Harnessing network anarchy for the common good

October 31 2008

Sharing the networking load. © Scott Maxwell - Dreamstime

(PhysOrg.com) -- Anarchy may be the bane of political conservatives, but on the internet it is the essence of the information superhighway.

No hierarchical authority controls the internet and users have the freedom to create information, and leave or rejoin the network at will.

Yet the essential freedoms users have on shared networks such as the internet – described famously by political scientist Dana Ward as the "quintessential example of a large-scale anarchist organisation" – makes them difficult to manage efficiently.

A team of European researchers set out in 2004 to solve the problems inherent in keeping such networks operating efficiently, while

maintaining the personal freedoms users find attractive.

The Delis project, which ended in February 2008, puts Europe at the cutting edge of network development.

“Our purpose was not to change the internet but to understand it,” says Friedhelm Meyer auf der Heide, the project’s coordinator and a computer science professor at the University of Paderborn in Germany.

The Delis team coupled the algorithmic techniques used in computer science with the expertise gained from biological and social behaviour studies, statistical physics, economics and game theory in a bid to develop better methods of managing such networks.

Prototype software – such as a search engine based on peer-to-peer (P2P) sharing techniques, a new network management system for internet providers, and a spam database – has attracted the interest of companies such as Yahoo.

Large-scale networks such as the internet have become so big that we can no longer deploy and manage them using traditional techniques, says Meyer auf der Heide.

“The reasons for this are their sheer size, with millions of users and interconnected devices and their dynamics,” he says. “They evolve dynamically over time, with components changing or being removed or inserted permanently. For such systems, we have to abandon the goal of global optimality.”

P2P approach to network management

A new approach is needed. The researchers based part of their approach on P2P networks, known best through online services such as Gnutella

and Skype.

P2P networks typically are used for file sharing, media streaming, telecommunications and discussion forums.

A P2P network's strength is its lack of a central server or router. Instead, each computer (or peer) acts as a shared server on the network. In theory, the traffic load is balanced evenly across a large number of peers and is resilient to failure, allowing the network to handle huge amounts of data in a distributed and self-organising manner.

However, the anarchic nature of such a system leads to an inherent problem – cheating or selfish behaviour by some users can lower the network's efficiency, leading to instability.

Anarchy in such a context is a technical term used in game theory and economics as a means of analysing the cost of selfish behaviour in a co-operative system.

For example, existing P2P networks often encounter the problem of 'free riders', those who use the computing resources of others without making a similar contribution to the network. The free rider problem eventually leads to congestion on the network, slowing it down. On the Gnutella P2P network about 70% of users are judged to be free riders.

A major task of the Delis project was to develop mechanisms that discourage such unco-operative behaviour, and encourage altruistic, sharing behaviour without dictating to users what they should or should not do, says Meyer auf der Heide.

The researchers aimed at designing efficient algorithms to encourage co-operation among many selfish agents and to affect the dynamics of self-organisation in large, complex networks.

Sharing search results

The algorithms they developed are at the heart of a prototype P2P search engine the Delis researchers created as one of a number of demonstrations of their theories put into practice.

“We applied methods used to understand economic market mechanisms and game theory in order to understand and organise the way peers compete for resources, such as bandwidth, computing power and data,” says Meyer auf der Heide.

Every user or ‘peer’ with the Minerva software on their computer owns a local search that indexes a small portion of the Web according to their particular interests. If it gains a large user community, the P2P search engine would work by using the input of everyone on the Minerva network to provide better query results than is currently possible.

As the data volume and the query load per peer are much lighter, the peer’s search engine can use the additional computing power to employ much more advanced techniques for concept-based rather than keyword-based searches.

In contrast to a search system that uses a central server, the P2P approach provides users with direct control over which aspects of their online behaviour may be collected and forwarded to other peers to help in their searches.

“Machines plus humans equals a type of social network with a social wisdom – the wisdom of the crowd,” suggests Meyer auf der Heide. “The collective knowledge and the interests are the system.”

The researchers also applied their multidisciplinary techniques to develop another prototype system – a means of automatically managing

internet service providers (ISPs) based on peer-to-peer networks.

The system can pick higher bandwidth links, or peers that are geographically closer, when routing traffic. The system not only reduces costs and eases traffic engineering for ISPs, but also results in higher bandwidth and shorter download times for P2P users.

Deutsche Telekom is testing the Delis system as a management tool on their networks.

Spam tool

Meanwhile, Yahoo Research in Barcelona is host to a database originally created by Delis to help analysts create better methods of determining what is spam and what is not.

The freely available WEBSPAM-UK2006 collection is aimed at helping researchers develop a better method of filtering spam email out of their mailboxes.

Spam email, the electronic version of junk mail, currently accounts for about 80% of all messages criss-crossing the internet, according to a Symantec report on the issue.

“The Web spam detection algorithms inspired new and efficient methods for detecting malicious peers in P2P environments,” according to the Delis project website.

Another prototype system developed by the Delis team is a management platform for telecommunication networks. The P2P-based platform integrates the wide range of current and future data formats and services in use.

The team also developed software tools for visualising routing systems, for simulating mobile ad hoc networks, for analysing experimentally evolutionary games, and for data management. The algorithms they developed can be used for computing the statistical and topological properties of large, dynamic networks.

Overall, the EU-funded Delis project has increased researchers' understanding of the structure and the evolution of large dynamic networks like the internet and P2P systems, says Meyer auf der Heide.

The project's achievements include the quantification of the price of anarchy in several complex networks. In addition, the researchers have developed ways to handle anarchy in a competition of coalitions and to incorporate co-operation in a network structure.

"We have developed self-regulating and self-repairing tools, methods and techniques that are decentralised, scalable, and that can automatically adapt to changes," he says.

Meyer auf der Heide hopes Delis has laid the groundwork for better network management systems that see humans as role players and not just as users. In this way, anarchy on the internet can be directed toward the common good of a network.

Delis was funded by the ICT strand of the EU's Sixth Framework Programme (FP6) for research.

Provided by ICT Results