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Governing Future Networks

The NSF GENI program seeks to develop new architectures and techniques for the Future Internet to offer enhanced capabilities that support flexible, collaborative applications. To accomplish these goals, GENI would require not only new networking technologies, but fundamental changes to how networks are architected.

A crucial challenge is that of *governance*. Governance involves the structures, processes, and policies by which organizations are governed. Traditional top-down management is usually a poor surrogate for governance: this is because management works best within individual administrative domains of ownership and control, whereas governance incorporates federations of autonomous administrative domains, wherein the constraints and preferences of multiple stakeholders must be entertained. Governance faces the challenges of collaborative decision making, and thus must be explicit in its structures, processes, and policies. Traditionally, in the context of the Internet, governance has been thought of primarily an offline activity carried out by august (and interrelated) bodies such as ISOC, the Internet Society, IETF, the Internet Engineering Task Force, and ICANN, the Internet Corporation for Assigned Names and Numbers. All the key decisions, such as the selection of protocols, are already taken before a user is involved.

The above bodies are clearly valuable. But they deal with *the* Internet. By contrast, modern applications require not just the public Internet, but heterogeneous collections of public, private, and community resources. This is clearly the case with government-funded scientific projects at academia and research labs; it is also the case increasingly with commercial infrastructures. To satisfy performance requirements and to achieve the various so-called “ilities” (availability, reliability, and other such qualities), application cyberinfrastructures often must cut across traditional administrative domains and compose resources in novel manners. From the perspective of computing applications, networking infrastructures are simply resources on par with any other resource. A typical application would involve sharing compute, data, and networking resources. The requirements imposed by business and science applications apply equally on networking resources as on any other computational resource.

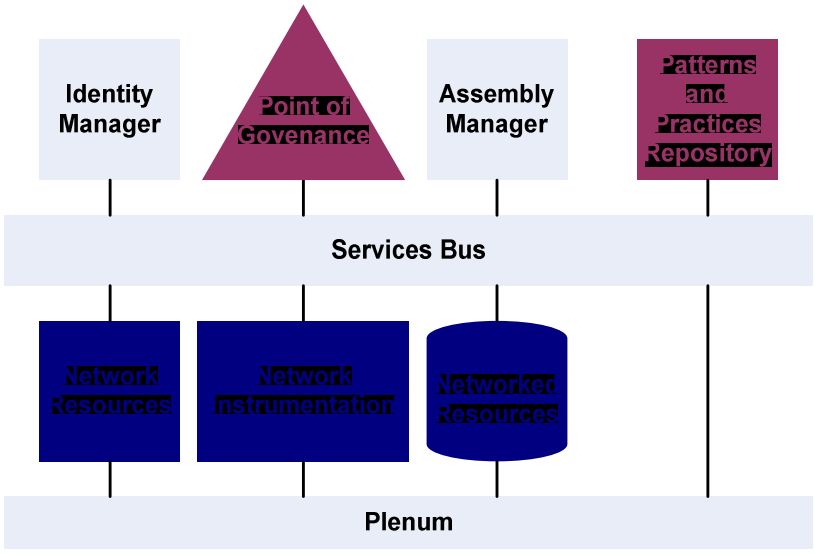
Challenges and Questions

The foregoing leads to key challenges, including the following. How can multiple stakeholders function collaboratively in a sustainable, efficient manner? How can individual ownership and control be respected as autonomous, heterogeneous facilities interoperate? How can commercial and other community needs be captured, negotiated, reasoned about, and applied? How can resources be added or dropped dynamically at runtime? How can dynamic organizations or coalitions be constructed and enacted to optimally share resources while entertaining challenges such as preemptive scheduling where appropriate? How to accomplish all of the above over a range of resource granularities and timescales? Our research program is inspired by the above questions.

Approach

We imagine that networking (and other) resources are assembled to solve specific application needs. Such *assemblies* can be thought of as virtual (private) networks, but dynamic, and well governed to suit their stakeholders' needs. Their constituent resources could be traditionally managed resources (the base case) or other such assemblies. The recursive, fractal nature of assemblies makes them interesting from a research standpoint. Assemblies could have lifetimes ranging from seconds to potentially forever.

Each resource is presented via a locus of autonomy and control that reflects the constraints and preferences of its owners and the administrative requirements of its owning facility. We term such loci **points of governance** and model them as *agents*. The abstraction of an *organization* is a natural extension. Agents form organizations. Crucially, organizations can act like agents in that they are autonomous and heterogeneous, thus mirroring the structure of networking assemblies. And, longer term organizations can dynamically spin off "ad hoc" coalitions that might only have a short lifetime, e.g., corresponding to a transient assembly of resources to support one or a few data-sharing and collaboration sessions. Organizations are formed based on contracts that reflect the needs of their stakeholders. Governance within an organization should respect its objectives; the policies of an organization should comply with its contracts. The privileges and duties of an organization's members are likewise determined by the contracts among them.



An agent captures and applies the internal policies of its *principal*, even as it engages in arms-length interactions with other agents to accomplish governance. Such interactions are naturally realized via the control plane of the networking infrastructure. A crucial observation is that the formatting and low-level processing of the messages are secondary to their content, which would reflect the organizational needs of governance. Our research on multiagent systems can help address key technical challenges, such as formulating realistic conceptual models of governance, e.g., those based on contracts and social relationships, and identifying patterns of governance incorporated in tools to build, verify, and maintain robust, flexibly governed networks of the future.