Energy Management

the challenges of self-managing virtual organisations

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Complex, intelligent, distributed systems in dynamic environments need to adapt continually, and thus need to be designed to this purpose. As central management of such systems is often not an option decentralised self management is required. This holds, for example, for energy/power management: for both resources and devices. Self management of emergent virtual organisations is needed.

SLAs provide a means to regulate interaction between individual systems within emerging virtual organisations, and between virtual organisations, as the basis for negotiating, monitoring and regulating provision, distribution and consumption. Relevant research questions include: 'What is the appropriate level of aggregation?', 'How can SLAs be (re)negotiated automatically to adapt to this dynamic environment?' and 'How can energy consumption be globally stabilized by using local self management?'.

Assuming energy consuming devices are autonomous systems, represented by software agents capable of self-management, virtual organizations of agents can emerge. Such organisations define communication structures between agents, e.g., hierarchical organizations, between and within which agents can choose to cooperate and coordinate their actions, or compete. Dynamically organized hierarchies can be used to support adaptive, aggregate, nonlinear behavior, as a means to reduce complexity.

Current research within IIDS focuses on global stabilization of the energy consumption of an electricity network (power grid), minimizing oscillations of all thermostatic controlled appliances (TCA) within a single household. Such devices, for example, refrigerators, air conditioners and water heaters, consume 25% of the total energy supply in the USA. Self management of these devices could potentially have a significant effect on the stabilization of global resource consumption. To this purpose software agents in TCAs autonomously and automatically negotiate their resource requirements, configurations, and SLAs, ultimately acquiring global stabilization in energy consumption, which in turn leads to higher reliability of the power grid and lower costs for consumers and producers.

Using relatively straightforward models of energy devices our current research has shown that hierarchical local coordination achieves emerging convergence of the global stabilization through local knowledge, local decisions and local interactions by individual software agents [4]. Self-management in this aspect has thus shown to be feasible,

as demonstrated in agent-based simulations, in the AgentScape [3] platform. The hierarchical organization plays an important role in the proposed method. Current research therefor focuses on self-managed robust hierarchical topologies designed to adapt to local failures, reorganising the topology as needed on the basis of local knowledge.

Distributed energy resource management also involves matching production and demand for power in energy grids. A number of potential management schemes, varying from central to completely distributed. Ongoing research within the IIDS group works towards a comparison of their relative performance. A test scenario has been designed, based on the concept of a virtual power station. Simulations, using real data from an existing system, produce estimates of the overall cost of electricity for a virtual power station over a given period of time. The type of coordination, group size, and flexibility influence the profit that can be achieved by a virtual power station. Initial experiments indicates that a balanced combination of loosely coordinated basic controllers [2] may be preferable.

In addition, distributed energy resource management in dynamic environments requires flexible, short lived SLAs that can be renegotiated 'on the fly'. IIDS' research focuses on using WS-Agreements for dynamically (re)negotiation of SLAs thereby enabling adaptive distributed energy resource management [1]. Simulations with several experimentally derived utility functions show that WS-Agreements can be used to structure interaction. A monitoring infrastructure and support for violations and penalties are the next steps to be pursued. Combining all of the above results in IIDS' latest research challenge: the deployment of SLAs in emergent configurations.

Complex, intelligent, distributed systems in dynamic environments need to adapt continually, and thus need to be designed to this purpose. Simulations and experimentation are key for local knowledge driven global emergent behavior.

References

[1] D. G. A. Mobach, B. J. Overeinder, and F. M. T. Brazier. A ws -agreement based resource negotiation framework for mobile agents. *Scalable Computing: Practice and Experience*, 7(1):23–36, 2006.

[2] E. Ogston and F. M. T. Brazier. Apportionment of Control in Virtual Power Stations. 2009. draft.

[3] B. J. Overeinder and F. M. T. Brazier. Scalable middleware environment for agent-based Internet applications. In *Applied Parallel Computing*, volume 3732 of *Lecture Notes in Computer Science*, pages 675–679, Berlin, 2006. Springer.

[4] E. Pournaras, M. Warnier, and F. M. T. Brazier. A distributed agent-based approach to stabilization of global resource utilization. In *the International Conference on Complex, Intelligent and Software Intensive Systems (CISIS'09)*. IEEE, March 2009.