Network Service Management with Constraint Technology

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Managing Network Services

Performant network management platforms have a distributed architecture of diverse agents, which are highly specialized in monitoring connection nodes, communication links, computing systems, and business applications along with their supporting services. However, managing enterprise networks is mainly characterized by "thresholding" solutions, where device or application events are monitored, logged, and filtered through predefined threshold levels. It seems that the challenge raised by Marshall Rose, author of the Internet management protocol, a few years ago, remains actual (Rose 1993), and that there is still a tremendous need for "thinkers", or management tools that can turn "data into information".

Knowledge-based network management systems do address this problem by adopting a model-based approach (Hamscher, Console, & de Kleer 1992) for representing and reasoning about management data. These systems maintain not only a structural model of the network topology, but also a behavioral model that captures the relations among network constituents. Model-based network management utilizes expressive models, which dynamically map to, mirror, and respond to the managed systems (Katker & Paterok 1997), (Dreo Rodosek & Kaiser 1997).

A general, expressive, and yet natural problem-solving model is the constraint satisfaction problem (CSP) (Freuder & Mackworth 1994). The CSP formalism has been successfully used to solve a representative range of problems: scheduling, planning, design, configuration, and diagnosis. In this position paper we report on the results we have obtained from applying the constraint satisfaction paradigm to the task of network service management. We briefly describe the constraint technology and illustrate with an example what makes this technology suitable to the network service management task. For a complete presentation of our constraint-based approach to modeling and solving network service problems we invite the reader to further examine our work as referenced at the end of this paper.

Constraint Technology

Constraint networks have been used to represent and diagnose special classes of randomly generated circuits (El Fattah & Dechter 1992). (Riese 1993) employs constraints to model and diagnose communication protocols. In our work, we have extended the problem domain to encompass management of network services (Sabin, Russell, & Freuder 1997), (Sabin *et al.* 1999). Our contribution in this application domain includes: (1) modeling network services, (2) detecting and isolating faults with the network services, and (3) proactive diagnosis and explanation support.

With our approach, we model the network service as a CSP. A CSP contains variables with associated domains of values, and constraints on some of the variables, which restrict the values the constrained variables can take. The service measurements are either configuration settings or on-line parameter values, and they instantiate the observed or measured variables. Solving a CSP is based on searching for value assignments that satisfy all the constraints. For the task of fault and configuration management, we look for violations of constraints which explain the observations and indicate the root causes of faults in the service. Thus, the CSP algorithm does not settle for "no solution found", that is, some constraints were violated. Instead it records as diagnoses or management results the partial solutions for which some constraints are violated.

Example

As example, we consider diagnosing configuration problems with the Internet Domain Name Service (DNS). Although this example is discussed in (Sabin, Russell, & Freuder 1997), for its CSP representation here we use a different modeling technique, which draws on a special class of CSPs, called composite CSPs (Sabin & Freuder 1996). The composite CSP representation has the advantage of facilitating modeling of complex systems by supporting composition, local models, and parameterized relationships or ports. A more detailed application of composite CSP to modeling replication groupware service can be found in (Sabin *et al.* 1999).

In Figure 1 we show a simplified part of the DNS resolution model. It contains variables (drawn within rectangles), composite values (drawn within ovals), and one constraint, on variables remoteHost and hosts. The constraint asks for the name of the remote host to be listed in the hosts file on the local machine. Let us assume that the value observed for the remoteHost variable is not in the list of host names of the hosts variable. By failing to check this constraint, the CSP-based configuration management tool catches the root cause of the problem. Instead of the DNS error message: "XXX host unknown", the CSP management tool provides a complete explanation: "Local resolution failed. XXX is not in the 'hosts' configuration file".

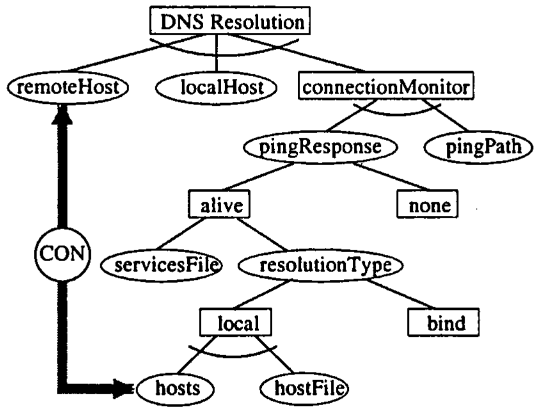

Figure 1: Composite CSP model of DNS management

More challenging than developing a CSP engine that would perform the diagnosis as shown above is the issue of casting the network management problem into a CSP in the first place. On the same example, we explain next the modeling capabilities of the composite CSP framework.

Composite values can instantiate variables in a CSP the same way elementary values can. However, while elementary values are restricted to simple types (numeric, string), composite values stand for entire CSPs. Instantiating a variable to a composite value leads to dynamically modifying the original CSP with the new subproblem. In Figure 1 the DNS resolution composite value extends the model with variables remoteHost and localHost, and the composite value connectionMonitor. The dynamic model's change through composition is represented graphically by an horizontal arc tying together the constituents of the new CSP subproblem. Variable instantiation on the other hand is represented by separate edges branching out from the instantiated variable to its possible values. The variable resolutionType for example can take either the value local or the value bind, at which point the model will capture either local resolution or the much more complex remote resolution.

A direct consequence of composing variables and constraints into composite values is the modeling capability of expressing local models. Local models are context-independent in the sense that they define only constraints among the variables they contain. To represent how a local model is used in a larger model, new constraints are defined between some of the local model variables and other external variables. The constraint CON in Figure 1 is not part of the local submodel. Instead, it tells how this local model is used in the larger DNS local resolution model.

Conclusion

In this position paper we presented an application of the constraint technology to managing network services. The technology uses an extension to the classic CSP paradigm, called composite CSP, to model and solve problems with configuring and running network services. The composite CSP class captures in a natural way both the dynamic aspects and complex structure specific to modeling network services.

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