Facilitating the Internet of Things with Policy Programming
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Policy Programming Research & Development Lifecycle

Research Objectives
Policy programming enables autonomic, customized behavior in wireless sensor networks (WSN), augmenting basic subroutines with extensible control logic. In WSN based on the tinyOS platform, state introspection and debugging is challenging and opaque; instrumentation embedded in WSN application nesc code is required, and the process of collecting data is difficult. Our state of the art Policy IDE[2] began with limited simulators to collect and display debugging data interactively.

Development has moved towards creating more robust Policy IDEs. Our latest approach pairs policy programming with advanced inter-node network communications protocols at the transport layer, replacing link-layer protocols' low-level communication with a new network stack. Policies can now be used on IPv6, extending WSN interoperability. Policy interaction between sensors, network appliances, desktop and mobile computing platforms will define the types of machine to machine communications on the future Internet. Additional benefits include simpler debugging, visible execution trace, and a shortened WSN application development lifecycle using real sensor motes which can be debugged in development or in the field.

Background
The Internet of Things (IoT) is a novel paradigm which is shaping the evolution of the future Internet. The goal is to enable interaction among mobile devices, desktop computers, network devices, and sensors. This interaction occurs throughout the Internet, local area, and personal area networks - in the home, vehicles, and a multitude of other environments. A simple and proven programming approach for the management of distributed systems is Policy Programming[3], and this has proven particularly effective in surmounting design challenges associated with tinyOS based WSN.

Products and Results
1. The Policy IDE was developed by Nidal Qwasmi and Daniel Smullen[2]. This concept was originally designed to allow for policy programming to be debugged, reducing the opacity in the development process. Debug messages were collected from the TOSSIM emulator [1] and displayed on a GUI in real time. Viewing these messages while manipulating policies on simulated devices allowed introspection into the results of policies. Policy programming was conducted using emulated sensor motes running the FingerII policy engine core[3].

2. The TOSSIM centralized TOSSIM service was developed, allowing the Policy IDE and TOSSIM device emulator/simulator to become platform independent. This also allowed future versions of TOSSIM to be interoperable with Policy IDE and allowed for simulation to occur across a network when desired, instead of localized on one machine.

3. The blip2.0 IPv6 network stack[4] was integrated with the FingerII policy engine and a UDP shell, allowing policy debugging to occur with real sensor hardware. Internode occurred by logging onto actual motes and directly entering commands into the shell, with feedback returned to the same terminal session in real time. An edge router was used to marshal interoperable traffic between the 802.15.4 6LoWPAN based sensor motes wireless radio and wired/wireless external IPv6 networks.

Future Work
A new concept (dubbed SupportDiscovery) would incorporate a policy discovery component that enables the FingerII engine to perform reflection and report on what device components, events, and tasks are available for policy programming. Development of a detailed architectural model for this software component along with integrating the Policy IDE with the IPv6-enabled FingerII would allow for a more robust IDE to be created. This would allow up to 228 sensors per network layer to be programmed with policies easily.

References
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Offloading Emulation/Simulation using TOSSERV

To date, most WSN applications are designed for one specific application, using programmed design to fulfill one limited role only. Policy programming enables these same hardware devices’ programming to become more adaptable and more flexible in changing circumstances while maintaining overall system autonomy and availability[3]. Developing tinyOS nesc applications is challenging - there are few libraries and only one set of development tools[2]. Engineering applications for WSN toward applications involving the IoT is on the cutting edge of wireless technology, internet protocols, and autonomic computing.

IPv6 WSN Configuration with Motes Running FingerII