Mobility in computer networks takes two distinct forms: physical (human) mobility among a network's access points and base stations, and virtual mobility of a user identity among the many networks that make up the larger Internet. Physical human mobility has played a central role in the design and operation of mobile networks (including cellular, Wi-Fi, and mobile ad hoc networks) and their protocols for hand-off, intra-network routing and location management, and more. Consequently, numerous research studies have developed models of human physical mobility and used these models in the design and evaluation of mobile network protocols.

Virtual mobility - mobility among networks - is a more recent concern of protocols such as Mobile-IP and new architectures such as XIA [1] and MobilityFirst [2], which aim to provide location independence (mobility transparency) by separating identifiers (names) from addresses or network locations. Here, the need to map a user's identity to his/her current network location via mobility registration and lookup/indirection protocols, are central concerns. Thus, a quantitative understanding of how a user identity transitions among access networks - the networks through which that identity is addressed and ultimately reached - is of great interest for mobility architecture and protocol design and analysis.

We perform a measurement study of user-transitioning among networks and discuss insights and implications drawn from these measurements. Our study thus differs from previous mobility studies that have developed models of a single device's changing MAC or IP addresses while physically moving between access points or base stations. Based on these measurements, we also develop and validate a parsimonious Markov chain model of canonical user transitioning among networks. Our measurement study, conducted using two sets of IMAP server logs (a year-long log of approximately 80 users, and a four-month log of a different population of more than 7,000 users) quantitatively characterizes network transitioning in terms of transition rates among networks, network residency time, degree of contemporaneous connection to multiple networks, and more. We find that users spend the majority of their time attached to a small number of access networks, and that a surprisingly large number of users access two networks contemporaneously. We also show that our Markov chain model of a canonical individual user, in spite of its many simplifying assumptions, can accurately predict aggregate transition rates, the degree of contemporaneous multi-homing, and other key network-transitioning performance metrics for an aggregate population.

Our measurements provide quantitative insight into the location management signaling overhead needed by modern and proposed name/address translation and location management protocols; our models provide the ability to design, dimension and analyze such systems. More generally, we believe that while physical mobility and the design of link-layer and intra-subnetwork handoff protocols are relatively well-understood, the behavior, modeling and measurement of users transitioning among networks and the design of protocols for managing that mobility at global scale are much less well-understood. This work is an important step in deepening that understanding.
