Mobility Centric Campus Area Sensor Network for Locality Specific Applications *

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Abstract

Research in sensor networks has begun to address the use of mobility to improve the reachability of the network, but a number of network principles and application patterns remain to be explored in this context. We propose here a network architecture that uses energy constrained devices for enabling new campus wide applications. Specifically, our demonstration illustrates a new network stack and application framework for a class of locality specific applications. The locality specific nature favors exploiting the limited, slow and regional mobility pattern present in large campuses, as opposed to exclusively exploiting the Internet or the cellular network.

Categories and Subject Descriptors

C.3 [**Special-purpose and Application-based Systems**]: Real-time and embedded systems; H.4.3 [**Communications Applications**]: Information browsers; J.4 [**Social and Behavioral Sciences**]: Sociology

General Terms

Design, Experimentation, Human Factors

Keywords

Mobile applications, Locality specific, Sensor networks

1 Motivating Scenario

We focus our attention on large campuses, such as universities or businesses, where a significant number of people naturally congregate in regions for extended but not necessarily fixed periods of time. It is increasingly common that most of these people carry with them a mobile device such as cell phones or PDAs. We are interested in scenarios that exploit the possibility of multi-hop networking on these mobile devices.

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Consider the scenario where a person walks into a Recreation and Physical Activity Center and wishes to locate a free squash court or treadmill. She also wishes to find out if any of her friends or other sports partners is presently there. While she may be able to check on facility availability by going to the information office in the Center, queries about specific equipment, friends or playing partners cannot be so easily answered. In this case, we propose that she post queries using her mobile device (say, her PDA or cellphone) that in multi-hop wireless collaboration with other mobile devices in Center are answered by a service that uses location-specific sensors and processors. WiFi or 802.15.4 communications, as opposed to cellular or internet communications, suffice for this scenario.

More generally, our motivations for studying campus area wireless sensor networks that leverage mobile devices include:

- There is adequate density of mobile users in certain parts of the campus to enable multi-hop mobile-to-mobile communication, provided that such communication does not sap the devices of too much energy.
- The mobility pattern observed in a campus area is such that there are "Regions" in the campus where the users remain mostly stationary or move about with low speed while there movements in between regions tend to be with moderate speed. In a university campus, for instance, students and faculty move infrequently once they are in their department classrooms or offices and tend to remain confined within the building for a while, but then they can travel at moderate speed between their respective departments and the cafeteria.

And the class of locality-specific applications we have considered includes:

- **Buddy Finder**: A user has a list of "buddy" nodes, and can ask a "Post-Office" (a resource rich base station associated with each region) to find which of these mobile users are currently present in the region.
- **Virtual Social Networks**: A user publishes a "self-profile" to the regional Post-Office, which other users could search for in terms of their "interest" so as to establish communication between themselves starting with individual messages.
- **Virtual Clubs**: Group of users can register as a "club"

and messages sent to the club can then be multicasted to all registered users in the region.

2 System Architecture

The system consists of densely populated Regions. Each Region consists of one or more of the following types of nodes:

- A special static node called Post-Office that is assumed to have significant storage and is not energy constrained.
- Zero or more mobile nodes that are assumed to move slowly within the Region. There is a time-of-day related rate at which mobile nodes join or leave the region. (For the purposes of our demo, we are presently using TMotes connected to cellphoned to serve as our mobile node; we understand cell phone manufacturers are considering 802.15.4 radios as one of several candidates for wireless mesh networking. But we could have used WiFi just as well.)
- Zero or more sensor nodes that need not need not be densely deployed and are not assumed to form a connected network on their own. That is, data from the sensors may be collected via the mobile devices.

Post-Offices of different Regions are connected by either wired, mesh, or mobile networks, yielding a campus wide network.

3 Technical Challenges

It is crucial that that our network stack consist of energy efficient protocols (this would be even more true if we were using a Wifi radio). Some of the research issues in designing our network stack include:

- Most of the energy in our mobile network is spent listening to the radio channel, especially in networks where the data load is very less. Hence to decrease the idle listening, we would use a receiver-centric energy efficient MAC protocol [2].
- Using timesync provides a basis for energy reduction, but we must use a time-synchronization protocol with reasonable accuracy and quick stabilization for mobile wireless networks [1].
- The set of users is dynamic and not known a priori. Hence we need a service that tracks the active users in the network at a reasonable time scale but with limited use of network bandwidth or energy.
- For our applications, data is routed via mobile devices. The mobile devices themselves are subject to highly dynamic links and disruptions; hence, we need a reliable, robust, energy-efficient and disruption-tolerant routing. Unlike a traditional sensor network where most data is a convergecast to the basestation or a broadcast from basestation, we need low energy protocols to support routing from and to individual nodes in the network.
- Since the network tolerates disruptions in communication, we need to buffer messages in the system using good distributed storage algorithms, which use efficient use of the little storage space in the devices.

4 Demonstration Scenario

We will demonstrating the Recreation and Physical Activity Center scenario that we discussed above using a surrogate application. A surrogate locality-specific application for a conference such as Sensys is one that senses the *Most Popular Poster & Demonstration*, measured in terms of the number of unique visitors.

The operational idea is to associate with each Poster and each Demonstration area a stationary TMote "Visitor Sensor". This TMote will use a rather low radio range of just a few feet to beacon to conference attendees, each of whom would carry a TMote that we have earlier loaned to them and which would respond to the beacon. Since we want to keep track of unique individuals who visit each poster, we prefer the above mentioned 'radio sensing' instead of an actual motion sensor attached to a TMote. Reports of the number of unique visitors sensed by each 'Poster & Demo Visitor Sensor' would be aggregated at a base station via the multihop mobile TMote device network and used to calculate the Most Popular ones at a base station. The mobile users can post queries to the base station or get periodic updates from the base station, regarding the popular poster.

We will have a backup "ground truth" collection mechanism to collect the sensed information directly from the 'Visitor Sensor TMote', to validate the reliability of the mobility-centric aggregation. Also, for each protocol in our network stack, we will collect data logs to analyze the different performance metrics of the protocols. During the time of the demonstration, we will be able to publish some of the metrics associated with our protocols.

5 References

[1] T. Herman and C. Zhang, "Stabilizing Clock Synchronization for Wireless Sensor Networks", to appear in Symposium on Stabilization, Security and Safety, SSS 2006, November 2006.

[2] H. Cao, K. Parker and A. Arora "OMAC: A Reciever Centric Power Management Protocol", International Conference on Network Protocols ICNP, November 12-15, 2006.