Toward Cooperative Inter-overlay Networks

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Over the past few years, overlay networks have emerged as a paradigm for sharing information and easily deploying disruptive technology. Overlay solutions have been introduced for multicasting, inter-domain routing, content distribution, content storage, quality of service, and peer-to-peer networking problems. Since overlays are easy to deploy, several diverse overlay networks may simultaneously exist in the Internet. These overlay networks may compete for the same resources on shared hosts and underlying network links and routers. The overlays may also have heterogeneous performance and service goals, such as minimum latency versus maximum bandwidth, and multicast distribution versus unicast forwarding. The possibility of cooperation among overlay networks to enhance their collective performance thus emerges. This cooperation may not only improve performance, but also enable sharing information. The wide spectrum of overlay cooperation possibilities has not been extensively investigated in the literature.

A spectrum of possible interactions among overlay networks is depicted in Figure 1. With overlay cooperation, overlays may share control information, share network measurements, cooperate in forwarding messages, and make joint traffic engineering decisions. Taken to an extreme, different overlays may be merged into a single overlay. In this work, we explore this spectrum of cooperative services among co-existing overlay networks, and study the associated scalability, security and heterogeneity problems.

We design a simple inter-overlay architecture, where agents facilitate inter-overlay communication. Each overlay network periodically designates one of its hosts as an inter-overlay agent. In addition, each overlay node joins a home overlay network as an active member (with full privileges and obligations), and may also elect to join a few other overlay networks as a passive member (with limited privileges and obligations) via inter-overlay agents. This allows overlays to benefit from each other in terms of performance and services, while maintaining the heterogeneity of individual overlays. Figure 2 gives an example of a shared forwarding service that exploits overlay cooperation. In the figure, the communication from sender host $\delta$ to receiver host $\beta$ in overlay network $A$ benefits from the cooperation between overlays $A$ and $B$. The route from $\delta$ to $\beta$ employs host $\phi$ in overlay $B$ as a transit node. This cooperation can yield shorter (or wider) routes than the routes that transit hosts in overlay network $A$ only.

We use three heuristics to select the inter-overlay agent: (i) the number of co-located overlay nodes, or (ii) the number of overlays represented in its neighbor passive overlay nodes, or (iii) the minimum maximum delay to other hosts in its home overlay network. An overlay node also considers three factors for selecting which overlay networks to join as a passive member: (i) performance improvement, or (ii) compatibility and loads of different overlays, or (iii) trust. We explore the first factor further by quantifying the advantage for an overlay network to have a new passive member join. An advantageous passive member is one that many hosts in the overlay can employ to forward their packets, and which will significantly improve performance. This can be determined by computing the number of members that will utilize this new member. Our preliminary simulation results indicate that our cooperative overlay architecture can reduce the mean delay between overlay network nodes, especially with the advantage heuristic. We also examine a number of additional services as examples of overlay cooperation, including reactive on-demand cooperative forwarding, shared measurement services, control information sharing, query forwarding in peer-to-peer networks, and inter-overlay traffic engineering.

We are currently implementing our algorithms on the PlanetLab wide area overlay network platform. Analyzing the results from these experiments will allow us to quantify the effectiveness of overlay cooperation in realistic environments. We are also examining different types of cooperative overlay services, with particular attention to the complexity, scalability, and security tradeoffs.