Study analyzes role of mobile software in the future Internet

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(PhysOrg.com) -- Although it's difficult to predict what the future Internet will look like, it's probably safe to say that certain trends we've seen during the past decade will continue. This means that the Internet will become further integrated into our daily lives, becoming more ubiquitous, available, autonomous, and mobile. The engineers who are guiding the Internet in this direction are doing so by developing mobile agents, which are pieces of software that can autonomously migrate from one computer to another and interact with each other.

One method for advancing network services in the future Internet consists of combining mobile agents with an evolutionary framework. In these methods, the mobile agents must decide for themselves the best course of action to take in order to handle users' requests most effectively, with the results of the decision impacting their survival. Currently, these methods are far from being practically implemented since they lack a basic theory of the migration behaviors of mobile agents on a large scale.

In a new study, Yongsheng Ding and Lei Gao from Donghua University in Shanghai, China, have performed a macrodynamics analysis of mobile agents' migration behaviors, which could provide a fundamental basis for the development of a more ubiquitous future Internet. Their study will appear in a future issue of *IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans*.

"We think the work is significant in being the first to conduct the

macroanalysis of large-scale mobile agent migrations," Gao told *PhysOrg.com*. "The study not only favors the design of composite services in a type of self-organizing network architecture, but also benefits the future deployment of an Internet-scale mobile agent system that holds myriads, hosts, and migratory movements of mobile agents."

Previous studies have predicted that the future Internet will have vast numbers of these mobile agents that can effectively handle users' requests. As Gao explains, mobile agents could have significant advantages compared with stationary agents, especially for mobile devices.

"Due to the resource limitation of mobile devices, agents are sent to some nodes/devices with rich resources for doing some tasks that have high requirements for resources, and then they bring the results back," Gao explained. "Mobile agents can automatically suspend their executions on one host and migrate to another to resume their computations without tedious and slow network communication."

As the researchers explain in their study, mobile agents can be considered in terms of an evolutionary framework: When a mobile agent performs a service, it gains a reward. The more rewards a mobile agent has, the longer it survives, while agents that run out of rewards die. So mobile agents evolve and become more effective at handling users' requests. They have several abilities to maximize their usefulness, such as adapting to changing environments, manipulating objects, and learning from past experiences. They also have the ability to replicate themselves individually or reproduce "children agents" with other mobile agents.

In the researchers' model, mobile agents that perform the same or similar services (e.g., performing a credit card transaction or providing GPS data) would form a community, or "niche." In these niches, mobile

agents can learn from their surrounding environment, improve their performance, and gain more rewards. Depending on user demand, these niches can grow or shrink. The researchers' model shows that the number of mobile agents in all niches eventually stabilizes, so that the average growth rate of the total mobile agent population reaches zero.

By understanding the macroproperties that emerge from the behaviors of a large number of autonomous mobile agents, the researchers hope that they can design improved network services with more advanced features. This kind of modeling is still in its infancy, and the researchers hope to continue improving these models, and eventually apply them in the future Internet.

"We believe the future Internet will be hundreds of times faster than the current one," Gao said. "We envision the future Internet as a global integrated platform for communication, education, entertainment, business, and other human activities. Network services are required to be highly available, ubiquitous, highly secure, self-managing, and adaptable to dynamic network environments and user requirements. The characteristics of the future Internet we envision resemble the self-organizing and the self-healing properties of natural ecosystems that have evolved over billions of years. The harmonious properties of natural ecosystems have shown us a promising way to build the future integrated platform."

More information: Yongsheng Ding and Lei Gao. "Macrodynamics Analysis of Migration Behaviors in Large-Scale Mobile Agent Systems for the Future Internet." *IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans.* To be published.