Generic Communication Structure to Integrate Widely Distributed Wireless Sensor Nodes by P2P Technology

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ABSTRACT
In this paper, we propose a generic communication structure to discover and access widely distributed wireless sensor nodes from various types of devices, including other wireless sensor nodes, by using Peer-to-Peer technology. A JXTA based implementation of the system using the Particle wireless sensor network is presented.

Keywords
Wireless Sensor Node, Peer to Peer, Discovery

INTRODUCTION
Wireless sensor nodes are typical devices in ubicomp environment and are organized in a Wireless Sensor Network (WSN). In order to access the sensor nodes from a client located outside of the WSN, a gateway is attached to the WSN to expose such sensor nodes to the Internet [2]. Although, it is assumed that many sensor nodes and WSNs should be large scale deployments to provide wide scale services, such as wild environment monitoring, location tracking in metropolis, the client has to discover the desired sensor node from a number of gateways. Moreover, if the gateways use different protocols, the client has to access them in different manners. To cope with these problems we combine Peer-to-Peer (P2P) technology with WSNs to exploit both high scalability and discovery functionality of P2P with direct access to real world information of WSNs.

Many closely related approaches (e.g. [1]) assume that consumers of sensor network information are powerful, resource-rich computers. In contrast to this, our system allows various types of devices to access and process remote sensor information: PCs, cellular phones but also (smart) sensor nodes. We show that the use of a generic P2P based communication structure allows to integrate widely distributed sensor nodes and other computing devices. This combination of WSN and P2P technology leads to a highly distributed and open, yet still very scalable sensor information system. The following sections introduce our architecture and explain some implementation details of the system.

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SYSTEM DESIGN

System Overview
Fig. 1 illustrates an overview of the presented system. Each WSN has a gateway called P2Pbridge to expose sensor nodes in the WSN to the P2P substrate on behalf of the sensor nodes. Clients, such as PCs, participate with the P2P substrate and discover and access desired sensor nodes through the P2P substrate (Fig. 1(1)). Because a client is a P2P peer, it is obvious that the client can pass processed data from raw sensing data to other clients through the P2P substrate. Resource restricted simple clients, such as cellular phones, that cannot perform the native P2P protocol themselves, may use a P2P Proxy to access the P2P substrate (Fig. 1(2)). The system also allows sensor nodes located in different WSNs to communicate with each other through the P2P substrate (Fig. 1(3)). This allows implementing real ubiquitous wireless sensor network applications.

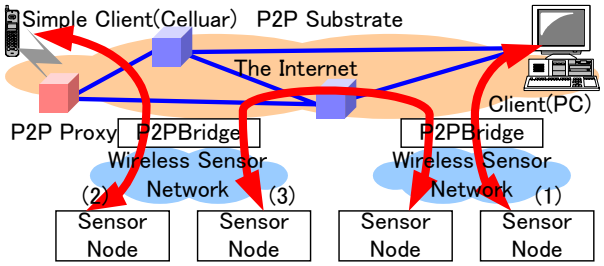

Figure 1. System Overview

System Requirements
The following describes requirements for the system, with corresponding solutions denoted in parentheses.

- Clients can discover desired sensor nodes. (*Detect &Publish, Node Discovery*)
- Clients can access desired sensor nodes. (*Remote Access, Forwarding Request*)
- Sensor nodes can communicate with each other, even if they are in different WSNs. (*Inter Sensor Network Communication*)

Detect & Publish

A P2PBridge detects the existence of a sensor node by actively (i.e. inquiring through special messages) or passively (i.e. scanning the network traffic) retrieving transmitted data from the sensor node in the WSN. Once the P2PBridge has detected the sensor node, it publishes an advertisement to the P2P substrate with the attributes of the sensor node *(ID, type of artifact, available sensors, etc.*) that can be acquired from the data. Also, the P2PBridge can put additional attributes concerned with the sensor node or the WSN in the advertisement (e.g. *location description* that describes where the WSN is located).

Node Discovery

A client makes a query to discover desired sensor nodes by using a set of attributes as a query key. The query is resolved by the discovery functionality of the P2P substrate (e.g. Distributed Hash Table). If an advertisement that matches the query is found, it means that the client discovers desired sensor nodes. For instance, a query that has *location description* attribute with the value of "TECO" can discover all sensor nodes located in TECO.

Remote Access

Once the client discovers the advertisement of the desired sensor node, it can access the sensor node by establishing a connection to the corresponding P2Pbridge that published the advertisement. The P2PBridge forwards all transmitted data from the sensor node in the WSN to the client through that connection.

Forwarding Request

Alternatively, the client can retrieve data without establishing the connection explicitly by publishing an advertisement as a forwarding request that contains a set of attributes to specify the data of interest. All P2PBridges that discover the advertisement forward the data that matches the set of attributes to the client. This function is suitable for retrieving a specific sort of data from a number of sensor nodes (e.g. retrieving low battery alarms).

Inter Sensor Network Communication

A sensor node can specify destined sensor nodes in the transmitting data as a set of attributes of them. When a P2PBridge receives data that contains the set of attributes, it performs a *Node Discovery* according to the attributes and forwards the data to the corresponding P2PBridge. The corresponding P2PBridge transmits the received data to its WSN, and destined sensor nodes receive it.

IMPLEMENTATION OVERVIEW

Implemented System Architecture

Fig. 3 illustrates the architecture of the implemented system. We applied JXTA 2.3.2 as P2P platform, because it has a well-defined application programmer interface (API) for implementation and supports P2P Proxy for Java 2 Micro Edition (J2ME) client. We implemented a P2PBridge on PC (Windows 2000) and a simple client J2ME application on a PDA (Windows Pocket PC2003). Particle computer [3] was utilized as sensor nodes in our example implementation. Particle data are transmitted by low power radio in the WSN and encapsulated into UDP/IP broadcast packets through the XBridge [3].

P2PBridge

The P2PBridge consists of two function blocks, data routing and ingress filter. Data routing receives UDP packets from XBridges and performs *Detect & Publish*. It also covers *Remote Access* and *Forwarding Request* from clients and forwards data from the requested Particle to them. If the data from a Particle contains the destination nodes, it performs an *Inter Sensor Network Communication* to forward the data to the destined Particles. The Ingress filter checks incoming data from other P2Pbridges whether the destined Particles exist in the WSN or not.

Client Application for the Simple Client

This application can discover Particles according to their ID, location, and artifact type. The JXME platform is restricted to the use of the Hyper Text Transfer Protocol (HTTP). The JXME Proxy acts as a mediator to the JXTA P2P substrate in this case. The systems allows to access and discover Particles sensor nodes, e.g. from a PDA located in a remote network, by this application.

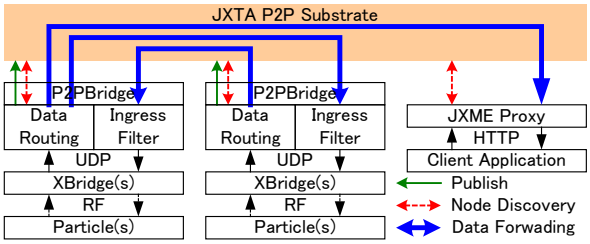

Figure 3. Implemented System Architecture

CONCLUSION

In this paper, we proposed a generic communication structure for widely distributed wireless sensor nodes by using Peer-to-Peer technology. Currently, we are going to collaborate with other organizations that are using Particle computer to implement widely distributed ubiquitous applications on this communication infrastructure.

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