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

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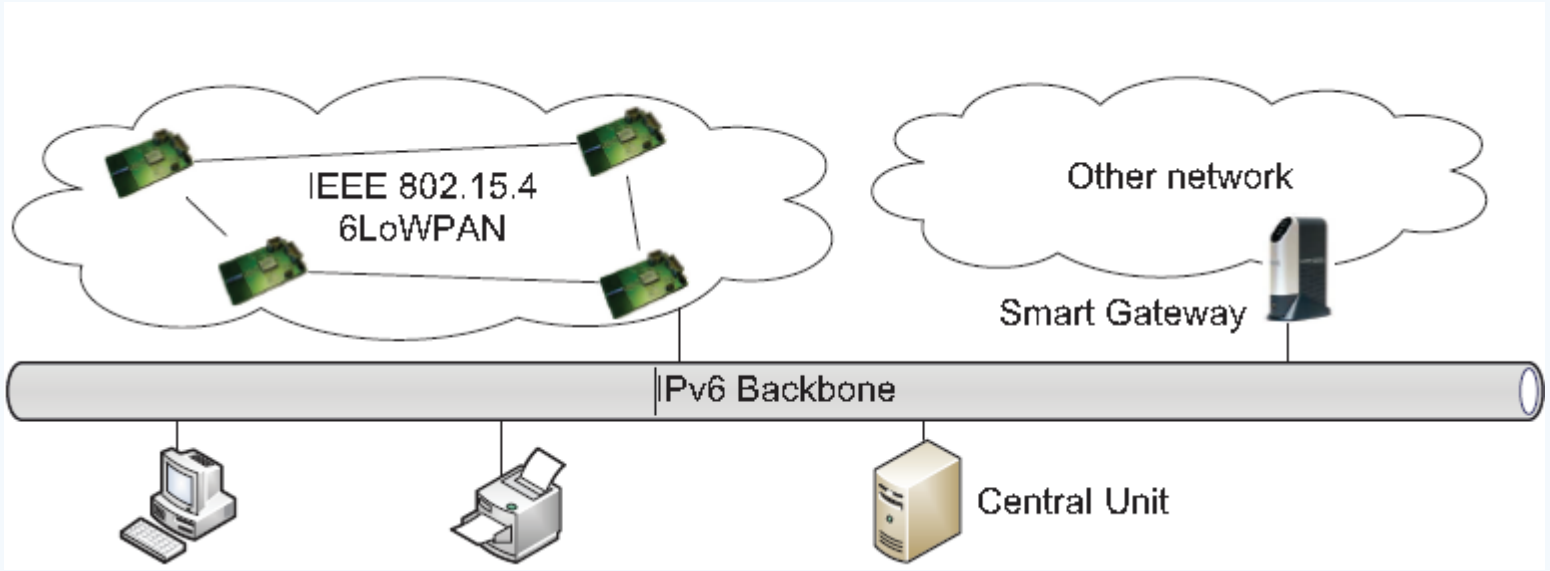
Introduction

- 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

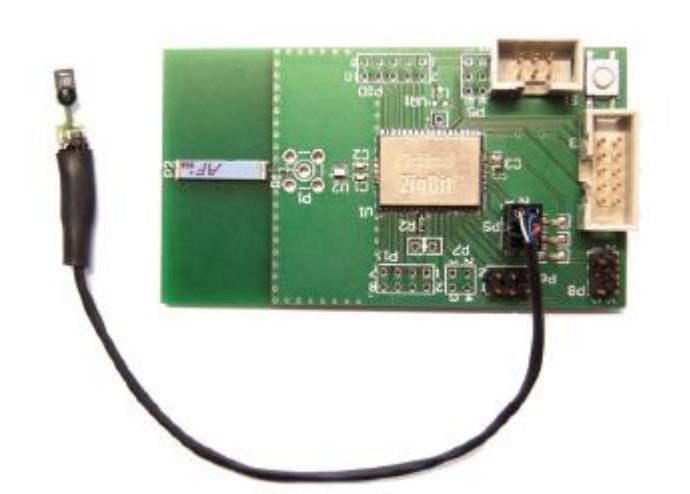
Hardware and Software OS

- ZigBit 900 MCU of Atmel: radio module and Atmegal 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

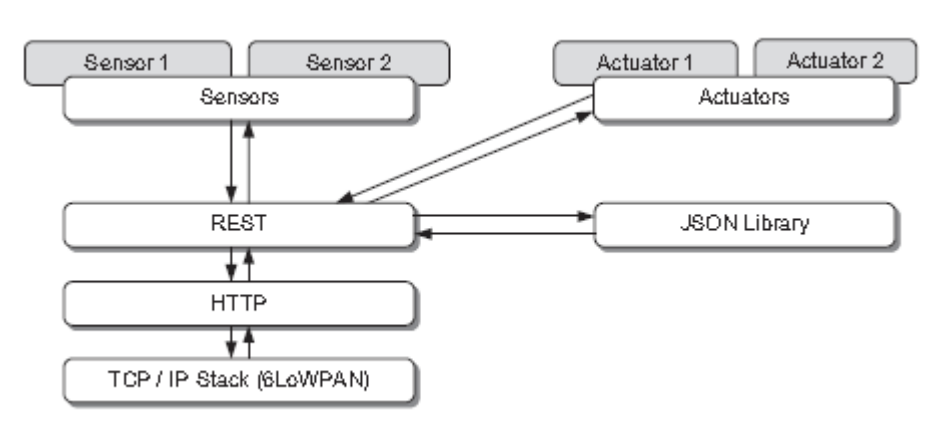
Pixie node prototype:

Temperature sensor



Web service API and example

TinyOS Implementation of RESTful Web service API:



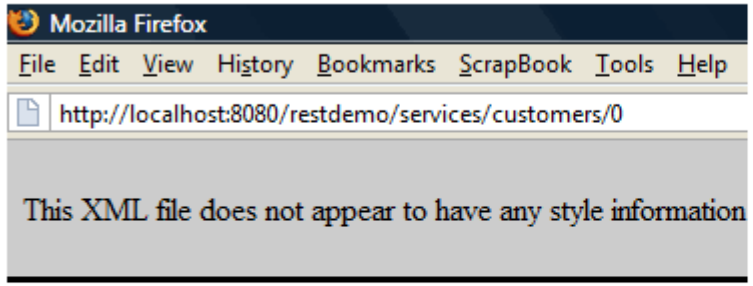
Example of JSON objects sent by RESTful Web service on the nodes:

```
{
  "device": "temperature",   // name of the resource
  "method": [                // supported methods
    "G"                      // of the resource (GET)
  ],
  "param": [                 // array with all parameters
    {
      "n": "celcius",        // name
      "v": 26,               // value
      "t": "i",              // data type (integer)
      "u": 0                 // updatable
    }
  ]
}
```

Example of RESTful Web Service Query

Example of Central Server Web Query (GET action):

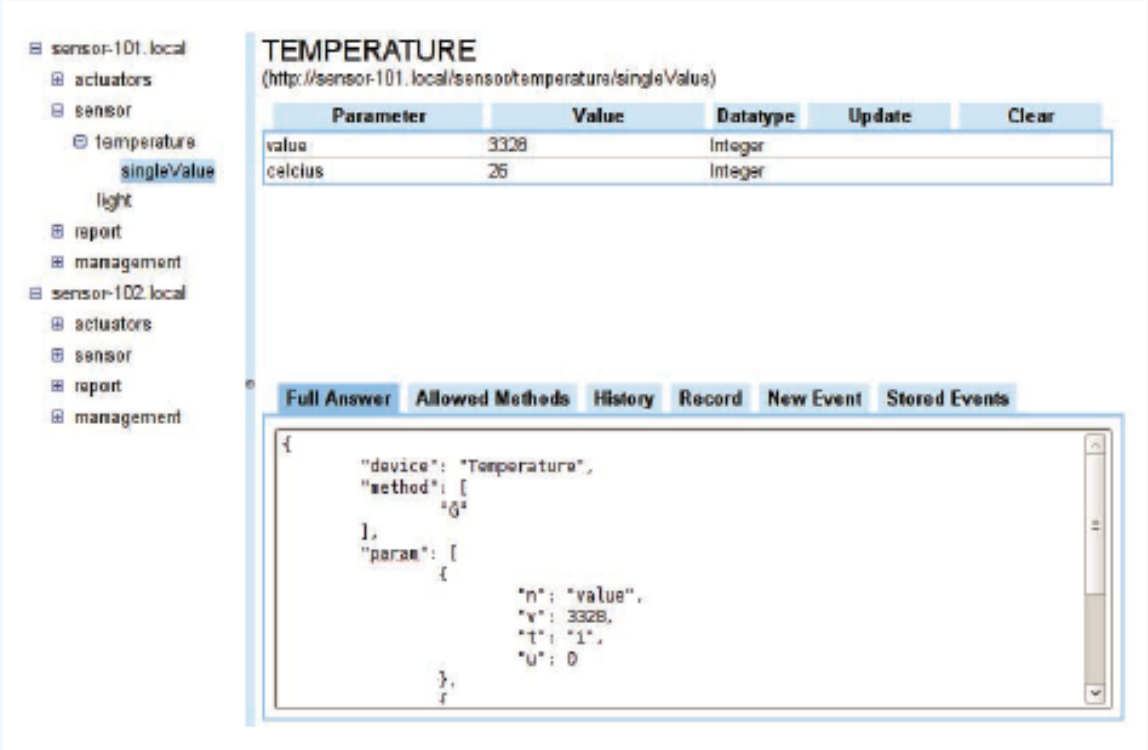
1. Open http://localhost:8080/restdemo/services/customers/0 in your browser to see the first customer in XML.




```
−<customer>
    <address>Sheffield, UK</address>
    <id>0</id>
    <name>Harold Abernathy</name>
  </customer>
```

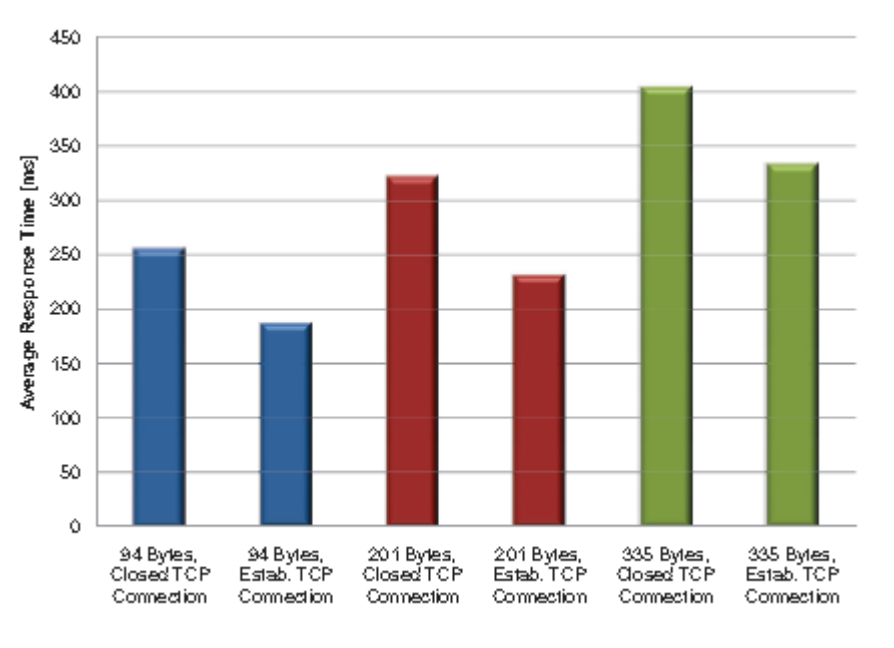
Server Web Service Query

Example of Central Server Web Query:



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 senors 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?