IOT - INTEROPERABILITY AND DYNAMIC WORKFLOW COMPOSITION – CHALLENGES AND PERSPECTIVES

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Abstract: *In the Internet of Things, inter-devices communication technical features such as range, data requirements, security and power demands and battery life have not been provided much thrust evidently but that as it may, there is an essential need to incorporate prerequisite and difficulties from this zone, as there are a ton of basic issues like stockpiling and extra esteems like catching the greatest advantages will require a comprehension of where genuine esteem can be made and effectively tending to an arrangement of system issues, including interoperability. Interoperability and M2M communication can be made seamless when the data-models and operations are abstracted out and expressed using semantics. A detailed study on the above provided different avenues of approach. A high-level language construct is proposed, along with Semantics, which can enable dynamic workflow composition. The construct is named as Things Markup Language (TML).*

Key words: *Interoperability, Semantic methods, dynamic workflow, Things Mark-up Language*

1. 1. Introduction

'Internet of Things' understands the possibility of a huge number of heterogeneous "mindful" and interconnected gadgets with exceptional IDs collaborating with different machines/items, foundation, and the physical condition. A thing, in the Internet of Things, can be a person with a heart monitor implant, a ranch creature with a biochip transponder, a car that has worked in sensors to alarm the driver when tire weight is low or some other characteristic or man-made object that can be allotted an IP address and gave the capacity to exchange information over a system.

The integration of embedded devices in IoT brings in many challenges with respect to data management, storage management, security, privacy, apart from server technologies also. The effectively existing Web innovations and conventions were not ready to adapt up to the outline prerequisites of the new class of implanted gadgets. These installed gadgets are normally intended for minimal effort and low power utilization and subsequently have extremely constrained power, memory and preparing assets and are regularly debilitated for long-times (sleep periods) to save energy.

Dissemination of Internet protocol technology to new domains is increasing in an alarming rate where embedded devices such as sensors and actuators play a prominent role. This development of the Internet is practically identical in scale to the spread of the Internet in the '90s and the subsequent Internet is presently regularly alluded to as the Internet of Things (IoT) [1]. The network shaped by these installed gadgets additionally have unexpected attributes in comparison to those average in the present Web. These obliged systems have diverse movement designs, high parcel misfortune, low throughput, frequent topology changes and little helpful payload sizes.

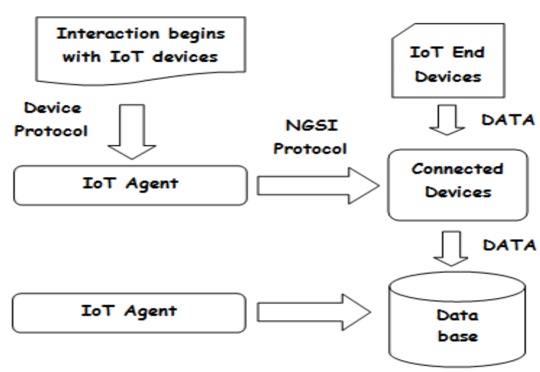

Figure 1. IoT – Interactive model

Kevin Ashton, cofounder and executive director of the Auto-ID Center at MIT, explains the hidden potential of the Internet of Things [2] as follows. "Today computers -- and, therefore, the internet -- are almost wholly dependent on human beings for information. Nearly all of the roughly 50 Petabytes (a petabyte is 1,024 terabytes) of data available on the internet were first captured and created by human beings by typing, pressing a record button, taking a digital picture or scanning a bar code. Here the problem is, people have limited time, attention and accuracy -- all of which means they are not very good at capturing data about things in the real world. If we had computers that knew everything, using data they gathered without any help from us, would be able to track and count everything and greatly reduce waste, loss and cost. We would know when things needed replacing, repairing or recalling and whether they were fresh or past their best."

The challenge of the next decade is to see that the benefits of the Internet of Things revolution, both socially and technically, are shared by all the citizens of the world, not just those fortunate enough to live in the most developed and emerging economies. From the fanciful start-ups like 'the I-enabled Toaster', 'the only Coke Machine', a vigorous technical development to enable "smart object networking" happened [3]. This technical advancement helped create the foundation for today's Internet of Things.

2. IoT and Interoperability

2.1 Interoperability

Interoperability is "the ability of two or more systems or components, having different attributes, to exchange data and use information". This definition gives many difficulties on the most proficient method to get the data, trade information, and utilize the data in understanding it and having the capacity to process it [4].Heterogeneity of hidden gadgets and correspondence advancements and interoperability in various layers, from correspondence and consistent coordination of gadgets to interoperability of information produced by the IoT assets, is a test for growing bland IoT answers for a worldwide scale.

H. van der Veer and A. Wiles [5] discussed that the categories of the interoperability as follows: Machine to Machine communication can be enabled by hardware/software components, systems and platforms. This comes under 'Technical which is frequently focused on (communication) conventions and the framework required for those conventions to work. 'Syntactical Interoperability 'is typically connected with information positions which can be spoken to utilizing abnormal state language structures, for example, HTML or XML. 'Semantic Interoperability' implies that there is a typical comprehension between individuals of the importance of the substance (data) being traded. 'Authoritative Interoperability', as the name suggests, is the capacity of associations to adequately convey and exchange (important) information (data) despite the fact that they might utilize a wide range of data frameworks over broadly extraordinary foundations, potentially crosswise over various geographic locales and societies. Authoritative interoperability relies upon fruitful specialized, Syntactical and semantic interoperability.

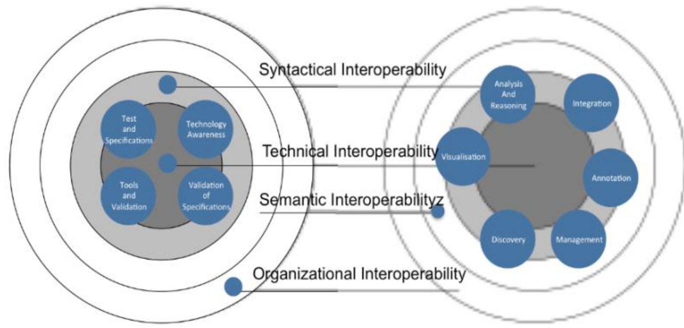

Figure 2. Dimensions of Interoperability

In reference to the most widely recognized difficulties for interoperability and our region of concern, the essential challenges [4] are (i) Combination of different information sources (ii) Semantic Interoperability (One of a kind ontological perspective) and (iii) P_2P Communication. The first depicts the need to be interoperable at the information/occasion level so it ends up noticeably less demanding to join/total information/occasion originating from heterogeneous information sources. The second one, Semantic interoperability, implies having an extraordinary perspective at the philosophy level. This can be understood by outsider in charge of deciphering between various plans or by means of philosophy consolidating/mapping. There could be additionally conventions for concurring upon a particular philosophy. Third one manages the need for applications to impart at a more elevated amount through trade of particular learning. Interoperability can be disregarded at bring down levels and can be executed at a more elevated amount.

Apart from the above three, the following are also considered as key challenges in Semantic Interoperability. Data Modelling and Data Exchange, Ontology merging / Ontology matching & alignment, Data/Event Semantic Comment (and committed ontologies), Learning Portrayal and related ontologies, Learning Sharing, Information Correction and Consistency, Semantic Disclosure of Information Sources, Information and Administrations, Semantic publish/subscribe and Semantic routing, Investigation and reasoning and much research concentrate must be done on these difficulties.

2.2 Semantic Interoperability - Challenges

As IoT encompasses numerous old and new technologies under its umbrella, there is a huge diversity in types of devices, protocols and mechanisms that are to be supported. Interoperability issues can be attempted to be solved in broadly three different ways - publishing standards, reference architectures and frameworks, defining protocols and media-type standards and by using abstract interface definition languages and semantic technologies. So far, none of these solutions have been successful to solve the interoperability challenge as it is difficult to propose a standard or a specification that can fit all kinds of requirements.

There has been lot of standards for management of IoT / M2M devices, reference architectures, open-source frameworks, few custom protocols and languages developed by consortia of vendors. IPSO - RESTful mechanism[6], ETSI/oneM2M- standard for end-to-end M2M Communications[7], SWE - decoupled approach where items can together take an interest in an extensive variety of choice workflows[8], IoT-A/OpenIoT - device management with no explicit support for workflow[9], AllJoyn/IoTvity- Custom data-models[10], LwM2M- consideringthe factors such as low bandwidth and lossy networks[11], SenML - data-model in JSON format[12], Weave - provide a shared understanding between devices, humans, and smart-phones[13], Thread - secure and reliable connection[14], Vorto- facility to define the capabilities of the devices in entirety[15,16], Ponte - abstraction for various application protocols[17,18,19].

Table 1: Workflow composition in IoT

Solution	Workflow Composition	Workflow Composition Requirements				
		Properties	Behavior	Semantics	Message	Protocol
IPSO	IP based addressing; using standard HTTP verbs and URIs.	Y	Y	N	N	N
ETSI/oneM2M	Provides ontologies. Models can enable workflows to be defined	Y	Y	Y	Y	N
SWE	Decoupled approach where objects can jointly participate in a wide range of decision workflows	Y	Y	Y	Y	N
IoT-A/OpenIoT	Reference Model provides device management with no explicit support for workflow building	Y	Y	N	N	N
AllJoyn/IoTvity	Custom data-models and behaviours	Y	Y	N	N	N
LwM2M	Provides only management interfaces and operations	Y	Y	N	N	Y
SenML	Provides only the data-model in JSON format	Y	N	N	N	N
Weave	Language based control of communication, workflow composition is possible	Y	Y	N	Y	Y
Thread	Reliable communication protocol for the Things. Can be used in the lower layer of the communication for seamless workflow execution	Y	Y	N	Y	Y
Vorto	Shared Information model ensures interoperability and abstract models gives flexibility to define workflows	Y	Y	N	N	N
Ponte	Provides abstraction for various application protocols	N	N	N	N	Y

This has led to a lot of fragmentation in the solutions for interoperability in the M2M space. Due to this fragmentation composing a workflow when multiple such devices are involved is a difficult exercise.

In Table 1, the standards, reference architectures and interface definition languages have been abstracted out the varied differences, to a large extent. The advancement of IoT can be made possible when the applications and solutions are built with a focus on interoperability at all layers of the application stack. A formal specification or a language construct can be defined at the application layer. This specification can be used to generate bindings at various layers of the application stack automatically, these can be used to expose standard interfaces which are aware of the communication standards, data types etc. Such mechanisms can foster development of autonomous systems yet be interoperable.

3. Semantic Ontology's Integration using TML

The above interoperability challenges can be overcome by abstracting the various differences in data model, service interfaces using a high-level language construct, Things Markup Language. Thefollowing solutions are proposed to overcome the above challenges, if not completely, to a certain level and it is strongly believed that it will definitely open up many different innovative avenues in order to provide possible explanations.

Interoperability is of high importance when potentially different systems need to interact with each other, considering the difference in data-models, service interfaces, discovery, capabilities and methods. IoT-ML will provide a high-level language construct abstracting the various differences in data-model, service interfaces while the integration with Semantic Ontologies provides the context awareness and "what" the data means. Things Markup Language (TML) allows modelling context and semantic awareness into the workflows which will decide the right service for a given event, time and location – workflow models must be aware of the operating environment (ontologies).

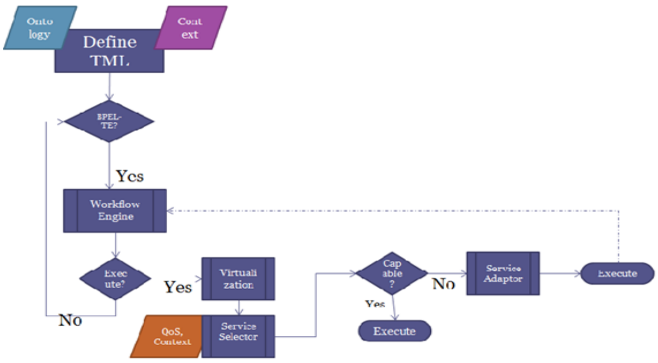

Figure 3. Context aware workflow Execution

TML can be used to define a workflow regardless of the underlying implementation device make or type. Simple annotations can be used to identify, discover, call a service interface, determine the context, convert among data-types/models, interpret the dataand take decisions based on the data values and context. Matchmaking here refers to finding the right device/system for a given scenario and executing the desired service on it.

As most devices are resource constrained, workflows may have to be compiled to native service. The selection of service from a set of candidate services must be optimized using a hybrid model using Bayesian learning and ontology. This service execution must be QoS aware (Throughput, Response-Time, Cost, Availability, Reliability, Reputation, User preferences). When the objects/services need to be changed at runtime, Dynamic(reactive) workflow composition, reconfiguration and execution are very much required.

4. Conclusion

The current IoT and in general M2M is too much diversified. Diversification is a result of many mechanisms, often some custom protocols in use due to the nature of solutions that have been developed over time. Many of the standards have been an afterthought after the actual solution has been developed while in many cases the standard isn't generic enough for adoption. With the introduction of more standards there is definitely a churn in the adoption cycle. At the same time the rapid advancement in hardware is an influencing development of more efficient solutions. The standards, reference architectures and interface definition languages have to be, a large extent, abstracted out. The advancement of IoT can be made possible when the applications and solutions are built with a focus on interoperability at all layers of the application stack.

A generic specification or a high-level language construct can be defined at the application layer. This specification can be used to generate bindings at various layers of the application stack automatically, these can be used to expose standard interfaces which are aware of the communication standards, data types etc. Such mechanisms can foster development of autonomous systems yet be interoperable.

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