondary rechargeable batteries, making it suitable for portable applications such as Laptops and PDAs. However, it is not suitable for any application requiring operation from a primary battery.

6.1. Sleep

In this mode, the module is shutdown. The on-board processor is in a sleep state and the RF circuitry is turned off. In this mode, the module draws less than 80uA. This mode is exited by sending data to the module.

This mode is used by applications that need to transmit data periodically, but do not need to listen for data from another module.

6.2. Active

In this mode, the module is always on, listening for data from other modules. This mode is used by applications that require low-latency data transmissions.

7. Conclusion

Wi.232DTS modules were designed to replace serial cables used in embedded application employing UART based communications. 802.11x was designed to replaced Ethernet network interface cards. Therefore, Wi.232DTS module can be integrated in less time and with less effort than an 802.11x solution, reducing time-to-market and improving project profitability.

A Wi.232DTS does a more efficient job transferring data in embedded UART based communication applications. It offers better range and lower power than an 802.11x solution.

Lastly, a Wi.232DTS module is a single-component, pick-and-place compatible solution. It is less expensive than a multi-component 802.11x solution. It improves productivity, eliminates the need for expensive production test equipment, ultimately reducing production costs.

Summary of Wi.232DTS vs. WiFi™ Comparison

	Wi.232DTS	WiFi™ (802.11x)
Cost	<$10[1]	$20+[1]
Link Budget	114dB	94dB
Integration Time	Hours	Months
Size	<1 in. sq.	Several sq. inches
Power	16mA (RX Mode)	>70mA (RX Mode)
Interface	UART	PCI/PCMCIA
Direct wire replacement	Yes	No
Transparent, master-less operation	Yes	No

1. In production quantities

More information about the Wi.232DTS module can be found at www.radiotronix.com.

