Evaluation of a Commercial IoT Platform

Emergent Research Forum Paper

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Abstract

Reference architectures for the development of software systems are used to bring clarity to complexity. By design, reference model architectures inform practice and help deliver superior solutions. A significant challenge in reference architecture design is to recreate in a model an approach that provides utility to the practitioner in the real world. Innovative and useful designs tend to either occur by adapting an existing reference architecture to a new context or by exaptation from an existing, successful commercial implementations of a complex system. In either case, we look to evaluate an extant reference architecture in context to inform researcher and practitioner alike. This research initiates a comparison of an existing, innovative commercial IoT platform - developed organically over a period of several years in multiple industry settings - against the Architectural Reference Model developed by IoT-A. The contributions of the paper include (1) an explicit description of the existing commercial IoT platform, (2) a description of the IoT-A reference model, (3) a mapping method for comparison and gap analysis between the two, and, (4) a discussion of a means to enrich IoT-A with the addition of features critical to a commercially viable IoT.

Keywords
IoT, IoT-A, Information Model, Ontology, Platform, Architecture, SCADA, IIoT

Introduction

The specific definition of ‘Reference Architecture’ varies across industry and literature. In most cases, the intent of a reference architecture is to provide vision and guidance in the development of new architectures by capturing the essence of existing architectures (Cloutier et al., 2010). The need for reference architectures has grown over time as the size and complexity of software systems has increased. Reference architectures capture patterns found in the architectural baseline of existing systems and use these patterns as blue print providing a common vision, guidance and context (Cloutier et al., 2010) for the evaluation and replication of the systems in similar and different contexts.

The IoT-A is a European consortium of business partners including Alcatel, Hitachi, Siemens, IBM and a number of reputable academic institutions. From September 2010 to November 2013 the group produced one of the most comprehensive Reference Architectures ever developed for Internet-of-Things (IoT) platforms (Bauer, et al., 2017). The IoT-A created an ‘Architectural Reference Model’ ('IoT ARM') to provide common guidelines and structure for the development and analysis of IoT systems. This research-in-progress effort seeks to compare and contrast the IoT-Arm reference architecture to a commercially developed IoT Platform. In doing so, we seek to identify gaps and overlaps between the two architectures and to use that analysis to provide recommendations on the fit and evolution of each. Ideally, reference architectures should evolve as system implementations occur and technologies change. Thus, reference architectures need to be continually reevaluated and refactored as new best practices and knowledge becomes available (Cloutier et al., 2010). The evaluation in this research of the B-Scada commercial IoT architecture with the IoT-ARM architecture will inform that evolution of IoT reference architectures.
The Commercial IoT Platform

An IoT Platform is a suite of software components providing capabilities like visualization, data archiving and analytics of information from Internet connected devices and equipment which are often located in geographically disperse locations. The software and data management of IoT platforms typically reside on computers remote from the data collection devices and are hosted in the cloud. IoT Platforms have Application Programming Interfaces (API's) that allow other software to access the information collected from the devices on site(s) (Bassi et al., 2013; Ray, 2016).

HMI (Human Machine Interface) and SCADA (Supervisory Control and Data Acquisition) software products are used for monitoring and controlling equipment and tracking key performance indicators (KPI). HMI and SCADA systems are used for monitoring building waste water treatment plants, oil wells, hydro-electric plants, subway systems, and almost every type of manufacturing facility. Maximizing operator effectiveness is essential to minimizing the risk of accidents, eliminating unscheduled downtime, and maximizing production quality.

Founded in 2003, the focus of B-Scada Inc.’s operations is building HMI and SCADA solutions. The company’s technology stack grew over a several year period, culminating in the launch of its Status™ product line of industrial software solutions in 2011. The Status™ system is sold worldwide in various vertical markets and served as the foundation for the company’s IoT platform. Status Device Cloud™ (SDC) was developed using technology from the Status™ SCADA and HMI solutions and made commercially available in February 2016 as an IoT platform (DeSerranno, 2016).

The commercial platform that defines the B-Scada IoT architecture is used in a variety of vertical markets and is not targeted to a particular industry. Therefore, unlike many of the IoT platforms documented in literature this architecture has been applied in a way that is not limited to a particular vertical or a particular application domain. Figure 1 provides a high-level model of the resultant IoT architecture implemented with SDC™.

![Figure 1. Architecture Diagram of Status Device Cloud (B-Scada, 2017)](image)

Choosing an IoT Reference Architecture

An extensive literature review led to the identification of a number of example IoT systems, their principle features, and uses as well as papers on architectural design concepts. The papers reviewed often had no comparison to any reference architecture, did not evaluate any commercial implementations, and did not draw on the expertise of industry experts. The papers were often written at a high level lacking sufficient
The IoT-A recognizes that the IoT domain covers a wide range of applications implemented in completely different manners. These applications are highly targeted with a narrow scope and with little or no interoperability within their infrastructure producing islands or silos of functionality cut off from other applications and systems. While differing implementations and domains are to be expected, in order for the IoT to function and scale on a greater level there needs to be interoperability (Lange, 2013). Solutions develop independently in the early stages of technology development, and then converge to a universally accepted set of protocols or interfaces later on (Hypertext Transfer Protocol (‘HTTP’) for example). By designing systems that are structurally similar in the most basic aspects, even if they are implemented differently, we set the stage for universally accepted common infrastructure upon which the global IoT vision can be realized. This was the motivation for the development of the IoT ARM. We use IoT ARM to perform a gap analysis study on our selected commercial IoT architecture.

**Platform Evaluation**

The evaluation of Status Device Cloud with the IoT ARM was done using a process known as ‘Reverse Mapping’ whereby an implemented IoT architecture is mapped to the reference IoT ARM architecture allowing any differences between the ARM and the evaluated architecture to be exposed (Bassi et al., 2013).

**Summary Diagram and Discussion**

A ‘Mapping Score’ is created for this evaluation and is designed to specify how the commercial IoT platform maps onto the IoT ARM. The scale is a range of 0–3, with 3 checkmarks indicating excellent mapping. Using an Action Research approach (Susman & Evered, 1978) the researchers were able to evaluate in situ the implemented commercial application against the reference architecture as described in Table 1. The mapping exercise lead to several notable observations.

- In our evaluation, we found that the elements of B-Scada’s SDC™ architecture could be mapped to the IoT ARM elements with the exception of IoT ARM’s architectural element called Service Organization. Service Orchestration resolves IoT services for other parts of the system. Within SDC, services are generally independent and interact with the Information Model for orchestration and invoking action and within the system. A Service Organization Function Group (FG) could be beneficial in some respects within SDC™.

- We found and noted the ways in which differences exist in how the information model is treated. For example, the IoT ARM treats the architecture as a series of discoverable services which are implemented with fixed interfaces. This suggests that an IoT system is implemented as a set of web services with Universal Description, Discovery, and Integration (UDDI). The IoT ARM Information Model and related Virtual Entity Services are therefore described as another piece of functionality in the system. While SDC™ does have services implemented as UDDI, they are primarily for the administration of the system. The Information Model plays a much broader role in SDC™ than in the IoT ARM. The Information Model implements not only the virtual entities, but also portions of the functionality found in the IoT Process Management group (Workflow), the IoT Service (Device Interaction and Configuration), Security (Users, Roles and Workspaces) and Management FG as well as providing discovery. Having these aspects integrated into the information model diminishes the need for the Service Organization FG in SDC.

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1 We are aware of a draft ISO/IEC IoT Reference Architecture document currently under review. Its evolving status precludes its use in this study.
• In the IoT ARM applications interact with a variety of services. SDC™’s pragmatic, system management approach attempts to abstract complexity away by having applications and users interacting only with the Information Model. This provides a central location for accessing the system. For example, B-Scada finds that when users want to know the temperature of a room, they generally do not need to know the configuration settings of the wireless sensor providing the value. Web services for configuring the system in SDC™ are for system configuration only and have no requirement to be discoverable.

<table>
<thead>
<tr>
<th>IoT-A</th>
<th>Status Device Cloud</th>
<th>Mapping Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>IoT Domain Model</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entities</td>
<td>Asset</td>
<td>✔ ✔ ✔</td>
<td>SDC use of OPC UA satisfies Entities.</td>
</tr>
<tr>
<td>Resources</td>
<td>Data Providers</td>
<td>✔ ✔</td>
<td>Resources and Data Providers are comparable.</td>
</tr>
<tr>
<td>Devices</td>
<td>Asset</td>
<td>✔ ✔</td>
<td>IoT-A has a specific definition for Devices. SDC uses the term assets to identify both devices and other entities.</td>
</tr>
<tr>
<td>Services</td>
<td>Services/ Assets</td>
<td>✔ ✔</td>
<td>SDC does have services as defined in the IoT ARM. However, within SDC some services are exposed through the object model.</td>
</tr>
<tr>
<td>Identification of Physical Entities</td>
<td>Asset Node IDs</td>
<td>✔ ✔</td>
<td>SDC use of OPC UA satisfies Entities.</td>
</tr>
<tr>
<td>Context and Location</td>
<td>Asset Properties</td>
<td>✔ ✔</td>
<td>SDC use of OPC UA satisfies Entities</td>
</tr>
<tr>
<td>IoT Information Model</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virtual Entity</td>
<td>Types / Assets</td>
<td>✔ ✔ ✔</td>
<td>SDC use of OPC UA satisfies Entities</td>
</tr>
<tr>
<td>IoT Functional Model</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IoT Process Management FG</td>
<td>Workflow and Tasks in Information Model</td>
<td>✔ ✔</td>
<td>Within SDC workflow is defined within the information model and is executed via a workflow service. This satisfies much of what is defined in the IoT ARM. The available workflow tasks within SDC are however limited.</td>
</tr>
<tr>
<td>Service Organization FG</td>
<td></td>
<td></td>
<td>Service Orchestration resolves IoT services for other parts of the system. This is the primary point of diversion between the IoT ARM and Status Device Cloud. Within SDC, services are generally independent and interact with the Information Model.</td>
</tr>
<tr>
<td>Virtual Entity FG</td>
<td>Information Model / OPC UA</td>
<td>✔ ✔ ✔</td>
<td>SDC use of OPC UA satisfies Entities</td>
</tr>
<tr>
<td>IoT Service FG</td>
<td>Data Connector Service / Information Model</td>
<td>✔ ✔</td>
<td>SDC does have some configuration services implemented in the form expressed by the IoT ARM. However, some end user’s services are implemented through interaction with the Information Model.</td>
</tr>
<tr>
<td>Communication FG</td>
<td>Various drivers, software services.</td>
<td>✔ ✔</td>
<td>SDC has connectivity to many different types of hardware, connectivity can involve direct drivers, standard protocols, web services, gateways and other communication methods.</td>
</tr>
<tr>
<td>Security FG</td>
<td>OPC UA, x509, Users, Roles, Workspaces</td>
<td>✔ ✔</td>
<td>SDC does implement the majority of the Security FG, it does not however calculate reputation scores.</td>
</tr>
<tr>
<td>Management FG</td>
<td>Audit Log, Information Model, Workspaces</td>
<td>✔ ✔</td>
<td>SDC implements most of the functionality of the Management FG, it does not however expose predictive functionality.</td>
</tr>
</tbody>
</table>

Table 1. Summary of Reverse Mapping of SDC to the IoT-ARM

• While SDC™ is largely consistent with the IoT ARM, there is one significant difference. It is not clear exactly if this difference is at a functional level or an implementation level. At a functional level the IoT ARM expects that certain services be exposed and discoverable. Much of the functionality with SDC™ is exposed through the object model as virtual entities not services. These entities are publicly exposed and discoverable as a requirement of the IoT ARM. So the SDC™ implementation, completed without prior knowledge of the reference architecture, does map to the IoT ARM elements.

• Moreover, IoT ARM is designed to be application agnostic. However, our secondary research into the IoT ARM identified that the recommended best practices for implementation of the architecture referred to the application of web services with fixed interfaces that were in turn discoverable using UDDI. While SDC™ does implement some services in this manner, the bulk of the service functionality is exposed through the virtual entities and the information model.
• The IoT ARM proposal provides extensive detail on structural requirements for IoT systems, but says little with respect to requirements for behavioral semantics of IoT system applications. Without rigorous behavioral semantics as a foundation for IoT applications such as SCADA and Smart Cities, attempts to develop and deploy these systems may pose unacceptable risks (Linger & Hevner, 2016). Thus, we identify a significant gap on human-centered (i.e. social and behavioral) issues of IoT applications that we plan to explore as a future research direction.

As the notes in Table 1 describe, the mapping of the practice-based commercial architecture to the reference architecture has the potential to inform both practitioners and researchers and could lead to modifications to either that would provide benefits to developers and users. In several areas, elements within the IoT ARM architecture could enhance the SDC™ architecture. While SDC™ implements the majority of the functional components of the IoT ARM, there are some pieces of functionality that could be added to the system to improve it. These enhancements were exposed through the process of Reverse Mapping of the functionality found in SDC™ with IoT ARM.

Conclusion

Reference Architectures are expected to change and evolve over time as better information, practices, and technology becomes available (Cloutier et al., 2010). The IoT ARM should not be a static document fixed through time. Implemented IoT architectures, like SDC™ can be used to identify gaps in reference architectures through a disciplined mapping exercise as conducted in this emergent research. This in no way implies that the implementation of SDC™ is superior or inferior to that of the IoT ARM nor does it suggest that SDC™ is the one “right” standard of practice for comparison. For the most part, the resulting overall functionality in the practice-inspired SDC™ maps well to the IoT ARM reference. The IoT ARM could benefit from significantly more emphasis on the importance of the Information Model and Virtual Entities that could influence the evolution of the design and utility of the IoT-Arm architecture for researchers and practitioners alike. Future extensions of this research will address an increased awareness of flow semantics in Reference Architectures, the inclusion of mapping to additional reference architectures as they are formulated (e.g. the forthcoming ISO/IEC IoT Reference Architecture), and, the evaluation of cases of applied reference models across multiple industries.

References