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Control and Actuation in Data-Centric Wireless Sensor Networks

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October 12, 2001

Abstract

In this paper we will explore control and actuation mechanisms in sensor networks. Dynamic changes in link quality encourage the use of connection-less, best effort communication protocols. Large scale and ad hoc methods of deployment, coupled with resource-constrained small form factor nodes, suggest the use of data-centric routing mechanics. Directed diffusion [1] is one of such mechanism. Through its use of data-centric routing, allows for energy savings during request and data dissemination in the network. This makes it suitable for use in wireless ad-hoc sensor networks in environmental sensing and monitoring. Sensing and monitoring applications have been the primary focus of most research in the area of data-centric networks. However, control and actuation in such networks has received insufficient attention.

Resource constraints and energy limits encourage the use of tiered architectures. Such architectures would include nodes with different sensing, actuation and processing characteristics. Some nodes may have fixed location, while others may be mobile. Static nodes might perform sensing and locally distributed computations, while mobile nodes roam the network providing additional services such as high-fidelity sample collection, augmentation, and in some cases remediation and computation. A scenario that would leverage such an architecture might be a set of static nodes requesting additional sensing capability from a mobile network tier. The mobile tier in turn would self-organize and attempt to fulfill the request. This scenario suggests the need for in-network control and actuation protocols. The latency benefits of distributed in-network processing (as contrasted with centralized edge processing) are particularly critical for actuation.

In this paper we explore one possible approach to control and actuation in data-centric sensor networks, Two-Way diffusion. The key to our approach is the use of the communication protocols that are native to the data-centric sensor network. Such homogeneity of communications seems to promise a more simple implementation, which translates into lower resource and energy requirements. The sequence of events is the following:

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Event source:
      Request robots with certain capabilities

All capable robots:
      Respond with position (and other attributes)

Event source:
      Pick one or more robots that are best suited for the task
      (ex. closer to the target location, have higher energy levels)

Robot(s):
     Lookup the event source.

[Event source: Respond with updates]

Robot(s):
     Establish one way communication channel with the source (this
     will confirm the request for robot and serve as a update channel
     for robot, and might aid robots in navigation).
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The paper describes the details of the algorithm and provides experimental results from our implementation on a field of 20-50 wireless sensor nodes and 1-3 mobile micro-robots. The static sensor nodes were developed at UC Berkeley. Mobile micro-robot (Robomote) has been developed by USC.

References

[1] . Intanagonwiwat, R. Govindan and D. Estrin, "Directed Diffusion: A Scalable and Robust Communication Paradigm for Sensor Networks," ACM/IEEE International Conference on Mobile Computing and Networks (MobiCom 2000), August 2000, Boston, Massachusetts.