White Paper

Smart Wireless Network For Reliable, Low Cost, Low Power Solutions

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Sensors and control devices, that can measure anything from temperature to air flows, have found their way into a wide range of applications, such as environmental monitoring, agriculture, security and shop floors. The high cost of designing, installing, wiring, and maintaining the network has inhibited their widespread adoption. Emerging wireless communication solutions, with integrated mesh networking capabilities, can be an ideal platform for a wide array of low-cost, energy-efficient, low data rate applications. However, existing wireless technologies such as Bluetooth and ZigBee have limitations such as power consumption and cost. This has become a barrier to the wide scale adoption of this type of technology.

This paper explains an alternative approach that really overcomes these barriers. Systems designers and decision makers can use this paper to compare the available solutions for their wireless sensing, control and tracking & tracing applications.

Today's Challenges

The applications that can benefit most from today's wireless solution are typically low transmission activity devices that need to be operational for a long period. Wireless mesh networking technology enables data collection and processing in a variety of situations, for applications that include environmental monitoring, context-aware personal assistants (tracking of location, activity, and environment of the user), home automation, machine failure diagnosis, medical monitoring, and surveillance and monitoring for security.

To develop a system that can carry out these functions, at very low cost and low power consumption is the key issue, which cannot be easily addressed using technologies such as Bluetooth and IEEE802.15.4/ZigBee. Bluetooth technology for example, has latency issues, and has an excessive current consumption due to its complex design. Moreover, unit costs are still quite high. ZigBee is positioned as the low power alternative to Bluetooth. However, it has similar issues as Bluetooth, such as complexity (which requires a stack size of typically 32K to 128K), scalability, and power consumption of the mesh networking devices. Important application areas such as tracking and tracing are very hard to implement efficiently using ZigBee technologies.

Even though there is currently a push for a unified standard that promises a singular world of interoperability between products from different vendors, this comes at a price. Standards can be limiting and reduce the degree of freedom available to the application developers in the system design. For a more local smart environment networks, customers can either choose products compliant to a standard and accept its limitations and delays in improvements or have freedom and choose a reliable leading edge solution with far better performance and most importantly a better business case and ROI. Therefore, many developers and users prefer to have a system with superior qualifications of efficiency, cost and performance, without any compromise on features.

The key to an economically viable system is to obtain the optimal tradeoff between complexity and simplicity sufficient to achieve reliable wireless functionality, but yet keep system cost and power consumption to a minimum.

Proposed Solution

We propose a system composed of µNodes, SmartTags, and Gateways. They self-organize at power-up and quickly re-configure as devices join, leave, or move around the network. They also adapt to changes in network traffic and propagation conditions. These capabilities enable mobility of individual devices or the entire network, and minimize installation and operating costs. The system is capable of executing local Business Rules, thereby triggering user-defined events such as an increase in temperature. The mesh network provides fault-tolerant paths to all nodes and long battery life at low-power sensor nodes. Adding devices makes sensing and control networks more reliable and more efficient. The scalable, self-organizing network adapts to changes in traffic and radio conditions, device status and location.

This is a variant of wireless mesh networking solution that consists of modules embedded with networking software and ultra-low power radio transceiver technology, using a decentralized, multi-hop mesh topology, where each node can communicate with its immediate neighbors. If a single node fails for any reason, messages are automatically routed using alternate paths. Due to its very energy-efficient design and networking protocols, network nodes can operate for several years on a single battery, or operate on an alternate energy source like ambient light. Flexible, powerful networking protocols reside on small and low-cost network processor modules

Further sections elaborate these topics.

Reliable communication

A wireless network with autonomous nodes will inevitably experience collisions from nodes trying to communicate at the same time resulting in overlapping communication packages. The probability of collisions is dependant on the number of active nodes in the network.

In our proposed approach, collisions hardly occur, using a combination of techniques such as frequency hopping, clustering, time synchronization, data-rate, and the actual small size of a communication packet. In comparison, the IEEE 802.15.4 standard, which has been adopted by the ZigBee Alliance as the basis of its own communication standard, is based on a DSSS (Direct Sequence Spread Spectrum) technology, which has good interference resistance characteristics, but comes with known disadvantages. DSSS coding implies that greater RF bandwidth is consumed per transmitted data bit. For example, devices support 8 channels in the 868 MHz frequency band at 50 kbs, as opposed to just 1 channel at maximum 20kbs for IEEE 802.15.4. Apart from the higher overall traffic needed for DSSS, it also leads to increased power consumption. Approach is to transfer data at the highest possible data rate, resulting in less occupancy of the wireless medium, and also in having a much higher number of alternative channels in case of presence of interference. The higher vulnerability to in-band interference is solved using state of the art techniques such as frequency hopping, clustering, and time synchronization.

Low cost

The networking protocols have been designed for low data rate applications, with reliability and low cost as primary targets, without compromises to other less useful functionalities. Therefore have a low complexity, with a small code footprint and RAM usage (less than 4k total). Moreover, due to its ultra low power design, and integrated capabilities to interact with the physical world (e.g. digital and analog ports to directly connect sensor and actuators), there are hardly any external components needed, and the node can operate on a very small button cell battery. The entire system can be fitted within the physical outline of a button cell, and still have battery lifetimes of years for low data duty-cycle applications typically targeted by ZigBee. This implies that the overall system cost is very low. Alternatively, most current ZigBee solutions require a separate, medium-range microcontroller device for network processing and application functionality. This is not required in our approach.

Low power consumption

We can achieve a truly ultra low-power system in tags as well as nodes by utilizing several techniques, and combining them in a low complexity and coherent networking protocol stack.

For example, the coding used in our approach, is highly bandwidth efficient, resulting in a very small packet, and thus also lower power consumption. A typical packet of an IEEE 802.15.4 compatible device would require twice as much bits as a functional similar packet on our proposed network stack. Even more efficiency is achieved due to highly energy efficient networking protocols.

The mesh networking functionalities provided by this approach, μNodes are designed to be battery powered, using the latest proven research in low power wireless networking. In contrast, Full Function ZigBee nodes that function as mesh routers typically cannot operate on a battery, since they need to be powered for most of their time. Low power in ZigBee is most prominent (and promoted) for the reduced functionality devices, which cannot act as routers or coordinator, and heavily depend on the existence of more advanced devices. Moreover, ZigBee networks depend on one special central device, the coordinator. This architecture obviously limits scalability, but also involves a significant communication load when devices in the network move. Typical applications such as tracking and tracing are therefore less suited for ZigBee devices, due to the required high number of devices, and the mobility patterns. In contrast, networking protocols are fully distributed, such that there is no special device in the network needed to coordinate the system. Networks, therefore, can easily scale to several hundreds or thousand devices in one network, which is a significant improvement over ZigBee.

Even though the communication capabilities of nodes are notable, devices are more than just a communication platform. Instead nodes are complete programmable sensing and control devices with integrated functionalities such as positioning, remote - over the air (re-)programming, etc.

Conclusion

A system architect is always balancing along many tradeoffs when designing a system. One can either choose products compliant to a standard and accept its limitations and delays in improvements, or have freedom and choose a reliable leading edge solution with far better performance and most importantly a better business case and ROI. The key to an economically viable system is to obtain the optimal tradeoff between features and complexity sufficient to achieve reliable wireless functionality, yet keeping system cost and power consumption to a minimum. This paper has introduced the primary challenges for low power, low cost, and reliable wireless networking, and has proposed an approach to overcome limitations with the prevailing standards.

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