Multi-Agent Control of Large-Scale Network Systems

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1 Framework

We consider the control of complex large-scale systems like power distribution networks, traffic networks, flexible manufacturing networks, and other transportation networks. The operation of these systems has a significant impact on amongst others economic growth, quality of life, and the environment. Many of the systems mentioned above can be modeled as *hybrid systems*, i.e., systems with both continuous and discrete elements. E.g., in power distribution networks the flow of power can be considered as a continuous element, while switching generators and loads *on* and *off* introduces discrete dynamics. In traffic systems the flow of cars through a network can be modeled as a continuous process, while actions such as traffic signal switching and variable speed limiting provide discrete interaction.

So far, most control methods for hybrid systems are based on a centralized control paradigm or on ad-hoc techniques. However, in particular when considering large-scale systems, centralized control is often not feasible in practice due to computational complexity, communication overhead, and lack of scalability. Furthermore, structured control design methods for these systems are lacking. We investigate the development of a structured and tractable design methodology for control of these large-scale hybrid systems.

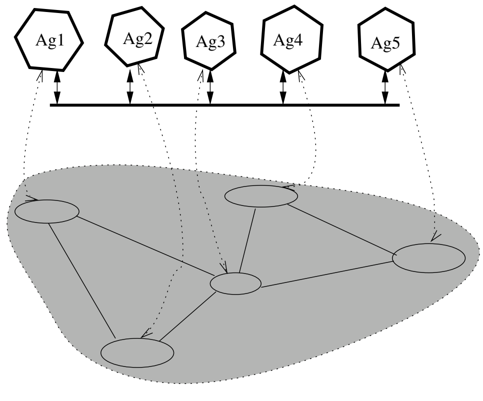

Figure 1: Single-level multi-agent control structure. The graph in the shaded area represents a physical network consisting of devices (e.g., generators and loads) and interconnections (e.g., power lines). Agents control individual devices and coordinate their actions through a shared communication channel.

2 Proposed Approach

Our approach is based on a model predictive control approach in a multi-agent setting in which local control agents solve local control problems using local information and information exchanged with other agents. The development of the envisioned design methodology is outlined as follows:

1. Definition of a generic network, consisting of elements with possible hybrid dynamics, e.g., sinks, sources, routers, transformers, storage elements, etc. This generic network forms an abstraction of the specific networks mentioned before.
2. Definition of constraints and control problems on this generic network, e.g., optimization of costs versus quality of service, and assessment of solutions of these control problems obtained by a single, centralized, agent using model predictive control.
3. Solution of the control problems using a multi-agent approach based on multi-agent model predictive control. Overall goals and constraints are translated into local goals and constraints for individual agents organized in a single layer (Figure 1).

The basic framework obtained can then be extended to more complex control structures, e.g., hierarchical structures. A hierarchical control structure in which at discrete event times higher-layer agents provide at a slower rate goals for lower-layer agents leads naturally to hybrid behavior.

3 Application Area

To demonstrate the value of the methods for the generic network, we will instantiate generic networks with networks from the domain of power distribution. Traditionally, large-scale power generators provide power which is transfered to urban areas and industry. In the future, so called embedded generation, in which power is also generated on the load side, will increase. This brings a new distributed structure in which our new multi-agent approach can be beneficial.

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