The role of state and layering in software-defined networking

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Research issues:

Dynamically deployed network services require both state and dynamic layering capabilities. State is required for both new data-plane protocols and also to deploy current network devices such as directional firewalls, NATs, and CDN services, and future services that involve compositions and more complex variants of these components. Dynamic layering is required to support adaptive protocol composition, such as transferring TCP streams to a native optical channel when traffic warrants, shifting between addresses or address types, and adapting to network conditions through the use of proxy-enhanced tunnels. These capabilities require an approach to network architecture that supports protocol layering as a directed graph through finite state machine protocol engines with persistent inter-message state, as well as state recovery between nodes using message context. It also requires a model of network resources that decouples the concept of network attachment point from that of processing, to enable gatewaying between heterogeneous name- and protocol-spaces, to support interlayer translation, inter-overlay federation, and mutifacted node emulation (i.e., where a NAT emulates a router from the private side, but a host from the public side).

Infrastructure requirements:

Support for stateful and layered networking requires infrastructure that supports deployment of new virtual routers and hosts. The OS abstraction needs to terminate at separate virtual network interfaces and processes; “slices”, which bind these together, remain incompatible with many aspects of recursive networking that were implemented over 15 years ago and interfere with gatewaying between virtual networks. We need infrastructure that requires less heavyweight revision than Emulab/Deter (i.e., not requiring OS deployment) but with more sophisticated and capable network services than currently available from PlanetLab or SDN, that can support both dynamic protocol composition and network virtualization concurrently. This infrastructure should be based on a structured network architecture environment, one that provides a much higher level of abstraction than Click/NetGraph/X-Kernel, i.e., that moves network and protocol architecture research above the level of assembly language, closer to that of LabView.

Background:

For the past 20 years, I have been developing network and protocol architectures to support multilayer recursive virtual networks that enable new approaches to fault tolerance, dynamic protocol use, and advanced distributed systems. This work has been used to support dynamic deployment of end-to-end virtual networks (X-Bone), multilayer spread-spectrum network defense (DynaBone), and secure fractionated satellite internetworking (DynaSat). These systems have been deployed on Linux, FreeBSD, and OS-X platforms supporting IPv4 and IPv6, with concurrent use of isolated dynamic routing and IPsec. I participate extensively in the IETF to develop tunnels and middleboxes for recursive use based on equivalence modeling.