

# Wireless TDMA-based Protocol for Long-term Periodic Monitoring of Batteries

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The CSEM ultra-low power Wireless protocol airTDMA offers configurable bandwidth, fault detection and recovery to long term operations to wireless sensor networking, in particular for battery monitoring, where the suppression of wires significantly save weight, simplify manufacturing and maintenance.

Time Division Multiple Access (TDMA) protocols divide time into periodic patterns made of multiple slots, which are allocated to unique transmitters. This scheduling prevents packet collisions as long as the nodes in the network are synchronized. CSEM initially designed the airTDMA, successfully providing low power real-time communication for aeronautical application, supporting periodic transmissions. This protocol proves to perfectly fit the needs of long-term battery monitoring applications, in which sensor nodes are integrated with a Battery Management System (BMS) to monitor battery parameters such as temperature and voltage, and to perform self-healing tasks.

AirTDMA exhibits the following properties:

- Configurable bandwidth: Each node can be configured with different allocated bandwidths, which can be changed in real time depending on the node's requirements. This allows for optimal use of the available bandwidth among all nodes. The configuration also permits control over packet latency.
- Robustness: The protocol includes an acknowledgment mechanism to manage packet delivery. Nodes check if packet were not received and trigger a retransmission of the packet.
- Low-power on the edge: The sensor node keeps its radio off except only when transmitting or synchronizing with the Wireless Data Concentrator (WDC), saving enough energy to allow the system to run on small batteries or through energy harvesting.

As illustrated in Figure 1, AirTDMA consists of cells managed by a Wireless Data Concentrator (WDC), which coordinates communication with multiple Sensor Nodes (SN) that gather data. Both the WDC and SNs interface a nRF52840 processor [1], which contains a 2.4GHz transceiver and run the airTDMA on a Nordic Semiconductor proprietary 1Mbit/s mode.

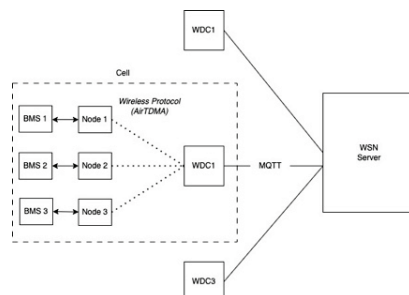


Figure 1: AirTDMA typical network topology.

WDCs are connected to an Ethernet backbone network, interconnecting the Wireless Sensor Network (WSN) server that manages the network. The MQTT publish/subscribe protocol facilitates the integration of multiple cells into the same WSN, enabling the creation of a larger network.

To simplify deployment, the network can be configured using a dedicated file format that includes the network topology, sensor definitions sampling rate for each node. With this file, the WSN Server will automatically associate sensor nodes with their respective WDCs and initiate data acquisition. During data acquisition, the WSN will continuously store incoming data and log, locally for debugging purposes and in a cloud-based InfluxDB for remote analysis.

For detection, the server compares the number of received data packets with the expected number, based on the configured packet rate. If the difference exceeds a certain threshold, an alert is generated to indicate a potential issue in the wireless network, such as a problem with one of the SN or the WDC. Other situations, like unexpected software conditions, can also trigger alerts. These alerts can be notified to the network operator via emails, Microsoft Teams notifications, etc.

Additionally, the WSN server can periodically trigger pre-configured battery self-healing sequences. In the future, these sequences could also be triggered based on the battery condition computed from the received data.

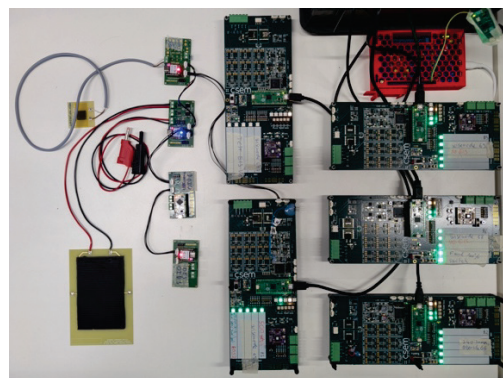


Figure 2: Setup picture.

As illustrated in Figure 2, a long test deployment was conducted with 6 nodes connected to a single WDC. Each node is sending a packet every minute containing a battery status. Additionally, a self-healing command is sent to the node every 1 hours. The packet loss was configured to a 10% loss threshold. During the test, a few alerts were triggered due to node failure but most of them didn't reports any problems.

This technology is currently being developed and tested within the scope of the EU-funded Phoenix [2] project. Future developments will focus on increasing the number of connected nodes and increasing the protocol's bandwidth.

[1] Nordic nRF52840 Processor: <https://www.nordicsemi.com/Products/nRF52840>

[2] PHOENIX is partially funded by the European Commission under Grant number 101103702; <https://phoenix-smartbatteries.eu>