Achieving Autonomicity in IoT systems via Situational-Aware, Cognitive and Social Things

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ABSTRACT
The Internet of Things (IoT) will exponentially increase the scale and the complexity of existing computing and communication systems. In a world of multi-stakeholder information and assets provision on top of millions of real-time interacting and communicating Things, autonomicity is an imperative property and a grand challenge. Autonomic Things will allow systems to self-manage the complexity, the dynamicity and the distribution of the IoT. In order to make Things able to manage themselves and contribute to the global self-management network, we have to empower them with mandatory properties like situational-awareness, knowledge, smartness and social behavior. In this paper we present the approach that the COSMOS project introduces in order to enable Things to evolve and act in a more autonomous way, becoming more reliable and smarter.

Categories and Subject Descriptors
I.2.6 [**Learning**] (K.3.2) - *Knowledge acquisition*, H.3.4 [**Systems and Software**] - *Distributed systems.*

General Terms
Algorithms, Management, Design.

Keywords
Internet of Things; Autonomous Management; Knowledge Management; Social Internet of Things; COSMOS project.

1. INTRODUCTION
Autonomicity provides a system with fundamental independence, essential to decide when it should or can act. The self-management depends strongly on how much situational-aware, cognitive, smart and social the Things are [1]. Smart objects able to communicate and to discover their situation are already available, while various proposals aimed at giving social-like capabilities to Things exist [2]. However, the IoT vision can be fully achieved only with the integration of available technologies and new inspired mechanisms and models that will make objects able to cooperate in an open and reliable way.

PCI '14 , Oct 02-04 2014, Athens, Greece
ACM 978-1-4503-2897-5/14/10.
http://dx.doi.org/10.1145/2645791.2645854

COSMOS [3] will provide a framework for the decentralized and autonomous management of Things based on service-, interaction-, location- and reputation-oriented principles, inspired by social media technologies. It supports real-virtual world integration by representing Things as Virtual Entities (VEs). VEs are described by ontologies and are provided with the key features of a social intelligent entity. They have social characteristics, can acquire knowledge, make plans, explain observations etc. Moreover, they expose IoT-services that can be reflected on the real environment.

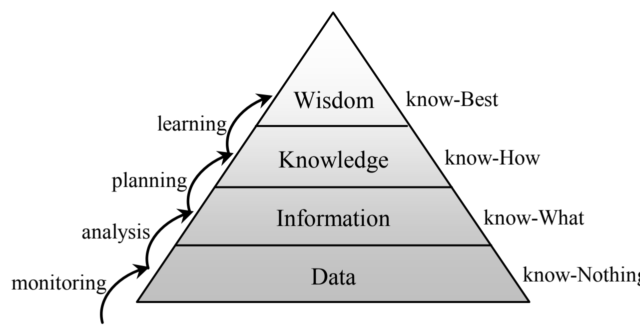

Figure 1. The COSMOS DIKW Pyramid.

2. KNOWLEDGE MANAGEMENT
The IoT will create a flood of real world information to the virtual world. The transformation of this huge amount of raw data into knowledge is one of the biggest challenges. A first step to designing a general architecture and realizing its capabilities and chances for evolution is the definition of its own Knowledge Management cycle. The COSMOS DIKW pyramid is presented:

- The *Data level* includes all the raw-data which are collected from the VEs through their IoT-services.
- The *Information level* includes all the information produced by analyzing the raw-data. Things attaining this level are characterized as situational-aware.

- The *Knowledge level* includes problems or detected situations associated with specific solutions (cases). It gives the VEs the advantage of learning from previous experiences. A Knowledge Base (KB) can be shared between VEs with suitable social characteristics, something that improves the decision making and leads to the best solution. Moreover, VEs that do not have their own KB, representing weak devices, take advantage from the KB of their social group.
- The *Wisdom level* includes high-level reasoning techniques, such as CBR and RBR [4], which give to the VEs the ability to reason and understand their situation and take decisions on their own, thus producing Knowledge on their own. Things attaining this level could be characterized as cognitive, intelligent or Wise, as they have the capacity to acquire, adapt, modify, extend and use knowledge in order to solve problems.

We focus on the value of experience and experience-sharing. Different kinds of experience are defined such as Models related to the Analysis component and Cases related to the Planner (Fig. 2). Moreover, we support experience sharing giving to a VE the opportunity to ask for help and find the most suitable solution by leveraging social features.

3. SOCIAL INTERNET OF THINGS

Things have to operate as social actors. COSMOS, designed as a Social Internet of Things (SIoT) platform [5], defines, monitors and exploits social relations and interactions between the VEs, and uses technologies from the domain of the social media. Social Network Analysis (SNA) [6] is used to identify local and global patterns, locate influential entities and examine network dynamics. In order to manage socialization, we introduce into our control loop the Social Monitoring and the Social Analysis components.

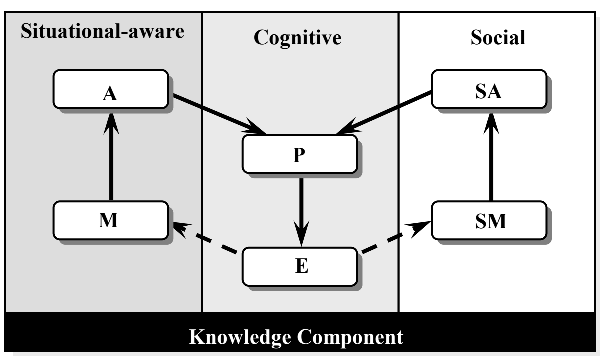

Figure 2. The COSMOS MAPE-K loop.

4. AUTONOMOUS MANAGEMENT

We are going to follow the MAPE-K model [7] as it is very close to the nature of the IoT management. Our components are:

i. *Monitoring (M)*: collects the details from the managed resources and correlates them into symptoms that can be analyzed.

ii. *Analysis (A)*: provides the mechanisms to observe and analyze situations to determine if changes are required. In such a case, it generates a change request and passes it to the Planner. The Analysis component contains functionalities such as events-identification, context awareness, pre-processing mechanisms, models extraction, Machine Learning techniques etc.

iii. *Planner (P)*: structures the actions needed to achieve goals and objectives. It constructs adaptation plans based on the results of the analysis process and passes them to the Executor component. The main functionality of the Planner is to match events to certain actions of the VEs. Depending on how "smart" we decide that the VEs have to be, the Planner evolves accordingly- e.g. it can provide recommendation services taking under consideration the input provided by the Social Analysis component too.

iv. *Executor (E)*: Once the Planner has generated an appropriate plan, some actions may need to be taken to modify the state of one or more managed resources. The Executor is responsible for carrying out this series of actions. It executes actions such as IoT-services calls, M2M communication, experience-sharing, and sends feedback to the Social Monitoring and to the Monitoring if the developer has created through his/her application such a loop.

v. *Knowledge (K)*: the place where the KB and other aggregated data such as topology information, historical logs, metrics, symptoms, policies and objectives of the VEs, provided by both the users and COSMOS, are stored. This repository serves for the initial configuration of the network and guides the operation of all the other components.

vi. *Social Monitoring (SM)*: contains the main tools and techniques needed for the monitoring of the social properties of the VEs.

vii. *Social Analysis (SA)*: is used for the extraction of complex social characteristics of the VEs, as well as models and patterns regarding the behavior and the relations between the VEs.

5. ACKNOWLEDGMENTS

The research leading to these results is partially supported by the European Community's Seventh Framework Programme under grant agreement n° 609043, in the context of the COSMOS Project.

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