Performance Comparison of Wireless Sensor Network Standard Protocols in an Aerospace Environment: ISA100.11a and ZigBee

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Wireless Sensor Networks (WSNs) can provide a substantial benefit in spacecraft systems, reducing launch weight and providing unprecedented flexibility by allowing instrumentation capabilities to grow and change over time. Achieving data transport reliability on par with that of wired systems, however, can prove extremely challenging in practice. Fortunately, much progress has been made in developing standard WSN radio protocols for applications from non-critical home automation to mission-critical industrial process control. The relative performances of candidate protocols must be compared in representative aerospace environments, however, to determine their suitability for spaceflight applications.

In this paper, we will present the results of a rigorous laboratory analysis of the performance of two standards-based, low power, low data rate WSN protocols: ZigBee Pro and ISA100.11a. Both are based on IEEE 802.15.4 and augment that standard's specifications to build complete, multi-hop networking stacks. ZigBee Pro targets primarily the home and office automation markets, providing an ad-hoc protocol that is computationally lightweight and easy to implement in inexpensive system-on-a-chip components. As a result of this simplicity, however, ZigBee Pro can be susceptible to radio frequency (RF) interference. ISA100.11a, on the other hand, targets the industrial process control market, providing a robust, centrally-managed protocol capable of tolerating a significant amount of RF interference. To achieve these gains, a coordinated channel hopping mechanism is employed, which entails a greater computational complexity than ZigBee and requires more sophisticated and costly hardware.

To guide future aerospace deployments, we must understand how well these standards relatively perform in analog environments under expected operating conditions. Specifically, we are interested in evaluating goodput – application level throughput – in a representative crewed environment in the presence of varying levels of 802.11g Wi-Fi traffic. To do so, we use the NASA Johnson Space Center Wireless Habitat Testbed (WHT), a metallic, habitation-sized module designed for co-existence testing of wireless systems. In its quiescent state, the sealed WHT provides an RF-quiet environment to which we can selectively add interfering systems; it also provides a realistic level of multi-path self-interference for systems under investigation.

In our test, we deploy two representative five node networks, configured in a star topology with all nodes reporting directly to a WSN gateway. Each ZigBee network WSN node is built using a Texas Instruments (TI) CC2530 system-on-a-chip radio running TI's ZigBee Pro Z-stack. Each ISA100.11a network node is built using a Nivis VersaNode 210 system-on-a-chip radio. In both cases, radios interface with TI MSP430-F5438 microcontroller implementing a common test application. Interference is provided by a D-link 802.11g Wi-Fi router transporting traffic generated using the Iperf network testing tool.   For the single-channel ZigBee network, effects of both direct and indirect Wi-Fi

interference are evaluated. For the channel-hopping ISA100.11a network, effects of interference from multiple Wi-Fi routers configured in non-overlapping 802.11g channels are evaluated. Our results show that, in general, the more lightweight ZigBee network performs well at low interference levels, but performance degrades as interference increases. Conversely, the more complex and costly ISA100.11a network continues to perform well as Wi-Fi interference levels increase.