Demo Abstract: Michigan's IoT Toolkit

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ABSTRACT

Building connected, pervasive, human-facing, and responsive applications that incorporate local sensors, smartphone interactions, device actuation, and cloud-based learning—the promised features of the Internet of Things (IoT)—requires a complete suite of tools spanning both hardware and software. We present a set of these pieces, including a gateway, four hardware building blocks, multiple sensor platforms, an indoor localization system, and software for connecting users and devices. Each piece plays an integral role towards enabling applications, from facilitating rapid development of wireless smart devices to composing data streams and services from a diverse set of components. By providing layered interoperable systems, our toolkit offers cohesive support for moving beyond single-device, cloud-centric applications—typical in today's IoT landscape—and towards richer applications that incorporate multiple data streams, human interaction, cloud processing, location awareness, multiple communication protocols, historical data, access control, and on-demand user interfaces. To show how the pieces in the toolkit cooperate, we demonstrate a location-based access control application where a user's smartphone can control a room's lighting, but only from within the room. Further, data streams from the phone and nearby sensors are used to provide a constant lighting service which attempts to maintain a user-set brightness under variable external lighting conditions.

Categories and Subject Descriptors

B.4.2 [**HARDWARE**]: Input/Output and Data Communications—*Input/Output Devices*; C.3 [**COMPUTER-COMMUNICATION NETWORKS**]: Special-Purpose and Application-Based Systems

General Terms

Design, Experimentation, Measurement, Performance

Keywords

Internet of Things, Bluetooth Low-Energy, Gateway, Application Architecture, Wireless Sensing

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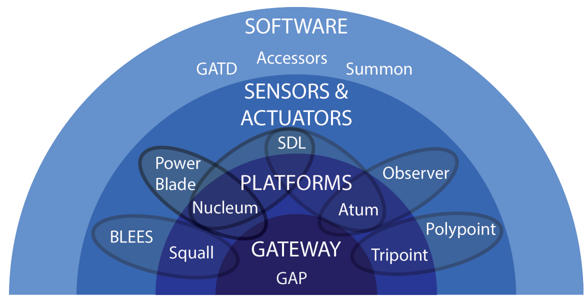

Figure 1: **The toolkit components.**

1. INTRODUCTION

As small, wireless, and low power computing integrates into more and more devices, the possibilities for dynamic applications involving people and things greatly increases. Current applications often suffer from several common pitfalls: they are limited to a single device, they rely on cloud support to connect devices and are susceptible to network failures, they require users to find, download, and install device-specific software, or they use vendor-specific APIs that limit reusability.

Our approach addresses these issues by providing software and hardware tools that explicitly facilitate local device-to-device communication, seamless device-to-user interactions, and data collection and processing. We provide hardware building blocks for creating new low power networked devices and sensor and actuator platforms built on top of the blocks. Further, we provide an indoor localization system that can provide real-time location updates. Figure 1 shows the layered toolkit and its components, from a gateway device to the software control layers, and Section 2 describes each piece.

We leverage our toolkit to build an office-centric application that highlights each component in the toolkit. The application allows users to read data from multiple sensors in a shared and universal smartphone application, but restricts control access to only users who are in the same room as the devices. In addition, the application simultaneously uses streaming light sensor data to provide a service that will maintain a constant lighting level as natural light changes throughout the day.

2. TOOLKIT COMPONENTS

Figure 1 overviews the suit of tools in our toolkit and Figure 2 shows the devices that are integral to building interesting Internet of Things applications. The base of this diagram is a Generic Access Point (GAP) which acts as a gateway for all of the IoT devices. GAP is a BeagleBone Black embedded Linux computer with cus-

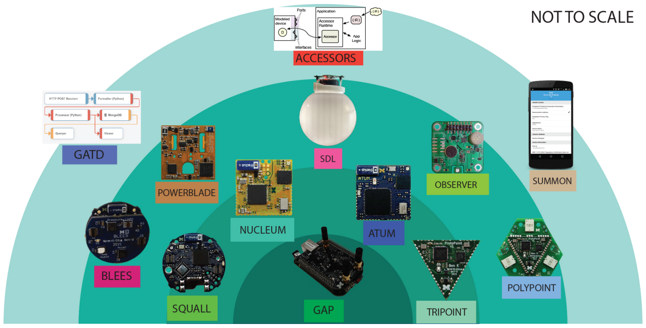

Figure 2: **Toolkit implementations.** All hardware, firmware, and software are available at https://github.com/lab11.

tom shield consisting of Bluetooth Low Energy (BLE) and IEEE 802.15.4 radios.

The next layer is a set of hardware platforms that can be used to create wireless embedded devices. Squall is a BLE tag platform that can act as a self-contained BLE beacon, or, by adding a shield on its stackable header system, a self-contained BLE sensor node. Nucleum and Atum are both solder-on modules that provide core wireless embedded functionality. Each consists of a radio (BLE and IEEE 802.15.4, respectively), a Cortex M microcontroller, a real-time clock, and non-volatile FRAM storage. Additionally, TriPoint is a solder-on support module that provides decimeter-accurate ultra-wideband (UWB) based RF ranging. Each of these platforms enables rapid prototyping of IoT sensors and actuators.

Next, our toolkit contains sensors and actuators that utilize our platforms. The Bluetooth Low Energy Environmental Sensor (BLEES) is a sensor board that stacks on top of Squall and captures temperature, humidity, pressure, acceleration and light intensity data. PowerBlade is a 1 in^2, plug through, BLE power meter [2]. Software Defined Lighting (SDL) [4] is a wall-powered lighting platform with both BLE and IEEE 802.15.4 radios and a high-power software controlled LED. Observer is an Atum-based, indoor environmental sensing platform that can sense temperature, humidity, pressure, acceleration, proximity, sound level, and light intensity, either as a stand-alone, battery-powered node, or as stack-on addition for GAP. PolyPoint [3] is an indoor RF localization system that consists of static anchors and mobile tags which utilize TriPoint modules to localize the tags.

Finally, a software layer is necessary to store data, organize communication between multiple sensors and actuators, and provide UIs for interacting with these devices. Our software tools include GATD, a service for receiving, storing, processing, and displaying streaming data; Accessors [1], a system of device interface wrappers which allow for application logic to be described and executed in a cloudlet; and Summon, a system that enables users to discover and automatically retrieve user interfaces to interact with nearby devices.

3. DEMONSTRATION

The demonstration, diagrammed in Figure 3, is an office setting where an occupant, using the Summon application on a smartphone, can scan for nearby BLEES, PowerBlade, Observer, and SDL devices and pull up a read-only UI for each. The user is also carrying a PolyPoint tag that is localizing the user, and when the user is located within a simulated room, the SDL application will be configured to permit the user to adjust the lighting. The Accessor infrastructure executes the logic for the application by listening for localization data and configuring the SDL devices with permitted users.

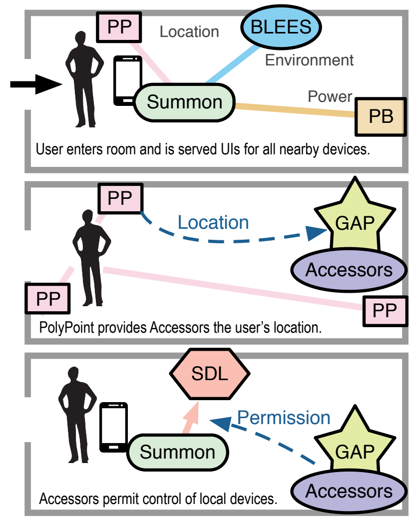

Figure 3: **Demo interaction.** When a user enters a room, PolyPoint updates the running Accessor application with the location of the user. Summon provides UIs for all BLE devices in proximity of the user, allowing the user to interact with nearby devices. Users always have read access to the devices, but when a user attempts to interact with a device, the Accessor infrastructure verifies that the user is located near the device and explicitly grants write permissions.

While the user-facing application is executing, the GAP gateway device is listening for the sensor data and forwarding the streams on to GATD. GATD archives the sensor data for observation and future processing. The data streams from the light sensors on BLEES and Observer are also fed to another Accessor based application that uses real-time lighting data to provide a "constant-lighting" service. This service can adjust the lighting in the room to keep the brightness level constant over the course of a day. This service can be enabled on the SDL devices if the user has control access based on location.

These applications demonstrate how the toolkit can provide the sensors, actuators, and infrastructure tools needed to build sophisticated applications.

4. ACKNOWLEDGMENTS

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