An OGC Open Standard-based Internet of Things Prototype of Vegetation Recovery Monitoring in Northern Alberta

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Abstract

This paper describes an end-to-end Internet of Things (IoT) prototype system that uses open source hardware, and interoperable IoT standard for environmental monitoring. The system was designed to monitor the physical conditions of a boreal ecosystem in northern Alberta. In summer 2016, eleven IoT sensor nodes were deployed in three different sites in a boreal forest environment. Real-time ambient environmental data were sent back from the remote area via 2.5G mobile networks to an Open Geospatial Consortium (OGC) SensorThings API cloud server. This research demonstrates the IoT prototype system based on the OGC architecture is power and data transmission efficient and can survive in a harsh deployment environment. To our best knowledge, this deployment is world's first real-world evaluation of the OGC SensorThings API for environmental monitoring applications.

Background and Relevance

The emergence of wireless sensor networks(WSNs) attracted intensive research efforts from habitat and environmental monitoring field due to the advantage of low cost and easy deployment.

Mainwaring and his group[1] are the pioneers of developing the WSNs for monitoring. They presented a collection of requirements and guidelines for a general sensor network architecture. Their practical experience had guided the creation of an abundant WSNs for habitat monitoring. A lot of WSNs for habit and monitoring have been built. For instance, Lofar Agro project[2] invested the use of WSNs in precision agriculture in the Netherlands. Cao et al[3] presented a WSNs for micro-environmental monitoring which integrated Matlab to perform on-line and real-time data processing. Yang et al[4] developed a large-scale soil moisture monitoring sensor network with using CrossBow motes. Recent innovations in Internet of Things(IoT) technology, such as open-source hardware platforms and open IoT standards, have allowed researchers to collect large and highly accurate datasets on the environment while vastly decreasing the time and cost of gathering such data. Ferdoush et al[5] developed a low-cost and highly scalable WSNs using Raspberry Pi, Arduino and XBee for environmental monitoring. Shafiril et al[6] made an automated system for the monitoring of forest activity using Arduino.

Using open source hardware and open standard in WSNs for environmental monitoring is the trend. However, IoT devices created by different manufacturers follow heterogeneous proprietary protocols to communicate with each other. Interoperability is a major challenge in IoT which requires layers of standards to addresses the heterogeneity issues among sensors, data and networks. Therefore, we need to follow an open and interoperable standard to connect various devices in WSNs. Among the existing IoT standards, the Open Geospatial Consortium (OGC) SensorThings API[7-8] standard supports comprehensive conceptual model and query functionalities. This standard defines an open-source interface to interconnect IoT devices, data, and applications over the Web. By using OGC SensorThings API and open source hardware, we are able to develop a WSNs which will interconnect IoT devices,data and applications over the web for environmental monitoring.

Methods and Data

The system architecture (Figure 1) contains several components, Devices, Cloud and User-front-end.

1) Devices: It records the ecological parameters with different kinds of field sensors. The device should provide computing power, local storage, network connections and bidirectional communication with other devices in the system. It doesn’t need a strong computing power but can detect and calibrate sensor data based on threshold filters automatically. The device not only store the temporal sensor data but also archive its state data. Different sensors can be added or removed depending on the monitoring requirements in different area. These small devices will be deployed in areas without an always-on power source. Therefore, battery (e.g., Li-ion battery or portable external battery) or solar energy will be the power supply of these devices. In consideration of the conditions of boreal forest, the device will be put inside a case which protect them from direct sunlight, water and wildlife interference.

2) Transit Network: There will be two kinds of transit network. One is built among these devices and allow them communicate with each other, such as ZigBee or one kind of Low-Power Wide-Area Network(LPWAN). The other one should have WAN connectivity which allows one or multiple devices to upload sensor data to the cloud.

3) Cloud: It is a place where store and analyze the sensor data. The cloud acts as the bridge allowing sensor devices to interact with each other and with the user-front-end web application. It processes sensor data, organize them in a uniform way and provides a simple interface for user to access, which improves the accessibility of data collected by the geo-sensor network.

4) User-front-end: It is a web application works like a "dashboard" to visualize and to control the geo-sensor network. Users can browse the data by sensor location and view time series charts of the observation data between any two time periods with a graphical user interface. Not only the dashboard will show the simple statistics of sensor data, but also all received data can be downloaded for further analysis. The application also allows the user to manage the behavior of sensor nodes, such as the sampling period, changing running mode and monitor the running status of sensor nodes.

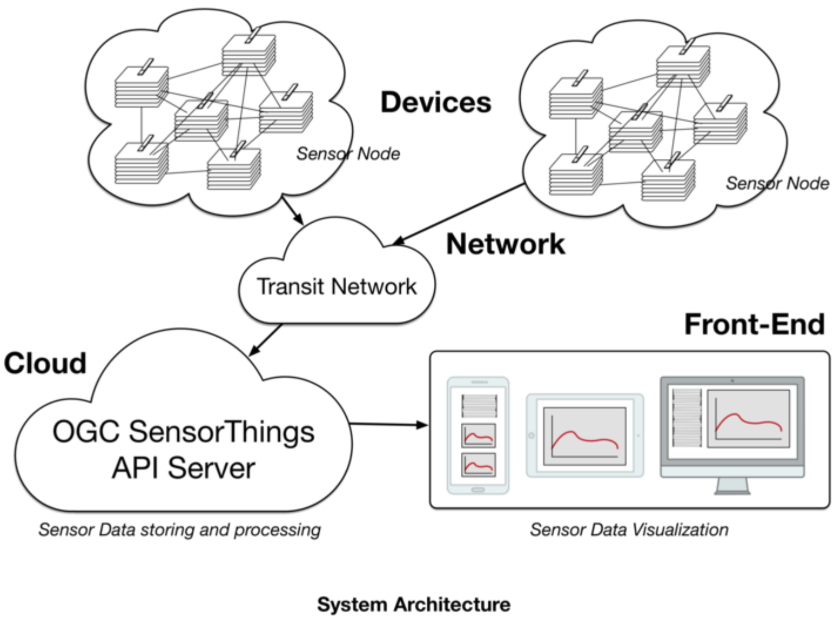

Figure 1 System Architecture

In our implementation, we are using LinkIT One as the IoT device development board, which provides computing power, network connections, and local storage. We use an Arduino-compatible C-like language to program the LinkIT One boards.

Multiple digital sensors connect to the LinkIT One development board. Each sensor observes an observable property of the ambient environment. These sensors include air temperature, relative humidity and light exposure. Our design goal is extensible so that more sensors can be integrated into our architecture easily in the future. To ease the deployment each device contains a Li-ON battery and a portable USB battery, allowing it to be placed in locations where there is no access to the electric grid.

One of the challenges of working with research data is finding it and sharing it with other researchers.In order to provide interoperable service to facilitate access to the sensor data, we use the OGC SensorThings API. OGC SensorThings API works like a record database for sensor data, where data producers can submit data in an open and well-defined format to a web URL and the data with sensor metadata will be stored.

Three of them use the 2.5G mobile network and send real-time data to an OGC SensorThings API cloud server. When the mobile network was not ready or the data transmission was failed, the sensor data were archived in a log file on the micro-SD card. The system performed periodically check for the existence of the sensor data in the log file. If log file existed and the mobile network was ready, the system will upload the sensor data again and will delete the log file after successfully data transmission.The rest of the eight devices did not use mobile networks.Instead, they only store the data locally. At last, we install each device in a Davis Instrument solar radiation shield, that is a shelter against precipitation and direct heat radiation from outside sources.

Results

Eleven LinkIT devices are deployed in three different boreal forest regions of northern Alberta. Each field test last one week. The devices with a large battery can run nearly a week. The other devices can last nearly four days.Within mobile network coverage in boreal-forest regions, the online devices sent back real-time ambient environmental data to an OGC SensorThings API cloud server. Meanwhile, the offline devices stored data on the on-board micro-SD card properly.

Conclusions

The main objective of this research is explore the feasibility of an IoT prototype that uses open source hardware, and interoperable IoT standard for a boreal ecosystem environmental monitoring. We designed and implemented the first prototype of the IoT sensor network. To evaluate our implementation, we have deployed our initial prototype in three different sites in North Alberta. The deployment contains a total of 11 LinkIT One devices and several sensors.The devices were able to upload readings to the OGC SensorThings API cloud server via 2.5G mobile networks.

The preliminary results show that our first prototype is power and data transmission efficient can survive in a severe development environment. What's more, the OGC SensorThings API significantly simplifies and accelerates the development of environmental sensor network, to collect large and accurate datasets while vastly decrease the time and cost of gathering such data. In general, this prototype network deployment demonstrated the feasibility for further prototyping.

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