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Social Area Networks: Data Networking of the People, by the People, for the People

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Abstract

In this position paper we explore a holistic approach for the integration of social and human-level concepts with all layers of the communication network. This integration is bidirectional - the social information can help inform and configure network-level parameters, while network information can contribute to the gathering and learning of social-level information. We review existing work and emerging trends in the area, as well as propose new ideas for socially-aware network applications. We present the motivations for a unified approach for integrating socially related information throughout the networking stack, and introduce the concept of a Social Area Network (SocAN), which encompasses network architectures built for and around people and their social relationships.

1. Introduction

Recent years have seen an emerging trend that breaches the traditional layered approach of data networking by making use of socially related information for network level decisions and configuration, for example [1-5]. This trend seems in correlation with the growth and increase in popularity of online social-networking sites such as LinkedIn, MySpace, and Facebook, as well as the availability of large user-behavior related datasets, such as [1, 6] and many others referenced at [7]. Two observations could be made with regards to the current work in this area: First, that most of the state-of-the art work in this field remains in a relatively narrow application space – mostly in the context of routing [1-3] or security applications [4, 8]. The second observation is that the current work is mostly in preliminary stages of simulation or feasibility analysis, and has not reached a stage of deployment or complete implementation. Perhaps now, while most of these works are still in their nascent stages, is the time to step back and take a broader look at this area. Rather

than focus on the use of social information for solving a specific problem (routing, network address translation, access-control-list, etc.), we argue for the general approach of using social information and socially inspired networking concepts, as compared to using existing approaches for network configuration and optimization.

We aim to demonstrate the following points: First, that there is a justification for integrating socially related information throughout the networking stack. Second, that the benefits are bidirectional. Third, that since the characteristics of this integration are similar for different layers and scenarios, there is place for standardization and creation of a unified architecture for doing so.

We develop our discussion in several steps: First, we frame the network configuration and management problem that we are dealing with (section 2). In section 3 we review some of the existing solution approaches, like autonomous configuration agents and game theoretic approaches that use economic incentives. In section 4 we introduce our socially inspired approach for network management and the motivations for using it. We then present our proposal for an encompassing socially-oriented networking concept, Social Area Networks (SocANs) in section 5. In this section we also give examples of different use cases for the bidirectional integration of social information and the networking stack. Finally, we discuss some steps that could move this work forward.

2. (Re)Framing the Network Management problem

Rather than look at optimization and configuration problems for a specific parameter or protocol, in this section we aim to frame the problem of network management and configuration from a high-level, cross-layered perspective. We look at the configuration problem in the context of experts (IT professionals, developers, and researchers) as well as lay end users.

Our discussion is focused more towards problems in the realm of distributed networking, where there is no central control. Such networks, ranging from peer-to-peer overlay networks, ad-hoc wireless networks, home-networks composed of a set of consumer devices and peripherals, and even the Internet itself, are much more challenging to manage and configure. Solutions for the distributed problem could be transferred to a centralized architecture much more easily than vice versa.

2.1. Experts: Manage the network

Communications networks, especially at scale, are both complicated and complex systems. End-users require service operators and IT departments to set up, configure, and maintain most of their network services. These services are complicated even to the experts: Most network protocols are made to be extremely flexible, offering dozens of configurable parameters like counters, time-outs, packet sizes, bitrates, and error correction settings. TCP, for example, has a large number of such variable parameters. Such parameters exist throughout the network stack and go down to the lower layers of the OSI seven layers model [9]. TCP's congestion control parameters, Ethernet's maximal transfer unit (MTU) size, Wi-Fi's exponential back-off configuration, or the countless Quality of Service (QoS) settings [10] are just a few examples.

The bottom line is that this aforementioned flexibility is merely a *façade*, since developers and service providers nearly always set the parameters to some *default* value. These defaults are "good enough" for common cases, but do not utilize the full range of these protocols. Understanding and improving these settings is commonly a matter of academic or corporate research, and the source of revenue for an entire business sector set up to provide products and services for managing large scale networks. The vast majority of network professionals either makes use of such services, or keeps the default parameter values in place.

This configuration problem has different scales of manifestation. Some parameters might affect just a single network device, like a Wi-Fi device's power management configuration that only affects its own battery life. Other parameters affect a bilateral communication, like some of the TCP window size configurations. There are parameters that directly affect groups of devices, for example medium access parameters in shared mediums like Ethernet or wireless LAN, which include values such as MTU size and the exponential back-off timers in case of packet collisions. These affect all devices that are in radio range or part of the shared medium, since they cause collisions and congestion on the shared resource. Finally there are

parameters that span the network itself, like routing or link-state protocol parameters. Even though our socially inspired approach could assist with single-device issues, the parameters that interest us the most in our discussion are those that affect a collection of devices.

2.2. End-users: Configure devices and services

Current user interfaces for controlling and monitoring the activity of networked consumer devices leave much to be desired. Many times, status information, if available to the user at all, is either very technical in nature, or over simplifies the state of the network. In this context we include functionalities like the configuration of wireless LAN (Wi-Fi) and Bluetooth connections as well as other physical interfaces that are part of today's consumer device, and also network software that runs on end user devices, such as network security, access permissions, and firewall programs. It could be related to configuring shared printer permissions, or access permissions to a home wireless router. In many cases, one would have to configure a large set of rules and permissions, or reduce the rules to "allow everyone" or "allow no one".

We can look at the case of Bluetooth as a symbolic example to the problem. Bluetooth technology was supposed to be the epitome of plug-and-play networking. However, many users do not make extensive use of Bluetooth functionality, especially when taking into account Bluetooth's pervasiveness in nearly every mobile phone and laptop. A possible reason might very well be its complexity to the user. [11] shows a new paid service by electronics retailer 'Best Buy' to help people pair their Bluetooth devices, a very basic Bluetooth functionality, for \$9.99.

3. Existing Approaches for Decentralized Network Management

There are different ways to approach the decentralized network management problem. We focus on two state of the art approaches – utilizing machine learning (ML) and artificial intelligence (AI) based methods, and utilizing economic and game theoretic methods. In the next section we discuss our own approach that makes use of social awareness.

3.1.1. Autonomous 'Intelligent' Agents. Nowadays, machine learning (ML) methods are being increasingly proposed for solution of complex networking optimization. We review some examples of such methods. Many of these are centralized, but some are distributed. Geurts and Leduc [12] propose to improve congestion control over wireless networks based on the

decision tree boosting method. Their algorithm can classify the cause of packet loss from information that resides only in the end-node on which it runs. Using this classification it is able to control the network congestion by modifying congestion window size. Boyan and Littman [13] propose a reinforcement learning (RL) algorithm for dynamic packet routing in a network, which uses packet delivery times as its benchmark. Brown [14] proposes an algorithm for packet switching using RL where the goal is to find the optimal contention arbitration policy. Ruiz et al. investigated the use of a distributed genetic algorithm agent for learning when to trigger quality of service (QoS) adaptation in a way that attempts to optimize for better user-perceived QoS (rather than absolute technical measurements) [15]. Koch and Westphall [16] discuss how centralized approaches to Network Management have demonstrated inadequacy for efficient management of large and heterogeneous computer networks. They propose a general approach and architecture for using distributed artificial intelligence (AI) agents for network.

So far, most methods utilizing the machine learning and AI approaches have not made it out of the realm of research. This is due to various reasons, from computational power to the obvious fact that real life is never as neat as a simulation or lab tests, and many of these algorithms fail to perform well in arbitrary conditions. Even when they do, these types of algorithms usually optimizes for just one or few parameters, and do not perform full network configuration. Many times, by focusing on solving one problem, they create another.

3.1.2. Economic Incentives Approach. One of the more recent approaches in designing distributed systems is to use “economic incentives” and draw on economic and game theoretic principles. Related work has been performed in this field with regards to wireless mesh and peer to peer (p2p) systems [17, 18]. Bittorrent is an implemented and wide spread system that uses these principles [19]. Current designs of such systems treat all nodes in the network in the same manner. These systems implement accounting mechanisms that give credits for services provided, or exchange actual micro-payments. However, when considering real-life relationships there is differentiation between the peers. Most people probably do not need or even want to do “tit-for-tat” accounting for sharing files with family and friends or routing mesh packets for them. Another example from a business scenario – in a conference mesh network - do I really want to route my data through my competitor’s machine? If we look at the communication network as an augmentation of our social interface to other people, shouldn’t it also represent our social affinities?

Another point to note about people is that their incentive systems are dynamic and not constant. In the

same way that we act differently when we are at work, at home, on the road or on vacation, perhaps our network incentives should change as well. One of the improvements proposed by the SocAN approach is to augment such economic incentive models with socially inspired weights, like trust or types of relationships, which will be modified according to context.

4. The Social Awareness Approach for Network Management and Interaction

As briefly mentioned above, our approach, embodied in Social Area Networking, is to use concepts from human social interaction for network configuration.

4.1. Inspiration: Human Interaction

Human societies are distributed, multi-agent systems. In these systems each individual is also a node in a (social) network. Actually, each person is a node in multiple such networks simultaneously. Each person possesses a set of skills allowing her to adjust to dynamic network conditions and ever-changing contexts. When conversing over an identical topic in different situations, people act differently, according to the situation, the identity of their counterpart(s), and even according to that of other people in the vicinity. They use different wording, different gestures, or in networking terms - different communication *protocols*. In our social world, if someone steps out of line – society has protocols to correct them. Society rewards those who act benevolently and penalizes selfish behavior. Many times, when one acts especially “good” or especially “bad” – the word would usually get around and affect how society treats that person. Social researchers such as Goffman [20] and Barker [21] studied these human behavior patterns. They define different terms related to relationships between individuals, social contexts, and social protocols. As part of our approach, we propose to build on such works from the social sciences when designing network protocols and architectures.

As mentioned, social context might include parameters like the social setting, or the number and identity of peers who are part of the conversation, as well as of peers who are not part of the conversation but may overhear it. As an exercise to the reader, let us look at how humans interact with each other. Think about the different social interaction protocol parameters - like word selection, tone of voice, volume, handling interruptions, etc. – that you might employ in the following situations:

- One-on-one conversations: With a friend; with one’s supervisor, vs. one’s equally ranked

colleague, vs. one's subordinate; In a noisy environment vs. in a quiet environment.

- Communicating with a few people: In a group/team meeting; during a business meeting; while engaging in remote interaction (such as a teleconference), or during a family dinner (in which the protocol is family-dependent...)
- Communicating with many people: Giving a lecture; Presenting at a shareholders meeting; At the airport, right after the ground crew informed the waiting passengers that the flight is overbooked and they will seat passengers on a first-come-first-served basis.

There are many parameters that might run through our mind during each of these situations: Is this an open discussion? Should I go first? Should I go last? How aggressive should I be in trying to get the right to speak? Should I whisper? Should I shout? Can I interrupt the current speaker? Is there a moderator? Can I get emotional? Do I have to answer this question?

There are usually no strict rules of nature as to how we are supposed to interact with our peers. Instead there are social norms. Goffman would treat these interactions with respect to “roles” and theatrical-like “performances” [20], Barker would call these interactions “executing a program” which is part of a behavior setting [21], and Meierowitz would probably use terminology of different audiences and categorization [22]. Another aspect to consider is that in social engagements there are always exceptions - Arguments with family members are different than those with strangers. Society has these sorts of “soft” protocols, and humans have an ability to detect social context and modify their behavior.

Could our devices ever act in a similar manner to well functioning members of society? For the most part of this discussion, we are assuming that such configurations would be explicitly defined, by manual setting or according to data gathered by observing user behavior. These would be used to set correlation between different social contexts to desired device configurations. Nevertheless, in the distant future our devices might be able to autonomously discover such behavior rules and create social-like network protocols. In addition to the relationships of their human users, these devices might be able to create relationships and communication of their own, with peer devices. Such devices would be able to create relationships of trust or distrust, and notions in the line of “friendship” or even “family”. However, this future direction is out of scope for our current discussion, and we shall hence focus on the aspects related to the integration of social awareness principles into the existing network stack.

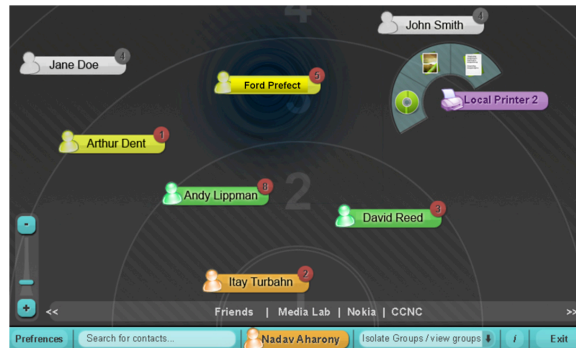


Figure 1. Social Dashboard interface concept.

4.2. Design Principles

Oviatt, discussing human centered design and cognitive load theory, touches on the importance of leveraging from users' experience, knowledge, and engrained behavioral patterns as well as accommodating the user's existing familiar work practice rather than attempting to change it [23]. These principles are directly relevant to our goal. Network-mediated communication, whether the end points of communication are human-to-human, human-to-machine, or machine-to-machine, is usually associated with social communication metaphors. For example the notions of “talking” or of passing messages between parties. In SocANs we extend this metaphor to the network management plane as well. This manifests in two levels:

- *Developers* – We want to create back-end mechanisms and definitions that would allow translation between social terms and social context to ‘hard’ engineering terms, which can be implemented and utilized with existing device and protocol parameters.
- *End user interface* – Since we want to enable users to administer their own devices, we should provide them with network interfaces and management tools that leverage their engrained social knowledge.

By doing so we present the users, as well as network developers, with a *vivid* model that they could utilize in order to take ownership and control over their networks. As a brief example, it seems more intuitive for an end user to configure his network printer to allow only his “friends” to print on it remotely, rather than set a long list of explicit permissions, or alternatively set it to allow everyone or no-one to print. The list of friends might be change over time, but anyone with the right “friendship credentials” at any given moment would be able to print. The Social Dashboard [5], depicted in Figure 1, is an example of a configuration interface that attempts to use socially inspired ideas for setting privacy and network

behavior, and is currently implemented on wireless mobile devices. The interface shows nearby peers and services on a “social distance” scale that represents varying levels of trust. We would like the network’s management as well as its regular interaction interfaces to be comprehensible and simple for the end-users, so that they could unleash the full potential of the network as a platform for advancing social collaborations and efficient use of information.

The idea of leveraging the social context to provide a framework for applying different sets of configuration parameters is some sort of practical middle ground between using default parameters which is an easy but limited solution, to attempting to dynamically and automatically optimize for performance, which is complicated and impractical. This approach is by far not claiming to provide optimal dynamic configurations, but there is good reason to believe that it will lead to better performance over the default situation, simply because there is not just one single default value, but the option to provide multiple values to pick from in each situation. By having these multiple values correlated to social-network and human-level terms, it should be much more intuitive for users and experts to apply these sets of configurations.

This approach intends to augment and enhance existing solutions, rather than supplant. Also – we should remember that the user’s goal is not necessarily mathematical optimality. Using this approach, we hope to make it so that the network’s goal is the human owner’s goal – whether it is a single user with her personal devices, or a large corporation with scores of devices. An example to illustrate this would be a scenario where a company was able to simply set up its network QoS configuration and security parameters according to the company’s hierarchical structure and desired connections between different departments and employees. This is done manually today by IT teams, as they manually set parameters that would, for example, make sure the CEO’s network connection will have precedence over others, or making sure the customer facing departments will have continuous network service. Perhaps we could define a set of simple rules to automate some of this social knowledge and ‘networking-commonsense-knowledge’, and translate different relational links into network behavior configurations.

5. Concept of Social Area Networks

5.1. Overview of Existing Network Archetypes

Traditionally, data network types have been organized in a hierarchical manner according to

geographical and physical parameters, with Personal Area Networks (PANs) being the smallest and Wide Area Networks (WANs) being the umbrella architecture, with other types such as Local and Metropolitan Area Networks (LANs, MANs) located along this axis.

Harte [24] presents an overview of the common types of networks hierarchies that are currently in use. Personal area networks (PANs) are short-range data communications systems that are primarily used to interconnect peripheral equipment (such as a mouse or keyboard) with a local computer or computing system. They are also used in the context of connecting different personal devices, like a user’s laptop, personal digital assistant (PDA), and mobile phone. Typically the connection is made by means of Bluetooth or infrared (IR) communication. Local area networks (LANs) are designed to reliably transfer large amounts of data quickly and error-free over a very small area such as an office. Metropolitan area networks (MANs) facilitate LAN-to-LAN information exchange in a local telephone exchange area. The use of a wide area network (WAN) allows for information to be exchanged between LANs located at significant distances from each other. For example a LAN in Chicago sharing information with a LAN Seattle would do so across a WAN.

However, a PAN also presents an exception to the locality-based hierarchy, as it introduced a more progressive notion: PANs are not about connecting just any arbitrary devices residing a few feet from one another – they add the concept of networking devices being used or even owned by a *specific user*. Another example of a network type that transcends the physical and geographical boundaries is a storage area network (SAN), which presents a view of the network from the perspective of a storage element. A SAN provides not just a service of connectivity but also other features that are relevant to storage devices, such as dealing with backups and survivability of the stored data. It is along these lines, of networks that are defined by context and use cases that the concept of “Social Area Networks” emerges.

5.2. Definition: Social Area Network

We shall define a Social Area Network, or SocAN, as a term encompassing network architectures built for and around people and their social relationships. In these architectures, the users’ social information pervades all the way through the network stack, down to the lower layers of the OSI model [9], and is used for configuring the network’s behavior and its services to the users. The SocAN’s main component can be thought of as a social awareness layer or a “social engine” that could be implemented either as a vertical layer that crosses the

boundaries of all existing OSI layers, as seen in Figure 2. Analogously, it could also be viewed as a component that is part of the management layer of a network device, which is able to interact with the existing layers and protocols and set their configuration parameters. The social layer uses the network stack’s state and additional information as input, and its socially related output can set parameters and provide additional functionalities as part of the control plane of the device

Note that in Figure 2, as well as this document’s general approach, we add an eighth layer at the top of the traditional seven OSI layers, depicted as “End-User Application Layer”. OSI’s layer seven, “Application”, refers to network applications that end users are not necessarily aware of, like File Transfer Protocol (FTP), Domain Name Server (DNS), or Dynamic Host Configuration Protocol (DHCP). The end-user application layer refers to network applications that the user directly operates, like email clients, instant messengers, or peer-to-peer file sharing applications. These applications could also be configured by the social awareness layer and inform it with updated social parameters of the user. In fact, most of the related work on socially inferred parameter configuration is performed in this realm.

5.3. Use of Social Information for Network Configuration

In this section we review both existing works as well as new ideas related to the use of social information as the basis for configuration of network parameters.

5.3.1. Related Work. Pentland et al.[25] build on results from the reality mining experiment [6] and propose to use the inferred social data in order to aid in setting privacy, sharing, and interest settings. In the context of our discussion, these settings would happen at the top most layer of the application stack – at a level that the user is aware of. The ideas we present here attempt to take similar social information, but make use of it *throughout the network stack*, down to the lower layers. A clue that this may be a useful approach can be seen in [8], where the authors used the same reality mining database in order to simulate several network scenarios and show that DTN routing protocols, simple firewalls preventing a worm infection, and a mobile P2P file-sharing system can benefit from exploiting social information. Others have also suggested using a social network to inform routing decisions for DTNs – delay tolerant networks, for example [1-3].

Initiatives like Facebook’s API [26], Open Social [27], or Data Portability [28] make it much easier for developers to build socially aware applications in the top

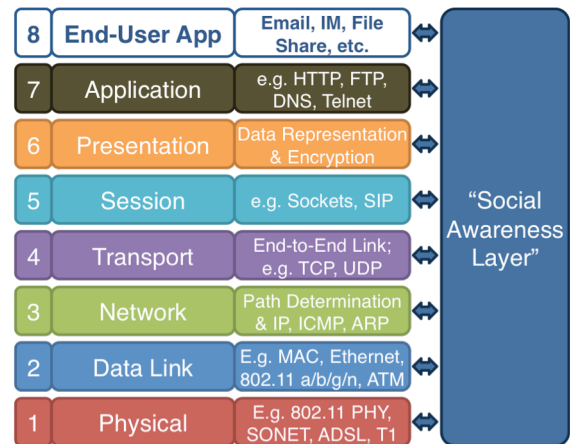


Figure 2. The traditional seven OSI layers, with our added “Social Awareness” vertical layer and “End-User Application” layer.

layer. For example, attempts to create search engines where results are influenced by one’s social network [29, 30]. Other initiatives use social information for inferring privacy and content sharing settings. The Mob-Media project deals with learning media sharing and social interaction information for use in media distribution and privacy settings [31].

5.3.2. Additional Examples. As can be seen from reviewing existing works, a lot of work is focused on the end-user application layer, with some of the state of the art focusing on the network layer (e.g. routing), or on security aspects of other layers. In this section we aim to give additional examples for possible application of social information throughout the network stack.

To the best of our knowledge, there has not been prior work that suggested using social information below the “network” layer. It is important to define an interface model that would connect the lower layers to this information, and open up this potential area of innovation. In the Physical layer, for example, SocANs could be integrated with the ongoing work on cognitive and software defined radios [32, 33]. If a cognitive radio would be aware of the relationships of its owner, for example be able to recognize the devices of the owner’s family members, these devices could coordinate a frequency hopping sequence of their own, improving both performance and security.

In the Data Link layer, the SocAN approach could configure medium access parameters. For example, in Wi-Fi there are timers and counters that configure how it should act after a packet collides, like how long to wait before trying to retransmit the packet, or how many times to try before giving up. These parameters are usually left at a constant default. A firm’s devices could use the firm hierarchy or other social preference rules to dynamically change these parameters according to sensed devices. For example, an employee’s laptop may

be more “polite” when the boss’s device is around, giving the boss a better chance to send his data. Alternatively, a server or printer may get these privileges from nearby personal devices, since their activity has precedence. In a similar way we could play with ‘politeness’ and ‘aggressiveness’ in other contexts. Another example at the Data Link layer deals with authentication. Currently, one type of authentication is usually implemented by ‘authenticating parties’ – for example a Wi-Fi access point. Social information could be used to select one of several possible methods. For example, do a different authentication for familiar peers vs. strangers. Familiar peers might have a quicker authentication process, whereas strangers might be diverted to one that is more secure and demanding, and might even force them to expose themselves in real life (e.g. – “Pick up your access code at the front desk”).

The Presentation layer deals with aspects like encryption. Another corporate example would be to automatically turn on encryption when communicating with a co-worker, but not when interacting with devices that belong to friends or family. Sensing ‘stranger’ devices in the vicinity might cause a family’s device to encrypt information.

The difference between specific network layers is not always clear-cut. A multi-layer application the SocAN context could be an advanced “social firewall”. Miklas et al. [8] suggest that a device could use the differentiation between friends and strangers to repel digital ‘worm’ attacks. A more complex version of a socially aware firewall could be devised, that would configure parameters in multiple network layers, as well as react to a range of social relationships and groupings (and also protect the boundaries between one group to another).

5.4. Use of Network Information for Social Inference

Previous work has shown how social sensing can be performed through mobile wearable devices, and how through offline analysis we can reliably recognize social patterns in daily user activity [6, 34, 35]. Particularly relevant is the reality-mining project, which used a mobile phone application to collect data from more than a hundred people over several months. Wireless mobile devices are especially useful as social sensors, since the presence of a device usually implies the presence of the device’s owner in physical proximity. For example, Jabberwocky [36] uses Bluetooth radios on mobile phones to scan for peers and visualize sensed encounters, helping users develop a sense of urban community and foster ideas like Milgram’s ‘familiar stranger’ [37].

Similarly to the network configuration examples, such data collection could be performed from various

layers of the network stack, making use of existing network logs and parameters. Radio level scans can give indication of presence and proximity, while logs from higher layers could inform on the type of interaction between networked peers and other communication features. Sensed social information can be used to build a user’s network of relationships.

A large part of these experiments has been performed with specialized hardware [35, 38] or preconfigured mobile devices that were given to participants [6]. This means that most of the data was collected in closed contexts and for a limited time – in campus or corporate environments, and in experiments of predefined length. By formalizing and standardizing the data collection interfaces, we could allow social experiments that people can download and install on their existing devices, and use in their everyday lives for long periods of time (with user permission, of course). This could lead to social data collection at unprecedented scale, helping boost the burgeoning field of computational social science.

6. Contributions

In the paper we presented the following contributions:

- Justified that social-awareness could be useful as a general approach to deal with network configuration and data collection tasks.
- Demonstrated that there are enough potential uses for social-awareness throughout the network stack, whose characteristics are similar enough to warrant a unified and cross-layered way to approach them.
- Presented Social Area Networks as that unifying framework, in the hope that once fully defined SocANs would merit standardization and could eventually drive device vendors to expose more capabilities for collecting information and setting communications parameters.

7. Moving Forward

There are more examples of work that combines social information with network functionalities. However, our goal was not do an exhaustive literature review, but to show that there are enough examples spread over the network stack that would need similar functionalities, features, and parameters. There little use in creating individual solutions for each of these small problems.

Aside from the high-level architecture design, there are many modules and interfaces that need to be defined. For example, we need a common language for connecting social terms to networking terms. This language might stem out of existing standards for high-

level social information on the web, like XFN[39] or FOAF[40]. After we have the formats to do this translation, we need to define how exactly the configuration changes would occur – different parameters have different frequency of changes - some might change many times per session, and some might be parameters that are fine tuned over many days or weeks. There is also a desire define formats that unify the different logs and telemetries from the various layers, so that they could be aggregated for doing the “social learning” and forensics.

We call for the community of those interested in the boundary of human networks and data networks to get together and create a working group on this subject, to discuss and define the many building blocks and bridges that are required.

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