Scripting Problem-solving Agents in Decentralised Smart Grids

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Abstract

We assume the use of a universal interface for accessing data and invoking actions across many systems under diverse ownership. The interface is based on state manipulation of interconnected resources, both purely virtual ones and ones that extend to the physical world. We present a rule-based language to specify dynamics, i.e., the interaction between resources. We explain how decentralisation, a key feature of the abstraction under consideration, facilitates scale and provides some degree of privacy. Finally, we speculate on ways if leveraging cryptocurrency blockchains for providing a decentralised, secure transaction ledger. The ultimate long-term goal is the ability to script problem-solving agents for increased automation and productivity.

1 Motivation

Data need to be integrated and systems need to interoperate to achieve efficiency gains. As examples, consider coordination of meeting dates via integrated calendars (e.g., using Microsoft Outlook), and remote switching of electrical appliances using one's mobile phone (e.g., using Belkin's WeMo Switch)[1].

Increased productivity can be achieved via surrendering one's data and systems to a single organisation. Consider Google. In addition to the vast amounts of data the company already collects, Google recently acquired Nest[2], a home automation company, giving them physical access to people's homes. Nest uses a "cloud" infrastructure to not only store appliance data, but also to exert control over systems in the physical world. While a breach of access to data can lead to psychological trauma, unauthorised access to systems that extend to the physical world can lead to physical harm. Using such systems requires trusting the (centralised) infrastructure and also the company itself. Centralisation may magnify the effect of breaches[3].

Centralisation may lead to useable end-user services quicker compared to decentralised approaches. In contrast to a motley collection of individuals, a centralised infrastructure is easier to coordinate, and a single company can provide the necessary aggregation of capital for investment into deployment and maintenance of infrastructure. Sometimes, centralisation seems to be favoured not out of technical necessity, but arguably for the purpose of collecting usage data[4].

The goal of our work is to create environments where one retains individual authority over data and systems to the degree possible. In other words, we want to push as much functionality into decentralised infrastructure as possible, reducing or eliminating the need for relying on a central instance of any kind.

[1] For the purpose of the paper, we focus on scenarios involving individuals instead of enterprises or the public sector.
[2] https://investor.google.com/releases/2014/0113.html
[3] Technology monoculture, too, is problematic in the face of attacks.
[4] Why does my internet radio refuse to work when mysqueezebox.com is down, even with the local internet connection and the radio station's audio stream working? Why does the light switch have to consult with a remote "cloud" for operating the light bulb?

2 State Manipulation Interface

We advocate the use of a state manipulation interface in cyber-physical systems such as Smart Grids. That is, we assume that resources expose a minimal interface which allows agents to get or set the state of resources.

Read-write Linked Data[5] essentially provides such an abstraction for getting and setting state, with the addition of hyperlinks to be able to discover resources without a central catalogue. The Linked Data Platform[6] goes further, specifying mechanisms to create and delete resources (in accordance with web architecture and RESTful architectures). These interfaces represent a suitable mechanism for state manipulation. Given the universality of such interfaces, we can apply them not only to purely virtual information system but also to systems that extend to the physical world (cyber-physical systems) such as Smart Grids.

In the following, we briefly summarise our work on applying Linked Data technologies in Smart Grids, in particular with regards to privacy. In [7], we describe an approach for decentralised storage and access to Smart Grid appliances. Data is stored locally (i.e., on the appliance itself) so that users retain full control over their data and systems. The appliance also checks access based on data-centric policies [4]. An agent asking for data has to specify the purpose of the data request, and the appliance then grants or denies access with user-specified policies. We have shown that policy enforcement performs satisfactorily on low-powered devices [5]. In [3], we extend the interface to allow, next to read access, also write access to resources. The goal of that work are means to balance energy production and consumption in hierarchically organised energy grids.

3 Scripting Behaviour

Creating applications that use many diverse data sources and systems becomes easier if all sources implement the same interface (such as read-write Linked Data). A unified interface is indeed the assumption in information integration systems, so that developers can more easily write imperative code that ties the various systems together.

However, the uniform interfaces also allow for a declarative approach to specifying the interplay between resources [2]. We advocate such a declarative approach for scripting behaviour, based on if/then rules [6]: given a specified state of resources, update the state of other resources. We have implemented an interpreter for programs (collections of rules) called Linked-Data-Fu, and continue to conduct experiments with such rule-based programs for interoperation in cyber-physical environments.

4 Transaction Ledgers

We would like to end on a more speculative note. In current Smart Grid systems, we have to separately handle data used for billing purposes, due to regulatory requirements. Ultimately, the billing data has to arrive at the utility that operates power plants; due to unbundling in the energy markets, however, the data might be transmitted via multiple intermediaries. Such data has to be recorded and transmitted securely, not the least to satisfy legal requirements. Systems envisioned for such data exchange are centralised[7].

[5] `http://www.w3.org/DesignIssues/ReadWriteLinkedData.html`
[6] `http://www.w3.org/TR/ldp/`
[7] So called "Datendrehscheiben" in German, roughly "data carousels"

What is required is a mechanism for securely exchanging transaction data, ideally in a peer-to-peer fashion without a central instance. Blockchains (used in cryptocurrency systems) could provide means for keeping a transaction ledger in a distributed, secure fashion [1]. As blockchains in cryptocurrencies are anonymised/pseudonymised, the utility would need to keep a mapping between blockchain pseudonyms and internal customer identifiers if payment is to be carried out using the traditional bank transfer mechanisms.

Acknowledgements

Work presented in this paper has been supported by the German Federal Ministry of Economics and Technology (MeRegioMobil, Grant 01ME09005 and iZeus, Grant 01ME12013), the European Commissions Seventh Framework Programme (PlanetData, Grant 257641), and ONR Global (Grant N62909-13-1-N024).

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