Reactive Low-power Software Stack for BTLE Implementation

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CSEM has combined its strengths in ultra-low power transceivers and optimized software protocol stacks to create one of the most power efficient Bluetooth Low Energy platforms. The slave protocol stack meets all of the BTLE timing constraints and is realized entirely in software. Updating to new versions of the protocol may then be performed by software updates without any need to redesign silicon.

CSEM has a long tradition of developing ultra-low power RF transceivers that are ahead of the competition in terms of their energy efficiency. The same applies to protocols. These two strengths have been combined to create a BTLE slave node that it entirely software upgradable. The platform complies with the Bluetooth Core Specification for a slave device. It can be upgraded to new versions of the standard via simple software updates.

Combined with the 2 Mbits/s analog front end, CSEM's IcyTRX-65 chip supports, among others, the Bluetooth LE and IEEE 802.15.4 (ZigBee) modulations. A customizable packet handler offers the ability to adapt the stack to support various protocols. The circuit also enables the platform to handle the hard BTLE timing constraint of the Inter Frame Space (T_IFS), which must be precisely 150±2 µs.

The transceiver is connected to a TI MSP430F5528 microcontroller on which the protocol stack operates. The developed stack includes all the BTLE slave features and functions: the link layer, L2CAP, GATT & GAP and a Security Manager for the “Just Works” scenario. This provides all of the necessary functionalities for a peripheral device to offer an easy interface to the most common smart phones and tablets.

Additionally, the software architecture is fully event-based, exploiting the rich pallet of interrupt sources generated by the transceiver. This results in a stack which is highly reactive while very power efficient. As an example, let us consider the case of advertising, which is likely to consume a large share of the energy budget in a typical sensor application. Figure 1 shows the current consumption during an advertising event. The microcontroller exchanges with the radio via SPI, captured by a logic analyzer, are superimposed in green on the picture.

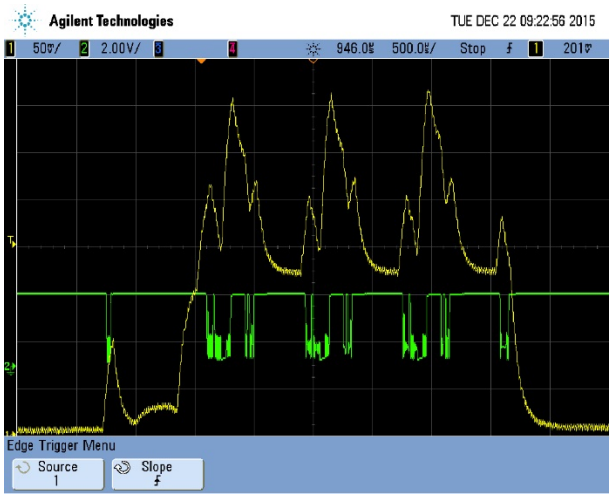

Figure 1: Advertisement current on the 3 channels.

The measurements reveal an energy consumption per advertisement of 28 µJ on one channel and 65 µJ on three channels. With an advertisement period of 100 ms, the average current is approximately 93 µA and 218 µA respectively (voltage over a 30 Ω resistor serially connected).

A typical connection includes the discovery phase (0.8 s), the connection event (CE) and the transmission phase (in our example 20 bytes). Once the discovery has been completed, the average current is approximately 75 µA (empty PDU) and 90 µA (with the 20 byte payload) with a connection period of 100 ms. The energy cost of a CE is between 21 and 30 µJ. As such, the autonomy of the platform with a CR2032 battery (240 mA.h) is expected to be more than 1.5 years with an advertisement period of 1 second.

Our test board includes several sensors (accelerometer, magnetometer, barometers, temperature & humidity, etc.) and can be powered by a battery or an energy scavenging source. Its tiny size of 16 mm by 16 mm is suitable for applications where a small volume is required.

Figure 2: CSEM Memsplant V2 test board.

The protocol software implementation provides for the coexistence, on the same processor, of the stack with the sensor application, measurement and pre-processing. This leads to an economy of silicon and space.

A such coexistence allows the application to be defined, designed and implemented so that it requests the use of resources only when needed. This enables further reduction in the overall power consumption.

The comparison with a TI CC2541 during a connection with a CE period of 1 s reveals a clear advantage: TI requires a consumption of 27 µAs while the CSEM test board is around 18 µAs.

The results confirm that the optimized co-design approach followed by CSEM yields technical advantages and performance enhancements which ultimately translate into better products in various application domains, such as home automation, gaming, health, care, transportation, safety, etc.