Optimal information placement for Smart Objects

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Nowadays, when we use computers, we don't care where the actual processing is taking place. High performance broadband connectivity and the recent advance of cloud computing allow us to forget where the information actually exists and where the processing happens. Wherever we have broadband connectivity, we can access information we need instanteously. The storage in the cloud also allows us to store as much information as we need. From the user's point of view, the details of the system should be invisible. In this respect, the cloud computing is a huge success. But is this architecture suitable for smart objects?

When we design nodes which sense or actuate in real space, we consider the unique aspects of the real space system. As noted in the Call for Proposals of the Interconnecting Smart Objects with the Internet Workshop, there are several working group activities at IETF in progress: CoRE, 6LoWPAN and ROLL, for example. The focus of these efforts is how we can efficiently and effectively extend the Internet with regards to the diversity of the devices and power efficiency.

We often call such smart objects the "Internet of Things," but in reality, usually, we need other service components – supporting information systems – to create flexible, secure and sustainable services. Smart objects alone do not have enough computing power. A smart object is only able to run a simplified server, a full-fledged server require powerful computing like detailed data analysis, nor high request rate web services using AJAX. Smart objects are power constrained. They can't provide cryptography powerful enough to support flexible authentication/authorization. Smart objects do not have enough of storage. They must rely on some other entities to keep the information for the long term. Clearly, service components are important.

However, one important design choice for the service architecture is overlooked: the placement of the information or supporting services. There is a mismatch between the location of the origin of information, the information system which handles the information and the entity (or user) which uses the information via the information system. For example, when we check conditions – like rain condition and temperatures – we want to know the weather condition for where we are, and where we are going to visit. A sensor is always located at the target location, which is why we installed it there. However, the location of the information itself and the entity that wants to retrieve that information often are not related to the sensor's physical location. If a person in Kyoto wants to know the current temperature of Kyoto, even thgough the information is generated in Kyoto, it may flow from Kyoto to a datacenter located in Tokyo, then back to Kyoto. The entity that wants to retrieve the information often is located near the physical location of the sensor, but the information may flow along an unnecessarily long path.

For some applications, the effect is dramatic. One example is a supply chain management (SCM) system using RFID. The current de-fact standard RFID system architecture for SCM is a set of standards for middleware based on networked RFID system created by EPCglobal[1] . Networked RFID systems use the ID number recorded on an inexpensive tag as a hint to locate and access information held in networked databases. Information bound to the ID number is distributed all over the world. The RFID middleware provides two functions: a distributed repository which stores the information, and a mechanism to discover the relevant repository locations based on a tag's ID. There are several peculiarities of RFID systems which cause new challenges for the distributed systems architecture – to create an efficient system, these peculiarities force us to switch to a new paradigm:

- because it is designed to detect the movement of the objects among physical locations, the system must be distributed;
- information generated by the equipment is also distributed; and
- to track an item among these locations, we need to integrate information generated among distributed sites.

With this peculiarities in mind, designing the optimal placement of the information system for SCM is challenging. Think about this scenario: A manufacturer in China ships a product made in China to the United States. If a server in either the US or China collects all of the information, any query travels between continents. If several servers scatters across the US and China collect the information, the client needs to query all servers, possibly internationally.

To optimize operation in this scenario, we have proposed an information placement strategy – "Otedama" – which is radically different approach from current standards but still compatible with them[2]. The proposed scheme *moves* the information bound to an ID alongside the physical movement of the RFID tag. Usually, the person or entity most interested in an object with an RFID tag is colocated with the object itself. If we move the information along with the object, we can effectively place the information near the entity most interested in the object, or the information bound to it.

As shown in Otedama's case, if we carefully analyze the peculiarity of the information, we can optimize the system. To achieve service placement flexibility, or information flow flexibility, we need to design the "Internet of Things" not just as an network of objects, but an information platform as whole. Connectivity is important, but we need to carefully review on the flow of the information, and optimize the entire information system.

References

[1] "EPCglobal." `http://www.epcglobalinc.org/` (Verified 2011/2/9).

[2] S. Suzuki, R. Van Meter, O. Nakamura, and J. Murai, "Otedama: A Relocatable RFID Information Repository Architecture," IEICE Transactions on Information and Systems, vol.Vol.E93-D, no.11, pp.2922–2931, 2010.

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