Integration of Lift Systems into the Internet of Things and the Need for an Open Standard Information Model

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Keywords: Internet of Things, smart lift/elevator services, open standards, information model, semantic interoperability.

Abstract. The Internet of Things (IoT) is currently the subject of hype and is still in the process of consolidation from a number of visions of its purpose and the benefits it will bring. This paper starts with a review of the development and current status of, and motivations for, the IoT and continues with a discussion of the potential for integrating lift systems into it. The conclusion is that a top-level semantic layer for the IoT architecture is key to the successful delivery of so-called smart building and smart urban services - particularly when machines talk to machines without human intervention. It is at the semantic level that raw data is transformed into valuable and meaningful information, and it is the semantic level that can unlock the imaginative potential to engineer a smart urban environment in which lift systems play an important role. The new services will inevitably require the exchange of information across disciplines, between different corporate as well as private third-party agents and will highlight the importance of agreed standards upon which systems from different suppliers can interoperate. The paper concludes with an overview of an open standard information model for representing the semantics of lift (and escalator) operation which could support this requirement.

1 INTRODUCTION

For the Internet of Things (IoT) to have generated as much excited discussion as it has already received it must encompass more than simply a network of interconnected devices. Indeed, the term brings to mind a vision which parallels the Internet as it currently exists, offering ubiquitous access at any time to an enormous number and range of devices sharing information and cooperating in an open flexible and ever-changing manner. The reality as it evolves may turn out to be less impressive than the current hype would suggest, but it is apparent that success will depend on the development of standards for interaction at all levels in the hierarchy of application software.

Following an overview of the IoT, this paper discusses some opportunities for integrating lift systems to enable a mode of operation that is "*smarter*" and more integrated with the urban environment. Innovative business models will be required, in addition to new technology, for this level of integration to be achieved. The paper concludes with a discussion of standards for information exchange within the domain of lift system operation.

2 DEFINITIONS AND OVERVIEW OF THE INTERNET OF THINGS

In common with many rapidly evolving computer technologies the definition of the Internet of Things has a variety of interpretations which varies according to the vision of its developers.

Also, in common with other significant innovations in computation, the IoT is the combination of several developments that have matured at the same auspicious moment. It is difficult to say which is the cause and which the effect, but it is certainly true that the massive uptake of such innovations is the result of rapid reduction in cost of ownership and that the cost of supplying products and services is immensely reduced by its massive uptake.

The IoT is the subject of hype that can be characterised by the Gartner "Hype Cycle" graph [1] (see Figure 1) and, as Haller[2] wrote, there are conflicting views of its correct definition. In August

2015 Gartner[3] published a "Hype Cycle" report on the IoT, marking several key areas of application development as "On the rise" whereas key platform technologies are already at the peak, with some early application areas already sliding into the "trough of disillusionment" possibly due to the immaturity of those areas that are currently being "hyped".

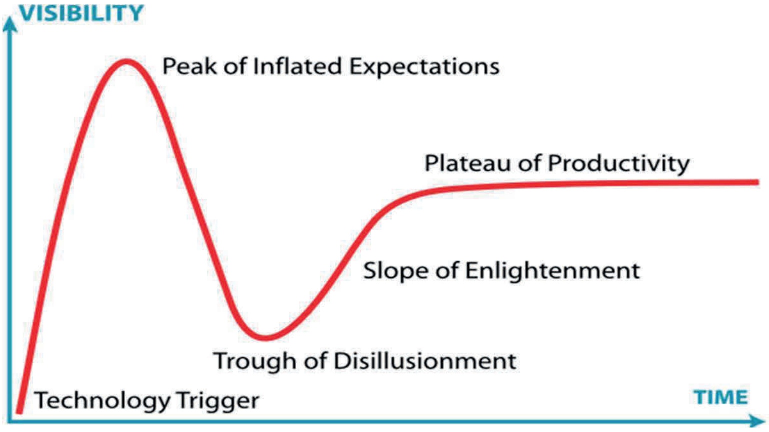

Figure 1 Gartner Hype Cycle [1]

The Wikipedia definition of IoT[4] leads us to the "Overview of the Internet of Things" published by International Telecommunication Union[5]

> " A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies"

Other definitions[6] stress the ubiquitous nature of the Internet, its constant availability coupled with the scope and variety of "things": *anything, anywhere at any time*. A more refined view is offered by Uckelmann et al[7],

> " … accurate and appropriate information may be accessed in the right quantity and condition, at the right time and place at the right price. The Internet of Things is not synonymous with ubiquitous/pervasive computing, the Internet Protocol (IP), communication technology, embedded devices, its applications, the Internet of People or the Intranet/Extranet of Things, yet it combines aspects and technologies of all of these approaches."

Although the IoT is supported by a large number of technical frameworks and infrastructure with clear and standard definitions, the above demonstrates the importance of the conceptual nature of the IoT.

It is nothing new for pieces of equipment (e.g. the "machines" of Machine to Machine[8] or M2M) to exchange status and control information, or that elements of an installation (e.g. the "things" of IoT) are networked and can be addressed individually from multiple remote locations. So the value of the IoT lies in its power in " *enabling advanced services* "[5].

The IoT results from the convergence of a number of technologies that have reached a level of maturity. In this respect there is a parallel with the evolution of the "smart phone", which is the convergence of mobile phone, portable computer, internet access, camera and GPS receiver, thereby enabling a multitude of novel applications that require all these facilities to be combined in a pocket-sized user device. So the camera is also a bar-code scanner, the screen is a map, etc. It is not enough that the technology has been developed to a point where it can be mass-produced and so becomes affordable. It is also necessary that a soft, conceptual, virtual evolution has also taken place whereby engineers have imagined and then implemented new capabilities that are only possible by virtue of the interoperation of the new technologies.

Another parallel can be drawn with Wikipedia - we had encyclopaedia before, but the Internet has given open access to readers who are now able to view and provide comments on the collected knowledge of subject-domain editors in virtually every field of human understanding and that knowledge and the comments on it are continually being reviewed by those editors. It is available everywhere (in theory at least) and immediately. This universal accessibility and collective contribution is another characteristic synonymous with the Internet.

From the several overviews of the IoT, Jayvardhana et al[9] discuss "A Vision, Architectural Elements and Future Directions", Mazhelis et al[10] provide a commercial perspective, and the TIVIT report[5] provides an Overview, Technical requirements and the IoT reference model.

Helpfully Atzori et al[11] summarize three "main visions" of the IoT:

- "Things-oriented" vision - focuses on the things' identity and functionality
- "Internet-oriented" vision - emphasizes the role of the network infrastructure
- "Semantics-oriented" vision - focuses on systematic approaches towards representing, organizing and storing, searching and exchanging the things-generated information

and it is the third, Semantics oriented, vision that this paper focuses on in relation to the integration of lifts into the IoT because that is where the greatest value that is specific to the domain of lift operation can be added and because doing so is key to fulfilling the requirement of the IoT in "*enabling advanced services*". Although significant developments and technical challenges have been overcome in the first two visions it is the semantic vision that is possibly the hardest to realise but which offers the greatest potential for innovation.

Similarly, the IEEE[6](p7) paper, presents a model of "Technological and social aspects related to IoT" and a three-tier architecture[6](p11) with an "Applications" top tier independent of the supporting "Networking and Data Communications" tier and below that the "Sensing" tier. Again it is the "Applications" tier where there is most scope to add value that is specific to the operation of lift systems.

Ragget [12] of the W3C organisation looks at the challenges and the risk of fragmentation of the IoT and proposes a "Web of Things"

- Things standing for physical and abstract entities
- Applications decoupled from underlying protocols
- Shared semantics and rich metadata

The "Applications" here will be specific to a business domain or discipline and the "Shared Semantics" need to be described by a formal definition, such as a UML domain model[13].

Another feature of the current "human" Internet, which is taken for granted, is search facilities. In support of this, services in the IoT must be discoverable so that devices which have never communicated with them before can use these services and vice-versa that services can discover devices. Datta et al[14] provide a categorization of the current landscape for the discovery of resources and propose a framework.

3 LIFT SYSTEMS AND THE INTERNET OF THINGS

3.1 Current initiatives

There are some well publicised commercial initiatives, in the context of lifts and escalators, which use Internet technology although they do not fulfil the IoT vision of semantic interoperability and information sharing (this is by no means a comprehensive list):

3.1.1 Thyssenkrupp MAX

The Thyssenkrupp website[15] announces:

> "… MAX analyzes real-time data from elevators around the world and provides our maintenance control hub with a vast level of detail. This allows us to assess the health of connected elevators and their components."

The resulting data is processed by software applications which "learn" to interpret the information in terms of maintenance requirements rather than simply presenting it to a human operator in its original form.

3.1.2 KONE

Kone also recently announced[16] a collaboration with IBM to gather and analyse trend information from a global distributed network in an initiative to provide proactive maintenance. Significantly, the announcement mentions[17] provision of an Application Programming Interface (API) for use by application developers.

3.1.3 Otis Elevator Company Gen2 lift

In March 2016 Otis Elevator announced[18] services for Gen2 lifts:

- eCall™ mobile application developed exclusively by Otis, through which residents or visitors to buildings can call and direct the elevator at a distance from their smartphones.
- eView™ offers building managers the opportunity to provide customized information directly to passengers.
- Connected reporting and access in real-time equipment to performance data.

3.1.4 flexyPage displays

flexyPage[19] displays located in cars or on landings provide integrated status information on lift status accompanied by information (graphics and text) relevant to the building as a whole, or possibly the destination floors selected.

3.2 Some possibilities for the future

The above examples are early entries into a complex application environment that inevitably will be complimented by others and which will evolve to provide greater sophistication, scope and integration with other services that support the concept of smart buildings. The following are outline suggestions for possible applications that exploit fully the visions of IoT, particularly that of semantic interoperability allied with controlled accessibility for the public, crossing discipline boundaries previously marked by "vertical silos"[20]. However, it must be recognised that initiatives for such cross-fertilisation can only be developed in an open market:

3.2.1 Monitoring and Generating Twitter feeds

I would like to thank Beth Allan for tweeting:

> " **Beth Allan** @adolwyn 1 Nov 2015
> I should know better than to try & use the **elevator** in my building before 5pm on a weekend at the beginning of a month. **#movingday #longwait**".

This information *could* be used very constructively if monitored by intelligent applications. Whilst not controlling the lifts directly, such applications would influence high-level policies of smart lift control systems or smart buildings.

An important aspect of this example is the ability of a member of the public freely to provide information which can lead to modification of the operation of the services that they use thus fulfilling both the community participation and semantic-interoperability roles of the IoT.

To make such an application a reality would require the combination of very diverse business capabilities and would no longer be practicable or commercially viable for a lift manufacturer or a social media company to develop and maintain in isolation. Perhaps new business models will be required, based on the sharing and trading of information.

3.2.2 Smart lifts cooperating with the smart buildings they serve.

Smart buildings interacting with smart cities[20] need to share information about the operation of their lifts and also feed the lifts with external information such as calendars, weather conditions, public transport availability and delays, to build a picture of likely passenger demand. However, any such applications must remove all personal data from communications.

Hotels and commercial buildings might provide personalised "intelligent" and "pro-active" lift service through apps running on personal mobile devices - suggesting destination floors based on interests and affiliations of passengers, or their access permissions to different floors. At the TEDxAmsterdam 2015 event, architect Ron Bakker[21] said of The Edge building in Amsterdam:

> " It’s Monday morning. You enter your office building. The elevator is waiting for you and knows on which floor you need to get off." ... "It might sound like fiction, but if you work at the Edge this is your reality. "

This is in fact the Internet-enabled version of the vision offered by Barney and dos Santos[22] back in 1985! It is a particularly useful example, because it emphasises the need for open interaction with external information services that was not yet practicable in the vision of reality for "The lift for the Year 2000" but now proffered by the visions of the IoT.

3.2.3 Integrated Energy Management

New business models might be established through lifts that predict estimates of their energy requirements for the next 24 hours to the building, or directly to energy suppliers. Or conversely, it might be the building that produces estimates based on a catalogue of energy usage reports acquired from the lifts, given a knowledge of the factors likely to affect lift traffic demand profiles. In return for such predictions, which would contribute to more efficient scheduling of energy provision, the supplier could offer a cheaper tariff. Again, semantic interoperability of the IoT is a pre-requisite.

4 GENERIC STANDARDS

The IoT relies on many standards and standard services e.g. Wi-Fi, IPv6 addressing (required to addresses every individual connected thing uniquely), http and web-service protocols, time-of-day services, load-balancing, cloud computing, etc. Critical to the widespread adoption of IoT is a standardised and reliable security infrastructure. As ETSI says on its website[23]

> "Smart objects produce large volumes of data. This data needs to be managed, processed, transferred and stored securely.
>
> The use of standards
>
> - ensures interoperable and cost-effective solutions
> - opens up opportunities in new areas
> - allows the market to reach its full potential

The more things are connected, the greater the security risk. So security standards are also needed to protect the individuals, businesses and governments which will use the IoT."

5 DOMAIN- SPECIFIC STANDARDS

In order to implement applications for the IoT that are specific to a business domain we must be able to understand the domain-specific information contained in any data that is generated and transmitted via the network. This is a more significant requirement if there is a machine (rather than a human who can make inferences and interpretations) in both the generating and the consuming roles, which is often the case in the IoT. A lexicon or dictionary of the relevant terms and the rules for their use is required to support such applications. A formal definition of the information terms of the business domain and the relationships between those terms is described by an ontology[24] or schema[25][26]. Schemas and ontologies are usually machine-readable and at the same time perform the role of documentation to explain the terms to human readers.

There are already schemas and ontologies, which describe the information in a number of specific domains, and libraries are published and supported by some standards organisations such as the Smart Appliances Reference ontology (SAREF published by TNO[27]) for devices commonly used in buildings eg a light switch[28] (see Figure 2) or an HVAC unit, though significantly this library does not include a lift (or elevator).

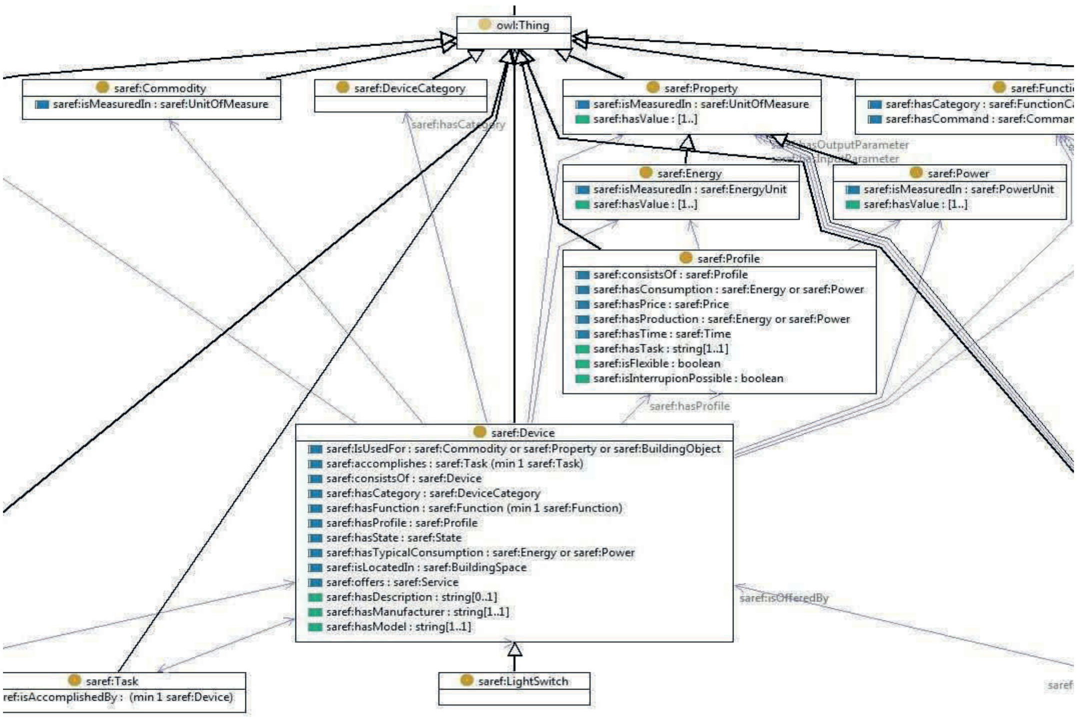

Figure 2- SAREF: Extract from ontology for - Light Switch

5.1 Standards specific to the Lift Systems Domain

Some standards specific to lift systems do exist, and continue to be enhanced, which describe the component parts - BIM (proposed)[29] - and the current state of the basic elements - CANopen-Lift[30] - of a lift. However, there is a real need for an agreed and adopted formal schema to describe the day-to-day operational characteristics of a system of lifts and this is a key requirement for successful integration of lifts into the IoT.

5.2 Standard Elevator Information Schema

The Standard Elevator Information Schema (SEIS)[31] was developed, by the author of this paper, in 2003 from earlier work to model the information and operation of a lift system, using standard software development tools and methods. While it certainly describes the data normally associated with remote monitoring (car and landing call registration and cancellation, car movement, floor-position, and door state) the SEIS is much more comprehensive, including elements of processed information such as demand profiles, journey plans and energy consumption. This level of detail enables the development of sophisticated applications and services, against a common standard, which therefore do not have to concern themselves with, for example, the intricacies of individual car control. The current state of development of IoT applications for lifts makes it thoroughly appropriate that such a standard should now be widely adopted throughout the Building Services industry.

SEIS is a formal specification of operational information of Lifts (and a similar schema exists for Escalators). It describes the information entities, their interrelationships and the possible values that may be assigned to each of their individual attributes. It is not a protocol - it doesn't describe a sequence of messages.

The schema defines many complex data types which display a hierarchical structure. At the highest level of granularity there are:

- Static data
- Dynamic data
- Events
- Exceptions

All dynamic data and events are time stamped so that network latency is not a problem and periods of disconnection or non-availability of consumer services can be overcome simply by concatenating information in a buffer until the relevant service is ready to receive it.

Another significant point of note is that the classes of information described in SEIS do not have definitions of the "Services" which they might offer because it is felt to be too early to standardise them. This work should be postponed for a subsequent revision of the standard after the current version has become well used and understood.

SEIS is described in a formal language - an XML Schema Document (XSD) [26][32][33] - which means that in addition to providing legible documentation for a human readership, the schema can be referenced automatically by the devices (the "things") that are processing the information which it describes. Thus it can be used by an application on a receiving device automatically to validate incoming information that the sending device claims is conformant to the standard. The SEIS can also be used by many commercially available software development tools automatically to generate the software code for a complete class library to manipulate data conforming to the schema. For example, the tool with which the schema itself was developed can generate such code in a variety of languages (C++, C#, VB6, VB.Net or Java) but many other options are available from a range of tools. This level of automated code generation can reduce significantly the cost of developing and subsequently maintaining the applications that will underpin "smart" lifts connected to the IoT whilst leaving application developers free to choose their preferred implementation language.

The scope of SEIS is deliberately constrained within the domain of lift operation in order to minimise the risk of duplication (or contention) with other standards, for example:

- geospatial information properties,
- access authorisation
- security (for example see IET Cyber Security Consortium report[34])

5.2.1 Building Information Model

Currently, it appears to be possible to integrate SEIS with the requirements of BIM for lifts as defined in the CIBSE Elevator Product Description Template[29]. There is no benefit in re-inventing or competing with this information model nor any intention to, but certainly it could be very beneficial to align and integrate these two standards. However, an open BIM library for lifts is needed at least as a base for manufacturers to produce their own specialisations. Resources to accomplish this can be found on the OPENBIM[35] and buildingSMART[36] websites and tools such as DigiPara[37] could be used to deliver the resulting library to lift system designers.

5.2.2 CANopen-Lift

CANopen-Lift concentrates on monitoring and controlling the state of individual standard components of a lift and so, in a similar manner to BIM, represents a very complimentary model to SEIS. To this end, it could be overlaid with a schema (XSD).

6 CONCLUSIONS

The IoT is a much "hyped" and rapidly developing environment offering enormous scope for new joined-up applications and services in a parallel of those offered so far by mobile technologies and the Internet in its current form. It embodies a vision of integrated applications sharing information with an understanding of its semantics.

Key to the success of the IoT is the availability of standards and in particular domain-specific standards that will enable applications from different suppliers to interact in novel ways.

The SEIS is an enabler for new applications and services in the lift systems domain to be integrated within the IoT. It offers a standard model to developers of services and applications for the IoT platform, regardless of the underlying networking and physical technologies used. It embodies a level of "expertise" which therefore doesn't have to be developed and, more significantly, to be maintained by individual suppliers.

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BIOGRAPHICAL DETAILS

Jonathan Beebe graduated in Electronics and was awarded a Ph.D for his research into the use of computers in the management of lift systems. Subsequently, he was employed to design and implement software for dispatcher algorithms, single car controllers and also for remote performance monitoring of lift systems. He has continued this work throughout his career as a part-time consultant along with an active interest in research. Dr Beebe also spent 25 years in full-time employment as a software Design Authority developing large applications for government departments, banks and other financial institutions using Internet technologies. Much of this work involved modelling the processes and information of clients' businesses as well as designing methods and tools for the software development process itself.