Wireless Sensor Networking in E-NEXT

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Abstract

E-NEXT is an EU FP6 Network of Excellence that focuses on Internet protocols and services. This short paper presents a synopsis of several projects in the area of wireless sensor networks that are being conducted by E-NEXT partners. In doing so it conveys the breath of interests and expertise in this important and emerging area.

1. Introduction

E-NEXT [1] is an EU FP6 Network of Excellence that focuses on Internet protocols and services. It builds upon two EU COST Actions - COST263 on the Quality of Future Internet Services, and COST264 on Networked Group Communication. E-NEXT commenced in January 2004.

The general objective of E-NEXT is to reinforce European scientific and technological excellence in the networking area through a progressive and lasting integration of research capacities existing in the European Research Area (ERA). The Network currently has 41 partner institutions, representing academic and industrial interests across a large number of countries in the ERA. Activities within E-NEXT are organised in four overall themes:

1. Mobile and Ambient Networking
2. Content Networking
3. Self-Aware and Scalable Networking
4. Service-Aware Networking

Within the first theme listed above, University College Cork chairs a task force on Wireless Sensor Networks (WSN) research. Within the context of E-NEXT, this short paper presents an edited collection of brief descriptions of key WSN projects. The selection is not intended to be comprehensive, but simply to provide a broad perspective on some of the activities, and information of where to solicit more detailed information.

The projects focus on current research areas of WSN hardware technology, communication protocols, systems software and novel applications.

2. FOKUS, Univ. Athens, LIP6 & LNCC

FhG-FOKUS, the University of Athens, the LIP6-CNRS University of Paris VI, and LNCC Brazil are collaborating on a project entitled “Potential-based Clustering for WSN”.

In budget-based clustering algorithms, an initiator node A (the cluster head) is assigned an initial budget b(A), from which it accounts for itself and distributes b(A)-1 to its neighbors. These neighbors do the same and so on until the budget is exhausted. Existing budget-based algorithms blindly apply this method in the sense that they disregard the nature of the neighborhood. It is proposed to use a potential-based clustering algorithm that uses existing hello messages to disseminate node connectivity, which we call the potential of each node. Every node maintains a database containing the potential of its neighbors, which serves for determining the amount of budget assigned to each one of them.

Potentials are also used to identify the cluster heads (CH).

A distributed, randomized timer scheme is introduced, where the timer to start the clustering procedure at each node is configured with a value that is inversely proportional to the potential of that node. In this way, high-potential nodes trigger the clustering procedure first, becoming candidates to be the CH. The proposed potential-based clustering has a number of advantages over previous solutions such as: faster network decomposition, minimization of contention between clusters, scalability, and limited communication overhead.

In a dynamic WSN nodes can change location, be removed, or added. A topological change occurs when a node disconnects and connects from/to all or part of its neighbors. In case of clustered networks modification of the cluster structure in the presence of topology changes leads to performance degradations in the network. For that reason cluster maintenance procedure is required. The clustering maintenance scheme has to be designed in the sense to keep the cluster infrastructure stable in the face of topology changes.

A mobile WSN with topological clustering structure and single level hierarchy is assumed. Each cluster has a CH. The network is a multi-hop one. They are no border nodes introduced. The potential-based clustering algorithm based on budget allocation (see p.1) is applied for clustering creation and will be compared with two existing cluster creation algorithms, the Rapid algorithm and the Persistent algorithm. An advanced clustering maintenance scheme is developed and shall be implemented in the case of topology changes e.g. when *New node is added* and when *Old node is moved away*.

For details see [2].

3. Swedish Institute of Computer Science

The Computer and Network Architecture Laboratory of the Swedish Institute of Computer Science is conducting an active program of sensor network research. In particular, the Contiki operating system and the uIP TCP/IP stack, which are both freely available, have been widely adopted and ported to several platforms.

The current hardware platform is the ESB/2, developed by Jochen Schiller and colleagues at Freie University, Berlin. The Contiki operating system provides an event-driven kernel and programming model, with support for both lightweight stackless threads and preemptive multi-threading. Operating system support for dynamic processes and loading facilitates system development and allows field upgradeability. The TCP/IP layer has been optimized for resource constrained devices, allowing a sensor network to be connected directly to the Internet infrastructure, enabling useful management functionality. A Contiki emulation/simulation environment also assists development and debugging. Recent applications based on the ESB/Contiki platform include monitoring building security, marine environmental measurement, and HVAC monitoring.

Energy efficiency is another area of study, with a current emphasis on the development of an adaptive, energy-efficient MAC layer suitable for the decentralized sensor network environment.

Related research at SICS includes work in self-configuring networks, especially mechanisms that allow a sensor network to adapt its behavior to changing user objectives. Multi-dimensional visualization techniques and advanced service interfaces assist users to visualize sensor data and define appropriate objectives.

For details see [3].

4. Swiss Federal Institute of Technology

Service discovery (e.g. finding the closest data sink) in sensor networks is challenging because of the absence of any central intelligence in the network. Traditional solutions are hence not well suited for sensor networks. A new service discovery mechanism has been devised, which is designed to support multiple service instances which is implemented in an entirely distributed way. The basic idea is to distribute information about available services to the network neighborhood. This is achieved by using the analogy of an electrostatic field: A service is modeled by a (positive) point charge, and service request packets are seen as (negative) test charges which are attracted by the service instances. In this approach, the physical model is mapped to a sensor network in a way where each sensor calculates a potential value and routes service requests towards the neighbor with the highest potential, hence towards a service instance. This approach allows for differentiation of service instances based on their capacity.

The required protocols and methods are defined and implemented in a network simulator. Using extensive simulations, an evaluation of the performance and robustness of the mechanisms has been conducted. In addition, methods to further improve the control overhead and battery lifetime with regard to accuracy are analysed. The results indicate good performance and convergence even in highly instable environments. It is argued that this technique can and should be further exploited, e.g., as a routing protocol in MANETs.

For details see [4].

5. University College Cork

The Mobile & Internet Systems Laboratory (MISL) in the Department of Computer Science at University College Cork (UCC) has an active research programme on wireless sensor networking. One key project is D-Systems, funded by Enterprise Ireland and carried out in partnership with UCC's National Microelectronics Research Centre (NMRC).

The objective of the D-Systems project is to develop a platform, incorporating innovative hardware and software enabling technologies, that will realise distributed autonomous sensors (in the range of several hundred nodes) for future ad-hoc networks in the ambient systems and intelligent environments arena.

The key output on the hardware side will be miniaturised autonomous sensing units that can be dispersed within, and around, materials and structures for use in the everyday environment. The target sensing unit will consist of a 5mm cube incorporating commercial-off-the-shelf microsensors, ICs for signal processing, computation, and wireless communications, and a power source combined together within a highly innovative microelectronics packaging configuration.

On the software side, the output will consist of a power-aware operating system for the miniaturised autonomous sensing units, protocols for developing scalable and mobile distributed ad-hoc networks, and software solutions for fault tolerant and intelligent computation across the distributed network.

The initial prototypes are 25mm cube running TinyOS and a custom low-power MAC layer. An application to traffic/parking management is being explored.

For details see [5].

6. University of Cyprus

The Network Research Lab (NRL) at the University of Cyprus is currently conducting research in developing a network of sensors that detects toxic contaminants and estimates the location of the contamination source. Such a network can be of tremendous help to emergency personnel trying to protect people from terrorist attacks or responding to an accident. One of the most dangerous types of terrorist attacks is contaminant transport by the releasing of chemical, biological or radiological substances. This requires immediate tracking of the source of contamination and action by the proper authorities to deal with the crisis.

Various types of sensors can measure the level of toxic contaminant and when networked together they can provide real-time detection, identification and assessment of an event. The group uses estimation techniques- least squares, maximum likelihood, Bayesian estimators- to find the plume source location and *CSIP* (Collaborative Signal Information Processing) techniques to address the difficult problem of tracking the chemical plume. Furthermore, NRL is investigating issues relating to directed diffusion routing and will employ data aggregation techniques to come up with an energy efficient way to communicate this information back to the sink. A testbed using Berkeley “modes” is currently being established.

For details see [6].

7. University of Mannheim

A project by Marcel Busse presents a novel topology control algorithm to conserve energy in wireless sensor networks. In contrast to existing approaches, that algorithm is timer-based and does not exchange adjacency information in a two-hop neighborhood while still guaranteeing network connectivity. The algorithm works in three phases and in a distributed and localized fashion. First, cluster heads are elected. To connect these nodes, a second and third phase is carried out where gateways and bridges are added. All other nodes are suppressed and become sleeping nodes with their radio transceivers turned off. In preliminary performance evaluations, we show the efficiency of our approach in terms of extended network lifetime. With 70 nodes in transmission range, our algorithm achieves a network lifetime approximately 10 times higher than that of a sensor node that never sleeps.

In a project by Thomas Haenselmann the world coordinates of an unlocalized node N in a wireless sensor network can be determined GPS-less with the help of established neighbors that already have obtained their coordinates. A number of approaches have been suggested to localize N using an adjacency-matrix, the field force of the incoming radio signal or even the packet loss-rate. The goal is to improve the position-determination of N by means of the position suggestions by the localized nodes within the radio range. It can be shown that the prediction of N's position can be improved significantly by this unequal weighting scheme of the neighbor's suggestions. Briefly speaking this weighting scheme emphasizes the position suggestion of nodes with good prediction quality while it decreases the weight of far-away nodes which are only able to localize N coarsely.

For details see [7].

Acknowledgement

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10. References

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