論 文 の 内 容 の 要 旨

論文題目　Improving Packet Transport in Virtual Networking by Encapsulation Techniques
（仮想ネットワークにおけるカプセル化技術を用いたパケット転送性能の向上）

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The commoditization of Internet technologies has caused both positive and negative effects in the practical implementation of the Internet. The Internet Protocol (IP), a core protocol of the Internet, has achieved worldwide data communication, however, we cannot modify or replace IP, although it is not sufficient for current demands and requirements. The Internet has become a critical common infrastructure due to its remarkable scalability, technical and operational features. As a result of the deployment and adoption of the Internet technologies, IP has become the integral communication protocol. Almost all of applications have utilized IP for their data communication. Additionally, commoditization of IP often forces us to use commodity IP-based network devices for practical network construction because of their cost per performance considerations. Therefore, it is not feasible today to modify this existing dominant protocol. We have to continue to use IP as is without any modification. Meanwhile, it may be recognized that IP is insufficient for current demands and requirements, which have been diversified by the increase of applications' and users' diversity. For example, virtual machine-based clouds require separations of network domains between users, and the packet forwarding based on IP sometimes causes inefficient link utilization due to shortest path forwarding. Namely, we are facing a dilemma that we have to continue to use IP as is in practical ways, even though we aim to improve IP networking because it is not sufficient for all the requirements from emerging applications.

In this dissertation, we solve the dilemma by focusing on tunneling techniques because tunneling allows us to add new functionalities such as network multiplexing without any modifications to existing protocols and network devices. However, tunneling causes performance degradation at end hosts due to additional protocol processing, and it is not aimed at inefficient link utilization at

networks. To tackle the drawbacks of the tunneling approach, we introduce a new architectural view on tunnel-based virtual networking and propose exploiting its potential for optimization. This view separates two aspects of IP networking: host identifiers for data communication and locators for packet transport. Virtual networks that flow through the inside of tunnels are responsible for the identifier space of data communication, and physical networks where encapsulated packets transferred are responsible for simple packet transport. In contrast to the current tunneling design that handles both types of networks by a single network protocol stack, we separate virtual and physical networks into individual network protocol stacks. The network protocol stack for the locator aspect is isolated from the data communication context. Therefore, this separation brings a potential for optimizing the physical network protocol stack to improve packet transport preserving data communication in virtual networks.

Based on the architectural view, we propose two implementation methods that exploit the potential for optimization through changing behaviors of protocol stacks. The first is a new lookup method to avoid the performance degradation due to tunneling. This method improves packet transmission performance at end hosts through optimizing physical network protocol processing separated from end-to-end data communications. The evaluation result of the method shows that the time required to transmit a packet at the end host network stack is reduced, and it improves transmission throughput in five protocols' implementation. By eliminating the additional protocol processing, we improve the performance of packet transport for virtual networking at the end host side. The second is an explicit path control method via a novel usage of tunneling protocols in commodity-based IP data center networks. Data center networks require many network devices to contain many server machines. Hence, using low-end commodity products is an important matter for the data center network construction from the aspect of economic cost. This method achieves host-driven path control at a physical network by an optimized network protocol stack separated from end-to-end data communications. In this method, end hosts add multiple locators as outer headers to packets, and the packets are routed through specified paths represented by the outer headers. By this path control method, we achieve efficient link utilization and improve the performance of a network. The evaluation result in the case of two data center network topologies shows that the method can utilize multiple paths efficiently with only commodity devices.

Through both methods and their evaluation, we demonstrate that exploiting the

potential of the architectural view can improve network performance without making any modifications to existing protocols and network devices. An optimized lookup method for tunneling improves packet transmission performance at the end host side, and a network protocol stack optimized for path control improves performance at the network side. These methods can be deployed to current networked systems easily. Existing applications can still work on virtual networks, and commodity network devices can still be utilized for physical network construction. Deploying such dirty-slate approaches requires less time, effort, and cost than replacing existing architecture with clean slate architecture.