AGENT AND WEB-BASED TECHNOLOGIES IN NETWORK MANAGEMENT

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Abstract

A close look at agent and web-based technologies and their use in the management of networks is the main theme of this paper. An analysis of how this area has changed substantially, resulting in new difficulties and challenges for information systems professionals is provided. The components of network management, including people, information; the network infrastructure, systems and network management, and their interactions are looked at initially. The changes that have occurred in this area will be outlined by this analysis, and the resulting problems and complexities described. From this point the potential role for agent technology in providing some degree of solution is explored. This exploration also considers some of the negative implications, and introduces a model proposed as the basis of an integrated agent and web-based network management environment.

The Components

The components of network management, including people, information; the network infrastructure, systems and network management, and their interactions are looked at in the following subsections.

People

Information systems, and in particular computer networks, are increasingly being thought of as a 'strategic resource' by organisations. The value of these systems as a mechanism of attaining competitive advantage is also being increasingly realised and utilised by organisations. With these realisations, the demands being placed on network managers, and systems administrators are intensifying. Network managers and systems administrators now require better methods of decreasing the likelihood of failure and demand better tools to perform their tasks.

Information

Additional information is now required in order to more accurately diagnose problems, or predict likely areas of future failure. In addition to this, information is more often coming from different sources, resulting from the changing network infrastructures, making it difficult to compare, and analyse.

Network Infrastructure

Organisations are increasingly moving towards distributed networks, that are often global in nature. It is hardly surprising that the numbers of these distributed networks have increased as they have, considering the numerous benefits they provide. With these advantages though, comes a more difficult entity to control, and efficiently manage. In addition to this already complex environment, more and more users want to be mobile. This adds even more complexity to the already complex network infrastructure. Intelligent network entities have evolved, but still fail to adequately meet the new requirements of network management.

Systems and Network Management

This area has become crucial to most if not all organisations that use networks. As a result of the people, information, and infrastructure components changing so dramatically, methods to aid the 'people', in coping with the 'information' in order to deal suitably with the 'infrastructure' are needed.

Interactions

With the conventional process of network management the emphasis is on the 'people', and the 'infrastructure' components. With only moderately sized networks, and a relatively small number of tasks for the administrators to perform, it is intuitively obvious that the 'information', and 'management' components are comparatively less important. This results from the predictable nature of the

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physical network, and the set format that the information is stored in.

The size and complexity of modern networks has increased dramatically, placing an increased burden on those who are expected to manage it. In addition to this, the physical location, and also the format of information is no longer static.

The Problems

Most organisations now realise how difficult it is to quantify the value of information. The evidence of this realisation is apparent, not only by the size and complexity of networks increasing, but also by the recent interest in technologies such as data mining, data warehousing, and also data security.

The major problems can be summarised as:

- *Increased importance of managing the network*
- *The complexity, including integration difficulties and heterogeneous data representation, and size of the network*
- *The weaknesses in conventional management*

Increased importance of managing the network

Adding network management staff does not guarantee in any way that the network will be effectively managed. The complexity that is now common in network architectures, make comparisons of heterogeneous information necessary- a function that additional staff alone cannot efficiently perform. What this means is that simply 'throwing money' at the management issue only partly solves the problems at hand. To amplify these problems there are cases where management staff sizes are not even increasing to cope with the issues described, resulting on the remaining staff being burdened with increased responsibility [2].

The complexity and size of the network

The sizes of the networks within many organisations have increased substantially, especially when considering the growth of local and wide area networks. This is a result of users wanting to utilise benefits available from the use of different computational environments [3]. In addition to this, previously separate networks are being joined to form amalgamated networks. The size factor alone creates numerous difficulties in adequately managing networks. Controlling the interconnected devices, and diagnosing problems on the network becomes exceedingly more difficult to accurately perform as the network grows.

The trend, and move towards client/server computing, as described by [4], has also intensified the complexities of the systems that need managing. This results from these systems requiring centralised management despite the systems being distributed, and also heterogeneous in nature.

The Weaknesses in Conventional Management

The conventional methods, by which networks are managed, are showing obvious inadequacies when given the burden of coping with 'modern networks'. Network Management (NM) procedures are affected by the lack of a common approach based on standards. Network administrators and operators need to adopt different methodologies and learn about new tools for each segment of their multi-vendor configuration. At the other end, users wish to have a top-down or general overview of a network that has essentially been built in a piecemeal, bottom-up fashion. This initial bottom-up approach to network management failed because of the problems related to lack of standards, and the cost incurred by each vendor trying to develop and maintain their own management systems. The other approach tried by the industry is a top-down centralized "Supersystem" which has as its main function to integrate the existing NM systems. Paradoxically this latter approach was doomed by the same reasons. The heterogeneous nature of existing NM systems proved a shaky foundation upon which to build a super system. It proved difficult to try to present a common front when the building blocks were often distinct and sometimes contradictory. Finally, the platform-centered paradigm has struggled with the issues of scalability [1,5] and manageability; it clearly needs a complementary technology in order to develop its full potential.

The Role of Agent Technology in solving these Problems

The first issue that needs to be addressed in this area is in distinguishing between the current use of, and the proposed, or required use of agent technology in this area. Most of the current use of agent architectures in network management can be described as "fixed function", as opposed to "intelligent" [4]. This distinction is crucial as the "fixed function" architectures fail to fully address any of the problems outlined in the previous section.

The problem area that can benefit most from intelligent agent architecture, is the issue of complexity and size. An intelligent agent working in cooperation with other intelligent agents on the network, can far more efficiently navigate, test, and diagnose problems, or potential problems on the network [6]. By using an architecture that embodies a "middle layer" [4] performing translation functions, the system would even be more adept in coping with the heterogeneous nature of modern networks.

Intelligent agent architectures for network management also provide benefits in coping with the increased importance placed on the network management function. Through the numerous benefits the agent-based system provides, the new and increasing demands can be met by providing functionality previously not possible. Agent technology allows faster, and often preventative maintenance as opposed to slow, and often reactive maintenance, which is substantially more costly to perform. This, in addition to the improved diagnosing and reporting capabilities, provides the vastly increased performance required to reduce the gap between networking, and network management technology. By incorporating the "agent-enhanced approach" [7] to working with intelligent agents, further functionality and performance can be achieved in the area of network management without the demise of network performance.

The shortcomings of the platform-centred paradigm can also be addressed by using collaborative agents in order to perform decentralised management and control [8]. This addresses the problem of scalability which conventional management methods fail to cope well with. Agent technology in this area does not directly support the scaling up of a network, but does facilitate it, by providing mechanisms to manage the implemented change.

The Implications

Numerous organisations are making use of Agent technology to cope with the increasing burden that efficient management, of typically growing networks, creates. This use of agent technology however, is mainly in the form of "fixed function" agents and does not represent the full potential of the technology in this area. At the same time the implications of true "intelligent" agents, performing network management, are largely uncertain [4]. Some likely negative implications of the technology include the loss of jobs [9], conflicting goals, and also the burden of allocating responsibility.

The concern of agents having conflicting goals results from the potential of autonomous intelligent agents acting in contradiction to one another. On a very large network, with potentially hundreds of these intelligent agents performing tasks, the potential for conflict is extensive. This obviously detracts from the major benefit this technology provides- that of efficiency. This situation raises an interesting question, as to how the 'conflict' can be avoided? One of two possible solutions seem apparent, either limit the capabilities of the agent to ensure conflicting goals cannot materialise, or, provide comprehensive management mechanisms to track the actions of all agents residing on the network. Limiting the capabilities results in undermining the technology, and does not present a feasible long-term solution. The other option is to provide a comprehensive management system, which offers a far more coherent solution. This however adds even more complexity to an already exceedingly complex area.

The final concern, the issue of allocating responsibility, is one that is apparent in several areas of intelligent agent technology. However, in regards to this application, it still needs to be addressed. If the situation where the agent "turns malignant" [10] arises, who will be expected to take responsibility? Can it be deduced that the systems and network administrators should be adequately controlling the agents, or perhaps the developer who designed the agent should bear responsibility? This outlines an area that could end up seeing responsibility justifiably denied by all people concerned. This is uncommon, and unwanted in an organisational context, as the delegation of responsibility is crucial in all organisations.

Agent Advances in Network Management

Examples of agent advances in the Network Management area include British Telecom Laboratories' efforts to use agents for monitoring and controlling networks [11]. Along similar lines is 3Com Corporation's work in distributing an intelligent agent-based solution for network performance statistics gathering [12]. The Plangent system (although not specifically designed for network management) is a model that enables mobile agents to make a plan based on user input and adopt it to information gathered from the network [13]. A Configuration Management application could use this capability, for example, to update its records on network elements. Mobile agents have been used to allow "thin" clients to participate in effective network management operations [14]. Java has already been used for developing network management tools [15,16,17].

Mobile agents have also been used as an enhancement of the Management by Delegation (MbD) mechanism [18] using a "mobile code" paradigm that provides more flexible network management [19]. In another research effort a mobile software agent, known as "representative", is used for distributing the mobility management load of a radio network (an increasing requirement for wireless network managers) within the fixed backbone network [20]. A team of researchers at the University of London had introduced an intelligent multi-agent system used for managing connection admission control in ATM (Asynchronous Transfer Mode) Networks [21]. Finally, Tcl-based mobile agents have been used for Network Monitoring and for Network Fault Diagnosis and Testing [22,23].

A Web-based Network Management Model

A model based on standard network management systems and using object oriented techniques addresses some of the problems mentioned in section 2 by providing a common communication protocol, shifting that responsibility away from the application programs, and by specifying a small, well-defined number of operations to be performed on all managed resources. Developers will be able to introduce new Managed Objects (MOs) as long as the MOs can respond to that limited set of operations.

The "surviving" approach (after the failure of bottom-up and top-down systems) to integrated network management is the open system standards-based approach, providing a common, open management "platform" that could be used by vendors as a basis for their element management systems. This platform approach needs to be complemented by techniques that defeat the restricted role of traditional Client/Server configurations. Figure 1 illustrates a model for web-based network management suitable to be used with agent technology. WBEM (Web-based Enterprise Management [24]) and JMAPI (Java Management API [25]) should be used as complementary technologies. The JMAPI techniques can provide the instrumentation needed at the device level and the specification for the agent-to-physical-device interface. Sun's tools can also be used to develop a common look and feel for browser-based consoles [26]. On the other hand the WBEM initiative provides a complete framework for data representation (HyperMedia Management Schema and HyperMedia Object Manager) and protocol communications (HyperMedia Management Protocol or HMMP).

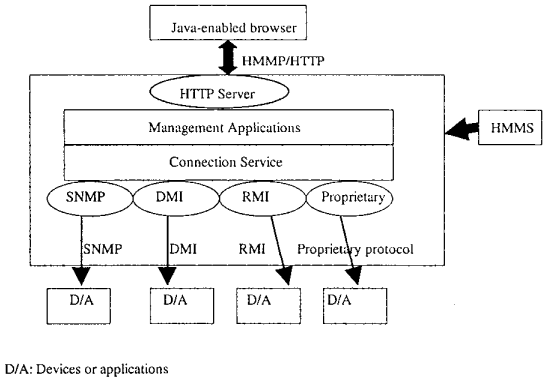

Figure 1: A Web-based Network Management Model

The WBEM initiative allows Clients and Servers to switch functionality therefore relaxing the rigidity associated with the traditional C/S roles. A client or a server can become both a producer and a consumer of information with notifications "pushed" to them by providers ("Indications" in HMMP's terminology). The WBEM's meta-model describes what types of entities make up the schema and how they can be combined into objects which represent real-world devices, and the standard schema is a set of published classes which represent a wide range of hardware devices and other managed objects.

Java with its "write once, run everywhere" operation provides the platform independence advocated by the Agent-based paradigm and security is based on the fact that only trusted code runs on a client. The configuration requires an HTTP server to start Java operations. The Browser User Interface contains the Admin View Module (AVM) with the key client side classes for developers of JMAPI-based applets, and the Managed Object Interfaces use RMI (Remote Method Invocation) to perform remote management methods. The RMI calls can be eventually encapsulated within HMMP [25].

Conclusions

The issues outlined in this paper indicate a positive outlook for the future of agent-based network and systems management. There are a host of issues that are escalating the demand for a solution. Agent technology provides substantial benefits to the major concerns discussed, without creating severe problems. Network elements with some degree of intelligence are becoming increasingly common. The combination of agents with Web-based technologies provides powerful mechanisms for implementing network management solutions. Several advantages are derived from its use: agents operate closer to where they are needed; improved security can be achieved by using technologies such as Secure Sockets Layer (SSL), Secure HTTP (S-HTTP), and trusted Java code; web push technology (example: Java applets "pushing" information to managers) can be used to increase "role flexibility"; use of platform-independent technology (anywhere/anytime accessibility); ease of use (training, integration); scalability; support for SNMP agents and support for mapping data to commercially available relational databases.

The factors mentioned above combined with greater research into platform independent languages, together make the goal of having intelligent autonomous agents managing, and controlling our networks more achievable. We are likely to experience a slow migration from "fixed function" to true "intelligent" agents currently impeded by the lack of a unified standard accepted by major vendors. At such time as vendor cooperation occurs, and an architecture supporting mobile intelligent agents is trusted, we are likely to see a significant increase in the use of this technology for network management.

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