Agilla: The Rapid Development and Flexible Deployment of Adaptive Wireless Sensor Network Applications

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Objective: Current applications for wireless sensor networks are limited in that they must be installed prior to network deployment and, once installed, can only be marginally tweaked through pre-defined parameters. This limits the network to run a single application and makes it difficult for the software developer to write programs that adopt to changing circumstances and requirements. We envision a new paradigm for programming and using sensor networks where applications consist of special programs called *mobile agents* that can migrate their code and state from one node to another as they execute. Mobile agents offer an unprecedented level of flexibility by allowing fluid applications to spread throughout the network and to position themselves in the optimal location for performing their task, whether it be detecting an intruder or tracking a wildfire. By allowing new agents to be dynamically injected, an already-existing network can be re-tasked. Also, the autonomous nature of each agent allows multiple applications to co-exist. Despite these inherent advantages, mobile agents have yet to be used in any real wireless sensor networks due to their severe resource constraints and unreliable network connectivity. Our goal is to demonstrate the feasibility by developing a middleware platform called *Agilla* that supports this paradigm. Furthermore, we want to determine the minimal set of primitives and abstractions (or services) that the middleware provides for helping software developers efficiently create highly flexible applications while reducing development costs.

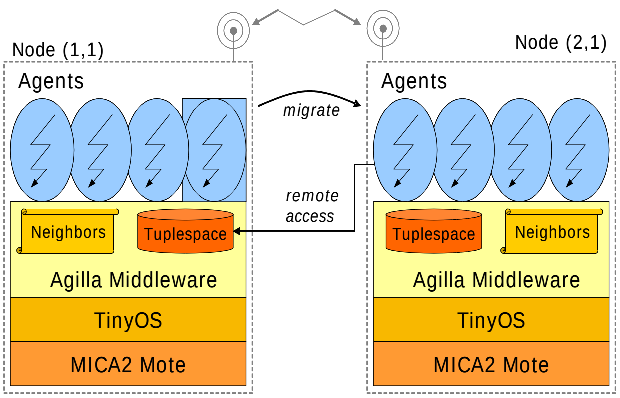

Figure 1The Agilla middleware architecture

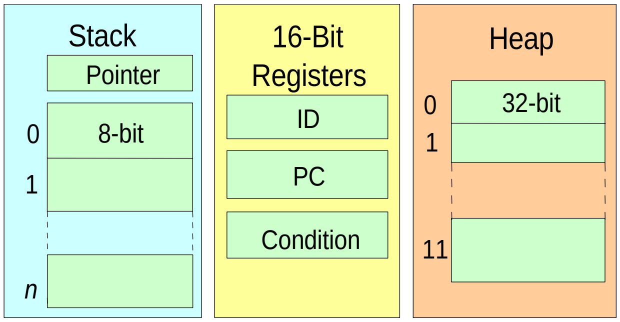

Figure 2 The Agilla agent architecture

Challenges: There are several challenges with developing Agilla. First, sensor network nodes have limited computational resources. For example, the MICA2 motes we use have a mere 128KB of instruction and 4KB of data memory. They also have a relatively slow 8MHz Atmel 128 microprocessor. Second, the wireless connectivity between motes is highly unreliable and provides very little bandwidth (38.4 Kbaud). Mobile agents are particularly susceptible to message loss because it interferes with the agent's ability to migrate and clone. Third, the Agilla primitives must be carefully tailored to address and/or take advantage of the salient properties of sensor network applications. For example, one property of sensor networks is they place a greater emphasis on spatial properties. This is because taking sensor measurements without knowing from where the measurements are taken is meaningless. In designing Agilla, we must recognize these properties and tailor Agilla's primitives accordingly.

Approaches: Agilla provides a stack-based architecture for each agent, as shown in in Figure 2. This reduces overhead by allowing the majority of instructions to be a single byte. To allow inter-agent communication, Agilla maintains a tuplespace on each node that is shared by all agents residing on the node, and is accessible to remote agents. By interacting through a tuplespace, each agent remains autonomous, decoupled both spatially and temporally. To minimize the impact of message loss, agents are divided into tiny packets (< 41 bytes), are migrated a single hop at a time, and utilize timeouts and retransmits. Since this hop-by-hop process introduces a significant amount of store-and-forward delay, it is only used while migrating or cloning agents, not for remote tuplespace operations. Instead, remote tuplespace operations are all non-blocking, preventing an agent from locking up due to message loss. In recognition of the importance of spatial data within sensor networks, Agilla addresses nodes based on its location. All remote operations take a location as a parameter. For example, instead of cloning to a node with id=1, an agent would clone to a node at location (1,1). By tailoring Agilla's primitives to sensor networks, Agilla provides a foundation for rapidly developing applications for wireless sensor networks with unprecedented levels of flexibility.

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