Challenges for Semantic LWM2M Interoperability in Complex IoT Systems

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Introduction

As the ideas and technologies behind the IoT take root, a vast array of new possibilities and applications is emerging with the significantly increased number of devices connected to the Internet. Moreover, the ongoing adoption of open and standardized Internet and Web technologies is resulting in more flexible, diverse and configurable IoT-based applications with widely scalable and distributed networks of heterogeneous devices, systems and services at any scale. However, there are still hurdles that require innovation regarding the interoperation and orchestration of these devices and systems from different ecosystems.

In this context, we see several standardization efforts (e.g. OMA LWM2M [1], IPSO Alliance [2]) defining appropriate semantics to boost the interoperability in the IoT Ecosystem. These efforts aim to create more loosely coupled systems, better interoperable and connective devices via common interfaces and data models. For instance, OMA LWM2M defines pre-structured URI templates resulting from an extensible object and resource model for application semantics. The IPSO Alliance follows the same approach to realize interoperability between Smart Objects' sensors and actuators and connected software applications. Used on top of RESTful protocols, they result in an efficient and deployable client-server architecture that delivers semantic interoperability and several features for managing resource constrained devices.

In the HyCoWare project [3], our objective is the interconnection of heterogeneous systems in warehouses, encompassing systems of multiple vendors, aiming to create IoT readiness for industrial warehouses. For that purpose, we aim to make use of open IoT technologies to ease deployment and interconnection between different solutions for connected goods, transport systems and operators. In this paper, we mainly present some limitations we observed in defining complex LWM2M/IPSO-compliant devices, based on real life industrial use cases in the HyCoWare project. Moreover, we also emphasize some properties that the current ecosystems should consider in order to achieve better semantic interoperability in more sophisticated IoT applications.

Hybrid Sensors/Tags

One of the targeted use cases encompasses the design of a Hybrid Tag, which will be used to improve the visibility of industrial trolleys. During warehouse operations, the transport trolleys will be monitored (position, temperature, humidity etc.) by a control unit which is closely interconnected with other systems such as chain conveyor or operator interfacing and navigation. For this purpose, the tag is equipped with wireless communication and indoor/outdoor localization technologies (RFID, LoRA, Bluetooth LE) and also other sensing capabilities. It will be battery powered, so energy efficiency is another important design criteria during the development of these tags.

In order to interconnect this Hybrid Tag with various systems with minimized integration cost, we are focusing on open IoT technologies and we tried to design LWM2M/IPSO compliant interfaces. Considering the target Hybrid Tag, in addition to device related resources, there will be several application-related resources including position information, battery level and temperature which need to be monitored periodically. Modelling all this information according to LWM2M results in a large number of objects and resources. Periodic retrieval can only be achieved at the level of individual resources, for instance by using the CoAP observe mechanism. This results in a multitude of client-server interactions. So, although

LWM2M provides what is needed to model the resources, there is no suitable mechanism to perform the retrieval or observation of a group of fine-grained resources of interest (e.g. position + battery level + temperature), resulting in a single representation and single request-response transaction.

For sophisticated devices, IPSO defines the concept of composite objects where different objects can be aggregated using Web Linking Framework. For instance, a thermostat object can be created by aggregating IPSO Temperature, Setpoint and Actuation objects linked with input, setpoint and output links. [2] However, since we have various objects which are not relevant (not linked) to each other, the concept of composite objects is not really targeting such uses.

In order to overcome this issue, one option could be to create a new, custom LWM2M object that contains all resources of interest and to perform the operations on the entire object. Firstly, this would not be a generic solution as one cannot easily reuse already existing models. Secondly, this approach would not make any difference if we want to target a set of resources within the whole resource set.

So, ideally, we have a mechanism that enables us to perform grouping, while maintain the possibility to have fine-grained interactions whenever needed. To this end, a new 'Batch' object can be defined, that is able to aggregate different existing resources from different objects into a generic batch object, with each of the aggregated resources adhering to the LWM2M specifications. An additional requirement should be that the set of resources can be dynamically defined and changed. This way, the device can periodically notify an observer of the updated values with a single message and that message would only need to contain the values of the various sensors aggregated in the batch object. As all aggregated resources are LWM2M resources, the result message can be automatically processed and interpreted.

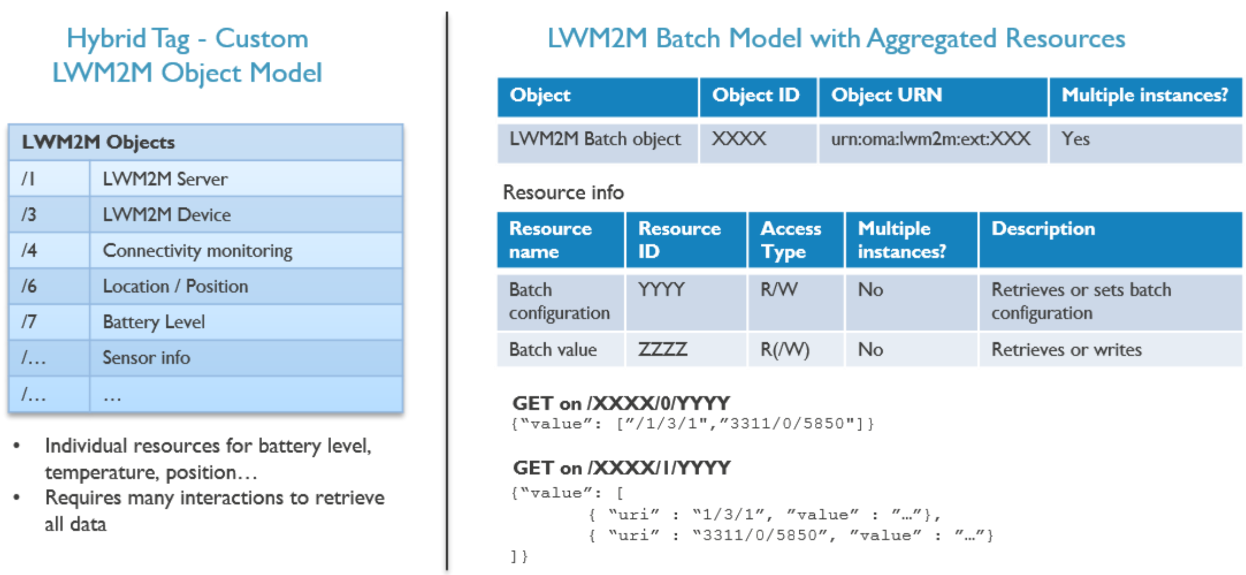

Figure 1: Custom LWM2M Object for Hybrid Tags and Proposed LWM2M Batch Object for Aggregating Resources

Support for a reversed LWM2M interaction model

According to OMA LWM2M specification, after bootstrapping and client registration, all the interactions (Read, Write, Execute, Create, Delete) are initiated by the LWM2M server. The client can start sending notifications for certain resources only if the server has send an observation request to the client for those resources. Several IoT solutions take a different approach, with the application logic on the IoT device being programmed to periodically send an update of a set of resource values. Applied to the example of our Hybrid Tag, this would mean that the application logic on the tag is configured to periodically send an update of battery level, position, temperature, etc. This interaction model is not supported by LWM2M. Our design would benefit from a mechanism that enables the tag to send the state of a collection of LWM2M resources to a configured or pre-defined server address. Such a mechanism can save an important amount of resources especially in case of several clients (thousands for our Hybrid Tag use case) with the same resources, while maintaining the LWM2M application semantics. This can also ease the collection of sensor data when sensor devices are behind a NAT box.

Bridging RESTful client-server and pub/sub architectures while preserving semantics

As mentioned, in the HyCoWare project we investigate the integration of multi-technology and multi-vendor systems in order to overcome the vertical silo problem and reduce integration cost. Within this context, we also consider multiple application level protocols, such as CoAP, MQTT, AMQP, with unique characteristics and architecture helpful for different types of IoT applications.

However, the LWM2M protocol only uses the CoAP protocol and messaging protocols like AMQP [4] and MQTT [5], which use a Publish/Subscribe (Pub/Sub) architecture, are not in the focus of LWM2M. In the sense of interoperability, MQTT protocol does not provide any support for message labeling with types or other metadata to help clients understand it. So the message formats must be known in advance by all clients in order to communicate [6].

In order to facilitate interaction and data exchange between RESTful hosts and Pub/Sub Hosts, we have prototyped a bridge that can translate between the two paradigms while preserving the LWM2M semantics. The broker is extended with capabilities to interact with RESTful LWM2M servers using CoAP Observe and publishes self-describing notifications to the Pub/Sub system. The other way around and using similar semantics, publishers can make use of the broker to perform REST request to LWM2M servers. This early concept works and proves useful to bridge both worlds while keeping the similar semantics. Therefore, we believe that IoT Semantic Ecosystems should consider defining standardized ways to maintain end-to-end semantic info even in the combination of RESTful and Pub/Sub interactions.

Conclusion

Although there are several efforts for the realization of semantic interoperability in the IoT domain, the interoperation and orchestration of devices and systems from different ecosystems is still a critical obstacle in the widespread adoption of IoT. Therefore, in this paper, we described some limitations we observed in defining complex LWM2M/IPSO-compliant devices and also emphasized some properties that IoT Semantic Ecosystem should consider in order to achieve better semantic interoperability in more sophisticated IoT applications.

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