Serdica J. Computing **12** (2018), No 1–2, 1–22

Serdica
Journal of Computing

Bulgarian Academy of Sciences
Institute of Mathematics and Informatics

CONCEPTUAL MODELING OF IoT ECOSYSTEMS: A BUSINESS-ORIENTED APPROACH

Rumen Andreev, Svetozar Ilchev, Alexandre Chikalanov, Yuliyan Petkov

Abstract. In this paper, a new approach to the conceptual modeling of IoT ecosystems is presented. Taking into consideration the business processes of an organization, this approach allows the creation of models which integrate IoT-devices and IoT-governed activities into the business flow of the company. The main purpose of this research is to help organizations make faster and more efficient choices based on formalized input/output from their IoT-resources and networks. The use of modeling and formal description is necessary in order to include IoT in ERP-systems, so that IoT is considered in the overall strategic planning and decision making on all levels.

1. Introduction. The Internet-of-Things represents the idea of globally interconnected devices from our everyday life, e. g., smart home appliances, smart personal gear, smart cities, etc. Hardware advances have put at our disposal a multitude of smart objects using various microcontrollers

---

ACM Computing Classification System (1998): C.2.0, K.6.0.

Key words: IoT ecosystems, business processes, Internet-of-Things, conceptual modeling, interoperability.

(AVR, ARM, PIC, etc.), communication environments (wires, radio, optics, etc.), data exchange protocols and models (Ethernet, Bluetooth, Zigbee, etc.) which are very heterogeneous and often not compatible with each other. Different microcontroller capabilities, communication frequencies, encoding technologies, frame formats and encryption standards are only part of the difficulties for transparent data flows through devices.

Due to the differences in complexity, energy requirements, licenses, etc., technologies may not be immediately capable of connecting to the Internet. Some devices may connect to the global network only through gateways (LoRa communication) others may not be accessible all the time (e. g., off-grid sensors) and still others (body wear) may gather data until in reach of the home WiFi network through which they upload the data to a cloud server. Another major problem for the interconnectivity is the closed approach of manufacturers to the design of smart objects. For example, in the field of home automation, home appliances often integrate with a cloud-based service provided by the manufacturer and industrial machines report back to a manufacturer service without any public documentation of the communication protocols or the cloud-based services. A third interconnectivity problem is the availability of communication, e. g., communication chips reach their end of life, regulatory requirements differ amongst countries, environments are riddled with noise, etc.

In order to provide both added-value for end-users and optimize the company's business processes and workflow, a smooth and transparent exchange of information needs to be guaranteed. Two major issues need to be covered. The first issue is achieving acceptable (reliable, secure, energy-efficient, etc.) data flow across different hardware, network topologies, environmental and power-supply conditions. The second issue is connected with storing and analyzing the data. We would like to have some form of structured description which can be integrated into existing ERP systems, so smart objects may become part of the overall enterprise information infrastructure. Such a description may be specified via BPMN, UML, ontologies, etc. The end goal is to make detailed models involving smart objects for a seamless integration with the company's business processes. An important point to make is that once smart objects are modeled within the

ERP system, we can use them to provide services to end customers (e. g., order automation and product delivery to partner companies) and to perform data storage, retrieval and analysis—the domain of classic business intelligence. Existing models present a potential for reducing the need for human intervention, e. g., elimination of phone calls to order consumables or report a machine fault, but they also necessitate some changes in the business processes of the company.

Besides the obvious advantages, the smartness of objects also raises some negative concerns—the privacy of the shared data, copyright issues, security and reliability of remote control services, (legal) responsibility for each part of the business process.

2. Related work. A good overview of IoT and its most important problems, challenges and goals, is presented in [1] and [2]. The authors discuss topics such as device heterogeneity, scaling, service-oriented architectures and protocols. Some popular communication protocols on the MAC and network layer of the OSI model are presented in [3], which also discusses some ways for localizing sensors. Wireless cooperative networks are presented in [4], where both fixed relaying schemes such as decode-and-forward and dynamic relaying schemes are discussed. Achieving adaptive routing through fuzzy algorithms in wireless sensor networks is discussed in [5]. The optimization of network communication through new clustering strategies is the topic of [6]. Communication of battery-powered sensors within a smart grid and the impact of transmit power and data acknowledgement on the sensor node lifetime is discussed in [7]. Some security issues and possible network attacks on IoT devices are presented in [8] and [9]. Several communication routing algorithms (e. g., LEACH, SEP) are discussed and compared with each other with regard to sensor lifetime in [10]. The use of semantic technologies (e. g., ontologies) to structure IoT information flow is discussed in [11] and [12]. These papers indicate the enormous diversity of the IoT landscape and motivate us for the development of conceptual models to allow intercommunication and interaction between heterogeneous devices as part of an overall corporate ERP system which also provides service delivery to end customers and data storage and retrieval interfaces. There are various approaches to integrating IoT into the business process models of a company. In [13], four different kinds of components are defined, which then can be mapped to smart objects. The authors use BPMN 2.0 to implement the mapping and to represent the components as business process resources. The authors expand the Lane element of BPMN and show how it can be used to model IoT devices in an external editor together with the corresponding XML representation. The authors also compare their approach with earlier efforts [14], [15], [16] and [17]. In [14] and [15], the focus is on REST principles and SOAP and the smart objects are regarded mainly resources of data. In [16], the authors discuss sensor nodes and automated code generation from a BPMN model. In [17], the author presents possible BPMN extensions to explicitly model the mobility of each device. A method for process modeling using SysML, UML and BPMN is presented in [18]. In [19], the focus is on dynamic properties of the IoT-ecosystem and a semantic access layer is proposed to enable service discovery and start of IoT-related business processes. Semantic queries can be generated by means of SPARQL to discover process services and resources and an example utilizing the DogOnt ontology [20] and the OpenHAB automation system is given in the context of smart homes. In [21], a system for process execution in an IoT environment is proposed. In [22], the authors discuss service-dominant logic, its fundamental principles, its differences from goods-dominant logic and the role of IoT in contemporary economics. Enhancing the BPMN 2.0 to include the concept of IoT is a topic discussed in [23]. In [24], the authors research wireless sensor networks (WSN) and their use in domains that are characterized by the presence of multiple business processes. The authors of [25] and [26] introduce ubiquitous BPMN (uBPMN)—a BPMN extension whose main goal is the modeling of IoT-related devices and activities. In [27], the principle of model-driven architecture is applied to IoT. In [28], the IoT interoperability is discussed and four layers are defined: technical, syntactical, semantic, and organizational. In addition to the modeling approaches outlined above, other important topics pertaining to the integration of IoT and smart objects into business processes are ontologies [29], topologies and network protocols [30], security [31], energy requirements [32], device service discovery [33], quality of service [34], cloud computing [35], [36], interoperability [37], etc.

3. An approach to conceptual modeling of IoT systems. The achievement of IoT interoperability is related to the modeling of IoT systems' architectures that requires determination of an "architecture framework", i. e., conventions, principles and practices for the description of architectures of systems of interest established within a specific domain of interest. We suggest that it is necessary to introduce a new layer for IoT interoperability and for the definition of our framework for architecture modeling of IoT systems, we used the main concepts related to the conceptual modeling as defined in the standards IEEE 1471 and IEEE 42010.

The consideration of an IoT system as an ecosystem is often similarly specified as IoT Ecosystem, IoT Innovation Ecosystem or IoT Business Ecosystem [38] and the authors talk about IoT Ecosystem for reason of simplicity. It is not correct, since "IoT innovation ecosystems could be created around specific solutions (ex: car, home, city, hospital, devices), and be based on open platforms to deliver for instance applications and services dedicated to families of connected devices" [39]. IoT Business Ecosystems are considered as evolutionary perspective for business development [40] while the two terms IoT Innovation Ecosystems and IoT Business Ecosystems present a bottom-up approach. In [41], the possibilities of using business models as the basis of an IoT Ecosystem are discussed, i. e., the business model is a determinant in the construction of IoT ecosystems. The ecosystem character of business models satisfies the ecosystem perspective of IoT Systems. This approach to the construction of IoT ecosystems determines the main stakeholders' categories necessary for their architecture description [42]: Vendors that supply components to the solution providers, Suppliers who develop IoT solutions or provide IoT related services and Customers/End-users who use IoT solutions or services.

From the above considerations we assert that the business viewpoint in the frame-work for architecture modeling of IoT ecosystems is very important. At the moment, there are several architecture descriptions that use the service-oriented viewpoint. The computational viewpoint focuses on functional specification and decomposition of IoT ecosystems into objects and their interfaces. The structural viewpoint defines the computational elements of a system and their organization, the elements that comprise the system, their interfaces, their interconnection and the mechanisms for interconnection described in UML. The capability viewpoint satisfies the requirements of an architect of a large, distributed IoT ecosystem to devise a strategy for the organization of system capabilities and the rules by which those capabilities are constructed. The capabilities are components intended to encourage reuse across the domain of application and facilitate plug-and-play composition. The capability view covers all system functionality for operating on data (Fig. 1).

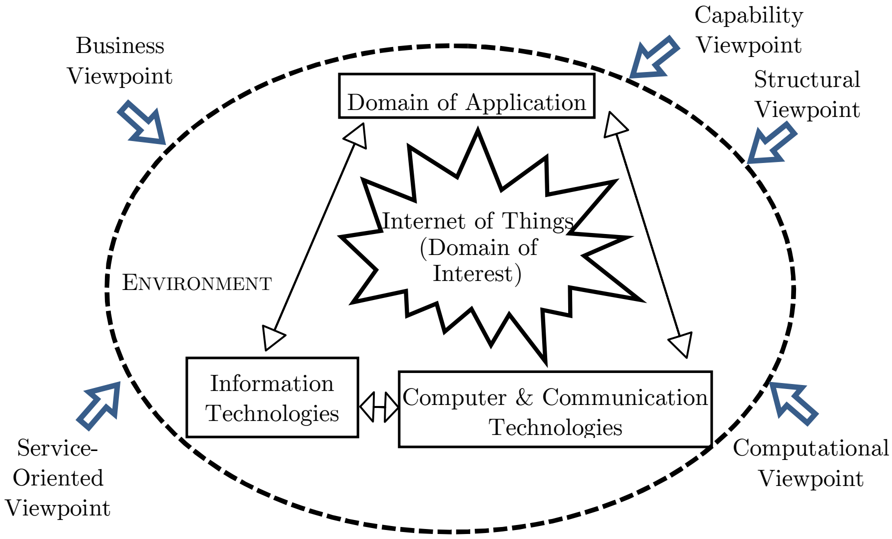

Fig. 1. A framework for architecture modeling of IoT ecosystems

There is no framework that could anticipate all possible concerns for a domain of interest. Concerns (and stakeholders) arise at all stages of the IoT ecosystem life cycle from conception, through requirements, design, implementation, maintenance and evolution. There are two approaches to conceptual modeling of a system of interest in architecture frameworks [43]. One approach is to provide a meta-model of the intended subject matter so that the full range of entities in the domain of interest is covered with little provisions for change. An alternative approach is to construct focused and composable meta-models organized around viewpoints or concerns.

We use the second approach and suggest a conceptual model of IoT ecosystems organized around the Business viewpoint. We present an approach to conceptual modeling of an IoT ecosystem that is realized at two levels: system of systems and IoT platform (subsystem).

4. A business-oriented conceptual model of IoT ecosystems. The main questions, which a system has to give an answer to, are: What, How and Why [44]. That is why we suggest a conceptual business model that consists of three components: Externally-oriented Product/Service (What), Customer Relationship Management (Why), and internally oriented Infrastructure Management (How).

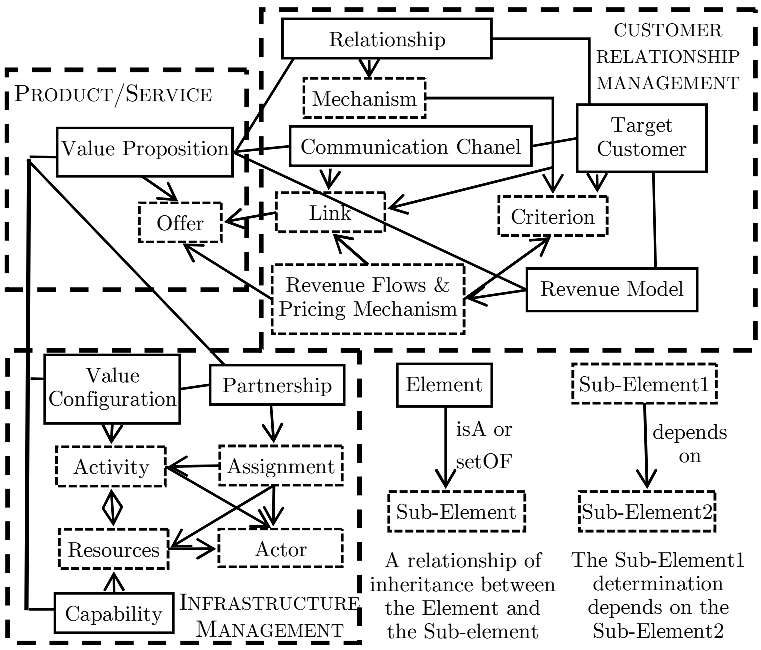

Fig. 2. Meta-model of the IoT ecosystem architecture at Business level

A Value Proposition is an overall view of a company's bundle of products/services that are of value to the customer. The Customer Relationship Management subsystem presents target customers of the company, the manner of products/services delivered to them, and the way of building strong relationships with them. The Revenue Model describes the way a company makes money through a variety of revenue flows. The subsystem

“Infrastructure Management” is described by technical architecture and consists of the following components: Value Configuration, Capability and Partnership (Fig. 2). As illustrated in the graphical description, element and a sub-element are related to each other through a “setOf” (decomposition) and “isA” (inheritance) relationship [45].

PRODUCT is composed of the element VALUE PROPOSITION, which can be decomposed into its elementary OFFER(s). Due to the falling costs of ICT and the increased connectivity of actors, value propositions tend to be complex and hard to communicate in an easy way. The major impact of ICT on product innovation was the separation of information and physical goods (i. e., the physical carrier of information) and the resulting ease of distribution. A company can easily reach a large number of customers and provide them with very rich information or added value in form of multimedia data, personalized information or customized products. The element VALUE PROPOSITION is an overall view of one of the entertainment's bundles of products and services that together represent value for a specific CUSTOMER SEGMENT. A VALUE PROPOSITION represents value for one or several TARGET CUSTOMER(s) and is based on one or several CAPABILITY(ies). An elementary OFFER illustrates a specific product/service, or even product/service feature and outlines its assumed value to the customer.

Customer relationships and CUSTOMER RELATIONSHIP MANAGEMENT (CRM) are considered as a conceptual management problem that can be resolved with the assistance of Information & Communication Technologies (ICT), which is particularly important in a time where the presence of mobile Internet-connected devices multiplies the number of channels, intermediaries and customer interactions and therefore causes more complexity. The CRM block of the Business Model describes how and to whom it delivers its VALUE PROPOSITION. The TARGET CUSTOMER element defines the type of customers a business wants to address (typically either business (B2B) or individual (B2C) customers).

A COMMUNICATION CHANNEL element is the connection between VALUE PROPOSITIONs and TARGET CUSTOMERs. It allows a company to deliver value to its customers by formulating a channel strategy and defining a set of mechanisms via which a company “goes to market”. Normally an enterprise uses one or several direct or indirect CHANNEL(s) that can be decomposed to their LINK(s), which de-scribe a specific channel role. The channel LINKs of the different CHANNELs may sometimes be interrelated, in order to exploit cross-channel synergies. Modern channels and their LINKs may become a part of the VALUE PROPOSITION itself and may be related to other LINKs. Therefore, the channel LINK element inherits the characteristics of the element OFFER as it can simultaneously be part of a channel and of the firm's value creating elements—either through use (a LINK creates value if it matches customer needs), risk reduction (customer integration into the value creation process through customization) or reduction of the customer's efforts (via ICT).

The RELATIONSHIP element describes the relationship a company establishes with a target customer segment. ICT now allows companies to gather and exploit knowledge about customers in order to personalize interactions. Personalization does not necessarily mean a one-to-one relationship. It could rather mean personalizing for a group of customers with common characteristics, which is known as one-to-tribe marketing. The REVENUE FLOW AND PRICING MECHANISMS element describes an incoming money stream (through selling, lending or licensing) and defines what mechanism is used to determine the price of the offered value (fixed pricing, differential pricing or market pricing).

INFRASTRUCTURE MANAGEMENT describes what abilities and what VALUE CONFIGURATIONs are necessary to provide VALUE PROPOSITIONs and maintain CRM and includes the firm's PARTNERSHIP network. A CAPABILITY represents a repeatable pattern of actions, which are based on a set of resources from the firm or its PARTNERSHIP(s). CAPABILITY and RESOURCEs are either assured in-house or can involve outside ACTORs with whom a firm enters a PARTNERSHIP to provide a specific business service. An ACTOR is an outside organization that is involved in the firm's business model and is integrated through a PARTNERSHIP—a voluntarily initiated cooperative agreement formed between two or more independent ACTORs in order to carry out a specific activity jointly by coordinating the necessary resources and activities. RESOURCEs are inputs into the value-creation process. They are the sources for the CAPABILITIES a firm needs in order to provide its VALUE PROPOSITIONs. They could be tangible and intangible assets, and people-based skills. A RESOURCE relates to one or several ACTIVITYies. An ACTIVITY presents an action that an enterprise performs to do business and achieve its goals. It is distinguished between Primary activities (creation of the value propositions) and Support activities (facilitate Primary activities, e. g., human resource management). The VALUE CONFIGURATION shows all activities necessary in order to create value for the customer and the links among them. The value proposition is the outcome of a configuration of inside and outside activities and processes.

A key feature of the proposed conceptual model for IoT Ecosystems is the dynamic interaction between providers and users. In this way the suggested meta-model overcomes the fragmentation of vertically-oriented closed systems, architectures and application areas and is in correspondence with the concept of IoT to include both a vertical and a horizontal dimension. It reflects an important feature of the Internet of Things—to guarantee synergies that are generated by the convergence of Consumer, Business and Industrial Internet. Fig. 3 presents an architecture description of IoT platforms and IoT application in horizontal dimension. It is a result of "Infrastructure Management" decomposition.

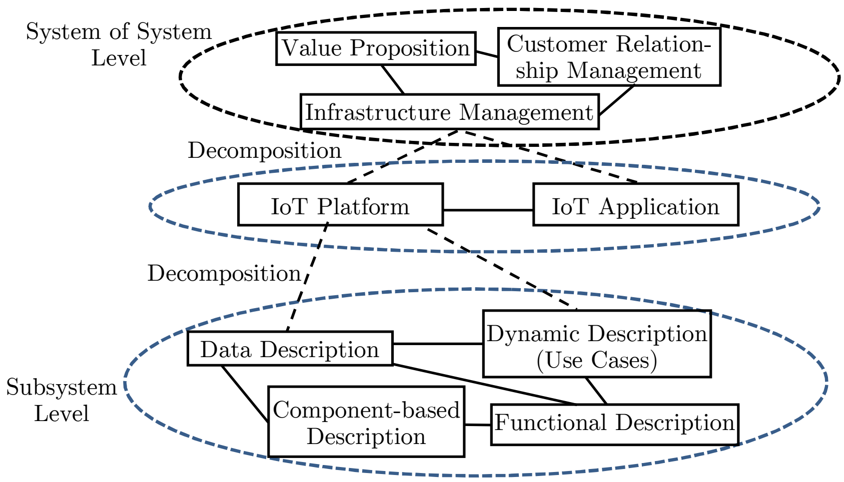

Fig. 3. Two-Layer conceptual modeling of an IoT ecosystem

Increasingly complex IoT solutions require advanced communication platforms and middleware that facilitate the integration of devices, networks and applications. This could be achieved through the suggested formal description of IoT platforms.

5. A formal description of IoT platforms. The following formal descriptions are based on the IoT paradigm. In the proposed IoT resource model, we consider two basic actors—a general abstraction of Thing and a Controller. In the proposed model we consider the Thing actor as a piece of hardware which is a restriction of the general definition of Thing in the sense of Internet of Things. Additionally, in the model it is a generic actor with two descendants—Sensor and Actuator. A generic case of the Thing actor is EstablishConnectionToController. It is an imminent case for each terminal node of the IoT network. As a Controller, we can consider either a piece of hardware or software—in our case a hardware unit. The basic use case model presenting some essential cases of resource actors is presented in Fig. 4. Let us consider two scenarios. The scenario for connection establishment between Thing and Controller consists of the following steps:

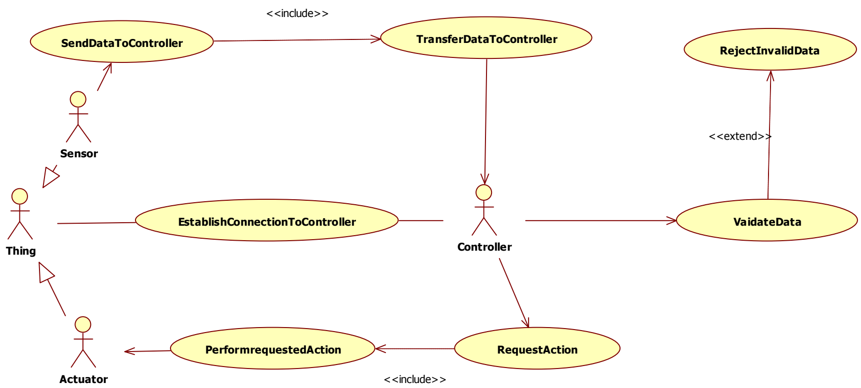

Fig. 4. Basic use case model of resources

- Controller actor sends a viewing signal to all of connected things.
- Each thing checks whether the signal comes from a trusted Controller.

- If the signal is from a trusted Controller it sends back an acknowledgement.
- The Controller establishes a list all available Things and also a list of non-responding Things.
- The Controller (as extension) may alert the upper level for unavailable Things.

For simplicity, the extension mentioned above is not presented in the UML model. It is not a mandatory feature of the Controller actor. The scenario for sending data from a Sensor to Controller is:

- Check Controller availability.
- If Controller is available, then start a data transmission.
- Controller checks data validity.
- After the end of data transmission, wait for Controller acknowledgement.
- In case of valid data, Controller sends a confirmation for data acceptance.
- In case of invalid data, Controller sends a request for data retransmission.

In both use cases, the handshake is a matter of user protocol—different than the TCP handshaking. In this way, we can achieve better security and reliability than relying only on the TCP/IP stack.

The static class diagram is an object implementation of the use case model presented above. The base class Thing has two operations necessary for the implementation of connection establishment to Controller and data exchange which can be a transfer in the case of Sensor and Receive in the case of Actuator. Both actors Sensor and Actuator are modelled by means of two classes having the same names. We consider the relation between Controller and Thing both as aggregation and association. The aggregation means that a Controller manages a list of Things—presented as a protected member and at the same time Controller has a bidirectional communication with each managed Thing. Additionally, we also consider a possible aggregation of hierarchically organized Controller classes. This approach provides room for building larger hierarchically organized structure of controllers. With such architecture, we can achieve a broad coverage with a single point of communication with the middleware—in our model presented as a package. The content of the Middleware package is beyond the scope of our current publication. It should contain at least a context broker component. The described static class diagram is show in Fig. 5.

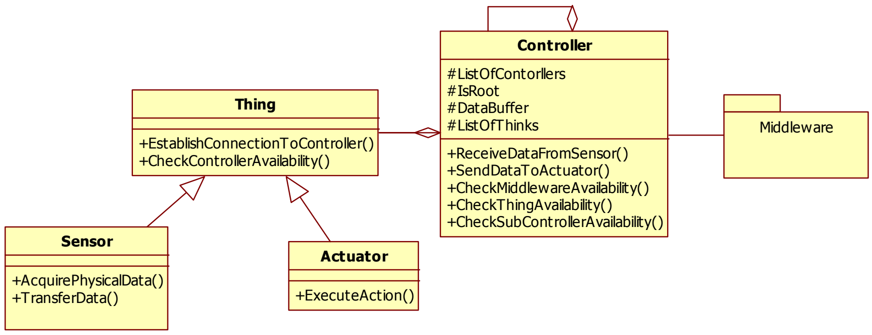

Fig. 5. Static class diagram modeling Thing, Controller and Middleware relationships

The UML diagrams in Fig. 6 and Fig. 7 show the dynamic model of information exchange between resources. The sequence diagram shown in Fig. 6 presents the order of stimuli and responses between objects of types Sensor, Controller and a Middleware component. Physical data is transferred to the data repository as follows:

- Object Sensor1 checks the controller availability with a stimulus CheckControllerAvailability().
- If available, the controller object Controller1 sends back a status reply ControllerStatus(). For simplicity, we do not consider the lack of connectivity or controller malfunction. A simple extension is periodical retry to establish a connection.
- If the connection between Sensor1 and Controller1 objects can be established, then Sensor1 sends a stimulus TransferData(), which models the data transfer.

- Controller1 object sends a stimulus CheckMiddlewareAvailability() in order to check whether the gathered data can be transferred to the Middleware component.
- If yes, the data is transferred.
- If no, the data is stored in an internal buffer.

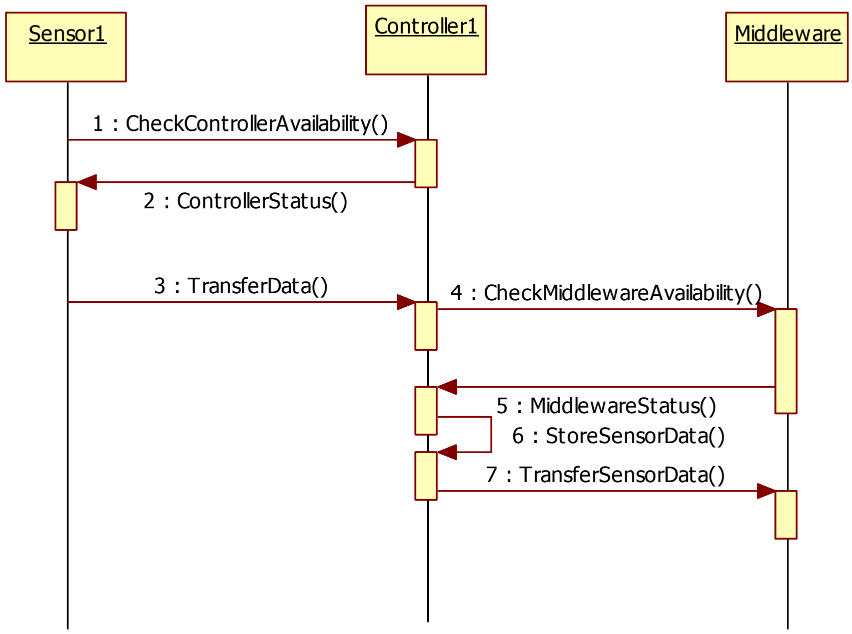

Fig. 6. Sequence diagram of data transfer from a Sensor to Middleware

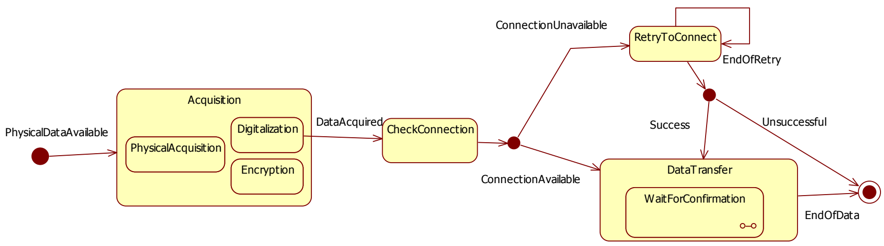

Fig. 7. State chart UML diagram of sensor data transfer

In some cases, the data storage, when the middleware is not responding, is not supported but it is highly recommended. In the static model presented in Fig 5, this feature can be implemented at a certain level of controller hierarchy.

Our last dynamic model is a state diagram presenting a finite state machine of data acquisition performed by Sensor1 (Fig. 6). We consider that a Sensor moves out from idle state when a new physical measurement is available at a certain time or other threshold condition. The sensor switches to state Acquisition, which is a composite state encompassing three sub-states—physical acquisition, digitalization of analog signals, and encryption of digitalized data. The third sub-state is not a mandatory but highly recommendable. When a data acquired event happens, the sensor switches to the state CheckConnection. Depending on whether the controller is available or not, there are two possible transitions to one of the mutual exclusive states—DataTransfer or RetryToConnect. In the DataTransfer state, the acquired data is transferred to the controller. This state has one sub-state WaitForConfirmation. In that sub-state an acknowledgement for received and validated data is expected from the controller. The end of the data transfer event leads to a final state transition. The transition to the final state can be also performed after several unsuccessful connection attempts. In the other case, the sensor switches to the DataTransfer state. The state chart diagram of the sensor is presented in Fig. 7.

6. Conclusion. Our conceptual modeling approach enables the formalized description of IoT ecosystems taking into consideration the business processes pertaining to these ecosystems. Our aim is to make IoT-devices more open and better integrated into possibly IoT-driven processes. They may pave the way for new types of products and services with better interaction speed than classical human-driven or ERP-driven business processes. The advancement of IoT may also create potential for better human networking, resource (knowledge, partner, etc.) acquisition and in general better use of the environments we interact within. In order to realize this potential and to scale it in the form of a value proposition to multiple customers, it is necessary to model IoT-ecosystems both on a conceptual and an implementation level.

Acknowledgement. This research was supported by the National Science Fund at the Ministry of Education and Science of Bulgaria under the research project *Conceptual Modeling and Simulation of Internet of Things Ecosystems (KoMEIN).*

REFERENCES

[1] Miorandi D., S. Sicari, F. Pellegrini, I. Chlamtac. Internet of things: Vision, applications and research challenges. *Ad Hoc Networks*, **10** (2012), 1497–1516.

[2] Boavida F., A. Kliem, T. Renner, J. Riekki, C. Jouvray, M. Jacovi, S. Ivanov, F. Guadagni, P. Gil, A. Triviño. People-Centric Internet of Things—Challenges, Approach, and Enabling Technologies. In: Intelligent Distributed Computing IX. *Studies in Computational Intelligence*, **616** (2016), 463–474.

[3] Perillo M., W. Heinzelman. Wireless Sensor Network Protocols. In: Fundamental Algorithms and Protocols for Wireless and Mobile Networks. CRC Hall, 2005.

[4] Mohammed A., B. Dai, B. Huang, M. Azhar, G. Xu, P. Qin, S. Yu. A survey and tutorial of wireless relay network protocols based on network coding. *Journal of Network and Computer Applications*, **36** (2013), No 2, 593–610.

[5] Minhas M., S. Gopalakrishnan, V. Leung. Fuzzy Algorithms for Maximum Lifetime Routing in Wireless Sensor Networks. In: IEEE Global Telecommunications Conference (GLOBECOM), New Orleans, USA, 2008, 1–6.

[6] Hao J., Q. Chen, H. Huo, J. Zhao. Energy efficient clustering algorithm for data gathering in wireless sensor networks. *Journal of Networks*, **6** (2011), No 3, 490–497.

[7] Kurt S., H. Yildiz, M. Yigit, B. Tavli, V. Gungor. Packet Size Optimization in Wireless Sensor Networks for Smart Grid Applications. *IEEE Transactions on Industrial Electronics*, **64** (2017) No 3, 2392–2401.

[8] Jan M., P. Nanda, M. Usman, X. He. PAWN: A Payload-based mutual Authentication scheme for Wireless Sensor Networks. *Concurrency and Computation: Practice and Experience*, **29** (2017), No 17. DOI: 10.1002/cpe.3986

[9] Farooq M., M. Waseem, A. Khairi, S. Mazhar. A Critical Analysis on the Security Concerns of Internet of Things (IoT). *International Journal of Computer Applications*, **111** (2015), No 7, 1–6.

[10] Naranjo P., M. Shojafar, A. Abraham, E. Baccarelli. A new Stable Election-based routing algorithm to preserve aliveness and energy in fog-supported wireless sensor networks. In: 2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Budapest, Hungary, 2016, 2413–2418. DOI: 10.1109/SMC.2016.7844600

[11] Maarala A., X. Su, J. Riekki. Semantic Reasoning for Context-aware Internet of Things Applications. *IEEE Internet of Things Journal*, **4** (2016), No 2, 461–473. DOI: 10.1109/JIOT.2016.2587060

[12] Maarala A., X. Su, J. Riekki. Semantic data provisioning and reasoning for the internet of things. In: 2014 International Conference on the Internet of Things (IOT), Cambridge, MA, USA, 2014, 67–72.

[13] Meyer S., A. Ruppen, C. Magerkurth. Internet of Things-Aware Process Modeling: Integrating IoT Devices as Business Process Resources. In: Advanced Information Systems Engineering: 25th International Conference (CAiSE), Valencia, Spain, 2013. *LNCS*, **7908** (2013), 84–98.

[14] Pautasso C. BPMN for REST. In: Business Process Model and Notation. Third International Workshop, Lucerne, Switzerland, 2011. *LNBIP*, **95** (2011), 74–87.

[15] Kumaran S., R. Liu, P. Dhoolia, T. Heath, P. Nandi, F. Pinel. A RESTful Architecture for Service-Oriented Business Process Execution. In: IEEE International Conference on e-Business Engineering, Xi'an, China, 2008, 197–204.

[16] Caracaş A., A. Bernauer. Compiling business process models for sensor networks. In: 2011 International Conference on Distributed Computing in Sensor Systems and Workshops (DCOSS), Barcelona, Spain, 2011, 1–8.

[17] Kozel T. BPMN mobilization. In: Proceedings of the European conference of systems, and European conference of circuits technology and devices, and European conference of communications, and European conference on Computer science, Tenerife, Spain, 2010, 307–310.

[18] Petrasch R., R. Hentschke. Towards an Internet-of-Things-aware Process Modeling Method. In: Proceedings of the 2nd Management Innovation Technology International Conference (MITiCON2015), Bangkok, Thailand, 2015, 168–172.

[19] Huber S., R. Seiger, A. Kühnert, V. Theodorou, T. Schlegel. Goal-Based Semantic Queries for Dynamic Processes in the Internet of Things. *International Journal of Semantic Computing*, **10** (2016), No 2, 1–25.

[20] Bonino D., F. Corno. DogOnt – Ontology Modeling for Intelligent Domotic Environments. In: The Semantic Web – ISWC 2008. Proceedings of the 7th International Semantic Web Conference, Karlsruhe, Germany, 2008, 790–803.

[21] Seiger R., S. Huber, T. Schlegel. PROtEUS: An Integrated System for Process Execution in Cyber-Physical Systems. In: Enterprise, Business-Process and Information Systems Modeling. Conference proceedings (BPMDS 2015, EMMSAD 2015). Stockholm, Sweden. *LNBIP*, **214** (2015), 265–280.

[22] TOMMASETTI A., M. VESCI, O. TROISI. The Internet of Things and value co-creation in a Service Dominant logic perspective. In: F. Colace, M. De Santo, V. Moscato, A. Picariello, F.A. Schreiber, L. Tanca (eds). Data Management in Pervasive Systems. Springer, Berlin, 2015, 3–18.

[23] MEYER S., A. RUPPEN, L. HILTY. The Things of the Internet of Things in BPMN. In: A. Persson, J. Stirna (eds). Advanced Information Systems Engineering Workshops. CAiSE 2015 International Workshops, Stockholm, Sweden, 2015. *LNBIP*, **215** (2015), 285–297.

[24] TRANQUILLINI S., P. SPIESS, F. DANIEL, S. KARNOUSKOS, F. CASATI, N. OERTEL, L. MOTTOLA, F.J. OPPERMANN, G.P. PICCO, K. RÖMER, T. VOIGT. Process-Based Design and Integration of Wireless Sensor Network Applications. In: A. Barros, A. Gal, E. Kindler (eds). Business Process Management. 10th International Conference, Tallinn, Estonia, 2012. *LNCS*, **7481** (2012), 134–149.

[25] YOUSFI A., A. DE FREITAS, A. DEY, R. SAIDI. The Use of Ubiquitous Computing for Business Process Improvement. *IEEE Transactions on Services Computing*, **9** (2015), No 4, 621–632.

[26] YOUSFI A., C. BAUER, R. SAIDI, A. DEY. uBPMN: A BPMN extension for modeling ubiquitous business processes. *Information and Software Technology*, **74** (2016), 55–68.

[27] RUPPEN A., J. PASQUIER, S. MEYER. A Component Based Approach for the Web of Things. In: Proceedings of the 6th International Workshop on the Web of Things, Seoul, Republic of Korea, 2015, Article 2.

[28] VERMESAN O., P. FRIESS, P. GUILLEMIN, R. GIAFFREDA, H. GRINDVOLL, M. EISENHAUER, M. SERRANO, K. MOESSNER, M. SPIRITO, L.-C. BLYSTAD, E. Z. TRAGOS. Internet of Things beyond the Hype: Research, Innovation and Deployment. In: O. Vermesan, P. Friess (eds). Building the Hyperconnected Society – IoT Research and Innovation Value Chains, Ecosystems and Markets. *River Publishers Series in Communications*, **43** (2015), 15–118.

[29] Gaglio S., G. Lo Re. Advances onto the Internet of Things. How Ontologies Make the Internet of Things Meaningful. *AISC*, Springer International Publishing, Switzerland, **260** (2014).

[30] Mohammed A., B. Dai, B. Huang, M. Azhar, G. Xu, P. Qin, S. Yu. A survey and tutorial of wireless relay network protocols based on network coding. *Journal of Network and Computer Applications*, **36** (2013), No 2, 593–610.

[31] Farooq M., M. Waseem, A. Khairi, S. Mazhar. A Critical Analysis on the Security Concerns of Internet of Things (IoT). *International Journal of Computer Applications*, **111** (2015), No 7, 1–6.

[32] Warrier A., S. Park, J. Min, I. Rhee. How much energy saving does topology control offer for wireless sensor networks? – A practical study. *Computer Communications*, **30** (2007), No 14–15, 2867–2879.

[33] Moschetta E., R. S. Antunes, M. P. Barcellos. Flexible and secure service discovery in ubiquitous computing. *Journal of Network and Computer Applications*, **33** (2010), No 2, 128–140.

[34] Misra S., A. Singh, S. Chatterjee, S., A. K. Mandal. QoS-aware sensor allocation for target tracking in sensor-cloud. *Ad Hoc Networks*, **33** (2015), 140–153.

[35] Hwang K., G. Fox, J. Dongarra. Distributed and Cloud Computing. From Parallel Processing to the Internet of Things. Elsevier, MK Publisher, USA, 2012.

[36] Zhou H. The Internet of Things in the Cloud. A Middleware Perspective. CRC Press, 2012.

[37] Žarko I. P., K. Pripužić, M. Serrano (eds). Interoperability and Open-Source Solutions for the Internet of Things: International Workshop, FP7 OpenIoT Project, Held in Conjunction with SoftCOM

2014, Split, Croatia, September 18, 2014, Invited Papers. *Lecture Notes in Computer Science*, **9001** (2015).

[38] Friess P., R. Riemenschneider. IoT Ecosystems Implementing Smart Technologies to Drive Innovation for Future Growth and Development. In: O. Vermesan, P. Friess (eds). Digitising the Industry Internet of Things Connecting the Physical, Digital and Virtual Worlds. *River Publishers Series in Communications*, **49** (2016), 5–13.

[39] Friess P., R. Riemenschneider. New Horizons for the Internet of Things in Europe. In: O. Vermesan, P. Friess (eds). Building the Hyperconnected Society – IoT Research and Innovation Value Chains, Ecosystems and Markets. *River Publishers Series in Communications*, **43** (2015), 5–13.

[40] Shveykovskiy A., P. Ahokangas. IoT Business Ecosystems: Evolutionary Perspective for Business Development. *Internet of Things*, **1** (2015), 18–20.

[41] Leminen S., M. Rajahonka, M. Westerlund, R. Siuruainen. Ecosystem Business Models for the Internet of Things. *Internet of Things*, **1** (2015), 10–13.

[42] Gusmeroli S., O. Lazaro, Ž. Pazin, C. Decubber, P. Pedrazzoli, D. V. Abeele, S. Tucci-Piergiovanni, J. Cassina, D. Cerri, S. Terzi, J. Sola, I. Arconada, K. Fischer, A. Felic, M. Sesana, R. Sanguini, L. Huertas, D. Rotondi, J. Cecil. Industrial Internet of Things and the Innovation Processes in Smart Manufacturing. In: O. Vermesan, P. Friess (eds). Building the Hyperconnected Society – IoT Research and Innovation Value Chains, Ecosystems and Markets. *River Publishers Series in Communications*, **43** (2015), 145–187.

[43] Hilliard R. Lessons from the Unity of Architecting. In: I. Jacobson, H. B. Lawson (eds). Software Engineering in the Systems Context. College Publications, 2015.

[44] Hilliard R. Aspects, Concerns, Subjects, Views, ... In: OOPSLA'99 Workshop on Multi-Dimensional Separation of Concerns in Object-Oriented Systems, 1999. https://www.cs.ubc.ca/~murphy/multid-workshop-oopsla99/, 9 October 2018.

[45] Osterwalder A. The Business Model Ontology: A Proposition in a Design Science Approach. PhD Thesis, University of Lausanne, Ecole des Hautes Etudes Commerciales, 2004. http://www.hec.unil.ch/aosterwa/PhD/Osterwalder_PhD_BM_Ontology.pdf, 9 October 2018.

Rumen Andreev
e-mail: rumen@isdip.bas.bg
Svetozar Ilchev
e-mail: svetozar@ilchev.net
Institute of Computer and Communication Systems
Bulgarian Academy of Sciences
Acad. G. Bonchev Str., Bl. 2
1113 Sofia, Bulgaria

Alexandre Chikalanov
e-mail: a.chikalanov@unibit.bg
Yuliyan Petkov
e-mail: y.petkov@unibit.bg
University of Library Studies and Information Technologies
119, Tsarigradsko Shose Blvd
1784 Sofia, Bulgaria

Received May 15, 2018
Final Accepted July 15, 2018