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USE OF THE ONTOLOGICAL APPROACH TO SEMANTIC SEARCH IN THE ENVIRONMENT OF THE INTERNET OF THINGS

Rogushina J.[*], Gladun A.[**], Andrushevich A.[***] , Kurbatski A.[***]

[*] *Institute of software systems of National Academy of Sciences Ukraine, Kiev, Ukraine*
ladamandraka2010@gmail.com

[**] *International Research and Training Center Information Technologies and Systems of National Academy of Sciences Ukraine, Kiev, Ukraine*
glanat@yahoo.com

[***] *Software Engineering Department, Faculty of Applied Mathematics and Computer Science, Belarusian State University, Minsk, Belarus*
{lastname}@bsu.by

In the article the multilayer ontological reference model of the Internet of Things and methods of it`s design and use for semantic search are proposed.
Keywords: Internet of Things, ontological model.

Introduction

The term «Internet of Things» (IoT) goes back into presentation of K. Ashton in 1999. Now IoT is undoubtedly becoming a reality, it now goes far beyond the original concept, encompassing not only RFIDs, but also sensors, actuators, mobile devices etc. In the new vision, all of these are considered to be things that can act upon, measure, or provide services based on real-world entities.The number of different interconnected through ICT physical objects/devices as well as their virtual representation has been growing rapidly in recent years. According to different estimations there will be around 25 billion devices connected to the Internet by 2015 and 50 billion by 2020.

Such numerous amounts of widely distributed and highly heterogeneous devices and technologies will need to communicate in different scenarios under various conditions. This implies that interoperability becomes one of the most fundamental requirements to support object discovery and retrieval as well as information representation, storage and exchange. IoT has started getting considerable interest from academia and industry that work on the related technologies. New protocols and industrial standards for low-level device communications in resource-constrained environments are also being actively developed.

However, IoT still has a lot of unresolved issues like high heterogeneity (networks of objects in IoT will be deployed by distinct entities, and the deployed hardware will display different operating characteristics, such as sampling rates and error distributions); scalability; unknown topology; incomplete metadata etc.

This complex subject requires a lot of joint integrated efforts from communities working in different fields, such as telecommunications, IT, manufacturing and material engineering etc. Moreover, it should be laid on foundations of modern knowledge-oriented technologies that assure full future interoperability of networks and devices and shared access to various IoT resources.

Data collected by different sensors and devices is usually polysemantic (temperature, light, sound, video, etc.). The diversity, volatility and ubiquity of the real world IoT data will cause a lot of problems with their processing, integrating and interpreting. Therefore the dynamic and resource-constrained nature of IoT requires special design of knowledge representation and processing that must take into account the semantic web technologies such as ontological analysis, semantic metadata, Semantic Web, Linked Data and Social Web.

Semantic descriptions can support the IoT integration by enabling interoperability between different sources. But analysis and mapping between different semantic description models is still required to facilitate the IoT data integration with other existing knowledge domains and establish the general reference model of the IoT semantics (Fig.1).

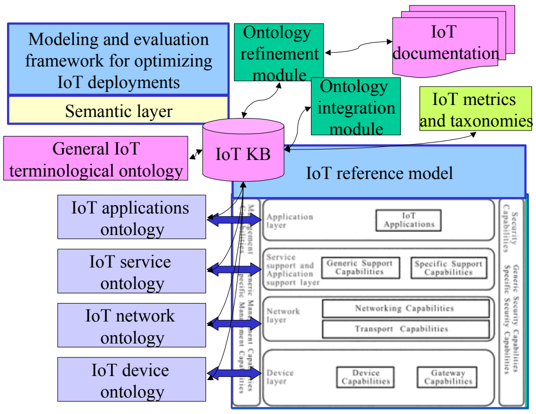

Figure 1 - IoT reference model

Current state of research in the field

The Internet of Things **[Kurakova, 2013]** may be considered as a heterogeneous network formed by autonomic and human controlled devices that communicate with each other in order to accomplish some specific, often delay or mission-critical, task(s).

The unprecedented design challenges related to IoT has caused it to receive great attention from both academia and industry as of late. Having a world of interconnected and automated devices facilitates the development of unprecedented applications and breaks with the current markets.

Taxonomy of IoT applications

Even by its term, the "Internet of Things" has an inherent fuzziness and dichotomy due to trying to merge the networking plane (Internet) and the objects' plane (Things). It is therefore very important to precede any foray into this field by achieving a clear understanding of the overall scientific as well as practical engineering contexts and objectives. Although IoT research field is comparatively young, there already exists sufficient body of literature that could be used as a basis for building such understanding.

Each of these fields may in turn contain an endless number of different visions, which will all together morph into creating a rich ecosystem of IoT technologies and applications. Even simply enumerating the technologies is a challenge, let alone harnessing their potential in a most efficient manner that would be both technically optimal and at the same time economically viable.

IoT Semantic Formal Modeling

IoT components (devices – sensors, actuators, mobile devices etc. – and services) are heterogeneous and dynamic, with unknown nature of the network topology. As one of the fundamental constituents of future Internet, IoT has attracted tremendous interests from various research communities and industry [Hachem, 2011]. Advancement in wireless sensor networks has led to a potential interest in integrating data and capabilities provided by physical world objects into the Internet.

Already, we have seen many applications using semantic Web technologies in IoT research, in particular the SSN ontology for annotating sensors and sensor networks; Linked Data [Bizer, 2009] for sensor data publishing [Pschorr, 2010], and semantic sensor observation services (SemSoS) [Henson, 2009].

Now IoT is undoubtedly becoming a reality but it needs some integration means with modern semantic-oriented Web technologies (for example, with standards of the Semantic Web approach) including semantic modeling that can be used for Scalable Search in the Internet of Things [Andrushevich, 2013]. An ontological approach can be used as a base for interoperable reused description of their semantics. Now a lot of researchers try to develop different ontological models of different IoT domains, like for example Semantic Building [Andrushevich, 2010].

Ontology for the Internet of Things provides all the necessary semantics for the specification of IoT devices as well as the specifications of the IoT solution (input, output, control logic) that is deployed using these devices. Technologies developed in the Semantic Web such as ontologies, semantic annotation, Linked Data and semantic Web services can be used as principal solutions for the purpose of realizing the IoT but there is no one universal ontology or a set of aligned ontologies that can be considered as a standard for all IoT community. A common solution to all challenges above is the use of semantic technologies to increment knowledge with metadata. The representation of the IoT-based real world divides into some different layers: a physical layer (things); an information layer (data and metadata about knowledge provided by things); and a functional layer comprising services provided by things.

To match this vision of the real world and its representation by IoT, we have to develop the integrated set of ontologies that actually models all three layers. The physical layer is represented by Device Ontology that is specific for IoT. The information layer is represented by the set of Domain Ontologies that can be exported and reused from different intelligent software. The service layer is represented by Functional Ontology that can use the research results in semantic Web-services area.

The other important problem is considered with the development of the algorithms and techniques that are oriented on efficient processing of IoT ontologies: for example, methods for semantic search of IoT devices interested for particular user; methods of collaborative search that can acquire the dependences in IoT world; methods of integration with domain ontologies etc.

Now we have a long-term experience in investigation of knowledge management problems in the Semantic Web environment in such associated areas as the Semantic Web technologies and their use in the design of intelligent applications in different domains that we try to apply in the IoT domain: design of intelligent and personalized ontology-based retrieval and recommending systems in the context of the Semantic Web technologies [Gladun, 2009]; design of the methods of ontological analysis – thesauri forming, mereological analysis, semantic markup of natural language texts with lexical ontologies [Gladun, 2012]; cognitive networks and ontological analysis in increasing of service quality in heterogeneous wireless environment [Rogushina, 2010].

Scientific significance of the planned research

IoT applications have to be intelligent and knowledge-based. Different relevant ontologies that define such domains as geographical objects, people, units of measurement can be reused in combination with specific IoT ontologies.

We think that IoT formal model on base of ontological approach becomes an important tool for integration and retrieval of different IoT objects and services. The use of standardized terminology provides the facility for formalized semantic definition of IoT elements. An important dimension of research is a development of means and instrumental tools for automated population and refinement of this model by knowledge acquired from natural language texts and other informational resources relevant to the new IoT elements. This model is an efficient mean of cooperation and collaboration in community of IoT researchers and their mutually beneficial communications with results of investigation in domains of the Semantic Web, semantic Web services and Semantic Grid, semantic informational retrieval etc.

IoT formal ontological model

Design of formal ontological model of the IoT objects includes some main parts:

- Analysis of the IoT domain knowledge structure, main objects and relations: use of mereological and ontological methods to acquire the IoT domain terminology and design of the OWL ontology structure;

- Reuse of existing taxonomies and ontologies of the IoT domain: retrieval and analysis of knowledge representation of the IoT means and standards, overview of relevant ontologies and other knowledge structures, integration of existing domain taxonomies;

- Design of methods for automated refinement of the IoT formal ontological model: design of methods for automated acquisition of knowledge (terms and relations) from texts relevant to the IoT domain, methods of automated linguistic processing of the natural language texts and refined OWL ontology;

- Semantic retrieval in IoT domain on base of domain ontology: semantic search of the IoT devices, analysis of the web search result lists in the IoT domain;

- Semantic search of the IoT services: methods of semantic search of the IoT services, recommendations about use of IoT devices and services and methods of the collaborative search in IoT community.

Semantic search in IoT

IoT connects a lot of embedded devices equipped with sensors to perceive their surroundings. Thereby, the state of the real world will be available online and in real-time and can be combined with other data and services in the Internet to realize novel applications such as Smart Homes, Smart Cities, Smart Grids, or Smart Healthcare. This requires an open representation of sensor data and scalable search over data from diverse sources including sensors [Andrushevich, 2013]. The Semantic Web technologies RDF (an open semantic data format) and SPARQL (a query language for RDF-encoded data) can be used to address those challenges: prediction models can be employed for scalable sensor search, encoded as RDF and queried by means of SPARQL.

We propose to use the structure of IoT domain as a base of for semantic search of the IoT items pertinent to user needs (Fig.3).

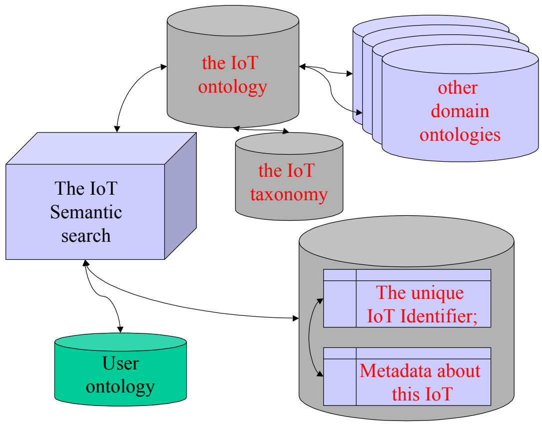

Figure 2 - Semantic search for the IoT

By this approach the formal model consists of: 1. the unique IoT Identifier – URI from the IoT repository; 2. metadata about this IoT corresponding into this IoT Repository to identified IoT; 3. the IoT ontology where different the IoT rules and correspondences are stored (this ontology can be supplemented by other domain ontologies).

Like regular search, semantic search can be deconstructed into its components. To create a semantic search that can use not only keywords but their meanings, for example, in [Amerland, 2013] semantic search is based on the three basic elements: Identifier (URI), RDF and an ontology library.

Universal Resource Identifier – a URL or a URI of the Web resource, or it can be a Universal Resource Name (URN). The URI is needed for the initial set of Web information resources (but that initial set of data is not sufficient for efficient search). But URI has to be refined before it can be proposed to user. This refinement is achieved with the help of metadata information – RDF that can be used as a set of transforming rules for data from URI database to another database without loss of meaning.

Ontologies are used for knowledge structuring by classes and rules that support an inference on them. Metadata from RDF and domain knowledge from ontologies can be used to infer the meaning of IR content in the search process. The IoT Device Ontology identifies what things should be looked up to satisfy an application's requirements. Different applications that use this ontology can identify devices relevant to provided services.

In [Smyth, 2011] the problems of mainstream web search engines that suggest the one-size-fits-all results of Web search are described: two different users with the same query will, more or less, receive the very same result-list, despite their different preferences. Web search needs to become more personalized so that the implicit needs and preferences of searchers can be accommodated. Now a lot of different approaches to personalizing web search by harnessing different types of user preference and context information to influence the search experience. For personalization of search for the IoT we have to use the knowledge about every user of the IoT and about the community of users in general.

We propose to integrate the knowledge about the IoT items with the knowledge about personal needs of users and domain knowledge represented in ontological form. For use of all of this information in semantic search process the ontological elements are matched.

Conclusion

Development of the IoT formal ontological model that integrates all main concepts (items, services, protocols, benchmarks etc.) and their relations of this subject domain becomes an important instrument of integration, retrieval and interoperability of heterogenous objects and services of the IoT on the semantic level.

Bibliography

[Kurakova, 2013] Kurakova T. Overview of Internet of Things // Proc.of the INTHITEN (INternet of THings and ITs ENablers) conference, Saint Petersburg, Russia, 2013. – P. 1-13.

[Hachem, 2011] Hachem S., Teixeira T., Issarny V. Ontologies for the internet of things // Proc. MDS'2011, N.3, ACM, New York, NY, USA 2011.- http://hal.archives-ouvertes.fr/docs/00/64/21/93/PDF/IotMiddleware.pdf.

[Bizer, 2009] Bizer C., Heath T., Berners-Lee T. Linked Data - The Story So Far // International Journal on Semantic Web and Information Systems (IJSWIS), 2009.

[Barnaghi, 2010] Barnaghi P., Presser M., Moessner K. Publishing Linked Sensor Data // Proc. 3rd International Workshop on Semantic Sensor Networks (SSN), in conjunction with the 9th International Semantic Web Conference (ISWC 2010), 2010.

[Pschorr, 2010] Pschorr J., Henson C., Patni H., Sheth A. Sensor discovery on linked data // Proc. of the 7th Extended Semantic Web Conference, ESWC2010, Heraklion, Greece, 2010.

[Henson, 2009] Henson C., Pschorr J. K., Sheth A. P., Thirunarayan K. SemSOS: Semantic Sensor Observation Service // Proc. of the 2009 International Symposium on Collaborative Technologies and Systems (CTS 2009), Baltimore, MD, 2009.

[Andrushevich, 2013] Andrushevich, A., Kurbatski, A., Basko, V., Klapproth, A. Towards information retrieval characteristics in the Internet of Things // Proc. of the International Congress on Computer Minsk, 2013.

[Andrushevich, 2010] Andrushevich, A., Staub, M., Kistler, R., Klapproth, A. Towards Semantic Buildings: Goal-driven approach for building automation service allocation and control // Proc. of the 15th IEEE International Conf. on Emerging Technologies and Factory Automation, Bilbao, Spain, 2010.

[Gladun, 2009] Gladun A., Rogushina J. Use of the Semantic Web technologies in design of informational retrieval systems// in Book "Building and Environment", 2009 Nova Scientific Publishing, New-York, USA. – P.89-103.

[Gladun, 2012] Gladun A., Rogushina J. Use of Semantic Web Technologies and Multilinguistic Thesauri for Knowledge-Based Access to Biomedical Resources // International Journal of Intelligent Systems and Applications, 2012, №1, P.11-20. – http://www.mecs-press.org/ijisa/ijisa-v4-n1/IJISA-V4-N1-2.pdf.

[Rogushina, 2010] Rogushina J., Lesko O. Use of the specialized lexical otology for automated formation of the domain ontologies on base of natural language texts // Information Models of Knowledge. Edited by K.Markov, V.Velychko, O.Voloshin. – ITHEA, Kiev-Sofia, 2010. – P.93-100.

[Smyth, 2011] Smyth B., Coyle M., Briggs P. Communities, Collaboration, and Recommender Systems in Personalized Web Search // in Ricci F., Rokach L., Shapira B., Kantor P. Recommender Systems Handbook. – Springer, 2011. – P.579-615.

[Amerland, 2013] Amerland D. Google Semantic Search: Search Engine Optimization (SEO) Techniques That Gets Your Company More Traffic, Increases Brand Impact and Amplifies Your Online Presence. – Que Publishing, 2013. – 230 p.

ИСПОЛЬЗОВАНИЕ ОНТОЛОГИЧЕСКОГО ПОДХОДА К СЕМАНТИЧЕСКОМУ ПОИСКУ В СРЕДЕ ИНТЕРНЕТА ВЕЩЕЙ

Рогушина Ю.[*], Гладун А.[**], Андрушеви А.[***], Курбатский А.[***]

[*] *Институт программных систем НАНУ, Киев, Украина*

ladamandraka2010@gmail.com

[**] *МНУЦИТС НАНУ и МОНУ, Киев*

glanat@yahoo.com

[***] *Белорусский государственный университет, Минск, Беларусь*

{lastname}@bsu.by

В статье предложена многоуровневая онтологическая эталонная модель для the Internet of Things и методы ее разработки, пополнения и использования при семантическом поиске.

Ключевые слова: Интернет вещей, онтологическая модель