WHITEPAPER

Lower your power consumption for battery-operated smart devices

Edition: v1.0
Date: 05/2024

www.infineon.com

Striking the right balance between battery life and customer experience

The number of connected smart home battery-operated devices is expected to grow as consumers look for new ways to retrofit their homes with IoT devices without power cabling. This change leaves device makers in search of new ways to make their battery-operated smart home products more power-efficient at all levels, while still enabling the devices to quickly respond to customer needs. Wireless design choices can either enhance or hurt customers' user experience in areas such as battery life and product responsiveness.

This white paper identifies the top issues and considerations for connected smart home battery-operated devices. Using a case study of an Internet Protocol (IP) camera design, we will examine design principles that can be applied for lowering power consumption on battery-operated smart home applications significantly. These same design principles also could be applied to other applications such as smart doorbells, smart door locks, and smart thermostats.

Top Issues and considerations for connected smart home battery-operated devices

Even though they are continuously connected to a network and expected to operate anytime, smart battery-operated devices are normally (90+% of the time) in a non-active state. To maximize battery life and device responsiveness, system designers must consider three key areas when selecting a Wi-Fi connectivity solution.

1. How to maximize battery life by optimizing time in a connected idle state?

Consumers expect their smart devices to be available on demand through a smartphone application to use them when not at home or through a smart speaker with voice commands when at home. This expectation means the device needs to be continuously connected to the cloud even though the door lock or camera or thermostat is rarely active during each day. The key design challenge for such battery-operated devices is how to keep the main system managed by a host processor in idle state and ideally the Wi-Fi device also in idle state as much as possible while maintaining a network connection.

2. How to keep idle devices from waking up unnecessarily?
With many IoT protocols and services running on these connected devices, they need to periodically send heart beats or responses to stay connected to back-end cloud servers or to even stay connected to home access points. Since these protocol stacks are usually running on the system host processor the challenge is how to maintain the network connection without waking this processor to service network traffic. Wi-Fi devices designed with low power in mind are able to respond to network traffic while the system host continues to sleep.

3. How to reduce power consumption operating in challenging networks?
IoT devices that operate at a distance from an access point or in a congested networks experience power drain challenges caused by inefficient use of the wireless spectrum. Since consumers can place their smart home devices anywhere in the home, choosing a Wi-Fi solution with proven access point interoperability and robust RF performance is critical to avoid wasting power with retransmissions. IP cameras and door locks are often placed at the outside of a home far from their access point. Another cause of wasteful retransmissions is operating in the increasingly crowded 2.4GHz band. Dual band devices that offer the option to use the 5GHz band will typically better handle network congestion and spend less time in an active mode waiting for their chance to transmit.

Maximizing battery life when devices are idle or in sleep mode

Wi-Fi and Bluetooth® connectivity solutions specifically designed with low power in mind and built with advanced manufacturing processes tuned for low power operation can improve consumer satisfaction with better battery life. The use case below demonstrates the benefits of implementing such a solution.

IP Camera Case Study
A company makes security video cameras that plug into the wall and can be instantly activated remotely using a phone-based application. This camera company has been choosing its Wi-Fi solutions to ensure range and video quality. With plans to expand into cameras that will be competing in the market on battery life, additional design considerations arise. A good starting point would be looking for a Wi-Fi solution with low transmit and receive power consumption when active and a low-current sleep state.

Consider Figure 1 where an IP camera connected to a Wi-Fi home router can be activated by a mobile phone anywhere in the world. The user expects the camera to be available promptly, yet the camera must usually stay in sleep mode to achieve acceptable battery life. Some camera systems add a dedicated hub between the camera and router with an additional radio used to relay wake signals to the camera. This approach is wasteful in multiple ways because it 1. Increases design complexity by adding another RF device in each camera, 2. Adds system cost by requiring the user to purchase additional equipment, and 3. Creates more clutter with yet another box to plug in. A more sustainable approach is to eliminate the hub and connect the camera directly to the home router as shown below, maintaining an end-to-end connection to the cloud beyond.

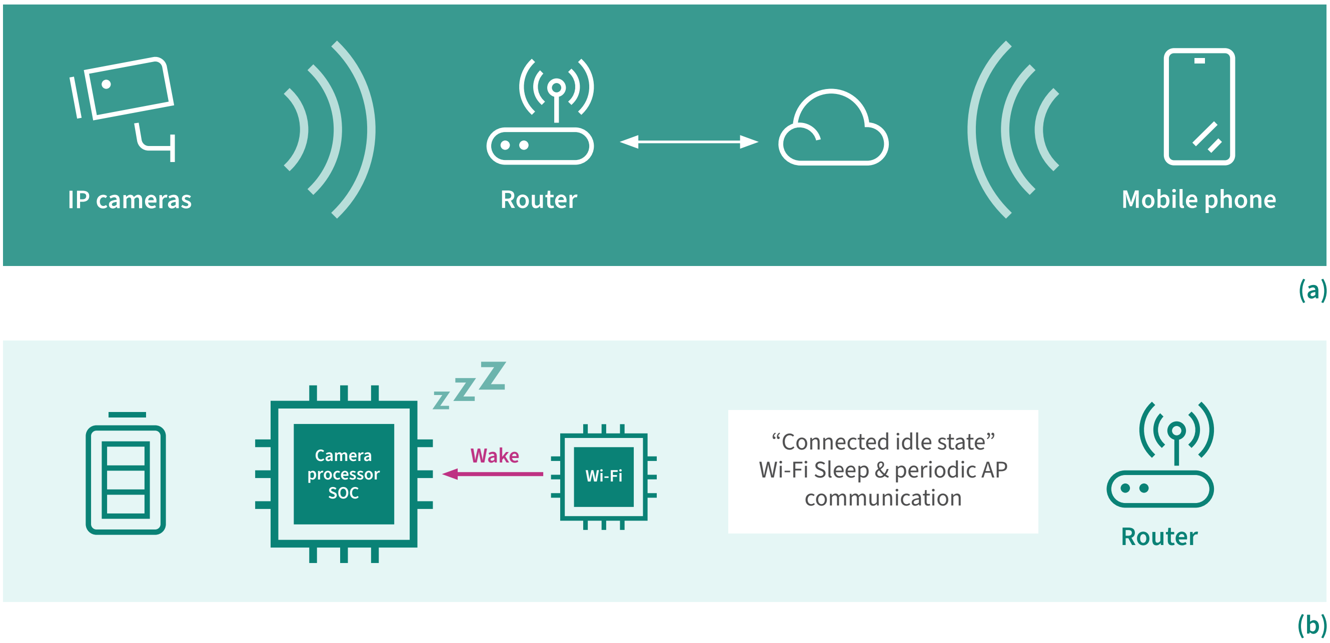

Figure 1
IP Camera connectivity **(a)** requires the camera to be instantly available to a remote user **(b)** maximizing the camera processor SOC's time in sleep through an ultra-low power Wi-Fi solution.

While connected to the cloud service using a TCP/IP protocol, the host processor might have to wake up periodically to send a heartbeat type message to stay connected. This activity consumes substantial power since the more power-hungry host processor needs to manage the network traffic that the Wi-Fi device needs to send and receive. An alternative and more efficient approach is to offload this process to the Wi-Fi chip which must be awake anyway. Now, the higher power consuming host only wakes up when there is an actual request to operate video, relying on the ultra-low power Wi-Fi device to maintain cloud connectivity. This process addresses our first two design considerations by keeping as much of the device as possible in idle mode and avoiding events that cause the whole system to wake. Network activity can include traffic specific to the local AP network, TCP/IP traffic enabling cloud connectivity, remote wake events and traffic supporting the new Matter protocol.

Our third design consideration, challenging networks, is often encountered by battery-operated cameras placed on the outside of a home. The addition of a dual-band radio allows switching between the 2.4GHz and 5GHz radio frequencies to best deal with network congestion that could cause retransmissions for a device already likely located far from an access point. A more subtle consideration is that a higher performance Wi-Fi chip can transmit and receive at a higher data rate at a given distance as compared to a lower performance Wi-Fi chip. This allows the chip to reduce the time it is consuming power with active transmit and receive operation thereby conserving battery life.

Using a low-power, high-performance Wi-Fi solution helps device makers meet consumer expectations since consumers want to avoid frequently recharging devices because it takes time and can also impact their safety and security while the camera is offline.

Why an ultra-low-power, high-performance chip works best

To easily implement the previously discussed power consumption reducing design considerations, Infineon's AIROC™ CYW43022 is an ultra-low power single-chip, combo (Wi-Fi/Bluetooth®) device featuring 1x1 dual-band 2.4 GHz and 5 GHz Wi-Fi 5 (802.11ac) as well as Bluetooth® 5.4. The CYW43022 builds on outstanding transmit and receive power performance with best-in-class deep sleep capability. Extensive network offloads can handle all types of network activity while monitoring for remote wake events allowing a host processor to remain in an idle state. On-chip power amplifier and low-noise amplifiers are included for the 2.4 and 5-GHz bands with an option to use long range external amplifiers.

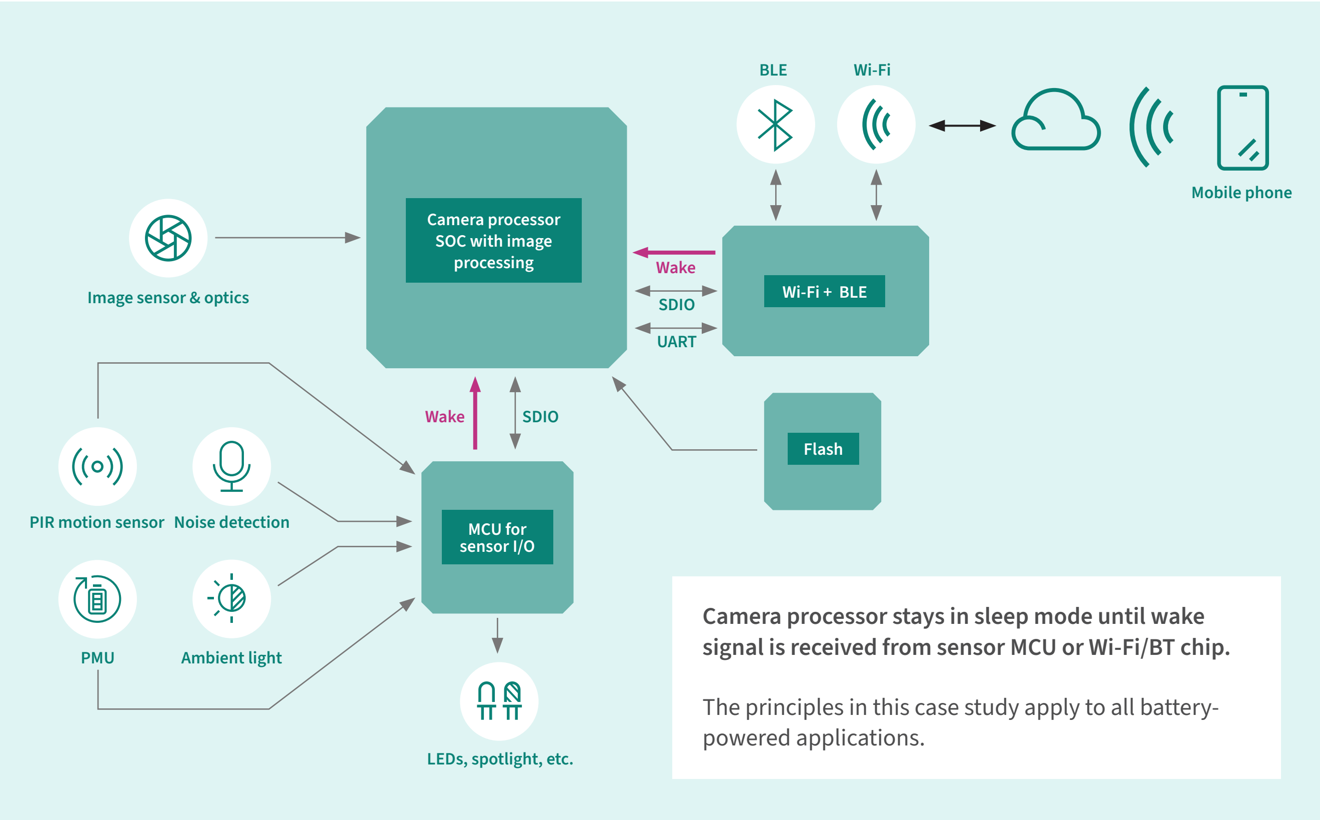

Figure 2
In a battery-powered, IP camera, the camera processor stays in sleep mode until a wake signal is received from the sensor MCU or Wi-Fi/Bluetooth® chip. The principles in this case study apply to all battery-powered applications.

Demonstrated battery life improvement

Let's dive into some of the details of how connections with Access Points can be maintained in a low power state. The IEEE 802.11-2016 standard for wireless local area networks (LANs) including Wi-Fi 5 (802.11ac), defines Delivery Traffic Indication Map (DTIM) to classify different connection modes to an Access Point. Three specific modes tradeoff response time versus power consumption:

- DTIM 1 = 1 X 100 ms beacon interval
- DTIM 3 = 3 X 100 ms (300 ms) beacon intervals
- DTIM 10 = 10 x 100 ms (1sec.) beacon intervals

In a typical Wi-Fi network, the AP periodically sends a beacon, set by the AP to a sleeping IoT device to indicate that network traffic is queued up (ready for signal transmission). Traditionally, the host processor wakes up to process the waiting network traffic. A better approach is for the Wi-Fi chip to monitor the network traffic without involving the host. Figure 3 shows comparative data using a Wi-Fi chip in the design, where the CYW43022 enables 2-3x longer battery life. In DTIM 10 mode, a product can stay connected to Wi-Fi access point and consume less than 140 microwatts. The figure shows just the relative contribution of the Wi-Fi device in processing beacons.

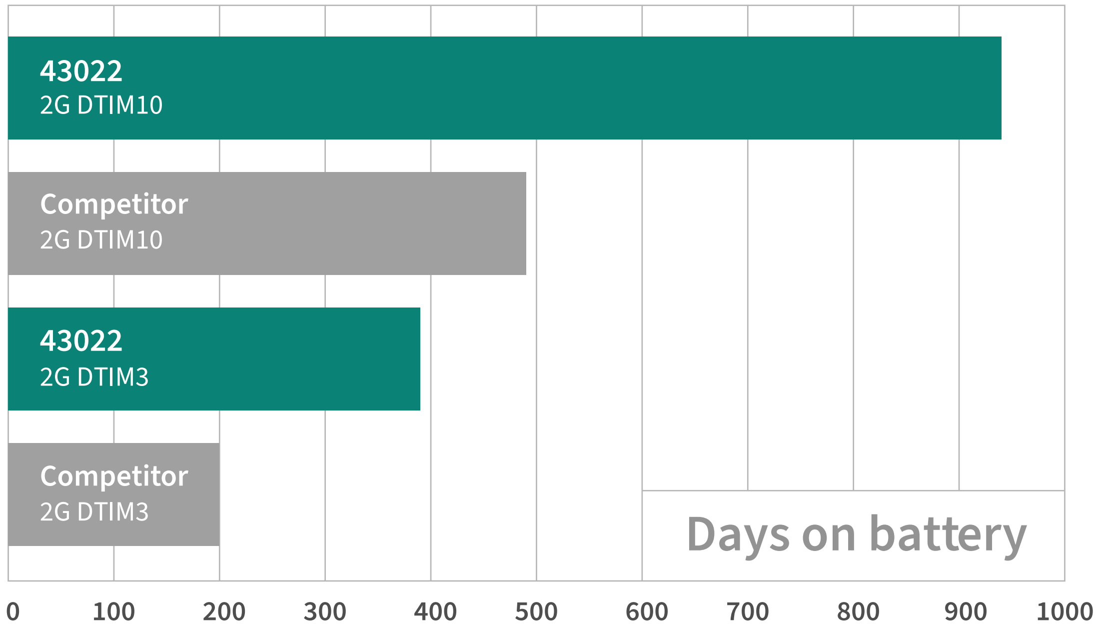

Figure 3
For 802.11ac battery life, the CYW43022 vs the nearest competitor shows significant improvement in both DTIM3 and DTIM10 modes. Note: 10 data exchanges per day, 100Kb TX, 10Kb RX for each exchange. Based on CR123A battery (1550mAh / 3V).

Design-in support
A standard reference board as well as a long-range reference design supporting external power amplifiers and low noise amplifiers are available. In addition, a Wi-Fi Battery Life Calculator shows how to profile power consumption in a specific application. From a software perspective, Infineon's ModusToolbox™ Software development ecosystem supports a wide range of Infineon microcontroller devices.

Summary: Smart home benefits using low-power, intelligent Wi-Fi solutions

Designing smart home products with minimized battery consumption comes with many benefits:

- Meets customers' growing expectations—enhancing their satisfaction, while elevating the device makers' brands.
- Helps manage network offload and congestion challenges in system design.
- Reduces recharging frequency by keeping the processors in connected smart home devices in the sleep mode most of the time, while still maintaining always-on cloud connectivity through the intelligent combo chip.

These benefits can be achieved by using a low-power, high-performance Wi-Fi and Bluetooth® solution such as the CYW43022, featuring an ideal mix of ultra-low power and rich network offload capabilities.

Reference

- CYW43022 product page

www.infineon.com

Published by
Infineon Technologies AG
Am Campeon 1-15, 85579 Neubiberg
Germany

© 2023 Infineon Technologies AG
All rights reserved.

Public

Date: 05/2024

Please note!
This Document is for information purposes only and any information given herein shall in no event be regarded as a warranty, guarantee or description of any functionality, conditions and/or quality of our products or any suitability for a particular purpose. With regard to the technical specifications of our products, we kindly ask you to refer to the relevant product data sheets provided by us. Our customers and their technical departments are required to evaluate the suitability of our products for the intended application.

We reserve the right to change this document and/or the information given herein at any time.

Additional information
For further information on technologies, our products, the application of our products, delivery terms and conditions and/or prices, please contact your nearest Infineon Technologies office (www.infineon.com).

Warnings
Due to technical requirements, our products may contain dangerous substances. For information on the types in question, please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by us in a written document signed by authorized representatives of Infineon Technologies, our products may not be used in any life-endangering applications, including but not limited to medical, nuclear, military, life-critical or any other applications where a failure of the product or any consequences of the use thereof can result in personal injury.