A Scalable Communication Infrastructure for Demand Side Management using Multicast

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I. Introduction

In Europe, and more specifically in Germany, a general trend is visible towards an energy transition from fossil to regenerative power generation. Regenerative resources such as wind and solar are very dynamic and therefore require an intelligent management of the energy demand. This relies on the coordination of highly distributed energy consuming devices through a smart grid infrastructure.

In this work we present an approach for scalable *Demand Side Management* (DSM) using multicast over public ISP networks. Our concept is based on a prototype implementation of the H∀Mcast architecture [1]. Accompanied by results from real-world measurements, we discuss the advantages of a multicast-based communication in smart grids for DSM.

II. Background & Motivation

Demand side management is a smart grid use-case that offers high potential to balance usage of electricity and level the load of the power grid. Empirical evaluations of smart home installations [2] have shown that by shifting loads, the peak demand of energy can be reduced by up to 17 %. Intelligent load balancing schedules thereby decrease average deviation from the mean energy usage. Long term studies [3] discovered a reduction of more than 20 %. Typically, DSM has delay requirements in the range of seconds between operator and energy consumer [4], whereas distributed leveling mechanisms may have stronger requirements in terms of latency.

A key challenge for DSM and smart grids is a scalable communication infrastructure that is able to connect and control numerous producers and consumers of electricity at the same time. This requires substantial investments in network technologies by energy companies, but also attracts non-energy companies such as Internet service providers (ISPs). ISPs already have a large network infrastructure deployed and can thus easily inter-connect energy devices of their customers.

III. Multicast-based Demand Side Management

Our concept of scalable smart grid communication is based on hybrid multicast. As IP multicast is not commonly available on the Internet, we use the H∀Mcast architecture for an universal multicast service. It provides a common multicast API with an abstract naming scheme for multicast groups, combined with a middleware and transparent multicast gateways. In our DSM scenario (Fig. 1) multicast home gateways connect energy consumers such as e-cars, freezers, and washing machines to a smart grid. Optional gateways on ISP level further increase scalability. Based on the amount of available energy supply, e.g. from solar plants and wind turbines, DSM mechanisms balance energy usage. Using multicast, energy consumers can easily be controlled in a scalable manner by pooling devices into groups. Group formation can be done on the basis of several aspects: device category (e.g. freezers), region or location (e.g. suburb), or both. This reduces management overhead and eases load balancing in smart grids.

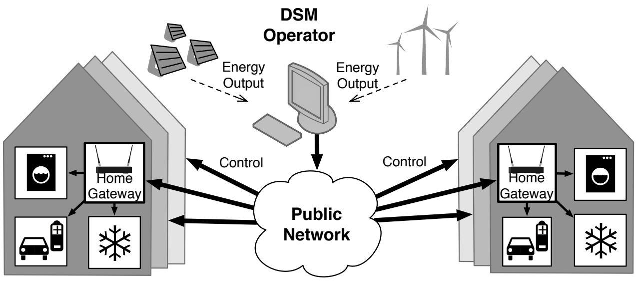
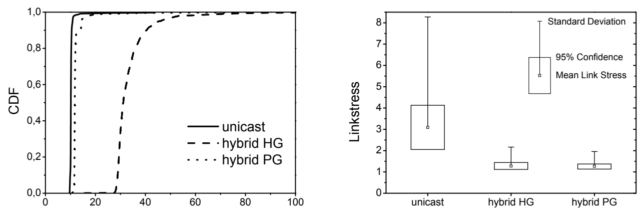


Fig. 1. Demand Side Management over public networks using multicast.



(a) Average message delays (ms). (b) Link stress statistic.

Fig. 2. Average message delay and link stress in a national deployment.

To evaluate our approach against requirements of DSM, we measured one-way delays and link stress [5]. We compared n-times unicast with two hybrid multicast schemes, i.e., home-gateways (hybrid HG) and provider-gateways (hybrid PG). Where unicast represents the current smart grid communication scheme. Fig. 2 shows the measurement results for a national (German) real-world setup. Though hybrid multicast exhibits higher one-way delays compared to unicast, it remains within required bounds (Fig. 2a). Both hybrid schemes significantly reduce link stress (network load), thereby eliminating bottlenecks and scale to a large number of devices (Fig. 2b).

Note, that our approach can also be applied to other smart grid use-cases such as *advanced metering infrastructures* and *virtual power plants*. In our future work we will implement and evaluate decentralized coordination algorithms for smart grids that rely on multicast communication.

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