HOW TO DESIGN A LOW POWER WIRELESS SENSOR NETWORK

Driven by the demand for "green" technology and better use of power, a new generation of extreme low power wireless networks is being developed for use in machine to machine networks, for industrial and control applications, as well as for health, security and other purposes. This article is about this new approach towards truly wireless networks – without any network cables or power lines.

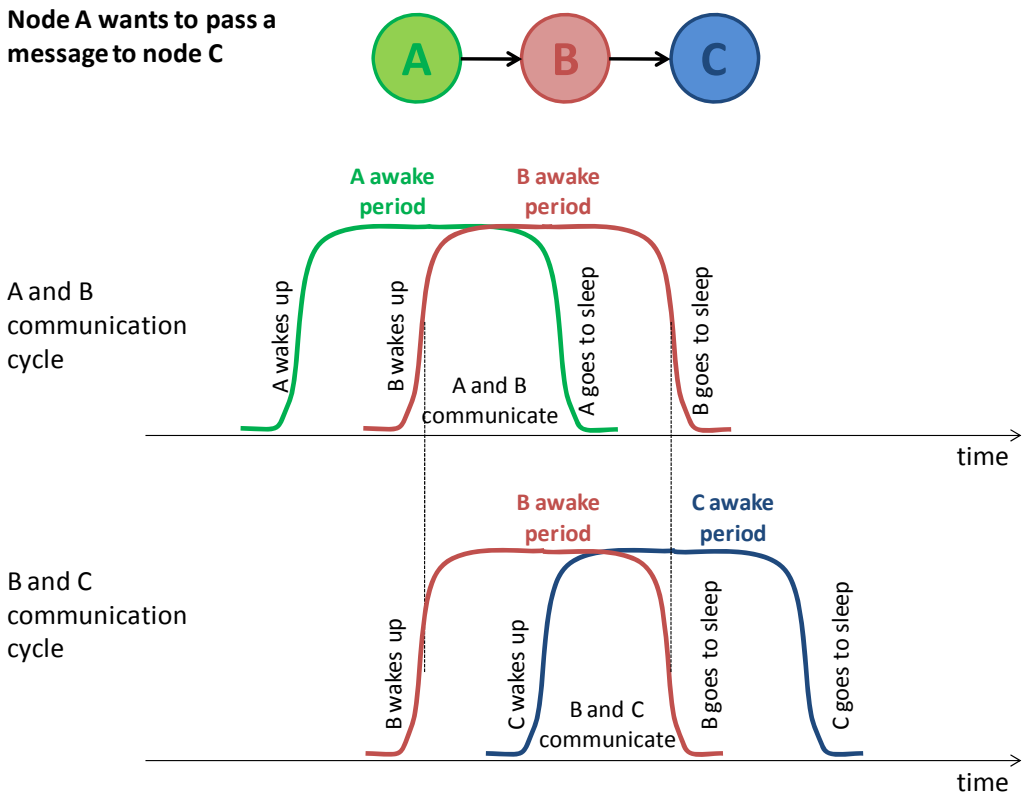
By using systems that require very little power, it is possible to develop wireless networks that can last longer than their batteries and therefore require little or no maintenance over the life of the device, or a device that does not require any batteries at all, instead, using energy harvesting to provide the power required.

Before the era of wireless sensor communication, low-power was synonymous to low current consumption. The lower the milli-amp figure, the better the device was at low-power operation. It was all about how many or rather how few milli-amps the electronics consumed. Furthermore, when the device did not need to communicate, it was turned off, to be awoken when an alarm situation was raised or a periodic status update was called for. This technique is called *duty cycling*.

Current consumption – milli-amps – and duty cycling are still important in wireless sensor networks. However, low current consumption is only part of the solution. Five other essential issues are key to developing low power Wireless Sensor Applications

1. **Low-power Wireless Mesh Routing:** One of the most dramatic differences between wireless sensor communication technology and other well known wireless technologies is the ability of sensor nodes to forward messages from other nodes further down a communication chain. This is called *mesh routing* or *multi-hop networking*. Mesh networking is an effective and reliable solution to span large infrastructures in a reliable wireless fashion, beyond the range of what a single wireless link can do.

   In a Low Power Mesh network all the nodes, including the mesh routing nodes, operate in low-power. The picture below depicts how Low-power-routing works when a Node A wants to send a message to Node C, through Node B. All nodes in the pictures are low-power nodes, sleeping most of the time.



The breakthrough lies in synchronizing the sleep/wake-up cycles of the nodes to each other. This means a node wakes up when it *expects* a message from a neighbor node. As a result the routing nodes too will be in a nearly powerless sleeping state most of the time, achieving ultra-low-power operation. The better the wakeup schedule can match the communication expectations, the less power is consumed by 'in void' wakeup periods.

2. **Peak current:** Peak current is a critical design parameter. When closely examining the power consumption behavior of electronic circuits, it becomes apparent that what looks like a flat current curve at a first glance, actually bears more resemblance to a mountain range with peaks and valleys. When certain functional blocks become active, they cause a peak. When two functional blocks switch on simultaneously, they cause a peak of double height. The secret in reducing the peak power lies in carefully managing when the functions are turned on and off and avoiding double peaks at all times.

3. **Graceful Power Failure:** When an energy source has dried out, the electronics cannot communicate and are *dead* to any meaningful purpose. This can be a normal event (solar cell at midnight) or as an exceptional condition (depleted battery).

   In both cases the power problem can be dealt with, provided the application is intelligent enough to detect the upcoming problem *before* the energy source has completely dried out. During this *last breath* the device should perform a number of actions to inform its environment of the situation, transmit some critical data and put itself in a state that allows fast recovery when the power is restored.

By using a built-in Graceful Power Failure function, the system is able to monitor various sorts of low-power energy sources including batteries and solar cells. They carefully monitor the state of the power circuits and raise different levels of alarms ranging from an early warning to a near-death. These alarms are escalated to other parts of the system such that they all can move into a state that fits the alarm condition.

4. **Sleep current:** Wireless chips are usually quoted on their power consumption in receive and transmit mode. Remember however that in order to achieve low power, the devices are duty cycled, moving between alternate states of sleeping and being awake. The longer the battery life-time needs to be, the longer the device will sleep before 2 wake-up periods. Unfortunately, electronic circuits are never really "sleeping". Although the powered-down circuits are not doing anything meaningful, a small leak current flows through the transistors. The leakage can amount to several 10's of µA. Sleep current is not usually considered an important design factor, but is becomes extremely important when designing a circuit to live for 5 years or more on a battery, sleeping most of its life.

5. **Wakeup time:** as duty-cycling is achieved by switching off as many parts as possible during the sleep state, all these parts need to be re-activated when returning to the active state : voltage regulators need to settle, clock oscillators need to start up, digital electronics which were powered down need to be put in a known state. Making the startup times as short as possible, without compromising current consumption in normal operation, and smart sequencing of such startup cycles, avoids unnecessary energy consumption, and is crucial for ultra low power operation.

Standards

Quite valuable, standardization can ensure interoperability across brands, provide second sourcing availability, ensure competition between technology providers to drive prices down, provide compliancy with global regulations and generate the opportunity to tap into a large body of knowledge. Here is a brief overview of the different standards bodies and groups working in the low power wireless networking space.

Feature	ZigBee	ZigBee PRO	ISA-100	Wireless HART
Transceiver technology	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.4
Support for wireless mesh routing	Yes	Yes	Yes	Yes
Ability to cope with very large networks	No	Yes	Yes	Yes
Latency determinism	No	No	Yes	Yes
Reliability determinism	No	No	Yes	Yes
Built in security features	Yes	Yes	Yes	Yes

Although standards were never developed to specifically suit the low power requirements, new low power routing (LPR) initiatives are currently being considered by ZigBee.

Some state-of-the-art chips enable an LPR network with battery powered devices to receive messages from nearby devices and forward these further down a longer communication chain. LPR adds a time synchronization mechanism to the network, allowing devices to wake up simultaneously to initiate communication and avoiding the need to be always on.

By integrating wireless mesh with low power, we are now entering an “internet of things” – where devices and sensors talk to each other, providing information and data, without the need for any network cabling, or even better, without requiring power lines, regular battery maintenance, or maybe, without the need for any batteries at all.

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