Panel on Mobility in Sensor Networks

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ABSTRACT

Sensor networks are promising unprecedented levels of access to information about the physical world, in real time. Many areas of human activity are starting to see the benefits of utilizing sensor networks, in almost all such cases, sensor networks are statically deployed. The next evolutionary step for sensor networks is to handle mobility in all its forms. This panel aims to identify the benefits from such a step and recognize the resulting research challenges.

Categories and Subject Descriptors

C.2.1 [**Computer - Communication Networks**]: Network Architecture and Design—*Wireless communications*;; H.2.4 [**Database Management**]: Systems—*Distributed databases, Query processing*

General Terms

Algorithms, Management, Design, Performance, Reliability, Security

Keywords

sensor networks, mobility, sensor informatics

1. SENSOR INFORMATICS

Sensor networks are quickly gaining momentum as a promising yet challenging data collection, management, and dissemination paradigm [3, 7, 14]. They are collections of individual sensors configured to address a common goal (e.g., monitoring a phenomenon). Each sensor node typically comprises sensing hardware, power source, minimal processing and storage capabilities, and the ability to transmit/received collected information.

Supported by advances in sensor technology and wireless communications, sensor networks enable the monitoring of complex events by collecting spatially, temporally, and thematically focused information. Each sensor is typically collecting a specific thematic type of information in its vicinity, measuring, for example, temperature or wind velocity, or even capturing optical imagery. Sensors operate over a period of time (as allowed by their power capabilities) and capture information at different temporal instances, triggered by variations in the phenomenon they monitor, or at specific pre-selected intervals. This information is then processed and aggregated across larger regions as it propagates along the network.

Due to the unique characteristics of information collection and management within sensor networks, sensor informatics present certain unique challenges. The defining characteristics of sensor informatics include:

- Information is collected in the form of spatially, thematically, and temporally distributed snapshots of the monitored events.
- Severe operational or functional constraints affect network operation [11].
- Sensors collect semi-infinite data streams [1, 2, 8].
- Information collected through sensor networks is typically of higher degrees of unreliability and uncertainty compared to traditional applications.

In the next section, we introduce on additional dimension: mobility.

2. MOBILITY IN SENSOR INFORMATICS

From an informatics point of view we can identify three major components of a sensor network system: the phenomenon that is being monitored, the sensor nodes, and the users that access this information. By considering the mobility status of these three components we can distinguish different classes of sensor networks [13]. In static networks, the mobility of sensors, users, and the monitored phenomenon itself is minimal or ignored. For example, sun and temperature sensors in a sunroom may collect relevant information and use it to control motorized shades in order to maintain these parameters within preset limits. This static paradigm may be expanded by introducing mobility in one or more of the abovementioned three levels of the sensor network system:

- Sensor level mobility: the sensors themselves may be moving. [4, 6, 10]. Examples include sensors mounted on moving cars or flying unmanned aerial vehicles (UAVs), collecting information as their carriers constantly change their location and/or orientation.
- Information level mobility: the event monitored by the network is mobile [5]. An example may be the evolution of an oil spill that we try to model through measurements at distinct buoy locations.

MDM 2005 May 9-13, 2005, Ayia Napa, Cyprus

- User level mobility: users accessing the information collected by the sensor network may themselves be moving, and thus the information that is pertinent to them may change over time. For example, monitoring the traffic conditions on the way to the nearest hospital changes as the user is changing his/her position.

Motivating Example One motivating application that exhibits all the above characteristics is a network of environmental monitoring sensors, mounted on mass transit vehicles, that are used to monitor the current pollution levels in a city (and also detect chemical, biological, nuclear substances). In this case, the sensors themselves are moving (e.g., being mounted on buses), the monitored event is also mobile (e.g., the smog generated by a poorly maintained truck is moving along with the truck), and the users of this network can also be mobile (e.g., environmental protection agency officers that are on the field and use a wireless-enabled PDA to access this information).

In the next section, we report on some of the challenges that the mobility dimension brings to sensor networks.

3. RESULTING CHALLENGES

Sensor informatics faces certain unique challenges compared to traditional data collection applications. They include:

- Adaptability in the face of failure (need to support failure-induced and resource-aware reconfigurations).
- Need for novel query approaches (assuming that a high-level declarative interface is more suitable than a low-level programming one) [7, 9].
- Computation in the presence of uncertainty in data and network topology.

The introduction of mobility in sensor networks is introducing some additional challenges, including:

- Space and time are receiving renewed emphasis as defining parameters in the data collection scheme.
- The timely dissemination and processing of collected information becomes much more complex than a network resource optimization problem, as it has to take into account user and phenomenon mobility.
- On demand network reconfiguration now has to consider sensor repositioning over time, to best monitor an evolving event.
- There exists the expectation of higher levels of modeling within the network, so that it can respond in a timely manner to emerging situations and reconfiguring itself to meet the corresponding demands. Accordingly, efficient and versatile techniques to model spatiotemporal information are a necessity.
- Multimodal, spatiotemporal query capabilities are required to extend the "standard" query capabilities in traditional sensor networks.

The goal of this panel is to identify benefits and opportunities resulting from the introduction of all aspects of mobility in sensor networks, and to recognize the corresponding research challenges.

4. REFERENCES

[1] H. Balakrishnan, M. Balazinska, D. Carney, U. Cetintemel, M. Cherniack, C. Convey, E. Galvez, J. Salz, M. Stonebraker, N. Tatbul, R. Tibbetts, and S. Zdonik. Retrospective on Aurora. *The VLDB Journal*, 13(4):370–383, 2004.

[2] S. Chandrasekaran, O. Cooper, A. Deshpande, M. J. Franklin, J. M. Hellerstein, W. Hong, S. Krishnamurthy, S. R. Madden, V. Raman, F. Reiss, and M. A. Shah. TelegraphCQ: Continuous Dataflow Processing for an Uncertain World. In *Proceedings of the First Biennial Conference on Innovative Data Systems Research*, 2003.

[3] J. M. Hellerstein, W. Hong, and S. R. Madden. The sensor spectrum: technology, trends, and requirements. *SIGMOD Rec.*, 32(4):22–27, 2003.

[4] A. Howard, M. Mataric, and G. Sukhatme. From Mobile Robot Teams to Sensor/Actuator Networks: The Promise and Perils of Mobility. In *Online Proceedings of the First Workshop in GeoSensor Networks*, 2003. Downloadable from http://www.spatial.main.edu/ gsn03/program.html.

[5] C. Jaynes. Acquisition of a Predictive Markov Model using Object Tracking and Correspondences in geospatial Video Surveillance Networks. In Stefanidis and Nittel [12], pages 149–166.

[6] T. Liu, C. M. Sadler, P. Zhang, and M. Martonosi. Implementing software on resource-constrained mobile sensors: experiences with Impala and ZebraNet. In *MobiSYS '04: Proceedings of the 2nd international conference on Mobile systems, applications, and services*, pages 256–269. ACM Press, 2004.

[7] S. Madden, M. J. Franklin, J. M. Hellerstein, and W. Hong. TAG: A Tiny AGgregation Service for Ad-Hoc Sensor Networks. In *OSDI '02: Proceedings of the 5th symposium on Operating systems design and implementation*, 2002.

[8] S. Madden, M. J. Franklin, J. M. Hellerstein, and W. Hong. The design of an acquisitional query processor for sensor networks. In *SIGMOD '03: Proceedings of the 2003 ACM SIGMOD international conference on Management of data*, pages 491–502. ACM Press, 2003.

[9] R. Newton and M. Welsh. Region Streams: Functional Macroprogramming for Sensor Networks. In *Proceedings of the First International Workshop on Data Management for Sensor Networks (DMSN)*, Toronto, Canada, Aug. 2004.

[10] J. Schiller and A. Voisard. Information Handling in Mobile Applications: A Look beyond Classical Approaches. In Stefanidis and Nittel [12], pages 97–122.

[11] A. Sharaf, J. Beaver, A. Labrinidis, and K. Chrysanthis. Balancing energy efficiency and quality of aggregate data in sensor networks. *The VLDB Journal*, 13(4):384–403, 2004.

[12] A. Stefanidis and S. Nittel, editors. *GeoSensor Networks.* CRC Press, 2004.

[13] S. Tilak, N. B. Abu-Ghazaleh, and W. Heinzelman. A Taxonomy of Wireless Micro-Sensor Network Models. *ACM Mobile Computing and Communications Review*, 1(2), 2002.

[14] Y. Yao and J. Gehrke. The cougar approach to in-network query processing in sensor networks. *SIGMOD Rec.*, 31(3):9–18, 2002.