PeerNet: Pushing Peer-to-Peer Down the Stack

Jakob Eriksson, Michalis Faloutsos, and Srikanth Krishnamurthy*

University of California, Riverside

Abstract. An unwritten principle of the Internet Protocol is that the IP address of a node also serves as its identifier. We observe that many scalability problems result from this principle, especially when we consider mobile networks. In this work, we examine how we would design a network with a separation between address and identity. We develop PeerNet, a peer-to-peer-based network layer for large networks. PeerNet is not an overlay on top of IP, it is an alternative to the IP layer. In PeerNet, the address reflects the node’s current location in the network. This simplifies routing significantly but creates two new challenges: the need for consistent address allocation and an efficient node lookup service. We develop fully distributed solutions to address these and other issues using a per-node state of $O(\log N)$, where $N$ is the number of nodes in the network. PeerNet is a radically different alternative to current network layers, and our initial design suggests that the PeerNet approach is promising and worth further examination.

1 Introduction

How would we design a network layer with mobile nodes and peer-to-peer interactions in mind? This question would have seemed like a theoretical exercise a few years back, but it has become legitimate, if not necessary, with the current technological trends and commercial initiatives. In fact, we observe an overwhelming popular and commercial interest in mobile wireless connectivity [1, 7], consumer owned networks [3, 2, 4] and mesh networking [5, 6]. A vision that we share with [12] involves pockets of peer-to-peer wireless connectivity interconnected with traditional wired lines. Implementing such a vision introduces new networking requirements, and we may need a novel network architecture. Here, we focus on the network layer of such a future architecture.

Although the Internet Protocol (IP) has been a spectacular success, this should not prevent us from assessing its suitability for the networks of the future. Most of the above initiatives seem to rely on the Internet Protocol. An implicit principle of this protocol is that the IP address of a node is tightly coupled with its identity. This has worked well so far, since the Internet supports mostly stationary nodes with wireline links and well defined consumer-provider

* This material is based upon work supported by the National Science Foundation under CAREER Grant No. 9985195, DARPA award FTN F30602-01-2-0535.
relationships. However, the address as identifier paradigm may encounter problems in highly mobile networks. We have already seen mobility and scalability push IP to its limits. While it is possible to satisfy most new requirements with patches such as NAT, DHCP, Mobile IP, the end result is seldom elegant and often plagued by new problems. One striking example of the above paradigm failing is the fact that a TCP session will break if one of the end points changes its address. This is an important issue as networks are becoming increasingly mobile.

The overarching question is how we would design the network layer for future networks if we were to start from scratch. Our target environment is very large potentially wireless and mobile networks. Therefore, we want an agile, plug and play, fault-tolerant, and scalable networking layer. A source of inspiration is application layer peer-to-peer networking, an area that has seen tremendous advancements recently. Therefore, we pose the question: what can we gain by bringing the peer-to-peer concept from the application layer down to the networking layer? We develop a set of guidelines that seems to satisfy our networking vision. We want the new network layer to: a) minimize the need for manual configuration, b) avoid centralized solutions and node specialization in favor of distributed and peer-to-peer solutions, and c) localize control overhead.

In this paper, we present PeerNet, a network layer with integrated support for routing between peers. PeerNet makes an explicit distinction between node identity and address. The address of a node reflects its current location in the network at all times. This simplifies routing but introduces two new challenges. First, we need a node lookup service that will provide the address for a given a node identifier. Second, PeerNet needs to maintain addresses dynamically: as a node moves, its address changes to reflect the new location. Our initial design suggests that PeerNet is feasible and potentially fundamental component of our vision for future networks.

**Our Work in Perspective.** PeerNet is a radically new architecture that brings peer-to-peer concepts to the network layer. Although the design presented here is not complete, it provides the backbone and several non-trivial algorithmic solutions. In our upcoming implementation, we expect to complete and finetune our design. Furthermore, we expect this work to provoke a constructive reevaluation of current networking architectures.

**Related Work.** Area Routing [11] and Landmark routing [16] are classical papers on hierarchical routing. LANMAR [13] and L+ [9] are modern extensions of Landmark routing, whereas PeerNet to our knowledge is the first protocol for dynamic networks with similarity to Area Routing. For a survey of ad hoc routing, see [10], and for a survey of distributed hash tables, see [14]. Recently, several efforts such as [15, 8] address some of the same issues as PeerNet but do so by adding functionality to the existing IP infrastructure.