Towards a Zero-Configuration Wireless Sensor Network Architecture for Smart Buildings

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Introduction

• Nowadays Building Energy use counts for 40% total energy use, 36% of $CO_2$ emission.

• Better managed and well insulated buildings can reduce the consumption in buildings tremendously. Therefore reduce $CO_2$ emission and help environment.

• Key to better monitor and management buildings is widely deployment of wireless sensors and actuators.

• Paper presents an approach to integrate tiny low power wireless sensor or actuator nodes into IP-based network.

• RESTful (Representational State Transfer) Web service with JSON format and IEEE 802.15.4 compliant radio transceivers was used.
System Architecture

- 6LoWPAN-enabled wireless sensor nodes are directly integrated into IPv6 network.
- IEEE 802.15.4 (vs. 802.11 WiFi, high energy consumption, high speed) physical layer standard was used for low power consumption.
- A smart gateway is used to provide access for IP-based protocols.
- Central Unit provides the management and monitor system.
Auto Configuration and Service Offering

- Stateless address auto-configuration mechanism of IPv6 was used.
- A new node addition will send a router solicitation request link-local multicast address at its startup.
- Router will respond with a router advertisement message.
- A sensor or actuator can obtain its IPv6 address.
- A node starts to advertise its offered services after initial address configuration.
- A node can also query certain service type by sending a DNS packet to link-local multicast address.
Web Services and JSON Data format for Sensor Nodes

- Web services allow sensor, actuator and server interaction over the network.
- Data exchange between peers using HTTP protocol.
- RESTful Web services with JSON Data format are used for low overhead.
- Not traditional RPC based SOAP and XML data exchange, it is too verbose.
- RESTful Web services: GET for new query; POST for creating new record; PUT for update a record and DELETE for removing a record.
System Implementation

• Data Access Schema is polling mode. Server polls sensors and modify state of actuators with same interface.

• Web services API was implemented at sensor and actuator level.

• Based on RESTful API, sensors and actuators are introduced as plug-and-play approach. Which accomplishing automatic configuration and advertisement its services in a wireless network.

• REST uses HTTP protocol as application platform. Functionality of a system can be implemented as a set of resources with corresponding URI.

• Clients interact with resources with GET, POST, PUT, and DELETE basic operations of HTTP protocol
Hardware and Software OS

- ZigBit 900 MCU of Atmel: radio module and Atmelag 1281 Microcontroller was used.
- TinyOS 2.1 was ported to this system.
- Additional IP, TCP and HTTP layers were added for implementation of RESTful Web services API.
- 6LoWPAN stack was included in TinyOS 2.1.1. It satisfy low-power requirement.
- Persistent TCP connections reducing latency of request and resource cost.
- 8 Kbytes of RAM powered by battery.
Prototype and Implementation Block Diagram

Pixie node prototype:

Temperature sensor
TinyOS Implementation of RESTful Web service API:

Example of JSON objects sent by RESTful Web service on the nodes:

```json
{
  "device": "temperature", // name of the resource
  "method": [ // supported methods
    "GET" // of the resource (GET)
  ],
  "param": [ // array with all parameters
    {
      "n": "celsius", // name
      "v": 26, // value
      "dt": "f", // data type (integer)
      "up": 0, // updatable
    }
  ]
}
```
Example of RESTful Web Service Query

Example of Central Server Web Query (GET action):

1. Open [http://localhost:8080/restdemo/services/customers/0](http://localhost:8080/restdemo/services/customers/0) in your browser to see the first customer in XML.

This XML file does not appear to have any style information.

```xml
<customer>
  <address>Sheffield, UK</address>
  <id>0</id>
  <name>Harold Abernathy</name>
</customer>
```
Example of Central Server Web Query:

```
{
    "device": "Temperature",
    "method": ".get",
    "param": {
        "n": "value",
        "v": 33.29,
        "t": 1,
        "o": 0
    }
}
```
Application to Smart Buildings

• RF212 Chip operated in power-save mode. Low-power listening mode (Wake up periodically from sleep mode to check radio channel for activity).

• A Web application was developed to detects a new device in a network and automatically discover the functionality offered by device. Then it will use the functionalities to issue command to devices.

• Average response times for HTTP requests to sensor nodes decrease with smaller payload and persistent TCP connections. See diagram:
Conclusion

• Present a direct peer-to-peer connection of Wireless Sensor Network

• A small Web server run on TinyOS 2.1.1 which powers wireless sensors and actuators.

• RESTful web services with JSON format runs on this small web server.

• A Web app runs on central unit server interacts with sensor and actuator web services to retrieve information or change the state of actuator

• Low power operation mode is achievable.

• System offers an acceptable performance given a limited computing power and small memory on ZigBit 900.
Thank you!

Question?