Communications Over On-Board Wireless Sensor Network For Active Aircraft Monitoring

Motivation

Aeronautics must satisfy constantly rising demands for lower travel costs, better service quality, the very highest safety and environment standards and an air transport system that is seamlessly integrated with other transport networks.

The European goals for 2020 include a 50% cut in CO2 emissions and a dramatic reduction in the impact of human error. These can be achieved by cutting down on fuel consumption, e.g., by monitoring drag (one of the largest sources of fuel usage) on the aircraft body and wings and taking corrective action as and when necessary.

Monitoring systems will also need to be designed to react to problems immediately as they occur, hence the need for dense sensor network capable of communicating with the control system in real time.

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Scope

The work aims at developing a cross-layer robust communication system for a wireless sensor network made up of groups of sensors densely deployed for monitoring and controlling key physical variables within or external to the aircraft, bearing in mind the ACARE goal of “more affordable, safer, cleaner and quieter” aircraft travel. To make a sensor network economically and technologically feasible, the sensors must be low-cost, low-power, dispensable and autonomous devices, with limited processing capacities, whose batteries are not expected to be recharged during the flight. In aircraft system’s monitoring crucial issues that arise are reliability, safety, and fault tolerance.

Research in this project is focused on reliable power-aware communication techniques and algorithms for the sensor networks ranging from the physical to the network layers in the protocol stack. The **physical layer** addresses needs for simple but robust modulation, transmitting and receiving techniques. The **data link layer** investigates a powerful adaptive forward error correction scheme with low complexity. At the **network layer**, we propose an energy-efficient routing scheme based on multi-hop transmission and address topology changes, constantly optimizing node distribution.

Challenges

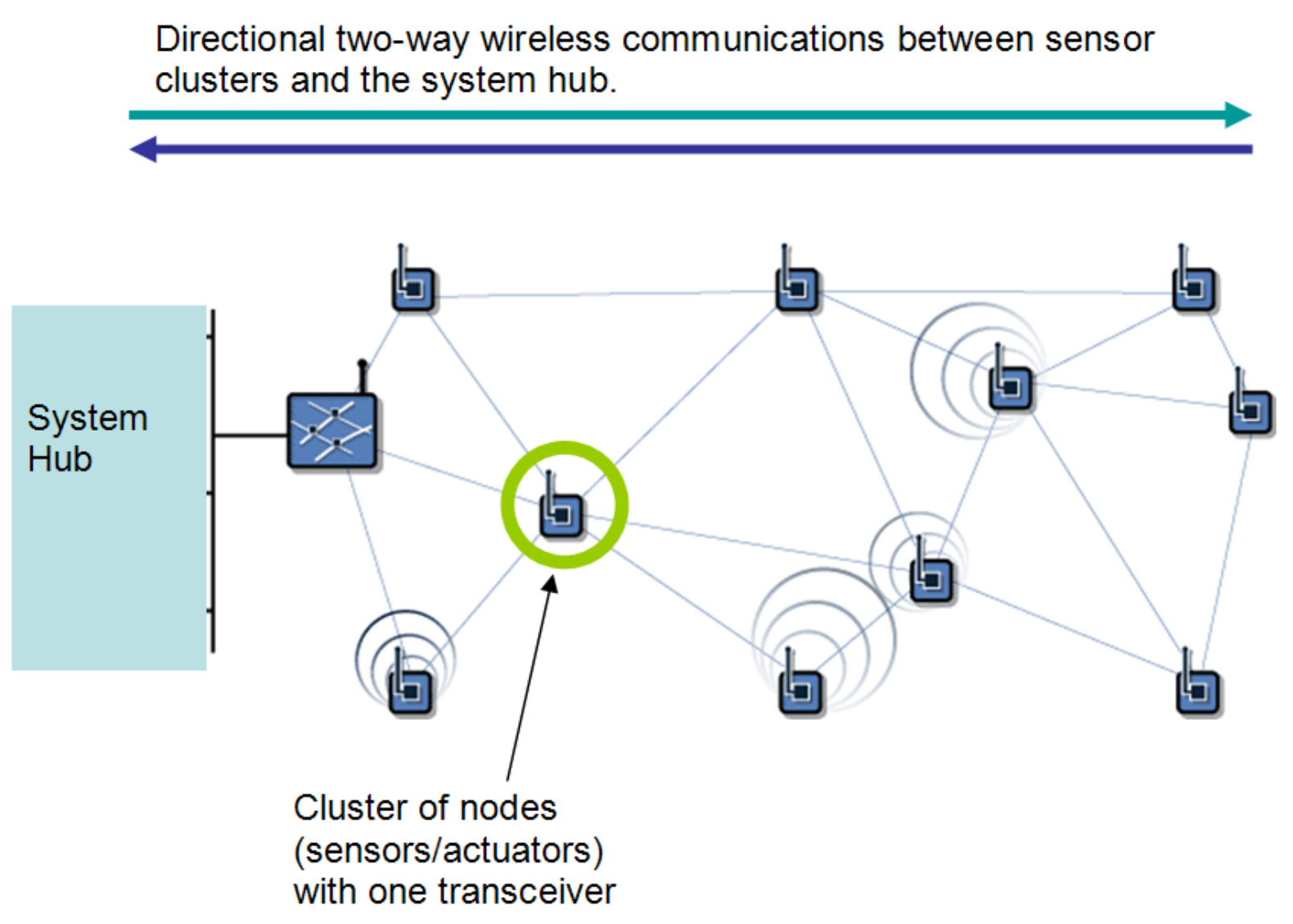
When deploying a dense sensor network in the aircraft several issues must be carefully considered:

- *Fault tolerance* in the presence of individual node/sensor failure,
- *Reliability and accuracy* of the sensed data,
- *Real-time* data delivery,
- Power *efficiency* and related to that the *cost* of the system since hundreds of tiny sensors are needed to be deployed on the small area,
- *Occupied bandwidth* since other devices, systems, and services should coexist,
- *Interference* (conflict) with other essential devices, systems, and services on-board.

Scenario

We resort to a short-range communication strategy that is wireless with low-risk of interference with other systems. A wireless solution can be fast and easy to install and eliminates the need to pull cable across the aircraft, leading to reduced weight and hence fuel consumption. The wireless system also offers the advantage of setting up a network in places which cannot be easily wired, while offering more flexibility and adapting easily to changes in the configuration of the network. As mentioned previously, the wireless systems can be configured in a variety of topologies to meet the needs of specific applications and installations. Configurations can be easily changed and range from peer-to-peer networks suitable for a small number of users to large infrastructure networks that enable roaming over a broad area.

Transceiver Design: Coding, Modulation and RF Transmission



For sensing and monitoring in aircraft off-the-shelf technologies (such as Zigbee IEEE 802.15.4, Bluetooth, WiMax IEEE 802.15, WLAN IEEE 802.11) cannot be employed for following reasons:

i we are limited to a narrow and specific spectrum range to avoid interference/conflict with RF enabled devices inherent in electronic equipment (such as PDAs, lap-tops, phones), as well as existing on-board systems (wireless and wired!),
ii the communication architecture of the sensor network being deployed on wings or other parts of the body of the aircraft needs to be flexible and adaptable to changes, e.g., change in weather, addition/removal (whether physically or a simple activation/deactivation) of sensors/actuators, reconfiguration, replacement/upgrade of aircraft equipment,
iii the transceiver design must be optimised such that it meets reliability, fault tolerance, low complexity and timing constraints, that are inherent in real-time systems, and this is not possible with the off-the-shelf RF technologies listed above.

Decentralized Communications: Multi-Hop Transmission and Transceivers Positioning

Once the design of the transceivers is complete, we position them cleverly to reduce interference and required transmitter power. Algorithms are developed for optimal transceiver positioning, hence defining the structure of the underlying wireless network and issues that arise due to the multi-hop and decentralized nature of the information delivery. The proposed multi-hop communication can effectively overcome interference, shadowing and path loss effects in a sensor network, if the node density is high enough. Another advantage of the multi-hop sensor network lies in its ad hoc distributed nature which enables rapid and random reconfiguration and adaptation to topology changes (e.g., due to sensor loss or reallocation, task or reachability change).

References

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