Reputation and Location Privacy in Cooperative Networks

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1 Introduction

Bands of computer users in urban areas around the world are pioneering a new type of network called cooperative networks. When two geographically distant devices need to communicate and cannot send messages directly to one another, the sender asks intermediate devices to forward its message to the recipient. The ownership of the networked devices is divided among many, possibly self-interested, individuals. Despite that the network devices' owners have no immediate interest in helping one another, they frequently configure their devices to forward traffic. The resulting collection of devices form a cooperative network.[1]

A cooperative network can use any network medium, but most use wireless network links for the bulk of their traffic. To connect with the Internet, a cooperative network requires that at least one user altruistically donates bandwidth connecting her own devices to an Internet service provider. The donating device incurs an opportunity cost of the use of her Internet connection. Mobile devices that contribute to the cooperative network incur similar costs, but additionally consume power more quickly in forwarding other devices' traffic, degrading the lifetime of battery-powered mobile devices.

Work with cooperative networks builds upon a large corpus from *ad-hoc* networking, but the current research frequently assumes that networked devices all share objectives. We assume that each cooperative-network devices operate in rational and self-interested manners without any centralized structure.

[1]Sometimes these networks are called "community networks," but that term is also used to describe web sites that serve a local community. We use the term cooperative networks to distinguish our work from the latter projects.

The overall performance of a cooperative network relies on decisions made under incomplete information at nodes spread throughout the network. In addition to routing packets, each device in the cooperative network must decide at what priority to forward other devices' packets. Our initial work with cooperative networks suggests that each device should track the reputations of other devices with which the device interacts. Documenting a device's reputation, however, may compromise its user's privacy, and we study the performance/privacy trade offs a cooperatively networked user faces.

2 Network Justification

The many devices that comprise a cooperative network do not share a common owner, though they rely on one another to forward traffic through the network. We measure the success of cooperative networks based upon the summed time-average available bandwidth to each user. This metric measures battery performance since available bandwidth is zero when a device expends its battery.

Much of the network traffic eventually flows to an uplink connecting the network to the Internet. Each uplink has limited bandwidth that we assume is free when the uplink is underutilized. Under network congestion, however, the uplink owner must allocate bandwidth among others' incoming connections as well as its own uses. We observe current use, and envision the future use, of cooperative networks mostly in urban environments with at least one of three motivating circumstances.

Shared Uplink: Users jointly pay for the cost of an Internet connection that they share using a wireless cooperative network. This scenario seems especially likely in remote areas, where no consumer broadband service is available, or in urban areas where users desire a low cost Internet connection. A shared uplink scenario presents the challenge to allocate bandwidth among the participants according to their level of pay. Ideally, a user closer to the uplink should not necessarily receive more bandwidth then a user multiple hops away.

Sharing Multiple Uplinks: In denser urban areas, where consumer broadband connections are common, a cooperative network can provide higher bandwidth and redundancy. In this model, we assume that each user has her own broadband connection and is free to share it. Because users are often active at different times, downloads of individual users can be distributed across the neighbors idle uplinks, yielding higher throughput.

Mobility: Further incentive to share in regions with consumer broadband service comes from mobile Internet access. A user may route traffic for others with the expectation that she can use other routers when traveling. Mobile devices may also forward traffic for other devices, but they realize diminished battery life through the extra operation.

3 Cooperation and Reputation

As community networks grow in participants, accounting the value that each node delivers to the network and identifying freeloaders become more important. Intuitively, a device contributes more value to the network the more it forwards others' traffic. Despite many academic studies that indicate efficiency of market-based mechanisms to allocate computation, bandwidth, storage, and media, users are resistant to embrace currency-based schemes. Spurred by their aversion, we investigate reputation-based mechanisms based on game-theoretic bargaining models [Rub82, Kra01]. Many e-commerce systems already use reputation information to guide trade. For example, sellers with higher e-bay reputations can command higher prices [AM02].

Each device in the cooperative network must determine how much bandwidth to allocate to each of its neighbors based upon their reputations and the maintenance of its own status. We model the possibility that each device tracks its neighbors' reputations and gauges the net benefit to cooperating as it effects the present value of personal network performance. We construct policies to determine the cooperation level as a function of another device's reputation to construct an iterated function system with which we use to investigate equilibrium stability [Bre03].

4 Locational Privacy

We rely on reputations established through a network node's past behavior to prioritize traffic and to punish freeloaders in the network. Reputation systems, however, typically require that nodes are uniquely identified, which gives rise to several privacy concerns.

We are especially interested in location privacy for mobile users of the network. If these users are identified, nearby network nodes can determine their position whenever these users communicate. This may lead to wholesale collection of users' paths to discover sensitive qualities. For example, a network sleuth using path information between a private residence and a clinic could discover that a particular user suffers from HIV. We expect that other concerns such as content and communication privacy (the danger of identifying communication partners) do not significantly differ from those in the wired Internet.

Switching identities can alleviate such concerns [GG03]; however, these mechanisms are in tension with the reputation system. We are investigating group reputation mechanisms that allow users to remain indistinguishable from a group of users, but still able to persuade nonmembers to cooperate based on their group reputation.

5 Conclusion

Cooperative networks present a wide variety of interesting research topics. We believe that we can model participation incentives through tracking reputations of devices' ability to forward network traffic. Collecting reputation information, however, could infringe on users' locational privacy and we investigate cryptographic mechanisms to deflect the infringement as well as model inefficiencies of changing identity.

References

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