Data Muling for Remote Monitoring

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Wireless Sensor Networks have been developed and deployed to collect data from sensors of any type. Those sensors need to be located at very precise places in order to ensure that the data collected is as relevant as possible. Unfortunately, in some cases, in remote areas, the link between the deployment location and the end user does not exist as the cellular network in not present. In such cases, someone has to manually go on site, extract the data, and bring it to the end user. The goal of this study is to facilitate the automation of this process by using a cell phone that will, without any intervention, copy the data when in the vicinity of the field, and populate the server when in range.

Muling data can be seen as "storing, carrying and forwarding" data. Typically, (Mobile Ubiquitous LAN Extension) MULEs are autonomous devices with wireless connection that travels between two endpoints. A MULE will download data from one endpoint, carry it until it reaches the second endpoint and forward it to the server [1]. If several MULEs are involved in the process, multi-hop routing between them is possible in order to attempt to reach the server faster, or to optimize the overall memory management between devices.

In order to evaluate what was possible to achieve, a set of scenarios were defined covering the different capabilities of a cell phone used as a MULE. The first scenario allows one MULE to transport the data from the field to the server, the second scenario allows more than one MULE transporting data from one field to the server and the third and last scenario allows many MULEs to collect and transport data from more than one field to the server (Figure 1).

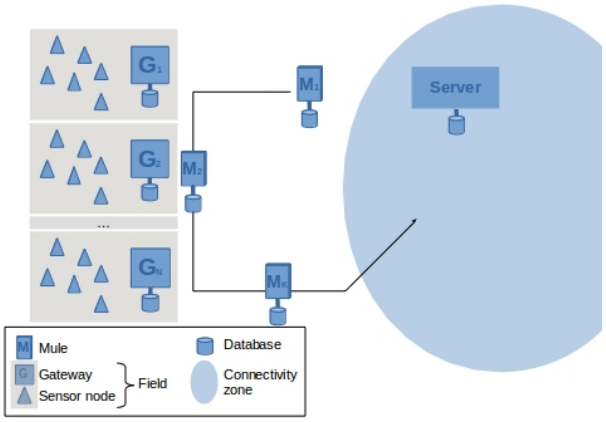

Figure 1: The most complex scenario allowing the monitoring of many fields with many MULEs.

A first test was conducted mixing different types of network protocols. Bluetooth was used between the gateway and the MULE and WiFi between the MULE and the server. The data transported between the gateway and the server (using the MULE) was coded in JavaScript Object Notation (JSON) simplifying not only the debugging but also the ability to expand the number of measured data to be transported. Evaluation of this first test showed that using the MULE as a protocol gateway between Bluetooth and IP was probably not ideal (Figure 2) and that an end-to-end IP solution should probably be preferred.

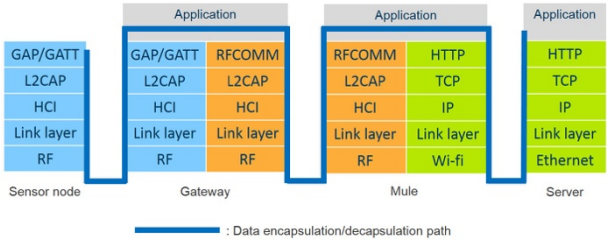

Figure 2: Heterogeneous network protocols.

The second setup was built to enable IP end-to-end. The gateway was responsible of formatting the data, making it available to the MULE through WiFi (Bluetooth was replaced) and in the same way, the MULE made the data available to the gateway. The data formatting, together with the application protocol needed to be homogenous and a HTTP–like protocol was used as the transport layer. This protocol is called Constrained Application Protocol or CoAP.

CoAP's goal is to enable Representational State Transfer (REST) environment on constrained devices like sensor nodes. It not only gives access to data in the same simple form as HTTP but also simplifies the interface with the database storing the data by including part of the database query in the Uniform Resource Identifier (URI) format. It also allows optimization of Machine-to-Machine applications.

This evaluation proved to be very successful. If only the first two scenarios were actually implemented, the results showed that choosing CoAP as a common application ease the implementation of the third scenario, in which part of the caching intelligence will have to be implemented in the MULEs themselves.

In order to generalize the end-to-end use of CoAP and thus to simplify even more the data representation, data handling and the network protocols, CoAP needs to be implemented in the sensors themselves. In addition, IP will be required on those sensors.

[1] U. Park, J. Heidemann, "Data muling with mobile phones for sensornets", Proc. ACM Conference on Embedded Networked Sensor Systems (SenSys), (2011) 162