AWARE: Platform for Autonomous Self-Deploying and Operation of Wireless Sensor-Actuator Networks Cooperating with AeRial ObjEcts

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Wireless sensor networks are used to increase the efficiency of many applications, such as target detection and disaster management. Wireless sensor networks with static nodes have been developed and also experimentally applied for detection and monitoring activities [1]. However, static wireless sensor networks have important limitations as far as the required coverage and the short communication range in the nodes are concerned. The use of mobile nodes could provide significant improvements. Thus, they can provide the ability to dynamically adapt the network to environmental events and to improve the network connectivity in case of static nodes failure. On the other hand, the aerial and remotely piloted vehicles are now able to be coordinated for missions such as the detection and monitoring of events.

The AWARE project (EU IST-2006-33579) is committed to the development of a platform that will enable the cooperation of unmanned aerial vehicles (UAVs) with ground wireless sensor-actuator networks comprising static and mobile nodes. The platform offers self-deployment, self-configuration and self-repairing features by means of cooperating autonomous helicopters. These features are highly relevant in natural and urban environments without pre-existing infrastructure or in situations where the infrastructure has been damaged or destroyed. The cooperation of these aerial vehicles with the ground wireless sensor network offers many potentialities such as disaster management applications. The aim of this paper is to discuss the requirements and challenges of AWARE platform with focus on fire detection scenarios. Also, some possible research topics related with those challenges will be mentioned in this paper.

The elements of an AWARE system designed for detecting fire are ground wireless sensor network (GSN) which consists of temperature, humidity, smoke sensors, UAVs, and the body area network (BAN) which is the network on the fire-fighters including body sensors that are capable of sensing the hearth rate, temperature, and oxygen saturation etc. The GSN monitors physical phenomena and gives the nodes context about their surroundings. UAVs with the ability to transport and deploy loads (i.e. communication equipment) are used for deployment of new sensor nodes into the existing GSN to repair the node failures and network connectivity. With BANs, the condition of the fire-fighters can continuously be monitored e.g. to prevent body heating.

Node failures (due to harsh environmental conditions during the fire) and communication failures (due to mobility of nodes or interference or even malicious interference) make the topology of the network in AWARE system very dynamic. Often, redundancy in the network is assumed in order to be robust against these dynamics. The networking protocols must be able to handle these dynamics and must be self-healing, when conflicts occur. Also, the integration of sensor nodes transported by UAVs and the GSN to repair node failures is very important since this self-deployment feature allows the operation in sites with difficult or impossible access and without communication infrastructure. Therefore, self-deployment system should be well designed.

The main objective of the AWARE system is to detect events (e.g. fire) by means of sensors and wirelessly communicate this event and assist other nodes to deliver the event. These two basic operations, event detection and data dissemination, must be well studied. A localized and distributed detection algorithm is highly preferred for the AWARE system. The basic idea of distributed detection is to have a number of independent sensors each makes a local decision (typically a binary one) and then to combine these decisions at a fusion sensor to generate a global decision. Such an event-detection algorithm must also be fault tolerant. On the other hand, it is crucial to design and employ an energy-efficient data dissemination protocol for AWARE.

The classical view of a wireless sensor network involves one or more stationary sinks gathering data from a sensor network. These sinks are usually multiple hops away from the sources of data. Therefore, routing of data to the sink is one of the fundamental operations in the network. Four important factors - energy cost, robustness, throughput and delay - should be considered for efficient routing schemes in wireless sensor networks. Most current solutions consider all the four factors but they are designed mainly for stationary sinks. The AWARE application characterizes itself by the mix of static and mobile nodes and (importantly) mobile sinks moving within the WSN. Therefore, the objective of message routing protocol of the AWARE system is to route data towards the moving sink in an energy efficient and robust way. When nodes are mobile, their location is key-issue in the interpretation of their sensor values. Several localization algorithms were studied for AWARE and geographical routing, which at first glance seems to fit the requirements perfectly, was looked into. Another approach under study, is "gossiping". The idea behind gossiping is that all information gathered by the WSN is diffused throughout the network. As such, any node can be inquired about events occurring elsewhere in the network. This approach might be valuable for moving sinks e.g. UAV's subscribing to sensor information in the wireless sensor network.

Moreover, the single-sink (gateway) architecture is not scalable for a larger set of sensors covering a wider area of interest since the sensors are typically not capable of longhaul communication. To allow the AWARE system to cope with additional load and to be able to cover a large area of interest while maintaining dependable services, network clustering is usually pursued for multiple sink cases. Multiple gateway nodes are placed and sensors are grouped around them forming a network clusters. Therefore, the routing protocol of AWARE must support multiple sinks and clustering architecture.

As a summary of this discussion, the project will develop and combine a number of cutting edge technologies, such as the development of self-deployment strategies, and the network-centric cooperation methods. The expected results and techniques seem transferable to many potential applications involving wireless networking of heterogeneous objects.

REFERENCES

[1] Mainwaring A., Polastre J., Szewczy R., Culler D., Anderson J., “Wireless Sensor Networks for Habitat Monitoring”. WSNA’02, Atlanta, Georgia, USA, September 28, 2002.