

## Q&A: Wireless Sensor Networks for Harsh Environments

3/1/06

- Q. What is a lost packet? Data that will never be received or a packet colliding that is going to be retransmitted and then received?
- A. In a wireless sensor network that uses TDMA, there are zero internal collisions because the network uses time-synchronized transmissions. A lost packet is defined as data that will never be received by mote (the mote counts the number of packet that it receives). When a packet is retransmitted and then received by the mote, the packet is considered to have been successfully transmitted.
- Q. What happens if the central manager goes down? This appears to be a single point of failure?
- A. Wireless sensor network providers may handle this issue differently. At Dust Networks, a central manager is backed up by a second manager that acts as an emergency failover manager.
- Q. You showed the way TDMA avoids collisions within a single network. How does this deal with external interferers, which you can't control?
- A. With our current TDMA implementation we do not have internal collisions. Regarding external interferers, each communication link between two motes cycles through all sixteen 802.15.4 frequency channels. Dust Networks has tested 30% of a 2.4GHz band blocked and maintained very high reliability.
- Q. How do you define path stability?
- A. Path stability measures mote-to-mote transmissions. It is the percentage of data packets that have successfully reached their destination over the primary path. If a transmitting mote does not receive an acknowledgement on the primary path it will resend on an alternate path. Due to the unique benefits of mesh routing, data reliability can be 100% even with very low path stability.
- Q. The limits of Aloha and S-Aloha are for star-networks only. What about multi-hop?
- A. It may get worse. There is a "hidden mote" problem where two transmitters cannot hear each other, but the receiver can hear both – the theoretical capacity with hidden mote problems goes down to about 17%.
- Q. How far are we from having wireless networks for control & actuation rather than just monitoring?
- A. This will be based on market adoption and perception. There are control and actuation use cases that can be supported by current generation wireless sensor networks.
- Q. What are some of the solutions to the issue of 'power scavenging' by sensor nodes to alleviate the requirement of replacing batteries?
- A. Dust Networks approaches the issue of power consumption in a much different way. Because our customers demand an extremely low-powered network, we utilize a synchronized communication protocol to enable extremely deep duty-cycling and unmatched power efficiency. Dust Networks' motes consume as little as 25 $\mu$ A of current and even heavily-burdened routing motes, handling traffic from dozens of neighbors, which typically consume less than 200 $\mu$ A – over one hundred times less than other mesh networking solutions.
- Q. Which issue of EE Times [was Kris referring to during the presentation]?
- A. Endless Energy is Harvesting's Promise, February 27, 2006, <http://www.eetimes.com/showArticle.jhtml?articleID=180207741>
- Q. Doesn't the 802.15.4 MAC layer protocol implement some form of CSMA?
- A. Dust Networks uses the 802.15.4 PHY layer but implements TDMA in the MAC. This is supported by the standard.

## Wireless Sensor Networks for Harsh Environments – Q&A continued

Q. Does Dust provide any sensor node localization algorithms for automatic node localization during an ad hoc deployment?

A. Dust Networks does not provide any localization algorithms for automatic mote localization at this time.

Q. Can you expound on why DSSS doesn't 'cut it'?

A. In 802.15.4, DSSS is still only using a small slice of the frequency band. As shown by Kris Pister during the presentation, other signals are much stronger and will overwhelm the 802.15.4. Dust Networks has demonstrated that Wi-Fi and Bluetooth cause non frequency-hopping networks to fail.

Q. Is a channel a frequency band? How are channels implemented?

A. That is correct, a channel is a frequency band. The channels utilize 802.15.4.

Q. In the case of a systematic noise in a large section of the spectrum is TDMA still more efficient than CSMA?

A. In this particular case, Dust Networks believes that TDMA is more efficient. TDMA will enable greater throughput through whatever slice of the frequency spectrum is available.

Q. What sort of industry acceptance has this protocol achieved? For example, Bluetooth has the SIG with 2,000 companies pushing to evolve the protocol.

A. Dust Networks is committed to standards and partners with industry and standards groups such as ISA, the HART Foundation, and WINA to ensure wireless sensor networking technology is easy to implement and interoperable. For more information about each organization, please visit their respective websites: [www.isa.org](http://www.isa.org), [www.hartcomm.org](http://www.hartcomm.org), [www.wina.org](http://www.wina.org).

Q. How does your technology compare to the latest (long-range) Bluetooth? Also all the industry heavy weights are currently committed to make Bluetooth the standard of choice - how does this impact your technology's market acceptance?

A. Our customers have suggested that Bluetooth has too much overhead for low-data rate applications in industrial environments. Bluetooth is targeted at high-bandwidth communications such as mobile phones.

Q. If the gateway is running at Ethernet data rates, what is the data rate on the mesh?

A. In the order of kb.