Sharing Networking Resources to Create a Pervasive Infrastructure

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Abstract

We propose a range of techniques to motivate people to share a small fraction of their available resources in designing a new networking technology to provide near-ubiquitous connectivity to others. Such technology can be used whenever the infrastructure is unavailable to provide general connectivity between individuals, and to to the Internet at large, and particularly in cases of emergency.

People's motivations for action range from selfish to altruistic, including mixed motivations that might be hard to classify as either one or the other. We would like to support individual choices to use our technology using any such motivations. Gaining credit within an online community and providing resources when abundant for the individual so that others will provide when the individual's resources are scarce are often considered selfish motivations, but they support the communication and online community as well. More directly altruistic motivations include participating in and supporting emergency communications, providing a service to others, and contributing in building a new online community.

Generally, we hope to cater to a range of motivations with the benefits that the new technology can provide to the individual, as well as the benefits the technology can provide to society and large numbers of individuals.

I. Introduction

There has been much discussion of using ad-hoc networks for emergency communications [1]. In an ad-hoc network, devices communicate directly with each other, with no need for any infrastructure. Such a network can be used to distribute information locally. If any of the devices in the network are connected to the wider Internet, they may provide Internet access to the remaining devices.

In most of the proposals to date for building ad-hoc networks for emergency communications, the networks require dedicated hardware that will be deployed after the emergency has struck [2].

We (and many others) have observed that most individuals in a wide variety of societies very frequently carry a dedicated communication device. These devices are so useful that they are almost always kept charged, and so useful, lightweight and rugged that they are often carried wherever the owner goes. Many of these devices are WiFi-capable or have other wireless capabilities which make them able to participate in ad-hoc networks. Although their owners frequently think of these devices mainly as cellphones or even cameras, the computational and communication power of these devices is substantial, and has been improving over time.

If we program these devices to participate in an ad-hoc network, local communication becomes independent of any infrastructure. If any of these devices has access to the wider Internet, it can share such access with other devices in the network. In cases of emergency, this network can be used to communicate situations of distress to authorities and rescue workers, as well as send messages of reassurance to family and friends. Such a network can also be useful in non-emergency situations. In general, it should be useful whenever the infrastructure is not available or accessible, including in locations that are not well served and when the infrastructure is too expensive for some of the would-be participants.

The network we have proposed, AllNet [3], provides pseudonymous, secure communication among people who know each other, and may be used to provide other kinds of communication as well. The people communicating need not be within range of each other, as long as intermediate devices forward the data in an ad-hoc fashion. Each device will forward data when, for any reason, it happens to be the device best positioned to forward the data. Devices may also store the data, and deliver it at a later time when they are able to communicate with the destination. The design of Allnet is summarized in Section II, and likely uses for Allnet are given in Section III.

One of the issues to be resolved with such a communication system is how to incentivate users to activate and support such a system. The system is designed to be useful while requiring only a small percentage of the resources typically available to a smartphone, so the cost of supporting AllNet should be negligible. But even if the cost is negligible, we believe that individuals need positive incentives to adopt such a technology. Section IV reviews some of the variety of human motivations for making choices and describes some of the incentives we plan to provide for adoption of AllNet. This is followed by a discussion in Section V, and a conclusion that summarizes the paper.

II. A LOW BANDWIDTH, SECURE NETWORK FOR HUMAN-TO-HUMAN COMMUNICATION

Technically, the design of a pervasive ad-hoc network for ubiquitous communication is relatively well understood. Many wireless ad-hoc networks have been proposed over the past decade, including mobile ad-hoc networks and mesh networks, and a few large-scale wireless mesh or wireless ad-hoc networks have been built.

The remainder of this section focuses on three characteristics of AllNet that distinguish it from other such wireless networks: limited broadcasting, the design for low bandwidth and resource consumption, and the pervasive encryption and pseudonymous communication.

A. Limited Broadcasting and Priorities

As well as unicast when appropriate, AllNet is designed to support limited broadcasting. Limited broadcasting can deliver a message to a limited geographic area, to a certain range (in hops) around the transmitter, or to multicast destinations defined in different ways.

Benefits of limited broadcasting include a reduced need for routing protocols and the resulting overhead, and the ability to take advantage of a variety of communication strategies, including addressing people within a neighborhood, local search for resources, and using data mules (devices that physically travel toward a destination) to deliver data.

If designed appropriately, limited broadcasting can also associate with many messages an estimate of the network resources needed to deliver that message. Devices forwarding the message can then prioritize those messages that require the least resources, both from the device itself, and from the network.

For example, a message directed to a specific destination might be given higher priority than a message broadcast widely. The latter message might only be forwarded if resources are abundant. Short messages have higher priority than long messages. Additional such heuristics can be developed to encourage effective communication and discourage unnecessary use of scarce resources.

B. An Interpersonal Network using Low Bandwidth Communication

Many forms of interpersonal communication require amazingly low bandwidth. SMS (text messages) and tweets are limited to 140 bytes or characters, for example, which is much less than the 8,000 bytes/second that uncompressed voice requires. While many technologies do require much higher bit rates, very effective communication can certainly be accomplished even with very low bit rates. Some forms of semi-automated communication, such as exchanging geographic coordinates, also do not require high bit rates.

The bit rates needed for communication are important because in a mobile device, any communication consumes resources. These resources fall into several categories:

- resources needed for device operation, including battery charge, storage, and CPU cycles.

- bandwidth used by the device for other communications, particularly voice and internet access.
- financial resources, if communication costs are based on usage.

If there were no cost to supporting AllNet, many individuals might be willing to contribute to helping others communicate. Realistically, there will be a cost. We have proposed that, whenever AllNet is forwarding messages for others, such support of others' communication should use no more than 1% of any given resource on a mobile device. We expect that this limitation will encourage people to support AllNet, while still providing useful communication capabilities.

Such resource limitations mean Allnet would not be very useful for generalized Internet access. However, what we propose might be sufficient for limited email access, for example by omitting multimedia attachments, and for text-oriented web browsing.

There will be cases when higher-resource communications should be supported, especially for communication among family and friends, and AllNet will be configurable to support such uses. However, the focus of this paper is on the operation of AllNet in the low-resource mode, and what incentives an individual may have to support communications that do not bring a direct benefit to that individual.

C. A Secure Network for Interpersonal Communication

We assume that, when our personal communications are relayed by strangers, the communication should be secure. That is, communication should always be encrypted between individuals who know each other, and messages are only sent in the clear when contacting new people. Within AllNet, user identifiers are randomly chosen numbers (usually with a large number of bits, and normally not directly displayed to the user), often corresponding to the recipient's public key, so that all messages are sent and received pseudonymously. Any user can choose any number of pseudonyms.

Security by itself is neither positive nor negative. Criminals can benefit from secure communications and pseudonymous identities just as much as law-abiding citizens, and possibly even more so. However, we believe that strong security is a requirement in any ubiquitous communication system that depends on strangers to forward our messages.

The mechanism for providing such security is based on public-key cryptography, as are, for example, SSL/TLS and `ssh`. SSL/TLS rely on certificate authorities to bind a key to an the identity, but this is not a good model for free interpersonal communication. Instead, as in `ssh`, a key may be accepted when first encountered, perhaps after querying the user. When two people carrying their mobiles are within range of each other, there can be considerable assurance that the key matches the individual.

III. Technology Adoption

Any new technology, however beneficial, runs some risk of not being adopted, due to any number of factors internal and external to each individual. Internal factors include how each individual feels about the technology, and may be affected by external incentives to use or support the technology. We propose to complement the intrinsic benefits of AllNet, that is, low-bandwidth connectivity for large numbers of people that is independent of any infrastructure, with specific incentives designed to appeal to large numbers of possibly very diverse people.

External factors will affect the appropriation, or lack thereof, of AllNet's infrastructure for different uses in different socio-technical contexts. We envision in this section some scenarios in which AllNet could be particularly helpful.

We have mentioned the usefulness of AllNet in emergency situations. Besides accessing the Internet when other infrastructure fails, AllNet users can also geocast help requests or other locally relevant information, e.g. the location of hazards and resources during accidents or disasters, even when no one nearby has Internet access. We expect users to become familiar with AllNet in everyday life, in any situation that results in lack of broadband access to the Internet, and therefore be able to effectively use AllNet during emergencies.

AllNet has the potential to become a pervasive tool for crowdmapping and crowdsourcing of virtually anything anytime. Users can tag their casts in order to allow other users to follow them or filter them out in their AllNet news streamline.

AllNet can be particularly beneficial for travelers. Indeed, travel often involves leaving behind the most convenient and powerful communications setup, and using ad-hoc mechanisms for communication instead. Moreover, access to local geocasts can be particularly relevant when approaching or exploring unfamiliar places.

Pseudonymous ad-hoc networks can be very useful in a number of scenarios. Examples include:

- People wanting to post socially sensitive information in chat rooms, like abuse survivors and those with stigmatized illnesses
- Whistle blowers who fear retribution
- Witnesses of organized crime and corruption
- Professionals such as journalists, lawyers, consultants, human rights workers, who need to protect their sources or clients
- People concerned by the right to anonymity for the freedom of speech

- Dissidents in politically rigid countries.

IV. Human Motivations: Selfish, Altruistic, and in between

AllNet draws from both Game Theory and Psychology to design a diversity of incentives, leveraging both selfish and altruistic motivations as well as extrinsic and intrinsic motivations. Such diversity of incentives recalls the successful experience of the Maniac Challenge [4].

Distributed Computing, P2P networks and Open Source Software are examples of the numerous successful projects that rely on voluntary resource sharing. Typically, studies in these areas have relied on Game Theory to identify and sometimes design reward-based incentives [5]. By focusing on external rewards, these studies rest mainly on extrinsic motivation, i.e. actions driven by external and usually measurable benefits.

However, several psychological studies [6], [7] show that external rewards may be ineffective or even hinder ("crowding effect") intrinsic motivation, actions driven by personal satisfaction in performing the action itself. Moreover, intrinsic motivation is shown to be very powerful and often more effective in facilitating sustained behaviors.

Although the two types of motivation may seem in conflict, it has been shown that the "crowding effect" can be avoided by taking factors of intrinsic motivations into account in the design of the incentive system [8]. In order to leverage both intrinsic and extrinsic motives, AllNet focuses on designing for sociability: although from a different angle, both Game Theory and Psychology underline the importance of social relations in motivating co-operation. Therefore, AllNet is likely to benefit from the development of a simple and easy to navigate social awareness interface such as studied by Erickson and Kellogg [9], which allows users to be aware of who is sharing bandwidth with whom, create their AllNet friends network, check friends in common and hops between them and other users, participate in reputation systems, and see who is gaining points and prizes. Such points and prizes might, for example, give access to advanced services or other benefits.

The social awareness interface introduces psychological and social incentives to support AllNet. These incentives can be seen to range from selfish to altruistic and anywhere in between.

With AllNet every user becomes a facilitator of human communication in a non-commercial way, which constitutes an altruistic motivation per se. This is similar to at least some individuals' motivation to contribute to wikipedia. The incentive design however can leverage also motives that one may consider more selfish. For instance, when one shares bandwidth and receives positive feedbacks (via automatic and manual systems) their reputation grows, as well as their points and their likelihood to access better services. These can be considered selfish motives, but at the same time feedback and reputation systems facilitate the awareness and the feeling of contributing, which is considered an altruistic motivation and is shown to be among the strongest motivators of online resource sharing [10].

Even ”selfish” and extrinsic incentives are likely to be more efficient when their acquisition can be shared with others via the social awareness interface, that is, others can see who is gaining points and winning further services.

Therefore, leveraging sociability, AllNet can integrate and make visible a diversity of individual, mutual and network benefits of sharing bandwidth with others.

V. Discussion

Free, pervasive, low-bandwidth access to the Internet is likely to be used in emergency situations, when traveling, and in a number of everyday life situations where infrastructure-based broadband access is not available. Pseudonymous geocasting can be used with great benefit in various scenarios mentioned in Section III. We expect that additional emergent uses will unfold as well.

Many of the applications we have envisioned here require AllNet to be widely adopted. Despite the benefits described in Section III and the incentives described in Section IV, success for any new technology is uncertain, especially for an ambitious new technology such as AllNet. Future research will identify and address possible hindrances while engaging in an iterative design process to progressively broaden AllNet adoption.

Whether AllNet will face a slow or rapid adoption, and even if widespread adoption unfolds slowly, the platform will be valuable even if only as a niche product. This is particularly true for the professional uses mentioned above that need pseudonymous secure communications, including journalist and professionals who need to protect their sources and clients, human rights workers, and whistle blowers who fear retribution.

Moreover, if the technology is adopted for a sufficient time, whether widely or by a niche of users, emergent uses are likely to unfold depending on external factors and socio-technical contexts. Such new uses will offer further inputs for the future development of the system.

VI. Conclusion

Section II briefly presented the design of AllNet, a new network technology to provide pervasive secure communications when the infrastructure fails to do so. In the remaining sections we have described in some detail a range of human motivations that might encourage people to use and support others' use of

AllNet, beginning with a description of inherent benefits of the network as well as selfish and altruistic incentives to use the system.

To justify the design of these incentives, we have searched for the common ground between two apparently divergent traditions of thought, focusing respectively on intrinsic and extrinsic motivations. We have found such common ground in social relations. Therefore we propose to facilitate and leverage sociability in order to facilitate wide adoption. This in turn permits the full realization of all the potential benefits of AllNet.

Overall, this paper gives our current understanding of the characteristics, benefits, incentives, and possible uses of AllNet. The project remains under active design and development through an iterative design process that takes into consideration possible contextual hindrances and emergent uses.

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