Publish-Subscribe Communication for Swarms of Unmanned Vehicles

P. Dallemagne, D. Piguet, J.-D. Decotignie

CSEM has combined Publish-Subscribe communication, filtering techniques and time constraints in an ultra-low power wireless embedded platform to reduce data traffic and power consumption. This platform will be used in the context of swarms of unmanned flying vehicles.

The Publish-Subscribe communication model (P/S) is a powerful and power-efficient concept that allows for data-centric exchanges in an uncoordinated network of nodes. It is particularly well suited for the data communication across swarms of mobile unmanned vehicles (UxV). In the RAWFIE EC project [1], CSEM and other partners are using this concept for several purposes and in different environments (e.g. Apache Kafka over Internet protocols). CSEM is developing a "Proximity" component that provides P/S mechanisms in low-power, low-resource controllers present on UxVs participating to large-scale experiments.

The Proximity component aims at discovering the identity of neighboring UxV nodes in real-time and to possibly interact with them, without depending on any other external middleware, infrastructure or equipment. Each UxV uses the P/S services to exchange data that feeds its flight coordination controller, such as the identification of other UxV, speed, estimates of relative distances, perceived neighborhood (notification of UxV appearance and disappearance), status of the internal components of the UxV and, finally, sensor readings. It bears similarities to the transponders used on commercial airplanes.

The Proximity component is based on a dedicated, low-power, radio communication platform running the "Head" element of the Proximity component (Figure 1), which implements the P/S protocols and services as well as the interface with the other vehicle components. The "Delegate" element implements the interface running on the vehicle controller.

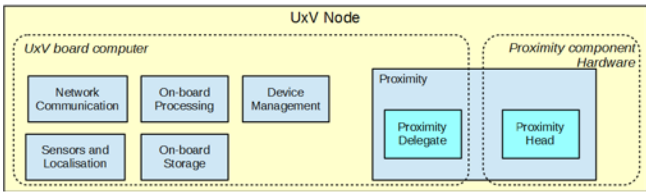

Figure 1: the RAWFIE UxV Node architecture including the Proximity component.

The Proximity component abstracts the mechanisms needed to store the acquired data waiting for subsequent transmission, either as a whole, or in parts. The Delegate allows the UxV to publish some of its attributes, which may be of interest for the other UxVs, such as identifier, status, etc. The Head transmits the corresponding data using the dedicated radio interface. Typically, the Delegate allows the UxV software for subscribing to Proximity component topics published by other UxVs. The Head forwards data received from the dedicated radio interface to the Delegate.

In order to reduce the traffic, the P/S services support filters on both content and context, as proposed in CCBR [2]. Filters on content data enable the publication of data only when the values are within a range of interest. Context filters are applied on some system properties for a fine selection of which UxVs can respond to a subscription. For instance, a content and context based subscription can request UxVs of type "aerial" to publish their battery level if it is below 20%. The way that content and context are filtered and the parties involved in that process are keys to the optimization of the P/S protocol.

The portion of the transmitted data that is not received by any legitimate subscriber, the protocol headers and the control messages, constitute the overhead. The Proximity component carries the filters in specific subscription messages, performs filtering primarily at the source on the out-going traffic to reduce bandwidth usage and energy consumption, and supports incoming traffic filtering in order to handle publications made from merged filters at the source

The content and context filters proposed by CCBR are versatile enough for many applications because they allow subscriptions to specify the kind of data and source nodes as well as provide some in-network calculation that help reducing the amount of data carried. To further reduce the traffic, CSEM added the mechanisms for taking into account timing attributes, such as subscription validity (aka. lease time) and information life-time. Subscriptions include, for example, data validity and delivery timing information, so that data that has expired before reaching the destination can be discarded.

Combined with the ultra-low power communication protocol WiseMAC, the solution enables operation for days even after a UxV's main battery is depleted. It offers convenient bricks for increasing the safety of the RAWFIE elements and their environment by providing increased autonomy and a better means for reaction to single and multiple UxVs (e.g. collision avoidance). Typically, the UxVs communicate with the RAWFIE system through a primary communication interface, which the Proximity component can replace in case of failure, for transferring data and notifying the RAWFIE managers about the situation and the location of the UxV (useful e.g. for finding a UxV when it is lost). Further, the Proximity component can be used to relay topics published by UxVs, which are disconnected from the primary network, as well as, to gather data stored by sensors deployed on the ground, or in the water.

[1] The RAWFIE project is partly funded by the European Commission (FIRE+ challenge, Horizon 2020) under Contract Number 645220.

[2] G. Cugola, M. Migliavacca, "A context and content-based routing protocol for mobile sensor networks", Proc. EWSN European Conference Wireless Sensor Networks (2009) 69.