Demo Abstract: Augmenting Reality with IP-based Sensor Networks

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ABSTRACT

We demonstrate low-power IP-based sensor networks by showing a system that interacts with the sensor network using a RESTful web service interface. The sensor data is displayed with overlaid 3D graphics on top of a live camera feed, so-called augmented reality. The augmented reality application is built with off-the-shelf components with no sensor network-specific code. The IP-based sensor network runs the Contiki operating system.

Categories and Subject Descriptors

C.2.2 [**Network Protocols**]: Protocol architecture

General Terms

Experimentation, Measurement, Performance

1. INTRODUCTION

Traditional sensor network deployments have consisted of isolated and homogeneous networks of sensors that periodically report their data to a sink. Although these networks have worked well in the past, a new set of emerging applications have increasing demands for integration with existing network infrastructures, interoperability with existing applications, and heterogeneity in both hardware, software, and communication technologies. IP-based sensor networks, first demonstrated by the Contiki operating system, have recently become popular as a way to mitigate these problems, but existing work has so far focused on specific link layers [3], on specific layers of the network stack [1, 2], or on specific application layer protocols on top of the stack [5, 6].

In this demonstration, we show how applications can be built on top of low-power IP-based sensor networks. Our demonstration consists of an augmented reality application that displays sensor data, overlayed on top of a camera feed of the sensor itself, as shown in Figure 1. We use a PC screen to show the augmented reality, but future applications could use a smartphone such as an iPhone to both capture the camera feed and to display the augmented reality image.

The application is built with off-the-shelf software components, with no sensor network-specific code. Sensor data is collected using a RESTful web service architecture, where a web server on each mote serves sensor data to the application. The application uses a standard RESTful web service library to communicate with the sensors in the sensor network.

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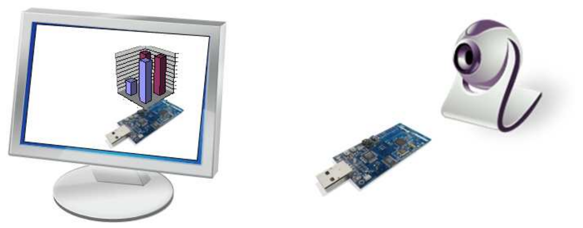

Figure 1: Sensor data is displayed overlaid over the sensor itself, as captured from the live camera feed. Sensor data is queried from the low-power IP sensor network using a RESTful web service architecture.

The system used automatic service discovery based on the IP service discovery protocol SLP. The services offered by each sensor node is displayed in the augmented reality feed shown on the screen.

Our demonstration is the first to show a web service-based low-power IP sensor networks with an interactive application running on top of it. The demonstration demonstrates our IP-based sensor network system architecture running on top of the Contiki operating system.

The system architecture for IP-based sensor networks that underpins the demo provides best-effort data collection, reliable stream transfer, and service discovery, while being interoperable with existing network infrastructures and applications. Our architecture is not tied to any specific low-power radio technology, but can communicate across heterogeneous systems. To maintain flexibility, the architecture uses strict layering.

The architecture uses the protocols in the IP protocol stack, as shown in Figure 2: IPv6, UDP, TCP, as well as standard application protocols such as HTTP. Seamless network bridging is used to make the sensor network part of the IPv6 network [4]. With our demo, we challenge the view that these protocols are too heavy weight for resource-constrained sensor networks. We demonstrate that the performance is enough for building interactive applications.

2. AN ARCHITECTURE FOR IP-BASED SENSOR NETWORKS

The aim of our architecture is to provide an interoperable and efficient system architecture for the emerging applications of wireless sensor networks. Our architecture builds on the established IP protocol stack, but with a number of optimizations that allow low-

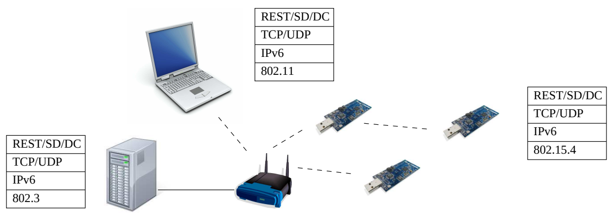

Figure 2: Being based on IP, our architecture supports multiple link layers. With seamless network bridging, the sensor networks become a natural part of the IP network.

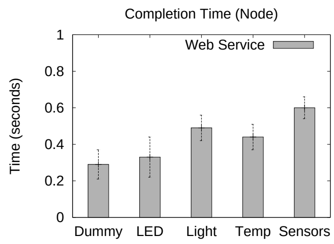

Figure 3: The completion times of RESTful web service calls on a Tmote Sky is well below one second.

power operation with a performance in terms of throughput and latency that is on par with that of existing sensor-network specific protocols.

Our architecture is designed around six principles:

Ease of integration. Our system is based on the notion that sensor networks should be easy to integrate with existing network infrastructures. The sensor network should be seen as a natural part of the existing network, not as an isolated add-on.

Leverage existing tools. Sensor networks should not require special software toolsets to be usable. Ideally, existing standard or de facto standard tools should be used when interacting with the sensor network.

Layering. Layering is an established principle for computer communication systems. Although layering was initially perceived inefficient for sensor networks, recent work has shown that layering does not necessarily affect performance negatively. We use the established principles of layering to provide a system that is both efficient and flexible. By defining strict interfaces between the layers in our stack, we can replace individual modules or protocols without requiring redesigns of other parts of the system.

Low-power operation. Long lifetime is essential to sensor network deployments. We build on years of efforts in the sensor networking community to design mechanisms that enable low-power radio communication through the use of duty cycling radio mechanisms.

Simplicity. Our architecture is intended to be useful outside the context of sensor network domain experts. Thus the architecture is built on well-known mechanisms and protocols used in general-purpose IP networks. This reduces the learning threshold for users, who may not be sensor network domain experts.

Portability. With an ever increasing number of sensor network hardware platforms, portability is important. Our architecture does not rely on any particular hardware device or system, but is portable across a range of different platforms.

At the application layer, we provide three basic mechanisms: service discovery, best-effort many-to-one data collection with UDP, and one-to-one reliable transport with TCP. On top of these basic communication mechanisms, more complex services may be built.

All protocols in our architecture are drawn from the IP framework. Service discovery is implemented with the Service Location Protocol (SLP), best-effort data collection on top of UDP, and reliable one-to-one data delivery with TCP.

On top of the TCP-based reliable one-to-one data delivery primitive, we build a REST-based web service layer. This layer can be directly connected to REST-based IT systems such as enterprise database systems, but can also be easily interfaced to other software systems. For this demo, we use off-the-shelf components to communicate with the REST-based web server running directly on each mote.

3. PERFORMANCE AND CONCLUSIONS

The completion time of a set of different web service requests are shown in Figure 3. The results were obtained through measurements from a Tmote Sky mote, running the low-power MAC protocol X-MAC [6].

Our demonstration shows the power of low-power IP-based sensor networks by demonstrating an interactive application developed with off-the-shelf software and no sensor network-specific code.

Acknowledgments

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