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SYSTEM ARCHITECTURE FOR WIRELESS SENSOR NETWORKS

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ABSTRACT−*System and three generations of a hardware platform designed to address the needs of wireless sensor networks. Our operating system, called TinyOS uses an event based execution model to provide support for finegrained concurrency and incorporates a highly efficient component model. TinyOS enables us to use a hardware architecture that has a single processor time shared between both application and protocol processing. We show how a virtual partitioning of computational resources not only leads to efficient resource utilization but allows for a rich interface between application and protocol processing. This rich interface, in turn, allows developers to exploit application specific communication protocols that significantly improve system performance. The hardware platforms we develop are used to validate a generalized architecture that is technology independent. Our general architecture contains a single central controller that performs both application and protocol-level processing. For flexibility, this controller is directly connected to the RF transceiver.*

Keywords: wireless,sensore.

I. INTRODUCTION

The emerging field of wireless sensor networks combines sensing, computation, and communication into a single tiny device. Through advanced mesh networking protocols, these devices form a sea of connectivity that extends the reach of cyberspace out into the physical world. As water flows to fill every room of a submerged ship, the mesh networking connectivity will seek out and exploit any possible communication path by hopping data from node to node in search of its destination. While the capabilities of any single device are minimal, the composition of hundreds of devices offers radical new technological possibilities.

The power of wireless sensor networks lies in the ability to deploy large numbers of tiny nodes that assemble and configure themselves. Usage scenarios for these devices range from real-time tracking, to monitoring of environmental conditions, to ubiquitous computing environments, to *in situ* monitoring of the health of structures or equipment. While often referred to as wireless sensor networks, they can also control actuators that extend control from cyberspace into the physical world.

The most straightforward application of wireless sensor network technology is to monitor remote environments for low frequency data trends. For example, a chemical plant could be easily monitored for leaks by hundreds of sensors that automatically form a wireless interconnection network and immediately report the detection of any chemical leaks. Unlike traditional wired systems, deployment costs would be minimal.

It depicts a precision agriculture deployment—an active area of application research. Hundreds of nodes scattered throughout a field assemble together, establish a routing topology, and transmit data back to a collection point. The application demands for robust, scalable, low-cost and easy to deploy networks are perfectly met by a wireless sensor network. If one of the nodes should fail, a new topology would be selected and the overall network would continue to deliver data.

If more nodes are placed in the field, they only create more potential routing opportunities.

There is extensive research in the development of new algorithms for data aggregation, ad hoc routing, and distributed signal processing in the context of wireless sensor networks. As the algorithms and protocols for wireless sensor network are developed, they must be supported by a low-power, efficient and flexible hardware platform. This thesis focuses on developing the system architecture required to meet the needs of wireless sensor networks. A core design challenge in wireless sensor networks is coping with the harsh resource constraints placed on the individual devices.

II. WIRELESS SENSOR NETWORKS

The concept of wireless sensor networks is based on a simple equation:

Sensing + CPU + Radio = Thousands of potential applications As soon as people understand the capabilities of a wireless sensor network, hundreds of applications spring to mind. It seems like a straightforward combination of modern technology. However, actually combining sensors, radios, and CPU’s into an effective wireless sensor network requires a detailed understanding of the both capabilities and limitations of each of the underlying hardware components, as well as a detailed understanding of modern networking technologies and distributed systems theory. Each individual node must be designed to provide the set of primitives necessary to synthesize the interconnected web that will emerge as they are deployed, while meeting strict requirements of size, cost and power consumption. A core challenge is to map the overall system requirements down to individual device capabilities, requirements and actions. To make the wireless sensor network vision a reality, an architecture must be developed that synthesizes the envisioned applications out of the underlying hardware capabilities.

Sensor network application classes

The three application classes we have selected are: environmental data collection, security monitoring, and sensor node tracking. We believe that the majority of wireless sensor network deployments will fall into one of these class templates.

III. ENVIRONMENTAL DATA COLLECTION

A canonical environmental data collection application is one where a research

scientist wants to collect several sensor readings from a set of points in an environment over a period of time in order to detect trends and interdependencies. This scientist would want to collect data from hundreds of points spread throughout the area and then analyze the data offline. The scientist would be interested in collecting data over several months or years in order to look for long-term and seasonal trends. For the data to be meaningful it would have to be collected at regular intervals and the nodes would remain at known locations.

Node tracking scenarios

A third usage scenario commonly discussed for sensor networks is the tracking of a tagged object through a region of space monitored by a sensor network. There are

many situations where one would like to track the location of valuable assets or personnel. Current inventory control systems attempt to track objects by recording the last checkpoint that an object passed through. However, with these systems it is not possible to determine the current location of an object.

Cost and ease of deployment

A key advantage of wireless sensor networks is their ease of deployment. Biologists and construction workers installing networks cannot be expected to understand the underlying networking and communication mechanisms at work inside the wireless network. For system deployments to be successful, the wireless sensor network must configure itself. It must be possible for nodes to be placed throughout the environment by an untrained person and have the system simply work.

Computation

The two most computationally intensive operations for a wireless sensor node are the in-network data processing and the management of the low-level wireless communication protocols. As we discuss later, there are strict real-time requirements associated with both communication and sensing. As data is arriving over the network, the CPU must simultaneously control the radio and record/decode the incoming data. Higher communication rates required faster computation.

Media Access Control and Routing

Media Access Control and transmission scheduling is a key area of wireless sensor network research. Media Access Control, the mechanism for determining who can transmit and when, must be used to optimize for device power consumption. Researchers at UCLA have demonstrated the benefit of exploiting application specific protocols by creating customized MAC layers adapted to sensor networks. Their customized sensor network communication protocols attempt to reduce energy consumption and have shown 2-6x energy improvement when compared to standard 801.11-like wireless networking protocols.

IV. CONCLUSION

Hundreds of applications have been constructed that demonstrate the efficiency and capability of the Mica, Blue and Spec platforms. We have presented three key applications that demonstrate several of the capabilities of the overall system. Low-duty cycle networks built with the Blue node have demonstrated the ability for this architecture to support precise synchronization which leads to very low network duty cycle and multi-year lifetime for the environmental data monitoring scenario. Additionally, complex vehicle tracking deployments have shown TinyOS’s ability to meet application specific needs for data communication, data aggregation, sensor analysis and multi-hop routing.

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